Cover_Cecilia.pdf 1 18/01/16 11:26

Analyzing the institutional challenges for the agricultural (re)use of wastewater in developing countries

Cecilia Saldías Zambrana

UNIVERSITEIT GENT

FACULTEIT BIO-INGENIEURSWETENSCHAPPEN

Analyzing the institutional challenges for the agricultural (re)use of wastewater in developing countries

Cecilia Saldías Zambrana

2016

ISBN 978-9-0598985-8-5

9 789059 898585

UNIVERSITY press

Promotors: Prof. dr. ir. Guido van Huylenbroeck

Department of Agricultural Economics

Prof. dr. ir. Stijn Speelman

Department of Agricultural Economics

Dr. Pay Drechsel

International Water Management Institute

Dean: Prof. dr. ir. Marc van Meirvenne

Rector: Prof. dr. Anne De Paepe

How to cite:

Saldías, C. (2016). Analyzing the institutional challenges for the agricultural (re)use of wastewater in developing countries. Doctoral Thesis, Ghent University

ISBN number: 978-90-5989-858-5

The author and the promotor give the authorization to consult and to copy parts of this work of personal use only. Every other use is subject to the copyright laws. Permission to reproduce any material contained in this work should be obtained from the author.

CECILIA SALDIAS ZAMBRANA

Analyzing the institutional challenges for the agricultural (re)use of wastewater in developing countries

Dissertation submitted in fulfilment of the requirements for the degree of Doctor (PhD) in Applied Biological Science: Land and Water Management

Members of the jury

Prof. dr. ir. Guido Van Huylenbroeck (Promotor)
Department of Agricultural Economics, Ghent University

Prof. dr. ir. Stijn Speelman (Promotor)
Department of Agricultural Economics, Ghent University

Dr. Pay Drechsel (Promotor)
International Water Management Institute (IWMI), Colombo, Sri Lanka

Prof. dr. ir. Mieke Uyttendaele (Chairman)
Department of Food Safety and Food Quality, Ghent University

Prof. dr. ir. Arne Verliefde (Secretary)
Department of Applied Analytical and Physical Chemistry, Ghent University

Prof. dr. ir. Jeroen Buysse
Department of Agricultural Economics, Ghent University

Prof. dr. Christopher Scott
Udall Center for Studies in Public Policy, University of Arizona

Prof. dr. Roy Brouwer
Water Institute, University of Waterloo

Acknowledgements

I would like to start by thanking Ghent University for awarding me with the BOF (Special Research Fund) scholarship, which allowed me to pursue my PhD degree at this institution, and to the International Water Management Institute (IWMI) for providing me with financial and logistic support for this research.

I am deeply grateful to my promotors: Prof. dr. ir. Stijn Speelman, Prof. dr. ir. Guido van Huylenbroeck, and Dr. Pay Drechsel. Thanks for believing in me and in this research study from the start; and for your guidance and valuable support throughout these four years.

My sincere appreciation goes to many people who collaborated with me during different stays as intern at the International Water Management Institute in Sri Lanka, India and South Africa. To the research team at IWMI HQ in Colombo: Dr. George Danso, MSc. Krishna Rao, Dr. Pooland Karimi, Dr. Miriam Otoo; to Dr. K. Palanisami, Dr. Krishna Reddy Kakumanu, and MSc. Mahesh Jampani from IWMI Hyderabad Office; to Dr. Luxon Nhamo, Dr. Girma Ebrahim, and Dr. Munir Hanjira from IWMI South Africa Office, many thanks for the friendly word and collaboration. I am also grateful to Dr. Kai Wegerich and Dr. Mark Giordano, who provided feedback in early stages of this research. Special thanks to Dr. Barbara van Koppen and Dr. Priyanie Amerasinghe for their encouragement and support during the fieldworks in Western Cape and Hyderabad.

To the colleagues at the Department of Agricultural Economics, at Ghent University, thank you for the collaboration. Special thanks to Dr. Evy Mettepenningen for her help and Dr. Prakashan Veettil (former colleague of the department), who guided me around the university when I first arrive.

I also thank Prof. dr. Nick Vink from the Department of Agricultural Economics, Stellenbosch University and his group, for their support during data collection in Western Cape. Mrs. Taryn Allie, Mr. Steward Knott and Mr. Kevin Andrews (in Western Cape) and Mr. Mohammed Qadir, Mr. Ramprasad Chiluveri and Mr. Randheer Samala (in Hyderabad) – your support in the logistics was highly appreciated. Also many thanks to: MSc. Eng. Juan Carlos Rocha, Eng. Luis Salazar, and Eng. Roberto Saravia, who facilitated my fieldwork in Cochabamba, Bolivia. And of course, thanks to all the farmers, who generously took part of the questionnaires, as well as other interviewees who shared information.

I furthermore wish to express my gratitude to the members of the jury and the reading committee for their comments and advise to improve the quality of this dissertation.

A papá, mamá y Héctor, muchas gracias por su amor y apoyo incondicional.

To my family and friends, thanks for the endless support and love.

Table of Contents

List of tables

List of figures

List of abbreviations

AP	Andhra Pradesh
APPCB	Andhra Pradesh Pollution Control Board
CCT	City of Cape Town
CE	Choice Experiment
CL	Conditional logit (model)
CM	Choice Modelling
DWA	Department of Water Affairs (South Africa)
DWAF	Department of Water Affairs and Forestry (South Africa)
DWS	Department of Water and Sanitations (South Africa)
EMAPAS	Municipal Company for Drinking Water & Sewerage Sacaba
EPSA	Public-Social Enterprise for Water & Sanitation
GDP	Gross domestic product
GHMC	Greater Hyderabad Municipal Corporation
GNI	Gross national income
IWRM	Integrated Water Resources Management
HMDA	Hyderabad Metropolitan Development Authority
HMWSSB	Hyderabad Municipal Water Supply and Sewerage Board
ICADD	Irrigation and Command Area Development Department
IAD	Institutional Analysis and Development (framework)
IDA	Institutional Decomposition Analysis
IMT	Irrigation management transfer
LC	Latent class (model)
LRI	Likelihood ratio index
MDGs	Millennium Development Goals
MLD	Million liters per day
MNL	Multinomial logit (model)
NWP	National Water Policy (of India)
NWRS	National Water Resource Strategy (of South Africa)
O&M	Operation and management
PIM	Participatory Irrigation Management
RPL	Random parameters logit (model)
SEMAPA	Municipal Service for Drinking Water & Sewerage Cochabamba
SDC	Departmental River Basin Service (Cochabamba)
STP	Sewage treatment plant
SWP	State Water Policy (Andhra Pradesh)
UASB	Up-flow anaerobic sludge blanket
UN	United Nations
WC	Western Cape
WTP	Willingness-to-pay
WUA	Water Users Association
WWTP	Wastewater Treatment Plant
WWTW	Wastewater Treatment Works

Chapter 1. Scope, objectives and outline

1.1 General introduction

Presently, several regions of the world face water scarcity challenges. While water scarcity is largely associated to drinking water, the major challenges are broader and include for instance water for food, for nature, sustainable use of water resources, closing water and nutrient cycles, flood management (Savenije, 2002). Moreover, water scarcity has been recognized as one of the major threats to global food security (Klohn & Wolter, 1998; Yang et al., 2003). It is partly due to erratic rain patterns attributed to effects of climate change and partly to an increase on the demand side. One of the main causes on the demand side is population growth especially in urban areas – the world's population tripled in the 20th century and the use of water resources grew six-fold (World Water Council, 2010). A person's requirement for daily drinking water is estimated at 2-4 liters and for food produce at 2000-5000 liters (Winpenny et al., 2010). By 2025, it is estimated that 1800 million people[1] will live in countries or regions facing water scarcity and two-thirds of the world's population would be under water stress (FAO, 2012a). Moreover, in developing countries water withdrawals are expected to increase by 50% and by 18% in developed countries for the same year (UNEP, 2007). In regions with high pressure on water resources, the use of water is therefore contested among the different sectors. This is particularly true for the domestic and agricultural sector, as water for irrigation accounts to up to 66% of the total global consumption (up to 90% in arid regions) whereas 10% is used for domestic purposes, 20% in industry and 4% evaporates from reservoirs (Shiklomanov, 1999). Figure 1-1 shows water withdrawals and consumption by economic activity.

At a global scale much effort has been put to find solutions regarding the issues of water resources management. Several international organizations – such as the United Nations (UN) and its organizations, the World Bank, among others – engaged in these issues at different levels and from different angles. Yet water related problems are still far from being solved. A benchmark regarding water resources management were the 1992 Dublin Principles[2], which put forward the need of an effective management of water resources in order to guarantee sustainable development and protection of the environment for future generations. In effect, the fourth principle emphasizes the need to attribute an economic value to water in all its competing uses and to recognize it as an 'economic good'. Moreover, the same principle recognizes the human right to clean water and sanitation at affordable price, and points out that past failure to recognize the economic value of water led to wasteful and environmentally harmful uses of water. It

[1] This represents around 23% of the world's population estimated at 8000 million for 2025 (UNPD, 2008).
[2] Also known as the Dublin Statement on Water and Sustainable Development, which resulted from the International Conference on Water and the Environment (ICWE) organized in January 1992 in Ireland.

also highlights that managing water as an 'economic good' will achieve efficient and equitable use, and encourage conservation and protection of water resources (Dublin Principles, 1992). This approach was favored by international funding organizations (e.g., the World Bank). A key element is that it introduces the notion of economic instruments[3] to deal with water resources management (see e.g., Briscoe, 1996, 1997; Rogers et al., 2002).

Economic theory suggests that efficient use of natural resources can be better achieved by allowing trading. A fundamental feature for trading is the clear definition of property rights (see Kolstad, 2011; Grafton et al., 2004). Likewise, water use efficiency is to be achieved by reallocating water to the higher economic value, so that the marginal benefit from the use of water should be equal across sectors in order to maximize social welfare (Dinar et al., 1997). Agricultural water use is often economically inefficient. Consequently, transferring water away from agriculture towards uses with higher economic value is today regarded as an attractive measure (Molle & Berkoff, 2006). However, the consequences of such transfers are expected to impact negatively on food production and food security at a global scale – there is higher demand to feed the world's population – not only due to the decrease in volume allocated to agriculture, but also due to an expected rise of social and equity issues (Klohn & Wolter, 1998; Molle & Berkoff, 2006). Farolfi & Perret (2002) discuss the negative effects – such as loss of crop production potential, income and potential for development – resulting from inter-sectoral water transfers in rural South Africa within a frame of free water rights markets, and the need to include policies that look after economic efficiency without compromising environmental and social sustainability.

It is clear that the highest quality water needs to be preserved for domestic purposes; whereas water of lower quality can be used for other purposes among which agriculture, this fosters the concept of '(re)use[4] of wastewater in agriculture'. This approach offers opportunities for multiple use of water if technology can treat water at affordable costs otherwise by applying risk management (see Scheierling et al., 2010). It also accompanies the increasing trend of an efficient use of water resources, as water reuse

[3] Economic instruments (EIs) are defined as "means by which decisions or actions of government affect the behaviour of producers and consumers by causing changes in the prices to be paid for these activities". EIs for environmental protection are fiscal or economic incentives/disincentives to include environmental costs/benefits into the budgets of households/enterprises and by doing this to encourage environmentally sound and efficient production and consumption through full-cost pricing (Source: http://stats.oecd.org/glossary). EIs for water management are suggested to provide financial resources to cover costs of providing water, to foster efficient allocation of water, i.e., to allocate water to higher value uses, to foster conservation, innovation and to provide signals to induce behavioral changes. Examples of EIs for water management are: pricing, taxes and water trading (PRI, 2005). EIs provide market signals by modifying relative prices (e.g., taxation) and/or a financial transfer (payment of a charge). EIs allow the economic agents to choose (e.g., in case of pollutions charges, polluters can choose between paying the charge and investing in pollution control) (Barde, 1994).

[4] The terms 'water reuse', 'wastewater reuse' or 'wastewater use' are used interchangeably.

can work as a major mechanism (Toze, 2006). Qadir et al. (2010a) point out that from the urban water only 15-25% is consumed (see Figure 1-1) the rest is returned to the urban hydrological system as wastewater. Moreover, around 20 million hectares in 50 countries are irrigated with raw or partially diluted wastewater, which represents 10% of the total irrigated land (FAO, 2012b). Therefore, to think of wastewater as a potential water source for agriculture offers a window of opportunities. Nevertheless, to include wastewater as part of the whole water management requires to look at water institutions, as it is widely recognized that institutions are the most critical component in water resources management, even more than technical or economic (Ingram et al., 1984). The different concepts that frame this research are put forward in the 'conceptual framework' (section 1.4).

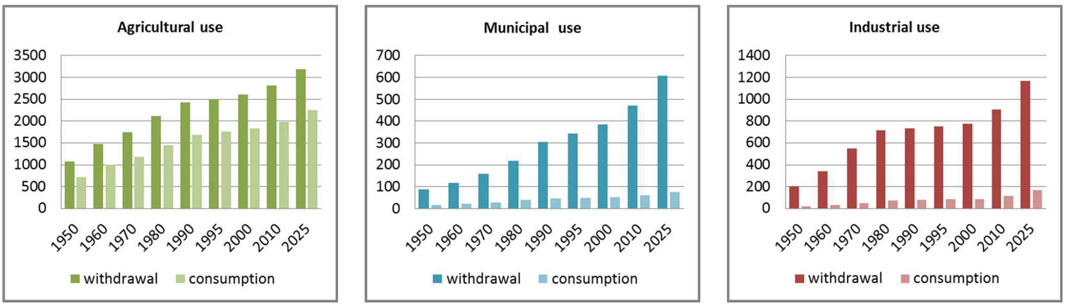


Figure 1-1 Water use at a global scale according to economic activities (in km^3/year)

Source: data from Shiklomanov (1999)

1.2 Overview of wastewater reuse

This section provides the reader an overview of the global wastewater production, reuse and problems related to it in order to contextualize this dissertation. For more detailed information the reader is referred to the literature cited in this section.

It is widely acknowledged that the demand for water grows in tandem with the population growth. This implies that more water is diverted to meet this demand and therefore more water is used in anthropogenic activities and transformed into wastewater. In this context, water reclamation and reuse become important and a central component of water resources management strategies to increase water supply reliability. In water stressed regions of developed countries, planned water reuse is practiced to preserve freshwater sources, to protect the environment and to economically use treated water at higher water quality standards; whereas in developing countries the need for increasing water supplies in arid and semi-arid regions and the use of polluted water due to the lack of sanitation is pushing unplanned water reuse by necessity (Jiménez & Asano, 2008).

In addition to the ever-greater demands on services (e.g., water supply and food production), the expansion of urbanization brings along another important aspect: that human consumption of services alters land use and cover, biodiversity and hydrological systems, and that urban waste discharge (including wastewater) affects local and global biogeochemical cycles and climate (Grimm et al., 2008). In this context, there is a link between water supply, food production and wastewater management, which is important for the agricultural sector in general and particularly for the poor farmers in peri-urban areas of the developing world.

In urban and peri-urban areas of the developing world, small-scale farmers use wastewater (usually untreated) to maintain their livelihoods, this demand has accompanied a range of new wastewater reuse practices (Scott et al., 2004a). Certainly water scarcity is an important trigger for wastewater reuse; however, it is also true that due the availability of wastewater (rejected by other users) small-scale farmers can practice agriculture and sustain their livelihoods and in turn cities can benefit from high-value edible crops from the vicinity. This aspect suggests that the productive use of wastewater has increased (Qadir et al., 2010a). These are important interactions embedded in the realm of wastewater reuse. Scott et al. (2004a) argue for an integrated stepwise management approach, pragmatic in the short and medium terms, which recognizes the economic niche and farmers' perceptions of the comparative advantages of wastewater irrigation that drive its expansion in urban and peri-urban areas. Furthermore, comprehensive management approaches for wastewater reuse in the longer term will need to include treatment, regulation, and user groups, market linkages that ensure food and consumer safety, and effective public awareness campaigns. However, to propose realistic, effective, and sustainable management approaches, it is fundamental to understand the context-specific tradeoffs between risks and benefits, the farmers' perceptions, and the institutional arrangements in place (Scott et al., 2004a).

1.2.1 Wastewater production and reuse

There are no reliable data on the volumes of sewage generated in cities of the developing world (Sato et al., 2013; Mateo-Sagasta et al., 2015), nor comprehensive assessments of the fate or use of urban wastewater (Scott et al., 2004a). Nevertheless, it is expected that the generation of wastewater will increase as a function of the growth in urban water supply; therefore, water supply coverage is a good proxy for projecting wastewater volumes (Scott et al., 2004a). Qadir et al. (2010a) estimate that in urban water only some 15-25% of water diverted is consumed, the rest is returned to the hydrological system as wastewater. Mateo-Sagasta et al. (2015) indicate that, based on compiled empirical records, globally more than 330 km^3 per year of mostly municipal wastewater are produced. Moreover, it is estimated that high-income countries on average treat 70% of the generated wastewater, followed by upper-middle-income countries (38%), lower-middle-income countries (28%), and low-income countries, where only 8% of the wastewater generated is treated (Sato et al., 2013).

One of the most complete surveys was done by Jiménez & Asano (2008). This study reports the use of wastewater for different applications. By far, agriculture is the most important user in terms of volume, basically because the activity is the main water user globally, followed by the industrial and domestic sector. In developing countries, wastewater is mostly used by the agricultural sector; in contrast to developed countries where wastewater reuse is oriented towards the industrial sector. The share of agricultural wastewater reuse is higher in the Middle East, North Africa and Sub-Saharan Africa (more than 80%) compared to other regions (Figure 1-2).

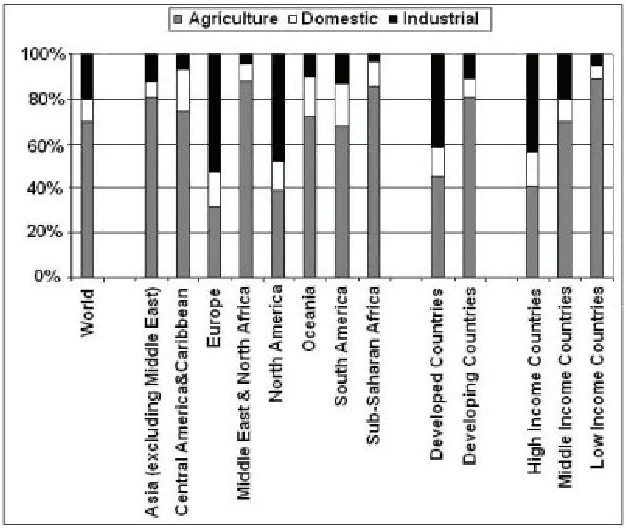


Figure 1-2 Water reclamation and reuse worldwide, water withdrawals by sector in 2006.

Source: Jiménez &Asano (2008).

The Middle East and North Africa have the largest number of water stressed countries; therefore, the main driver for reuse seems to be water scarcity. There are important differences among countries in the region, e.g. high income countries have water reuse schemes for agricultural and landscape irrigation, with high water quality standards, and use reclaimed water for uses with high water demand. In contrast, middle-low income counties in the same region reuse partly or untreated wastewater for agricultural irrigation, following the WHO guidelines. In Sub-Saharan Africa there is limited information on reuse practices, wastewater reuse is driven by water scarcity and lack of sanitation; wastewater is appreciated for its nutrient content and as a reliable source of water (Jiménez & Asano, 2008).

In Asia there is substantial variation in terms of water availability; many highly populated cities are situated in water stressed regions. Water reuse is driven by water scarcity; lack of sanitation; demand in highly populated areas; and by international political pressure such as in the case of Singapore. There, some countries reuse wastewater for agriculture and aquaculture; others reuse water for municipal and industrial purposes (Japan and Korea). Municipal reuse is mainly for low water quality activities, e.g. toilet flushing. In Singapore wastewater is reused for human consumption (Jiménez & Asano, 2008).

Latin America is a water rich region; however, there are water stressed areas, e.g. Mexico, and some parts of Central America and South America. Water reuse is driven by the interest in recycling nutrients contained in the wastewater in areas with poor soil conditions, lack of sanitation that makes sewage available for irrigation, and water scarcity in water stressed areas. Wastewater used in agricultural irrigation is mostly untreated, and it is appreciated by farmers due to its supply reliability, its nutrient content, and its low (or zero) cost. Most counties in this region theoretically follow the WHO guidelines for quality standards, but they have problems implementing them. Public policies aim to control unplanned reuse of wastewater rather than promote planned reuse (Jiménez & Asano, 2008).

Jiménez & Asano (2008) point out that it is difficult to establish the main countries reusing wastewater for two reasons: 1) reuse is measured differently in different countries, and most important 2) total country values can hide the importance of reuse at local level. Nevertheless, Jiménez & Asano (2008) report a list of countries with figures on wastewater reuse (treated or not) based on different criteria. They acknowledge that these figures are uncertain, especially for untreated wastewater, because censuses are rarely performed with respect to these informal practices or figures may be hidden for political or economic reasons. Table 1-1 presents figures on the use of wastewater under three different criteria to provide an overview of the quantity of wastewater used in different countries.

Table 1-1 Countries reusing wastewater (figures under three different criteria)

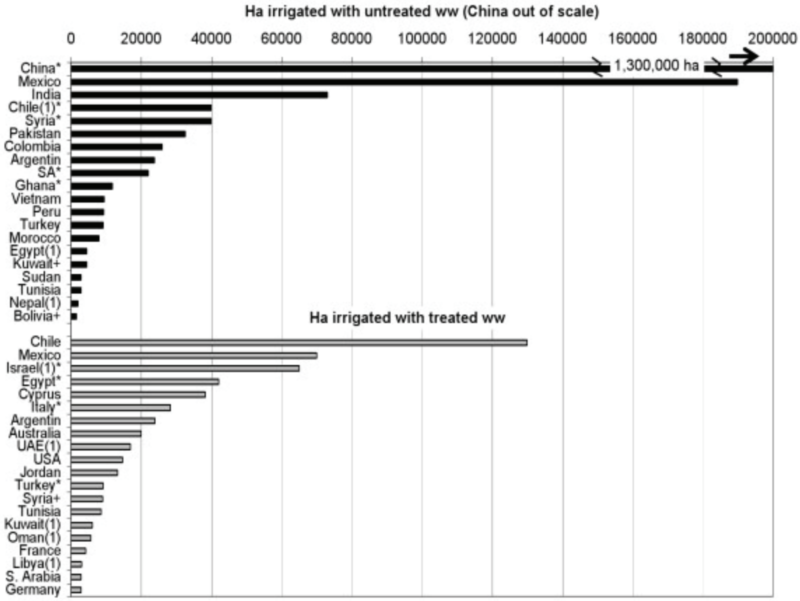
Rank	Country	Total reuse in m^3/d	Country	Reuse in m^3/d per million capita	Country	Reuse/ extraction in %
1	China	14,817,000	Qatar	170,323	Kuwait	35.2
2	Mexico	14,400,000	Israel	166,230	Israel	18.1
3	USA	7,600,000	Kuwait	163,330	Singapore	14.4
4	Egypt	1,920,000	Mexico	136,235	Qatar	13.3
5	Saudi Arabia	1,847,000	UAE	126,713	Cyprus	10.4
6	Syria	1,014,000	Cyprus	88,952	Jordan	8.1
7	Israel	1,014,000	Saudi Arabia	75,081	UAE	8.0
8	Chile	840,600	Bahrain	56,301	Malta	7.8
9	Spain	821,920	Syria	55,109	Tunisia	7.1
10	Japan	573,800	Chile	52,211	Mexico	6.7
11	Tunisia	512,328	Tunisia	51,233	Saudi Arabia	5.5
12	UAE	506,850	Jordan	40,179	Namibia	4.3
13	Peru	505,100	Malta	27,400	Bahrain	4.2
14	Australia	456,100	Oman	27,385	Chile	2.4
15	Iran	455,700	Egypt	26,301	Oman	1.9
16	Korea, Rep.	430,000	USA	25,486	Syria	1.9
17	Kuwait	424,657	Australia	22,805	Bolivia	1.1
18	Iran	422,000	Spain	20,436	Egypt	1.0
19	Jordan	225,000	Namibia	19,733	Libya	0.9
20	Turkey	136,986	Libya	18,966	Peru	0.9

UAE: United Arab Emirates

Source: Jiménez & Asano (2008). The original table ranks up to 47 countries, here only the first 20 are presented.

The agricultural land where wastewater (raw or partly diluted) is used for irrigation was estimated at 20 million ha (Scott et al., 2004a). According to Scott et al. (2004a, p. 6), this figure has generated different reactions, e.g. 1) this figure is an overestimation of ‘raw sewage irrigation’ considering that it includes areas irrigated with partly diluted wastewater; 2) wastewater irrigation is not a sufficiently important phenomenon to warrant resources for research and management; 3) the magnitude of the problem is greater than that implied by the figure; and 4) wastewater irrigation is pervasive and represents a major concern, which is not enough reflected in isolated case studies.

The largest user – in terms of land irrigated, is China with 1,300,000 ha irrigated with ‘untreated’ wastewater, followed by Mexico and India, with approximately 190,000 and 70,000 ha, respectively. Chile has the largest area irrigated with ‘treated’ wastewater with approximately 130,000 ha, followed by Mexico and Israel, with approximately 70,000 and 65,000 ha, respectively (Jiménez & Asano, 2008) (see Figure 1-3). Worldwide, some 200 million farmers are engaged in urban agriculture, often using poor-quality irrigation water (Qadir et al., 2010a).



Note: Information may vary from source to source. Some countries report agricultural wastewater use without mentioning the amount of hectares involved.
*Data are confusing.
+No data are available, although the practice is reported.
(1)Surface might be greater.

Figure 1-3 Countries reporting largest areas irrigated with treated and untreated wastewater

Source: Jiménez & Asano (2008).

1.2.2 Main problems related to the use of wastewater

Research on wastewater reuse is dominated by work on health risks (e.g., Drechsel et al., 2010; IWMI, 2006; Ensink, 2006; Scott et al., 2004b). The purpose of this section is to provide a brief overview of the problems related to the use of wastewater, without digging into detailed information, for which a vast literature exists.

The main problems related to the use of wastewater in agricultural irrigation are concerned with health and environmental risks. Untreated wastewater or polluted water overall represents risk to human health as it may contain excreta-related pathogens (viruses, bacteria, protozoan and parasites), skin irritants, toxic chemicals and pesticides. When wastewater is used for irrigation of crops, pathogens and some chemicals are the main risks to human health by exposure through different routes. Exposure routes are mostly contact with wastewater (farmers, field workers and nearby communities) and consumption of products irrigated with wastewater (consumers). However, contamination can also occur due to poor post-harvest handling that can lead to cross-contamination of farm produce (Bos et al., 2010). In Table 1-2, the health risks associated with wastewater use in agriculture are listed including their relative importance.

Table 1-2 Health risks linked to wastewater use in agriculture (in developing countries)

Hazard	Exposure route	Relative importance
Excreta-related pathogens		
Bacteria (e.g., *E.coli*, Vibrio cholera, *Salmonella* spp. *Shigella* spp.)	Contact; consumption	Low-high
Helminths (parasitic worms)		
• Soil-transmitted (*Ascaris*, hookworms, *Taenia* spp.)	Contact; consumption	Low-high
• *Schistosoma* spp.	Contact	Nil-high
Protozoa (*Giardia intestinalis, Cryptosporidium, Entamoeba* spp.)	Contact; consumption	Low-medium
Viruses (e.g., hepatitis A, hepatitis E, adenovirus, rotavirus, norovirus)	Contact; consumption	Low-high
Skin irritants and infections	Contact	Medium-high
Vector-borne pathogens (*Filaria* spp., Japanese encephalitis virus, *Plasmodium* spp.)	Vector contact	Nil-medium
Chemicals		
Heavy metals (e.g., arsenic, cadmium, lead, mercury)	Consumption	Generally low
Halogenated hydrocarbons (dioxins, furans, PCBs)	Consumption	Low
Pesticides (aldrin, DDT)	Contact, consumption	Low

Source: Bos et al. (2010) adapted from WHO (2006).

Due to the duration and intensity of contact with wastewater and polluted soils, farmers and farm workers are the most affected groups (WHO, 2006). Epidemiological studies of farmers using wastewater have produced important evidence of the high risk of helminth infections, which resulted in the strict WHO guideline value of ≤1 egg/l of irrigation water (Bos et al., 2010). More recent epidemiological studies conducted among rice farmers using wastewater found more evidence for increased diarrhea and skin problems than for risks of helminth infections (Trang et al., 2007a; 2007b). Bos et al. (2010) argue that some contradictions may occur between actual health risks and perceived health risks. This is because farmers may not associate infections and diseases with the use of wastewater (Rutkowski et al., 2007). This aspect can jeopardize efforts for the adoption of health risk reduction measures; at the same time, it highlights the need to educate farmers about the risks of using wastewater (Bos et al., 2010).

Health protection measures for farmers include: 1) treatment options pre-farm in municipal wastewater treatment plants (e.g., stabilization ponds, constructed wetlands), and on farm treatment systems (e.g., sedimentation traps, tanks, ponds, sand-filters); 2) post-treatment or non-treatment options on farm through the use of protective clothing (gloves and footwear), safer application of wastewater (e.g., low-cost drip irrigation, splash reduction, reduced helminth egg uptake from sediments), this last part also protects the consumers (Bos et al., 2010). Protective measures for consumers include post-treatment or non-treatment options 1) on farm, imposing a minimum period of time before the last irrigation and the harvest to promote pathogen die-off; 2) crop restriction, to exclude crops eaten raw or grow only non-edible crops; 3) off farm or post-harvest, produce-washing, disinfection, peeling, cooking (Bos et al., 2010).

Besides the pathogenic risks, the use of wastewater can present other potential risks, e.g. excessive addition of nutrients to the soil; build-up of salts in the soils (depending on the water source, mainly sodium salts); increased concentrations of metals and metalloids (mostly where industries are present) reaching phytotoxic levels over the long term; and accumulation of emerging contaminants (e.g., residual pharmaceuticals) (Qadir & Scott, 2010). Wastewater – depending on the source from which it is produced – can contain different types and levels of undesirable constituents. Domestic wastewater generally contains high levels of pathogens, and residues of detergents and soaps, which makes it alkaline. In contrast, industrial wastewater usually contains higher levels of contaminants – metals and metalloids, and volatiles and semi-volatiles compared to domestic wastewater, hence it requires treatment before disposal or use. In most developing countries, wastewater is a mix of domestic and industrial effluents; the composition of raw wastewater hence depends on the type and numbers of industries and the characteristics of their effluents (Qadir & Scott, 2010). Table 1-3 presents the main non-pathogenic constituents of wastewater and their possible implication for crop production and the environment, including soil and groundwater pollution, and aquatic habitat deterioration.

Table 1-3 Non-pathogenic wastewater constituents and possible implications

Constituent	Positive implication	Negative implication	Geographical occurrence
Macronutrients: nitrogen (N), phosphorus (P), potassium (K)	• Zero or minimal need for chemical N, P and K fertilizers • N supplied through wastewater helps in crop establishment in early growth stages, by mitigating the negative effect of excess salts added through wastewater or present in the soil • P added to the soil through wastewater helps in crop establishment throughout the growth period • Optimal level of K helps in crop maturity and quality, and in mitigating effects of excess salts	• Excess N applied through wastewater may lead to excessive vegetative growth, delay in crop maturity, and low economic yield • Excess N and P in wastewater can cause eutrophication of water bodies and irrigation systems, undesirable algae-growth, periphyton attached algae and weeds • Leaching of N can cause groundwater pollution and methaemoglobinemia (generally in infants) in case of drinking N-rich groundwater (mostly high levels of nitrates, NO_3) • P can accumulate in the soil where it is immobile	Mainly in developing countries, where wastewater has high organic content (from domestic and food-processing sources) and is used in untreated, partly treated and diluted form
Total dissolved solids (TDS) and major ionic elements: sodium (Na), calcium (Ca), magnesium (Mg), chloride (Cl), boron (B)	• Ca supplied through wastewater improves soil structure and counterbalances the negative effects of accompanying high concentrations of Na and Mg • High electrolyte concentration, resulting from Ca salts, improves hydraulic properties of low permeability soils	• Excess Na and Mg can cause deterioration of soil structure and undesirable effects on hydraulic properties e.g. infiltration rate and hydraulic conductivity • Excess salts impact plant growth through osmotic effects • Specific ion effects from Cl, B and Na possible, including phytotoxicity • Deterioration of water quality of natural surface-water bodies receiving wastewater or drainage from wastewater-irrigated land • Salt leaching into groundwater	Mainly in arid and semi-arid areas with high primary salinity, where large-scale wastewater irrigation is practiced, and agricultural drainage is either non-existent or non-functional, or where saline drainage water is reused in irrigation

Metals and metalloids: cadmium (Cd), chromium (Cr), nickel (Ni), zinc (Zn), lead (Pb), arsenic (As), selenium (Se), mercury (Hg), copper (Cu), manganese (Mn)	• Zero or minimal need for micronutrient fertilizers supplying essential metals ions such as Cu, Zn, Fe and Mn	• Excess levels in irrigated soils and the environment may reach phytotoxic levels • Systemic uptake by crops, mostly those consumed by humans and animals • Possible toxicity in humans and animals • Possible contamination of groundwater under highly permeable and shallow water table conditions	Mainly in rapidly industrializing regions, like south and southeast Asia, where industrial effluent is often mixed with domestic effluent. In Africa more localized e.g. near mining areas or tanneries
High organic matter content, suspended solids and algal particles	• Organic matter added through wastewater improves soil structure; enhance cation exchange capacity and bind, and gradually releases essential nutrients for crop growth • Organic matter may also hold some undesirable metal ions rendering them in less available form for plants • Can contain nutrients	• Plugging of micro irrigation systems such as drippers and sprinklers • Hypoxic conditions due to depletion of dissolved oxygen in water • Possible occurrence of septic conditions • Possibility of increased mortality in fish and other aquatic species	Mainly in developing countries, where wastewater that is high in food, industrial and/or organic content is used in untreated or partly treated form
Emerging contaminants (residual pharmaceuticals, endocrine disruptor compounds, active residues of personal care products)	• Only limited evidence of possible uptake by crops and the food chain, especially in developing countries where use of pharmaceuticals and personal care products is lower than in developed countries	• Possible contamination of groundwater with emerging contaminants and other contaminants, particularly under highly permeable and shallow water table conditions	Mainly in developed countries or where industries release residual pharmaceuticals, endocrine disrupting compounds and active residues of personal care products into wastewater without treatment

Source: Qadir & Scott (2010).

1.3 Problem statement

Increasing pressure on water resources, resulting from climate change, population growth and pollution of water sources affects across countries. Wastewater is a potential source to deal with water scarcity, especially for the agricultural sector (the largest water user). Yet wastewater is also a risk for public health and the environment, due to its content of pathogens and other pollutants. The use of wastewater for irrigation is often unplanned and informal, mainly in the developing world. Few countries include wastewater use in their policies; if they do enforcement barely happens. Given the potential of wastewater in terms of water availability and nutrient content, along with the risks associated, there is a need to move away from informal towards formal use of wastewater in order to protect public health and the environment, and to integrate wastewater use in the larger context of water resources management. This requires research on the institutional settings and analysis of the processes that countries followed along the trajectory from informality to formality, as well as understanding of the farmers' perspective regarding wastewater reuse. A comparative research is here proposed to fill the existing gaps between practices and policies, and so to contribute to the overall water resources management.

1.4 Conceptual framework

1.4.1 Defining wastewater: benefits and threats, and drivers behind the use of wastewater

The rapidly-increasing urban population in developing countries brings along a variety of socioeconomic problems. In 2000, the UN Millennium Development Goals (MDGs) identified water and the access to it as key to address some of these problems, for instance poverty alleviation (WHO, 2012a). Obviously, these goals are closely related to water management as they aim at increasing the proportion of people with adequate access to safe drinking water and basic sanitation, and reducing the proportion of people who suffer from hunger (UN, 2010). This implies, however, increasing flows of polluted water from the cities to downstream areas (Huibers & van Lier, 2005). In most urban areas water is discharged after use to the water receptors as 'wastewater' with little or no treatment. Farmers in peri-urban and rural areas use wastewater for irrigation deliberately or often because they have no other choice (Drechsel & Evans, 2010; Qadir et al., 2010a).

The use of treated or untreated wastewater for agriculture is already a reality in different parts of the world especially in peri-urban areas due to the proximity to the source (Bahri, 1999; van der Hoek et al., 2002; Scott et al., 2004a; Jayakody et al., 2007; Jiménez et al., 2010). This is not a new practice as it has been performed worldwide for many years, for instance in northern European and Mediterranean civilizations during the 14th and 15th Centuries (Soulié & Tréméa, 1991 in Jiménez et al., 2010) or in developing countries like China, Mexico, Peru, Egypt, Lebanon, Morocco, India and Vietnam as a source of nutrients for crops (Jiménez & Asano, 2008). Over the years this practice has become less accepted in the developed world, basically due to the awareness of environmental and health issues associated with it and the availability of new technology for water treatment. In the developing world by contrast, it has remained and even expanded (Jiménez et al., 2010; Drechsel & Evans, 2010).

Wastewater in agriculture is perceived as both beneficial and as a threat to public health and the environment (Raschid-Sally & Jayakody, 2008; Abaidoo et al., 2009). The benefits associated to wastewater include: its spatial and timely reliability of supply; its content of nutrients [e.g., nitrogen (N), phosphorus (P) and potassium (K)] (Scott et al., 2004a; Martijn & Redwood, 2005); the opportunity to grow cash crops and therefore to increase the household income; and the ability to supply cities with perishable food (Raschid-Sally & Jayakody, 2008; Weldesilassie et al., 2011). The threats associated to wastewater include: negative impacts on the health of farmers and consumers of wastewater-irrigated crops, due to the presence of pathogenic organisms and non-organic pollutants (van der Hoek et al., 2002; Raschid-Sally & Jayakody, 2008; Qadir et al., 2010a) (see Drechsel & Seidu, 2011 for a quantitatively estimation of health effects of wastewater-irrigated crops in Ghana). The environmental risks associated include: accumulation of heavy metals and effects on the fate of organics in soils; impacts on catchment hydrology including transport of salts; microbial contamination risks for surface and groundwater; and transfers of chemical contaminants from soil to crops (Hamilton et al., 2007).

The main drivers to use wastewater vary according to the different regions and along the sanitation ladder[5] (Drechsel & Evans, 2010). In general, there is a combination of the following factors: 1) a limited capacity of cities to treat their wastewater (polluting soils, water bodies and traditional irrigation water sources), 2) a lack of alternative (cheaper, equally reliable, available or safer) water sources, and 3) urban food demand and market incentives favoring food production in the proximity of cities (Raschid-Sally & Jayakody, 2008; Jiménez et al., 2010). Additionally, socio-economic factors at household level such as poverty, low education levels, lack of job opportunities, and limited awareness of health risks influence the practice (Jiménez, 2006).

The literature presents a variety of definitions of 'wastewater' depending on the quality or source of origin of the water. Herein the focus is on 'urban wastewater' which "[…] is usually a combination of one or more of the following which makes it polluted water:

- Domestic effluent consisting of black water (excreta, urine and fecal sludge, i.e., toilet wastewater) and greywater (kitchen and bathing wastewater);
- Water from commercial establishments and institutions, including hospitals;
- Industrial effluent where present;
- Storm water and other urban run-off" (Jiménez et al., 2010, p. 4 modified from Raschid-Sally & Jayakody, 2008).

When treated, it means that wastewater "[…] has been processed through a wastewater treatment plant up to certain standards in order to reduce its pollution or health hazard; if this is not fulfilled; the wastewater is considered at best as partially treated". In addition, "reclaimed (waste) water or recycled water is treated wastewater that can

[5] The sanitation ladder is a tool to monitor progress towards the sanitation target of the MDGs (see: http://www.wssinfo.org/definitions-methods/watsan-ladder/).

officially be used under controlled conditions for beneficial purposes such as irrigation […]" (Jiménez et al., 2010, p. 4).

1.4.2 Shifting realities in water management: towards the use of wastewater in agriculture

Wastewater for agriculture is a growing alternative to deal with pressure on water resources, especially in water scarce regions (Qadir et al., 2007a; Scheierling et al., 2010), as it reduces the amount of water extracted from the environment and traditional water sources for irrigation (Toze, 2006). However, considering that polluted water enters water receptors often without treatment, farmers downstream have no choice but to irrigate with polluted water, which implies that the use of wastewater is not necessary related to the overall level of water scarcity in the region, and certainly not restricted to arid and semi-arid countries (Huibers & van Lier, 2005).

Given the benefits and risks associated with wastewater, there is a need to shift the conventional water chain use by introducing concepts such as the 'reuse of water'. In effect, it is a promising mechanism to achieve greater efficiencies in water use that otherwise would be discarded into the environment (Toze, 2006). Yet the constraint is the quality of water. Wastewater applied in agriculture implies, however, less rigorous treatments (Toze, 2006; Haruvy, 1997) compared to that of drinking water, and therefore less costly. This favors developing countries that find difficulties in financing drinking water and sanitation infrastructure, and where a comprehensive wastewater collection and treatment seems like a long-term strategy (Qadir et al., 2010a; Fraiture et al., 2010; Drechsel & Evans, 2010).

Jiménez et al. (2010) differentiate between planned and unplanned use of wastewater. They refer to planned use as that one which tries to address physical water scarcity, whereas unplanned use results from poor sanitation. This is fundamental since they require different management approaches (Jiménez et al., 2010). Planned wastewater reuse is becoming more important for two reasons: the discharge of effluents into surface water bodies is increasingly difficult and costly, as treatment regulations are more rigorous to protect the quality of receiving water bodies for aquatic life and downstream users. Moreover, the cost of treatment can be so high that it may even become attractive for municipalities to treat their wastewater for local reuse rather than for discharge. The second reason is that wastewater is a potential water source that can be used for several non-potable purposes for instance: irrigation, industrial uses (cooling, processing), environmental enhancement (wetlands, wildlife refuges, riparian habitats, urban lakes), firefighting, dust control, toilet flushing, etc. (Bouwer, 2000).

Shifting realities towards reuse of water is certainly not clear-cut. Wastewater reuse for agriculture is a complex socio-technical issue, as it comprises a range of different elements such as food production, water quality and treatment, hydrology, health issues, socioeconomic issues including consumers and overall environmental risks, as well as an institutional framework with many stakeholders with different interest and responsibilities (Huibers & van Lier, 2005). Regardless the type of wastewater use (planned or unplanned) both offer socioeconomic benefits, but also institutional challenges, which require different management approach and guidelines (Jiménez et al., 2010). Very few countries have guidelines related to irrigation with wastewater, and even if guidelines exist, enforcement by authorities barely happens (Raschid-Sally & Jayakody, 2008). The WHO Guidelines (2006) is a step forward to rapidly address environmental and health impacts associated to the use of wastewater in irrigation, which include user and consumer health protection at farm level, post-harvest measures, and public policies to motivate appropriate management of wastewater (Qadir et al., 2010a; Fraiture et al., 2010).

1.4.3 The focus on the agricultural sector, and the economic value of wastewater

The agricultural sector is central for the analysis of wastewater reuse, and the institutional challenges associated to it. As previously mentioned, a benchmark in water management was the recognition of water as an 'economic good'. The question here is not "whether water is an economic good or not (it certainly is), but rather the extent to which water allocation and use can be guided by market forces or requires some extra management to serve social objectives" (Hellegers & Perry, 2004, p. 11). From an economic perspective, water is a production factor (an input in the agricultural production system), which increases farmers' set of choices in terms of available crops and processes (Bazzani, 2005). Moreover, increased yields increase the water's economic value (Ward & Michelsen, 2002). Qadir et al. (2010a) stress the increasing productive use of wastewater as a result of the growing population. In effect, for millions of poor households wastewater is an important resource used in profitable yet informal production systems, which supply food to urban areas (Scott et al., 2004a; Drechsel et al., 2006). The use of wastewater represents, therefore, livelihood support for farmers (Huibers & van Lier, 2005) and at the same time, it offers possibilities to reduce poverty as it represents opportunity for cash crops production and increased food supply (Jiménez et al., 2010). Having said this, herein it is acknowledged that wastewater can be deemed as an 'economic good', and therefore has an economic value. However, as indicated by Hellegers & Peters (2004), the associated management should also serve social objectives. This is important mainly because wastewater represents for small-scale and poor farmers livelihood security (Scott et al., 2004a; Huibers & van Lier, 2005).

1.4.4 The pillars of water governance

In developing countries, peri-urban agriculture, also known as 'urban agriculture' or 'urban farming' is mostly a marginalized activity without formal recognition of, for instance, water rights (Martijn & Redwood, 2005). In some cases, it is even forbidden with limited regulations resulting in an unofficial accepted practice, as for instance in

West Africa (Drechsel et al., 2006). Conventional water management systems consider only primary users as being entitled and burdened with water rights either formal or informally. Nevertheless, once reuse of wastewater is in place and once the benefits are acknowledged, it becomes difficult to alter users' behavior, especially if the use involves costs or it is linked to historical rights (Jiménez et al., 2010).

A shift towards the use of wastewater calls for expansion of the whole water chain concept. For public agencies in developing countries, the primary challenge related to wastewater use is to determine the appropriate scale at which treatment is possible and feasible (Huibers & van Lier, 2005; Martijn & Redwood, 2005; Qadir et al., 2010a). As Qadir et al. (2010a) point out the optimal treatment strategy depends on the economic and institutional capacities, wastewater sources and constituents, and should consider the requirements of reuse rather than focusing on standards which are difficult to maintain (Emongor & Ramolemana, 2004; Fine et al., 2006; Tidåker et al., 2006). At the national level, most developing countries have done little regarding the use of wastewater for irrigation; an exception is Tunisia that has largely included wastewater in its water governance structure or China (see Funamizu et al., 2008). Brazil, Mexico and Chile also mention water reuse within their water policy and legal framework (see Jiménez, 2008), or Peru that not long ago included wastewater reuse for urban irrigation purposes and plans to expand to agriculture (GWI, 2010a). As a way to cope with these circumstances, the new WHO guidelines (2006) aims at addressing wastewater reuse in agriculture by providing a framework that supports the establishment of national standards and regulations, taking into account the different levels of economic development of the countries (Scheierling et al., 2010). This new version is based on risk assessment and management approach. It is more flexible in terms of water quality standards and aims at balancing the risks and livelihoods (Scheierling et al., 2010).

In most developing countries, however, water governance structures are rather complex and face several problems (institutional, financial, legal, hydrological, etc.). There is no general agreement on what is meant by 'water governance' or how to set 'good governance' practices, different approaches take into account different elements as for instance questions of financial accountability and administrative efficiency, political concerns related to democracy, human rights and participatory processes, match between politico-administrative and ecological systems or in terms of operation and management of services (Rogers & Hall, 2003, p. 7). For further analysis, however, 'water governance' will be conceptualized as "the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society" (GWP, 2002).

1.4.4.1 Water institutions

Institutions are central to the broad concept of water governance. Water institutions or institutions that deal with water policy, law and administration are for instance ministries, national water boards, water users associations (WUAs) or rural communities that self-manage their water systems (e.g., community-managed irrigation systems). Scholars use different definitions regarding institutions each emphasizing the different aspects that characterize institutions.

Nabli & Nugent (1989, p. 1335) distinguish the following aspects: "(a) organizational, i.e., the extent to which organizations and institutions coincide, (b) formal, (c) created at a specific time and place by a specific means, as opposed to having evolved from more diffuse sources, (d) embedded in, as opposed to differentiated from, other institutions, (e) universal, as opposed to particularistic, in the interests they serve, (f) creating, as opposed to simply maintaining, a certain public good, and (g) technology linked". In line with the institutional economics, institutions are collective action in control, liberation and expansion of individual action. Collective action ranges from unorganized custom to organized concerns. Collective acts establish relations of rights (no rights) and duties (no duties) by means of working rules. Working rules are in continuous change and they are different for different institutions, but they indicate what individuals can, must, or may do or not do enforced by collective sanctions (Commons, 1931, p. 649 – 650). Moreover, individual actions are transactions instead of individual behavior or exchange of commodities, which marks the shift from commodities and individuals to transactions and working rules (Common, 1931, p. 651 – 652).

The new institutionalism also emphasizes rules in institutions and defines institutions as "general regularities in social behavior" (Schotter, 1981, p. 11) or "the rules of the game in society or… the humanly devised constraints that shape human interaction" (North, 1990, p. 3) or "the rules of a society or of organizations that facilitate coordination among people by helping them form expectations which each person can reasonably hold in dealing with others" (Ruttan & Hayami, 1984, p. 204 in Nabli & Nugent, 1989) or institutions as "a set of constraints which governs the behavioral relations among individuals or groups" (Nabli & Nugent, 1989, p. 1335). Hodgson (1998, p. 172) highlights the fact that institutions have a certain degree of invariance over long periods of time and outlast individuals. Concurrently, Uphoff (1986, p. 9 in Nabli & Nugent, 1989) also refers to institutions as "[…] complexes of norms of behavior that persist over time, by serving collectively valued purposes".

Ostrom (1986, p. 5) defines the rules and constraints of institutions as "prescriptions commonly known and used by a set of participants to order repetitive, interdependent relationships. Prescriptions refer to which actions are required, prohibited or permitted. Rules are the result of implicit or explicit efforts by a set of individuals to achieve order and predictability within defined situations by: (1) creating positions (e.g., member, convener, agent, etc.); (2) stating how participants enter or leave positions; (3) stating which actions participants in these positions are required, permitted or forbidden to take; and (4) stating which outcome participants are required, permitted, or forbidden to affect". Moreover, Nabli & Nugent (1989) recognize the importance of considering configurations of rules rather than singles rules separately within the institutional analysis. Finally, institutions are influenced by factors such as historical precedents, constitutional provisions, political arrangements, demographic conditions, resource endowments and economic development (Saleth & Dinar, 1999).

In line with institutional economics, water institutions are more than mere organizations; they set the rules and define the action sets for both individual and collective decision-making in the realm of water resource development, allocation and utilization. Rules are formalized in terms of three inter-related aspects: 1) a legal framework, 2) a policy environment, and 3) administrative arrangements (Saleth & Dinar, 1999, 2000, 2005). Therefore, water institutions are conceptualized as entities defined by its three main components: water law, water policy and water administration/organization [Institutional Decomposition Analysis (IDA) framework] (Saleth & Dinar 1999, 2000, 2005). The IDA framework suggests the analysis of water institutions from a formal perspective or the formal law, policy and administration, excluding the informal dimensions such as customs and administrative traditions (Saleth & Dinar, 1999). In developing countries, however, the use of wastewater often occurs as a marginalized activity (Martijn & Redwood, 2005). Consequently, it is important to also take into account the informal dimension of water institutions for further analysis.

1.4.4.2 Water rights

Water rights are central to water law either formal or informal. The new institutional economics approach considers water rights as institutions themselves that function as source of incentives for individual or group behavior governing water use (Veettil, 2011). Different scholars acknowledge the importance of well-defined water rights for efficient use of water resources (Rosegrant & Binswanger, 1994; Berck & Lipow, 1994; Ahmad, 2000; Ansink & Weikard, 2009; Speelman et al., 2010).

From an economic perspective, the Coase theorem (1960) suggests that if property rights are well established – in this case water rights – and if there are no transaction costs (information search, negotiation, monitoring) an externality can be internalized (Veettil, 2011). On the contrary, if water rights are not well-defined, high transaction costs are created for making decisions over water use (Challen, 2000; Wichelns, 2004; Speelman et al., 2010), externalities remain unresolved, which will ultimately lead to an inefficient outcome (Grafton et al., 2004). Moreover, the lack of well-defined water rights increases vulnerability of the worst-offs (Bruns et al., 2005).

Grafton et al. (2004) distinguish four types of property rights when it comes to natural resources, namely, 1) *private rights*, held by an individual agent or a firm, 2) *community rights*, 3) *state rights* or 4) a mix of all three types. In addition, six characteristics of property rights are emphasized: exclusivity, transferability, duration, quality of title, divisibility and flexibility (Devlin & Grafton, 1998 in Grafton et al., 2004). *Exclusivity* refers to the ability to exclude others to either use or benefit from a flow of benefits derived from the resource or asset. *Transferability* refers to the ability to transfer or alienate the resource or asset or its flow of benefits. *Duration* refers to the time over which the right holder is entitled to use or derive benefits from the resource. *Quality of the title* refers to the extent that the right is recognized in formal law. *Divisibility* refers to the ability of a right holder to divide the asset of the flow of benefits. Finally, *flexibility* refers to the limitations and obligations attached to the right (Grafton et al., 2004, p. 38).

From a social perspective, water rights are more than a simple relation of access and use of water (Boelens, 2007); they are strongly linked to power relations around water systems (Boelens & Doornbos, 2001; Beccar et al., 2002; Boelens, 2008). Water rights serve to analyze local empowerment processes as water is often the driving force behind common property institutions (Boelens & Doornbos, 2001). Water rights are dynamic institutions modified according to social, political, economic and physical changes. They are in constant (re) negotiation influenced by power relationships (Beccar et al., 2002; Zwarteveen et al., 2005).

Schlager & Ostrom (1992) identify the components of rights in common-pool resources which may include access and withdrawal, management, exclusion and alienation rights. Moreover, Herrera et al. (2004) point out that water rights are a bundle of rights that can be analyzed separately. Beccar et al. (2002, p. 3) add the factor of decision-making and define water rights as “authorized demands to use (part of) a flow of water, including certain privileges, restrictions, obligations and sanction accompanying this authorization, among which a key element is the power to take part in collective decision-making about system management and direction”. The right is granted by law either formal (State law) or informal (local agreements). Boelens & Doornbos (2002, p. 218) distinguish for the Andean region different mechanisms for obtaining water rights, which can also be extrapolated to other contexts of the developing world:

- “A water-usage rights concession: granted by the State administration to individuals or groups of applicants;
- Historic acquisition and socio-territorial rights: entitlement to water based on recognized claims in history, and/or allocation to the inhabitants of the socio-territory to which the water source ‘belongs’; riparian rights (based on the possession of land with a water source, or located along a stream) and prior appropriation rights (based on ‘first come, first served’ claims) are specific forms of these rights access mechanisms;
- Agreement to permanent transfer or carry-over of water rights from one right-holder to another (e.g., through sale, inheritance, marriage, donation, etc.);
- Acquisition by force: in several regions of the world, powerful groups have expropriated peasants’ and indigenous people’s water rights by coercive means;

– User investment of their own resources (e.g., labor, capital, goods, time, intellectual and ritual contributions) to build and/or rehabilitate the infrastructure of the system, therefore creating water rights".

Finally, although such mechanisms are not always in line with formal law, they often occur in developing countries; particularly in areas where the State has little access or when an activity is marginalized. Modern water rights include the following key features: 1) the description of the volume of water that applies to the right, 2) the duration of the right, 3) the number and content of conditions attached to the right, and 4) the mechanism that guarantees the security of the right (Hodgson, 2006).

1.4.4.3 Water policy

As water is of interest to the entire population and the different institutions at national and regional level, and water problems are increasingly complex, it can no longer be viewed in isolation (Biswas, 2001). In this sense, water policies are often interrelated to other policies for instance agricultural, energy, industry, environment, health, fiscal and trade policies (Saleth & Dinar, 1999, 2000; Biswas, 2001). Policy is defined in its broader sense as "a course or principle of action adopted or proposed by an organization or individual" (Oxford Dictionary). From the perspective of decision theory, Ciriacy-Wantrup (1967, p. 179) conceptualizes water policies as "a set of decision rules in a multistage decision process. In this process, a sequence of decisions extends over time and space in an 'open' system". Moreover, he refers to the need of studying the characteristics of water resource systems with which water policy is concerned.

During the 19th and 20th century, water resources development strongly focused on public development of surface water through dams, canals, and other hydraulic structures (Ciriacy-Wantrup, 1967). Scholars refer to this as the 'hydraulic mission' (see e.g., Wester, 2009; Wester et al., 2009; Molle et al., 2009). Based on the ideology of domination of nature, 'stirred by the colonial hydraulic feats and fueled by the technological improvements', in the words of Molle et al. (2009), large-scale water resources development characterized the 20th century. During this time, water resources development was centralized in powerful State water bureaucracies (Molle et al., 2009). These developments, however, were not always successful and by contrast bared failures in the sector, which revealed that water problems are multi-dimensional and muti-sectoral, and can only be solved by proper multi-institutional and multi-stakeholder coordination (Biswas, 2004). In the 90's a 'new' paradigm was introduced, which advocated for the integrated water resource management (IWRM). Although still ambiguous and difficult to be implemented (Biswas, 2001, 2004), IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000). It also suggests that to achieve effective water management the planning unit is the watershed (Newson, 1997; Grigg, 2008; Hoekstra, 2011).

Many countries around the world have engaged in the paradigm of IWRM and it is made explicit in their water policies, for instance the EU Water Framework Directive (EC, 2012) or South Africa's National Water Resource Strategy (DWAF, 2004a). The concept by default should also consider the introduction of wastewater management (see Bouwer, 2000). Biswas (2001) points out the importance of having rational national water policies – different to those from the 20th century – in order to deal with water problems. Saleth & Dinar (1999, p. 9) identified the following key aspects of water policy:

- Use priority
- Project selection criteria
- Cost recovery/pricing
- Water transfers (inter-regional/inter-sectoral)
- Decentralization/privatization
- Users participation
- Technology

Summarizing, water policy is essential for water management. As Wichelns (2004) indicates for the irrigation sector, policy is a necessary condition for achieving meaningful and sustainable improvements in water resources management.

1.4.4.4 Water administration/organization

Quoting Saleth & Dinar (1999, p. 8), "although water law and water policy are related, it is difficult to establish whether water law precedes or succeeds water policy […]. But, in any case, neither of them can be effective without the other in view of their mutual feed backs and adjustments occurring through time. Under ideal conditions, water law empowers water policy and water policy, in turn, provides a political economy translation for water law. Taken together, they define the framework and determine the capacity of water administration that actually implements the legal and policy provisions at the field level. […] water law and water policy form the software component of water institution whereas water administration forms as the hardware component of water institution".

Different approaches are found regarding water administration/organization, for instance, a top down approach with centralized water control, which mainly characterized water management along the hydraulic mission (see Wester et al., 2009 for an example in Mexico), or a more participatory approach founded on WUAs. This approach resulted from past experiences in decentralized water management irrigation systems, proposed as the way to solve problems commonly found in developing countries related to inefficient use of water, unsatisfactory performance of maintenance of physical infrastructure, and inadequate capacity to mobilize financial resources for investments in the irrigation systems. So the State would transfer the responsibilities of water management to the users grouped in WUAs (e.g., Hunt, 1989; Wester et al., 2003; Yercan, 2003). This is known as the irrigation management turning-over from the State to the users, or irrigation management transfers (IMT). Scholars largely discussed whether this approach captures the essence of participation, or whether it can be considered as the way to successful water management (e.g., Meinzen-Dick & Zwarteveen, 1998; Wester et al., 2003; Wegerich, 2008). In any case, WUAs are strongly linked to the IWRM paradigm.

Wastewater management and how it should be organized is sometimes not even mentioned in the national policies and laws, and often performed as a side activity with just individuals tapping water. WUAs have the potential to organize water users and management, but attention should be paid to avoid failures especially regarding the quality of water, which requires additional support from an upper-level organization (Smet, 2003). In the words of Smet (2003, p. 2), "WUA is essentially a cooperative and the concept empowers users. They have control over decision-making in planning, implementation, operation, maintenance, management, and financial arrangements". Saleth & Dinar (1999, p. 5) identified the administration-related aspects that should be considered for the organizational component:

- Spatial organization,
- Organizational features,
- Functional capacity,
- Finance (pricing/fee collection),
- Regulatory and accountability mechanisms, and
- Information, research, and technological capabilities.

1.5 The importance of farmers' preferences for wastewater reuse

A key aspect that has been identified for sustainability of water resources management, particularly for irrigation systems, is users' participation in the process of system design and management (World Bank, 2003). Participatory irrigation management (PIM) has been defined as: "the involvement of irrigation users in all aspects and at all levels of irrigation management. 'All aspects' includes the initial planning and design of new irrigation projects or improvements, as well as the construction, supervision, financing, decision rules, operation, maintenance, monitoring, and evaluation of the system. 'All levels' refers to the full physical limits of the irrigation system, up to the policy level in the capital city. Any management function, including the setting of policies, can and should have a participatory dimension to it" (Groenfeldt, 2000, p. 2). A more comprehensive variant of the PIM approach is the Irrigation Management Transfer (IMT) approach (Peter, 2004). IMT implies the relocation of responsibility and authority for irrigation management from government agencies to non-governmental organizations, e.g. water users' associations. It may include all or partial transfer of management functions, and full or only partial authority. On the other hand, it may be implemented at sub-system level, e.g. distributary canal commands, or for the entire irrigation system (Vermillion & Sagardoy, 1999). The PIM approach has emerged as an alternative to improve water use efficiency (Peter, 2004). Furthermore, it was considered that this approach might be more important in contexts of developing countries for the following reasons: 1) Costs: countries incur in high financial and social cost when governments agencies assume irrigation management functions that farmers could handle themselves; 2) Incentives: irrigation users have stronger incentives to manage water productively than the government bureaucracy; and 3) Efficiency: when management is decentralized to users, they can respond more quickly to problems or changes in the system (Groenfeldt, 2000).

Peter (2004) argues that improving water use efficiency can be done at different levels: technical, managerial and institutional level. Technical improvements include advance irrigation methods (e.g., drip, micro drip, sprinklers), conjunctive use of surface and groundwater, use of wastewater and recycled water, and precision agriculture through Supervisory Control and Data Acquisition (SCADA) systems. Managerial improvements include adoption of demand based irrigation scheduling systems and improved equipment maintenance. Institutional improvements may involve establishing water user associations, promoting multi-stakeholder platforms and water rights, introduction of water pricing, and improvements in the legal environment for water allocation (Peter, 2004).

Concerning the use of wastewater in agricultural irrigation, it certainly poses risks to humans and the environment, but it also offers benefits to the farmers, in terms of water reliability or nutrient input. However, in order to propose realistic, effective and sustainable management approaches for wastewater, it is fundamental to understand the context-specific tradeoffs between health risks (for farmers and consumers) as well as the environmental risks (quality of soils and water), and on the other hand, the benefits of wastewater irrigation, the farmers' perceptions, and the institutional arrangements (Scott et al., 2004a). A comprehensive management of wastewater in the long term will encompass treatment, regulation, users' groups, market linkages, and effective public awareness campaigns. Meanwhile, in the short and medium term, it is important to integrate stepwise management options that recognize the fundamental economic niche and the users' perception of comparative advantages of wastewater irrigation (Scott et al., 2004a). The trade-offs of wastewater use vary significantly between sites and regions, hence it is necessary to evaluate the use of wastewater for location-specific characteristics (Qadir & Scott, 2010). Wastewater reuse is indeed a complex phenomenon because it goes beyond the typical sectoral policy and planning boundaries, and it is influenced by perceptions (Evans et al., 2010). Furthermore, planning for wastewater use will require the involvement of a number of government agencies from different sectors (e.g., health, water, sanitation, agriculture and irrigation) as well as communities, researchers, and the private sector (Evans et al., 2010).

Hence, it is only logical to have an interest in understanding the farmers' preferences regarding the use of wastewater, primarily because they are the final users of the water, and secondly because their support is crucial for the sustainability – including financial sustainability, of any planned irrigation system that considers wastewater reuse; but even in unplanned wastewater reuse systems, farmers' insight is important to provide protection to farmers themselves as well as to consumers of produce. Tiongco et al. (2010, p. 129) highlight the importance of understanding awareness, knowledge and perceptions towards risks, and assessing farmers' willingness to pay for or adopt cost-effective risk reduction strategies for making choices as to which measure to adopt. Certainly, understanding farmers' preferences and perceptions can provide important insight knowledge from the users' perspective. This is consistent with the PIM approach, for which users' participation at different levels is central.

1.6 The role of technology in agricultural use of wastewater

Technology is more than just methods or techniques to master nature. In the words of Pfaffenberger (1988, p. 249), technology is "[…] to construct social and economic alliances, to invent new legal principles for social relations, and to provide powerful new vehicles for culturally-provided myths". Moreover, Winner (1986, p. 6) argues that technologies generate "significant alterations in patterns of human activity and human institutions". Technology is therefore essential to policy, as well as to the administrative/organizational component of the institutional analysis. Although it is not the objective here to engage in a philosophical discussion on technology, it is important to acknowledge that "technologies are not neutral artefacts but social constructs" (Hebinck, 2001, p. 122). This is important because very often technology fails to adapt to local realities and, for instance, the objectives of achieving levels of water quality sufficient to protect both public health and the environment are not achieved. Likewise, 'appropriate' technology is fundamental to close the gaps between financial and technical resources in developing countries. In the particular case of agricultural wastewater reuse, technology plays a fundamental role 'to reconcile the need to protect public health with the demand for water and fertilizers from farmers' (Jiménez, 2005).

There is vast literature on technology developed to treat wastewater for different uses including agriculture. An important difference among the various technologies is the costs involved to achieve the different levels of treatment. It is important to keep in mind that often developing countries lack of financial resources to adopt high cost technologies, and if they do, they may fail to encompass such technologies with adequate operation and maintenance (O&M) (van Lier et al., 1998). Therefore, it is fundamental to select technology according to the socioeconomic factors as well as to the climatic and topographic conditions of the area (Bdour et al., 2009). It has been acknowledged herein that wastewater offers opportunities for the agricultural sector in terms of water availability and soil fertilizers; however, one major challenge associated with agricultural use of wastewater – particularly for developing countries – is the adoption of technology that will maximize the efficiency of utilizing limited water and ensuring compliance with health and quality standards (Bdour et al., 2009).

Conventional sewage systems consist of centralized units for collection and treatment of wastewater. These types of systems are costly to build and operate (high capital and O&M costs) (Paraskevas et al., 2002; Massoud et al., 2009). Alternatively, the decentralized systems which combine onsite and/or cluster systems are gaining more attention as they provide flexibility in management and encourage sustainability (Massoud et al., 2009; Libralato et al., 2012). In some cases, however, the shift to decentralized systems is rather difficult, therefore a combination of centralized and decentralized systems at different levels offer potential to improve management of urban wastewater (Libralato et al., 2012). Wastewater treatment technologies range from conventional (e.g., activated sludge and bio-filters) to less conventional (e.g., oxidation ditches, aerated lagoons, natural treatment systems such waste stabilization ponds, and slow rate irrigation, rapid infiltration, and overland flow or constructed wetlands) (Kivaisi, 2001; von Sperling & de Lemos Chernicharo, 2002; Muga & Mihelcic, 2008; Bdour et al., 2009).

Technology should certainly accompany regulations and quality standards of water effluents (e.g., national guidelines or the WHO guidelines). Qadir et al. (2010a) suggest that there are opportunities for improving wastewater management via policies, institutional dialogues and financial mechanisms, which will ultimately reduce the risks associated with the use of wastewater in agriculture. Moreover, they argue that effluent standards combined with incentives can motivate significant improvements in wastewater management. In effect, the use of wastewater in agriculture is gaining important attention as it is nowadays considered a resource (Libralato et al., 2012). Therefore 'there is potential for control, capture and commodification', but at the same time this needs well-functioning treatment systems to provide the quality of water required (Scott & Raschid-Sally, 2012, p. 150).

1.7 Connecting the building blocks

Summarizing, the use of wastewater for agriculture is a growing practice to deal with increasing pressure on water resources mainly in water scarce regions, but also in other regions throughout the world. There are benefits and risks associated to this practice. In developing countries, however, the use of wastewater is not fully integrated into policies and legal frameworks, and the farmers' preferences for wastewater reuse are often overlooked. In the previous sections the main concepts were introduced in order to build up the framework in which this study will be developed, as well as the context for use of wastewater in agriculture was provided. The central elements are a) the type of water in terms of quality – polluted water (treated or untreated) to be reintroduced in the water chain, b) the components of the institutional framework to be addressed, namely water policy, water law and water administration/organization, c) the focus on the agricultural sector, here identified as the sector of analysis due to its relevance at different levels, namely global, national, regional and local, in terms of food security and water use, including the farmers, as central actors, and d) the role of technology for efficient and least-costly wastewater treatment systems. **Hence, the interest here is to analyze the institutional settings for the use of wastewater along a trajectory of development and increasing formalization, i.e. along a ladder from informal to formal governance structures for wastewater reuse.** This will lead to explain the effects or implications – in terms of benefits and costs – of such institutional frameworks on the users in particular and on the society as a whole; as well as to identify the processes that allows the different countries to move from informal to formal structures in given institutional frameworks. The building blocks are presented in the Figure 1-4.

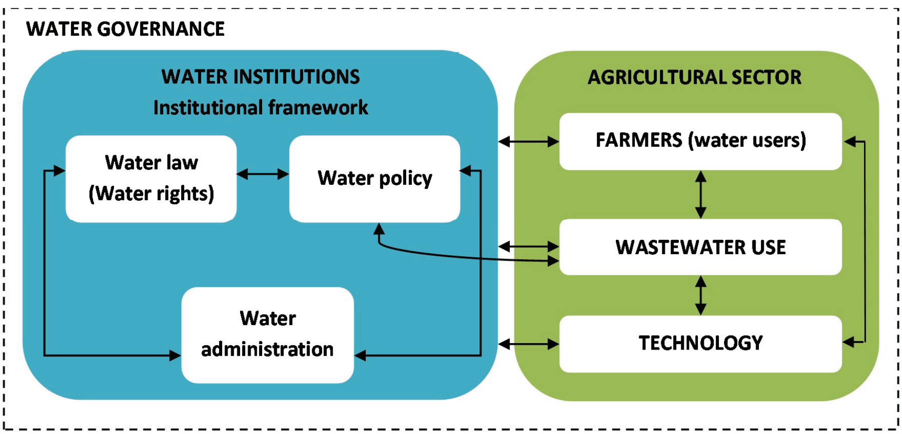


Figure 1-4 Conceptual framework

1.8 Research objective and research questions

1.8.1 Research objective

To provide decision-makers understanding on the incentives and drivers for (step-wise) change of institutional settings that move wastewater use in agriculture from its informality towards a formal, safe and productive reuse, by comparing countries with different governance structures along this trajectory.

1.8.2 Research questions

Research Question 1: How is the institutional setting associated to the use of wastewater in agriculture?

1.1 Where and how is ‘wastewater’ included in the national policy framework (e.g., agricultural, water and sanitation, environmental, health, etc.)?
1.2 Where and how is water and wastewater reuse for agriculture included in the national policy framework?
1.3 How does the current law (including customary laws) and regulations (e.g., on water, agriculture, etc.) address the use of wastewater in agriculture?
1.4 How is the administration/organization regarding the use of wastewater in agriculture?

<u>Research Question 2:</u> How the institutional setting could be changed?

2.1 In countries with formal use of wastewater: How was the institutional setting in the past? How was formalization implemented? What were the drivers and incentives to incorporate wastewater reuse in the policy and regulatory framework? What are the results of formalization?
2.2 In countries with informal use of wastewater: Is there a need for a change of the institutional setting? What are the perceptions on this respect? What issues restrict the development of formal wastewater reuse?
2.3 What are the socioeconomic implications of moving from informal to formal wastewater reuse structures (i.e., benefits and costs)?
2.4 In what ways formal wastewater reuse structures can be designed to maximize net social gains?

<u>Research Question 3:</u> What is the role of guidelines [including the WHO Guidelines (2006)] for the (current and future) institutional setting regarding the use of wastewater in agriculture?

3.1 What are the advantages and disadvantages of guidelines for wastewater reuse?
3.2 How beneficial are guidelines, such as the WHO Guidelines (2006), to informal wastewater reuse structures?
3.3 In informal settings of wastewater reuse, are the institutions of the country capable of implementing the WHO Guidelines (2006)? What are the main drawbacks (e.g., missing capacities, lack of education to support behavior change, complexity, etc.)?

<u>Research Question 4:</u> Considering the characteristics of water management at the different levels, and the local characteristics of wastewater reuse, what are the farmers’ preferences for frameworks of wastewater reuse for irrigation?

4.1 What are the main elements to consider in wastewater reuse frameworks?
4.2 What are the factors affecting the choice of farmers for different wastewater reuse alternatives?
4.3 How are health and environmental risks perceptions linked to farmers’ preferences?
4.4 What is the willingness-to-pay of farmers for reuse under different wastewater reuse frameworks?

1.9 Dissertation outline

The empirical part of this dissertation consists of a compilation of papers, some of which have been published in and accepted by international peer-reviewed journals, or that were presented at international conferences covering the scientific discipline of water resources management. Each chapter can be read as a stand-alone, and repetitions were kept at minimum. However, in some chapters repetition might exist, which was necessary to provide context to the analysis.

Previous the analysis of the institutional challenges, along the trajectory from informal to formal use of wastewater in agriculture, a set of countries were selected as case studies for comparison. This process of selection is described in Chapter 2. Since the purpose of this study is to work along a trajectory of development and increasing formalization, each case study represents one step in the process towards formalization of wastewater reuse.

Next, the analysis has been divided in two parts. Part 1 looks at the institutional analysis of four countries along the trajectory. The countries include India (Chapter 3), Bolivia (Chapter 4), South Africa (Chapter 5), and Israel (Chapter 6). Each country is analyzed in one separate chapter, which discusses the institutional settings and also relevant literature. **The different institutional settings were analyzed using two different methodological approaches, based on the characteristics of the case study and the type of data gathered**. These approaches are: the Institutional Analysis and Development (IAD) framework proposed by Ostrom (2005), and the Institutional Decomposition Analysis (IDA) framework proposed by Saleth (2004). The institutional settings of the different case studies are then compared to provide insights on the process of formalization, as well as on the factors influencing it (Chapter 7).

Part 2 analyses the preferences of farmers for frameworks of wastewater reuse. Choice modelling was the methodological approach for the analysis in all cases, which is described in Chapter 8. Three case studies were considered: Hyderabad in India (Chapter 9), Cochabamba in Bolivia (Chapter 10), and Western Cape in South Africa (Chapter 11). The results of each case study are presented and discussed in a separate chapter. Then, the findings of the farmers' preferences and perceptions for wastewater reuse in different geographies and contexts in terms of agricultural production are compared in a separate chapter (Chapter 11). Finally, the general conclusions of the study, and the recommendations proposed are presented in Chapter 13.

In total the dissertation includes thirteen chapters. Figure 1-5 presents the outline of the analysis.

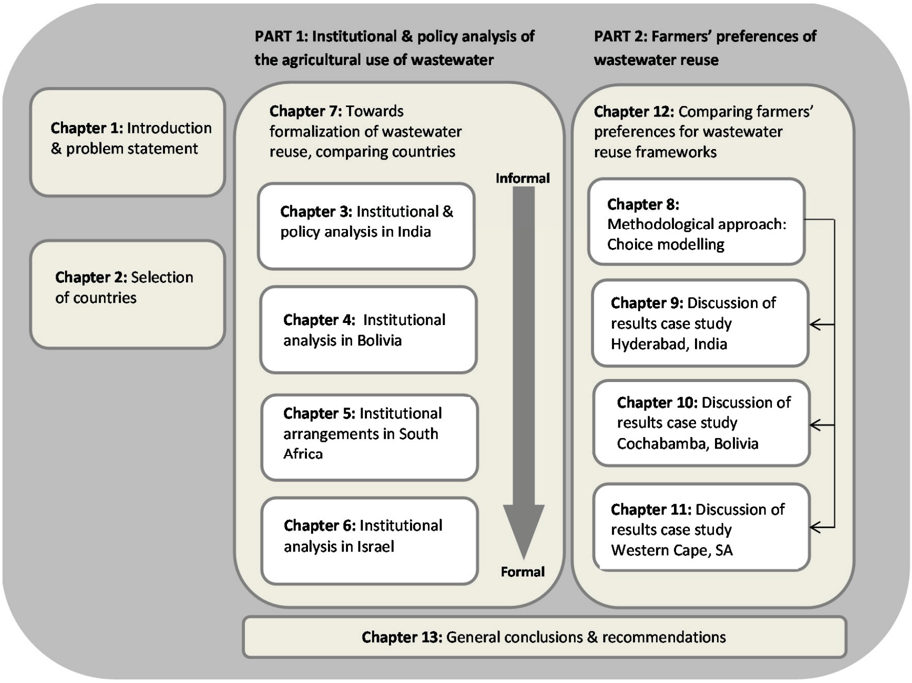


Figure 1-5 Dissertation outline

Chapter 2. Classifying and selecting countries for comparison

2.1 Introduction

Wastewater is used for several purposes such as irrigation of agricultural land and green areas, cooling in industrial processes, and even as a drinking water source (e.g., in Singapore). Agriculture is the most important wastewater user in terms of volumes of water (Jiménez & Asano, 2008). Wastewater is used for agriculture worldwide, either directly [from wastewater treatment plants (WWTP)] or indirectly (i.e., wastewater is discharged and diluted in fresh water sources). The use of wastewater can be included in the national water management plans, laws and regulations (formal use) or just practiced without any of those (informal use). Generally, the performance of water management is influenced by the governance structure in place, as well as by the level of economic development of the country. For instance, countries with more financial resources (i.e., high income countries) can address issues of water and sanitation, environmental pollution and public health, and in some cases even include wastewater in their general water management plans or strategies; whereas countries with limited financial resources (i.e., low income countries) often struggle to meet full coverage of water and sanitation services (see JMP, 2012).

It is possible to distinguish between two main drivers for countries to include wastewater management in their national agendas. These drivers are ‘water scarcity’ and ‘water pollution’ (or poor sanitation) (Raschid-Sally & Jayakody, 2008). Water scarcity is a primary driver for countries facing serious water shortage at the national or regional level. These countries often have an advanced stage of wastewater management, especially for agricultural use (e.g., Israel and Tunisia or Australia and USA). In countries where water shortage is not a major problem, they would be triggered to include wastewater management (for agricultural use) in the legislation as a response to public health and environmental protection, i.e., to protect farmers and consumers of crops irrigated with wastewater. For instance, an outbreak of cholera moved Chile to implement an emergency control program to improve water quality, change irrigation practices and consumer behavior, followed by a sanitation plan (Scheierling et al., 2010). In this view, agricultural wastewater reuse is often influenced by water scarcity, but also by issues of public health and environmental protection, embedded in the current economic development of a country and the overall governance structure.

In order to compare different institutional settings concerning the use of wastewater in agriculture along a trajectory from informal to formal governance structures, a group of countries was selected. This was preceded by a classification (raking) of countries, which provided the context where the countries are embedded. The methodology used is explained in the next sections.

2.2 Part A: Ranking the countries according to indicators

The first step to classify the countries was to choose a set of indicators that takes into account the general factors previously indicated. The indicators were adopted (and adapted) from different sources; some of which are suggested by the UN as the set of key indicators for the water sector (see UN, 2012). The indicators adopted include: 1) the Gross National Income (GNI) to reflect the level of economic development of the country; 2) the Water Stress Index use as a proxy for the level of water stress at country level taking into account the local variations; 3) the Water Availability Index to reflect the level of water scarcity per capita at country level; 4) the mortality rate to reflect the performance of public health; 5) the size of population using 'improved drinking water sources' and 'improved sanitation facilities' to reflect public health, water governance and issues of social justice; 6) the size of population connected to WWTP to reflect environmental pollution; and 7) the Government Effectiveness to reflect the government performance. In the following sub-sections each of these indicators is briefly described.

2.2.1 Level of economic development

The GNI was adopted as indicator to categorize countries according to income levels (see Scheierling et al., 2010). Based on the country's GNI, it differentiates between four income levels: high, upper-middle, lower-middle, and low income, to create a typology to analyze current issues, trends and priorities for improving agricultural wastewater use with focus on reducing the risks to public health (Scheierling et al., 2010). In this way, it positions the countries along the trajectory of economic development by clustering them in one of the four categories. The data for the GNI derive from the World Bank (n/d A).

2.2.2 Water stress index

The Water Stress Index was adopted from the '2010 Environmental Performance Index (EPI)' elaborated by Yale University and Columbia University. The 2010 EPI ranks 163 countries on 25 performance indicators tracked across ten policy categories covering both environmental public health and ecosystem vitality (EPI, 2010a). The Water Stress Index is one of these indicators; it estimates the percentage of a country's territory affected by oversubscription of water resources. The Water Stress Index is estimated as follows: "water use is represented by local demands summed by domestic, industrial, and agricultural water withdrawals, and then divided by available water supply to yield an index of local relative water use". A high degree of oversubscription is indicated when the water use is more than 40% of available supply (WMO, 1997 in EPI 2010b). This indicator was selected to capture the local variations in water use vs. water availability.

2.2.3 Water availability index

This indicator is also known as the Falkenmark Indicator (see Falkenmark & Widstrand, 1992). It is a worldwide accepted indicator to measure the scarcity as a relationship between water availability and human population. Specifically, it measures the water availability per capita (or the potential usable water per person) in the country, based on water resources and population data per year. The threshold is 1700 m^3 of renewable water resources per capita per year, taking into account the water requirements of the household, the agricultural, the industrial and the energy sector, and of the environment (Rijsberman, 2006). A country is considered to face 'chronic water scarcity' if the value is below 1000 m^3 per capita per year, where the region starts experiencing frequent water supply problems, both short and long-term (Jimenez & Asano, 2008). See Table 2-1 for all the categories. Although the Water Availability Index provides information on water scarcity at the national level, it does not provide information on the actual use or about the local variations in water scarcity.

2.2.4 Mortality rate, under 5 and deaths due to diarrhea

The mortality rate in children under five years was chosen as an indicator of the status of the country in relation to public health. Moreover, the number of deaths due to diarrhea illustrates how many of these deaths are related to diseases associated to deficient hygiene, sanitation and water supply, i.e., pollution of water bodies. Worldwide, around 1 billion people lack access to improved water, and 2.5 billion have no access to basic sanitation (WHO, 2009). Diarrhea is among the main causes of deaths and accounted to 11% of the deaths in children under five worldwide in 2011 (WHO, 2012b). Developing countries show high rates of mortality, which reflects the lack of access to clean water and sanitation or the high levels of water pollution; the opposite is true for developed countries. Data for both mortality rate and percentage of deaths due to diarrhea was extracted from the World Bank (n/dB). The latter is used only to show how many of the deaths are linked to water and sanitation; therefore not counted as one indicator itself. The MDGs target 4 aims at reducing the under-five mortality rate. The threshold is 29 deaths per 1000 live births (UNICEF, 2012).

2.2.5 Improved water sources, improved sanitation facilities

The percentage of people using improved water sources and improved sanitation facilities are indicators proposed by the UN for the water sector to measure the social performance of the use of water (UN, 2012). This is directly connected to MDG target 7c, which identifies access to water as key to address poverty alleviation (WHO, 2012a). The aim is to "halve by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" (UN, 2010). The higher the number of people connected to improved drinking water and sanitation facilities; the less the health burden, which has ultimately overall positive socioeconomic impacts on society. The thresholds are >88% and >75% for improved water and improved sanitation, respectively (JMP, 2012).

2.2.6 Population connected to WWTPs

The percentage of people connected to WWTPs was chosen as indicator to evaluate environmental sustainability. It expresses the number of people whose wastewater is treated at WWTPs, which reflects the pollution loads from cities. A low percentage of people connected to WWTPs, implies a high level of pollution, mainly of water bodies that are often used for irrigation without any control (indirect use). The data was available for 82 countries in the UNStats for environmental indicators (see UNStats, 2011). For additional 104 countries data was estimated based on the relation: percentage of the population with improved sanitation facilities times the percentage of treated wastewater at the national level, for which data was available for several countries. The latter is a rough estimate, but necessarily for the methodology. The sources for the percentage of treated wastewater include the World Bank, WHO and country reports elaborated for the workshops on the Safe Use of Wastewater in Agriculture organized by FAO, WHO, UNEP, UNU-INWEH and UNW-DPC in collaboration with ICID and IWMI. The threshold adopted was 50%.

2.2.7 Government effectiveness

This indicator is part of the Worldwide Governance Indicators (WGI) elaborated by the World Bank (see WGI, 2012). The WGI aggregates indicators of six dimensions of governance (e.g., Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption) (WGI, 2012). For more details on the six aggregate indicators see Kaufmann et al. (2010). For this methodology, only the Governance Effectiveness Indicator was used. It measures the effectiveness of the government in percentiles. It takes into account factors such as quality of public and civil services, policy formulation and implementation, degree of independence from political pressures, and credibility of government commitment (WGI, 2012). For the purpose of this study, this indicator gives an idea of the governance and institutional status in the country, which is expected to influence the overall water sector. The data was extracted from the WGI (2012).

2.2.8 Ranking the countries

The raking of the countries in this part started with a total of 224 countries listed. Data on the different indicators (GNI, Water Stress Index, Water Availability Index, mortality rate under 5, improved water supply sources, improved sanitation facilities, population connected to WWTPs, and government effectiveness) was collected for all countries with data available. The indicators are explained in more detail in Table 2-1, including the sources of data.

The first indicator, the GNI served to cluster the countries into four categories of economic development: high, upper-middle, lower-middle, and low income countries. This categorization assumes that there is a relationship between economic development and development of formal institutions for water resources management in general, and wastewater management in particular, which will guide the trajectory from informal to formal governance structures. Only 192 countries had data available for the reference year: 2008.

With the countries clustered in the four categories, they were then evaluated and ranked according to the level of water stress using the Water Stress Index. Data was available for 170 countries. They were ranked from high to low water stress. Countries with values above 40% were considered to be under water stress. To complement this information, the level of water scarcity was evaluated with the Water Availability Index. Data was available for 180 countries. Again, they were ranked from low to high water availability.

Next, the countries were ranked according to the mortality rate, in children under five years old. Data was available for 195 countries. Countries were ranked from low to high mortality rates. The assumption was that countries with high mortality rates are not succeeding in addressing issues of public health. The percentages of deaths caused by diarrhea were used to show how many of these deaths are related to water borne diseases, but not used as indicator itself.

Then, the percentage of the people using improved drinking water sources, and improved sanitation facilities tries to capture the social performance, as access to water is directly linked to poverty reduction. It reflects, as well, the current status on water governance. Countries were ranked from high to low coverage. High percentages indicate that countries are addressing the issue on water and sanitation with an overall positive impact on poverty alleviation. Data was available for 193 and 190 countries for improved water and improved sanitation, respectively.

Next, countries were ranked according to the percentage of people connected to WWTPs, which was a proxy of pollution, i.e., it reflects the pollution loads from cities. Countries were ranked from high to low coverage. High percentages indicate that countries are addressing the issue of water pollution; whereas low percentages indicate high risks of waterborne diseases. Data was available for 82 countries. Moreover, data was estimated with rough calculations for 104 countries according to the following relationship: percentage of the population with improved sanitation facilities times the percentage of treated wastewater, for which data was available for a larger number of countries.

Finally, countries were ranked according to the Government Effectiveness indicator. Data was available for 208 countries. Countries were ranked according to the percentiles from high to low. Countries positioned in the upper percentiles have ‘strong government effectiveness', i.e., they have strong governance structures, whereas countries positioned in the lower percentiles have 'weak government effectiveness', which means that they might experience problems of governance.

For each indicator a ranking of countries (with data available) was generated (see Annex 1). This ranking gives information about the performance of the country regarding the core issues for this selection, i.e., the level of water stress/scarcity, issues on public health, water pollution, government effectives. Then, the countries were evaluated according to the thresholds set up for each indicator (see Table 2-1 and Annex 2). The rational was to find out whether the country is above or below those thresholds:

- The country faces water stress at territory level (> 40%);
- The country faces water scarcity at per capita level (<1000 m^3/cap/year);
- The country reduced the mortality rate - MDG4 (< 29 per 1000 live births);
- The country increased the proportion of people with access to safe drinking water - MDG7c (>88%);
- The country increased the proportion of people with access to basic sanitation - MDG7c (>75%);
- The country addresses water pollution by treating wastewater in WWTPs (>50%)[6];
- The country has strong government effectiveness(> 0.6 ~ 70 percentile)[7]

Up to this level, only countries that cannot be clustered according to the economic development (without GNI data) were excluded, this makes a total of 192 out of 224 countries. Additionally, the data for the remaining indicators was not complete. This means that the number of countries with data varies from 192 for the other indicators, e.g., Water Stress Index: 162/192; Water Availability Index: 173/192; mortality rate: 188/192; improved water: 177/192; improved sanitation: 176/192; people connected to WWTPs: 172/192; and government effectiveness: 190/192. Because the purpose is to cut the number of countries further down in a rational way, the following step was to classify the most relevant countries in relation to the use of wastewater. This is explained in the next section.

[6] This threshold is assumed for this specific analysis.
[7] This threshold is assumed for this particular analysis, and it is not part of the indicator as defined by its authors.

Table 2-1 Indicators proposed to evaluate factors influencing agricultural wastewater use

Factors	Indicator	Criteria/Threshold	Sources
Level of economic development	GNI in USD per capita (year 2008)	- High income: >11,906 - Upper-middle income: 3856 – 11,905 - Lower-middle income: 976 – 3855 - Low-income: <975	Adapted from: Scheierling et al. (2010); Data from World Bank (n/d A): http://data.worldbank.org/indicator/NY.GNP.PCAP.CD?display=default
Level of water stress	Water Stress Index (WSI) in percentage (year 2010)	The target for a country is to have no area of its territory affected by oversubscription of water. A high degree of oversubscription is indicated when the water use is more than 40% of available supply (WMO, 1997 in EPI, 2010b).	Adapted from: EPI 2010b; Data from Environmental Performance Indicator (EPI 2010b): http://www.epi2010.yale.edu/Files
Level of water availability (scarcity)	Water Availability Index in m^3/capita·year (year 2009)	- Water stress < 1700: The region begins to experience water stress and the economy or human health may be harmed. - Chronic water scarcity < 1000: The region experience frequent water supply problems, both short and long-term - Absolute water stress < 500: The region completes its water supply by desalinating seawater, over exploiting aquifers or performing unplanned water reuse - Minimum survival < 100: Water supply for domestic and commercial uses is compromised, since the total availability is not enough to fulfil demand for all uses (municipal, agricultural and industrial)	Adapted from: Jimenez & Asano (2008, p. 4-5); Data from: 1. For year 2006 data extracted from: Earths Trend (2007) cited in Jimenez & Asano, 2008 (see Annex 1) 2. For year 1990-2000-2009 data extracted from: AQUASTAT (2011), http://www.fao.org/nr/water/aquastat/maps/AQUASTAT_water_resources_and_MDG_water_indicator_November_2011.pdf
Public health associated with deficient hygiene, sanitation and water supply	1. Mortality rate, under-5 (per 1000 live births) (year 2010) 2. Death due to Diarrhea, under-5 (%) (year 2010)	1. Under-five mortality rate is the probability per 1000 that a new-born baby will die before reaching age five, if subject to current age-specific mortality rates. Threshold is < 29 per 1000 live births (MDG4); 2. Diarrheal disease is a leading cause of child mortality and morbidity in the world, and mostly results from contaminated food and water sources.	Mortality rate, adapted and data from World Bank (n/d B): http://data.worldbank.org/indicator/SH.DYN.MORT) Threshold: UNICEF (2012). Deaths due to Diarrhea, adapted and data from: World Health Statistics 2012 (WHO, 2012c, p. 64-76), http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html Verificable at: http://apps.who.int/ghodata/?theme=country
Access to water and sanitation (social performance, public health, governance)	1. Population using Improved Drinking Water Sources (%) (year 2010) 2. Population using Improved Sanitation Facilities (%) (year 2010)	1. Improved drinking water sources include the use of: - Piped water into dwelling, yard or plot - Public tap or standpipe - Tube well or borehole - Protected spring - Protected dug well - Rainwater collection Threshold > 88 % of people served 2. Improved sanitation included the use of:	Adapted and Data from the JMP (2012): http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-report-2012-en.pdf Thresholds: JMP (2012).

		- Flush or pour-flush to: Piped sewer system, Septic tank, and Pit latrine - Ventilated improved pit (VIP) latrine - Pit latrine with slab - Composting toilet Threshold > 75 % of people served	
Environmental sustainability: efforts to reduce pollution loads from cities	Population connected to WWTPs in % (for latest year available)	The percentage of national population connected to public waste water treatment plants. The extent of secondary (biological) or tertiary (chemical) treatment provides an indication of efforts to reduce pollution loads from cities. Threshold is assumed at > 50%	Adapted from: UN (2012) - Set of key indicators for the water sector; Data for 82 countries from UNSD Environmental Indicators: http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm (last update: March 2011). Sources of data generated for other 104 countries: MENA countries: - Choukr-Allah, R. (2010) - WB-AWC (2011) Latin America & Caribbean: - Jouravlev, A. (2004) Asia, Africa & Oceania: - Jouravlev, A. (2004) Other countries: - Peru: Miglio, R. & Spittler, H. (n/d) - Ghana: UNW-AIS (2012b) - Zimbabwe: Thebe & Mangore (2012) - Iran: Tajrishy, M. (2011) - Egypt: Choukr-Allah, R. (2010)
Governance	Government Effectiveness in percentiles (year 2010)	Countries rank from 0 to100; 0 corresponds to 'weak' and 100 to 'strong' governance effectiveness: Percentiles: 0^{th} -10^{th} ; 10^{th} -25^{th} ; 25^{th} -50^{th} ; 50^{th} -75^{th} ; 75^{th} -90^{th} ; and 90^{th} -100^{th}	Adapted from: WGI (2012) Data source: http://info.worldbank.org/governance/wgi/index.asp

2.3 Part B: Connecting the countries to the practice of wastewater use

In this second part, countries (a total of 192) were ranked in terms of 1) the use of wastewater for general purposes (this includes all types of uses reported e.g., agriculture, municipal, aquaculture, potable unplanned indirect use, groundwater recharge, industrial, environmental planned and no-planned, and others not specified), and 2) the specific use of wastewater for agricultural purposes. The information was extracted from Water Reuse: International Survey (Jimenez & Asano, 2008).

The interest here was to find out whether a country uses wastewater, including treated or untreated, and planned or unplanned, for all the different uses. If a country had reported the use of wastewater (a total of 76 out of 192 reported this), then it passed to the next screening to find out whether that country uses wastewater for agricultural purposes. This results in a shorter list of countries. A total of 64 out of 192 countries reported the use of wastewater for agricultural purposes. Table 2-2 shows the number of countries shortlisted in respect to wastewater use in general, and agricultural wastewater use in particular. See Annex 3 for countries shortlisted in this step.

Table 2-2 Countries reporting the use of wastewater

Income level	Number of countries		Data sources
	various purposes	agricultural	
High	29	21	- Jiménez & Asano (2008, p. 10–22)
Upper-middle	17	15	- Country's report (UNW-AIS, 2012a) http://www.ais.unwater.org/ais/course/view.php?id=6
Lower-middle	19	18	
Low	11	10	- Wastewater Database (FAO, 2012b) http://www.fao.org/nr/water/topics_qual_reuse.html
Total	**76**	**64**	

Then, the next step was to find out how agricultural wastewater use is taking place. For instance whether the use is direct, indirect or both (16 countries reported direct use, 6 countries reported indirect use, and 19 reported both), and whether this use is formally or informally practiced (17 countries reported formal use, 9 informal use, and 9 reported both). As mentioned in the introduction of this chapter, formal use of wastewater implies recognition of the practice by the State through policies, laws, regulations, etc. This criterion gives an idea concerning the type of use of wastewater in the country. The data sources included: Wastewater Irrigation Database (information dated from 20-10-2011) and country's reports for the Regional Workshops on Safe Use of Wastewater in Agriculture organized by UN and other organizations (see UNW-AIS, 2012a). See Annex 3 for full list of countries.

In the next step, only countries that reported the use of wastewater for agricultural purposes were taken into account (64 countries), because the focus of the study is on the agricultural sector. The next step is about the practical issues related to research; this is explained in the next section.

2.4 Part C: Selection of countries on the basis of practical issues

At this point, the 64 countries shortlisted previously were equally suitable to be selected. However, aspects such as access to the country, to information, and the experiences on wastewater across countries are different. Therefore, the criteria used in this part to select the countries were related to more practical issues. The practical issues related to research include: access to official documents (language barrier), local contacts, availability of secondary data, access to the country (including fieldwork), and safety during fieldwork. The criteria were elaborated in consultation with the supervisors.

Furthermore, it was assumed that there are two main drivers influencing the formalization of wastewater reuse, namely water scarcity and water pollution. Then, it was possible to cluster the countries further, based on the level of water stress/scarcity. Finally, the countries proposed for comparison of the institutional settings for the agricultural wastewater use are presented in Table 2-3 (see Annex 3 for detailed information of the ranking). From this list, four countries were compared: India, Bolivia, South Africa and Israel (see Figure 2-1 for an overview of the countries selected in respect to the indicators). The geographical distribution of the shortlisted countries is presented in Figure 2-2.

Table 2-3 Shortlisted countries for comparison

Income level	Scarcity driven			Pollution driven		
	Country	Direct/in direct use	Formal/informal use	Country	Direct/indirect use	Formal/informal use
High	**Israel**	Both	Both	Australia	Direct	Formal
Upper-middle	Tunisia	Direct	Formal	Chile	Both	?
	Mexico	Both	Both	Peru	Both	Informal
	South Africa	Direct	?			
Lower-middle	Egypt	Both	Both	Ghana	Indirect	Informal
	India	Both	Both	**Bolivia**	Both	Both
Low	Pakistan	Both	Both	Ethiopia	Both	Informal
				Vietnam	Direct	Formal
				Nepal	?	?

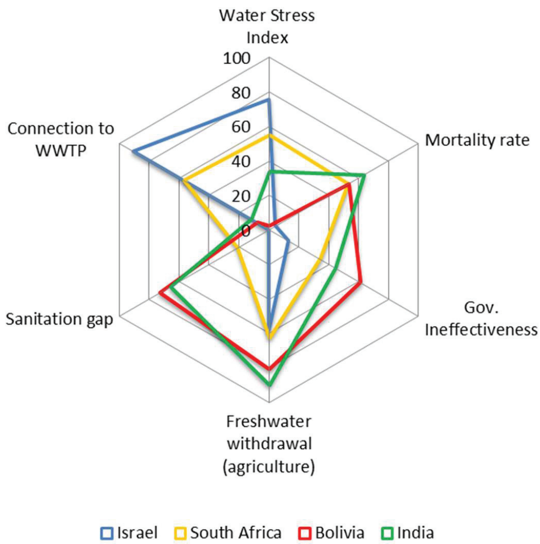


Figure 2-1 Selected countries in respect to the indicators

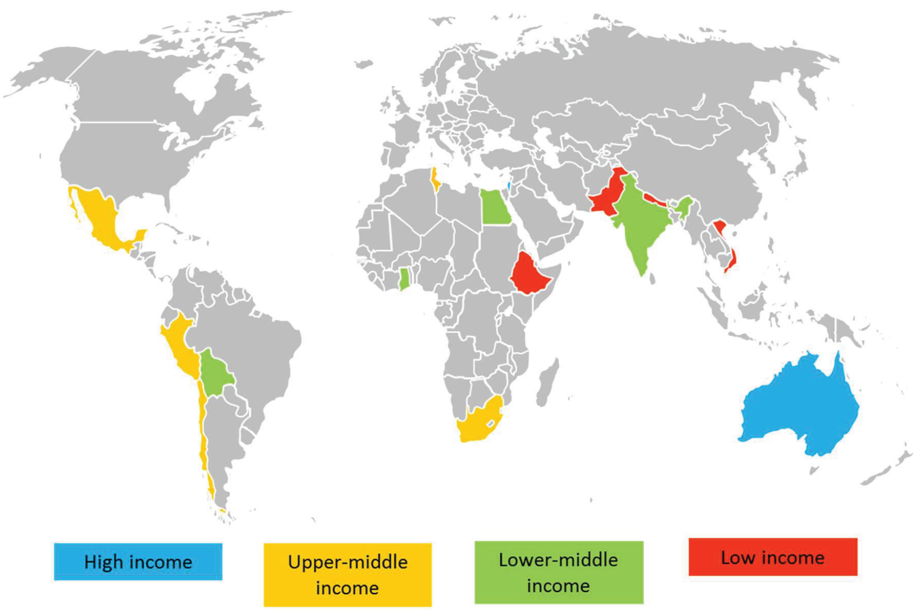


Figure 2-2 Geographical distribution of shortlisted countries

2.5 Remarks

It is important to emphasize that the process of country selection followed a sort of cluster analysis. Part A considered a number of variables, e.g., level of economic development, level of water availability (scarcity) and water stress, public health, environmental protection, and governance, which provided the context in which the different countries are placed. Contextualization of the countries was important because it provides information where the use of wastewater takes place; even if the practice of wastewater use is localized, it cannot be separated from the broader context of the country where it is embedded. On the other hand, Part B connected the countries to the reported use of wastewater for various purposes, including all types of uses, and then specifically to the use of wastewater for agricultural irrigation. This allowed zooming in into smaller clusters of countries representing a particular position on the trajectory from informal towards formal use of wastewater. A main drawback in the process of clustering the countries was the lack of information available for all countries listed. Nevertheless, to minimize that effect the first and second part were performed in such a way that countries were evaluated independently for each indicator, so the lack of information for one indicator will not affect another. In the last step – Part C, countries were selected based essentially on practical criteria such as easy access to the country for data collection, possibilities of finding a case study and characteristics of the case study, and access to local contacts or IWMI offices to facilitate the fieldwork. Finally, although the study focused on developing countries and countries in transition, it was necessary to include an example where formalization has been implemented. In this respect, Israel was selected since it is an important reference for the agricultural use of wastewater.

Part 1: Institutional and policy analysis of the agricultural (re)use of wastewater - from informal to formal

Chapter 3. Institutional and policy analysis of wastewater use in Hyderabad, India[8]

Abstract

Wastewater constitutes an alternative water source for the irrigation sector. To fully benefit from it, and reduce possible adverse effects on public health and the environment, we need to look at the regulation of the practice. A prerequisite for this is an institutional analysis, and the points to consider are the institutional mandates. The city of Hyderabad, India, is used as a case study. There, irrigation with wastewater is not supported or recognized, but it happens in practice. It takes place in an indirect and unplanned way. Institutions fail at enforcing regulations, and little attention is given to formalization of the practice. The aim of this chapter is to untangle the institutional setup, and by doing so, identify the constraints surrounding development of a formal practice. Ultimately, the aim is to contribute to the discussion on the agricultural use of wastewater.

Keywords: agriculture, India, institutional analysis, wastewater reuse

3.1 Introduction

Irrigation with wastewater has become a standard practice in developing countries, basically due to the inadequate infrastructure for wastewater collection and treatment (Drechsel & Evans, 2010). Indeed, most urban settlements discharge wastewater into natural drains without any treatment. Farmers downstream use this low-quality water for agricultural irrigation, due to its availability or because they have no other choice (Qadir et al., 2010a). The practice poses adverse effects on public health and the environment. To prevent this, and to benefit from additional water that would otherwise be discarded, a shift from informal to formal use of wastewater in agriculture is required. A drawback, however, is that formal institutional frameworks seldom keep pace with the challenges of a rapidly changing society. The purpose of this chapter is to untangle the institutional framework in relation to agricultural use of wastewater, and to identify the main constraints for developing a formalized practice. The focus is on the institutions because they are an important and often overlooked aspect of water resources development (Pagan, 2009). It is anticipated that an analysis of the institutional framework is required to identify lacunas. The region around Hyderabad, the capital city of Andhra Pradesh (AP) in India is taken as study area. Hyderabad is a rapidly growing city, with typical problems in terms of infrastructure development.

---

[8] This chapter has been published as: Saldías, C., Speelman, S., Amerasinghe, P., & van Huylenbroeck, G. (2015). Institutional and policy analysis of wastewater (re) use for agriculture: case study Hyderabad, India. *Water Science & Technology*, 72(2), 322-331.

The next section describes the analytical framework and data collection. Following that, the institutional setup is decomposed in terms of 'institutional environment' and 'institutional structure'. The latter is then assessed in more detail. Finally, the conclusions are presented.

3.2 Analytical framework

Institutions are 'the rules of the game in society or […] the humanly devised constraints that shape human interaction' (North 1990, p. 3). New institutionalism theory suggests that institutions matter because they influence norms, beliefs and actions, shaping the outcomes of society (Przeworski, 2004). The role of institutions in the water sector has also become prominent over the years (Pagan, 2009), as a consequence more and more emphasis is given to institutional analysis in order to understand the institutional arrangements, and ultimately to identify the changes needed in the water sector.

The first step of our analysis is to understand the institutional environment and structure underlying agricultural wastewater use. Considering that the practice lies within the irrigation sector, this sector is central for the analysis. We use the components identified in the Institutional Decomposition Analysis (IDA) framework, to describe institutional setup. In the IDA, the institutional environment is determined by, e.g., socio-economic, political, legal and physical conditions, while the institutional structure is composed of water law, water policy and water administration. Each of these is further decomposed to highlight important institutional aspects (Saleth, 2004). The water law component includes, e.g., inter-governmental responsibility, water rights and accountability. The water policy component includes policies, users' participation and privatization initiatives. Next, the organizational component includes the organizational framework, financing and management responsibilities, regulatory arrangements, and conflict resolution mechanisms (Saleth, 2004). The IDA framework excludes the informal dimensions, such as customs and administrative traditions.

In a second step, this institutional structure is assessed, based on five generic characteristics that typify 'good' institutional outcomes: clear institutional objectives, interconnection with formal and informal institutions, adaptability, appropriateness of scale, and compliance capacity. They were proposed by Pagan (2009), built on New Institutional Economics and the concept of transaction costs. Figure 3-1 illustrates the analytical framework.

3.2.1 Data collection

The primary source of information was an extensive literature review, including policy documents and acts [e.g., Hyderabad Metropolitan Water Supply and Sewerage Act, 1989 (AP Gov., 1989); AP Farmers Management of Irrigation Systems Act, 1997 (AP Gov., 1997); National Water Policy 2002 and 2012 (Ministry of Water Resources, Republic of India, 2002, 2012); AP State Water Policy, 2008 (AP Gov., 2008)].

Furthermore, the official websites of different institutions were consulted. The information was complemented with semi-structured interviews with officers of selected institutions and a questionnaire for farmers.

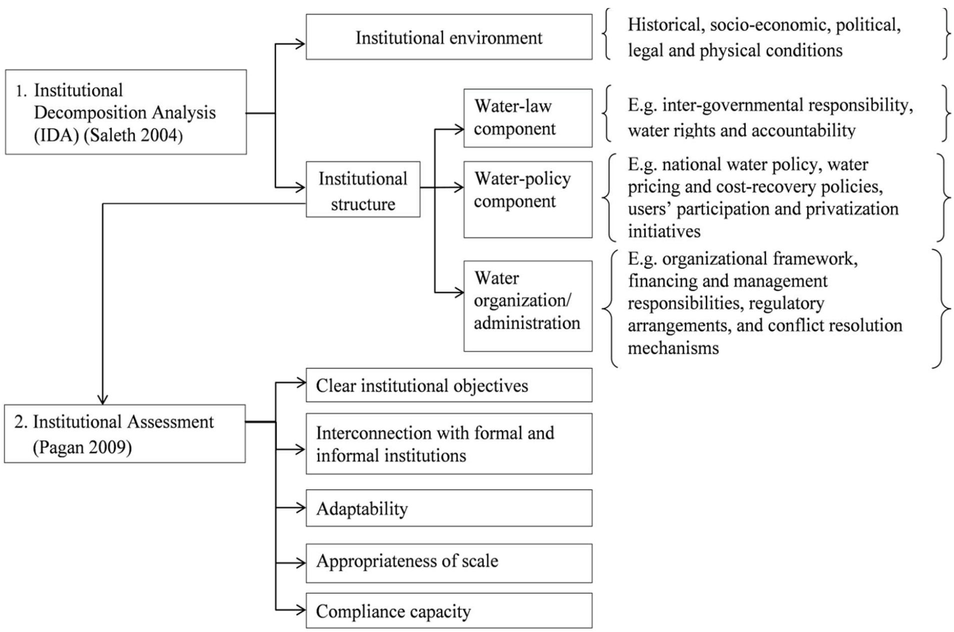


Figure 3-1 Analytical framework

3.3 Institutional Environment

3.3.1 Physical, socio-economic context

Hyderabad is situated in the semi-arid region of the Deccan Plateau at 540 m above sea level. It is home to 6.8 million people (Census, 2011a). The average annual rainfall is between 700 and 800 mm during the monsoon season (June–October) (Buechler et al., 2002). The Musi is the main river, with a catchment area of 11,300 km^2. It represents about 4% of the Krishna River basin. Traditionally, this river has provided farmers with irrigation water (Ensink et al., 2010).

As with many other cities in India, Hyderabad has experienced fast economic development. This has aggravated the deficiencies in public services. In 2005, the water supply–demand gap was estimated at 56% (van Rooijen et al., 2010). This is mainly due to an increasing population and the lack of water sources in the vicinity. New water sources are sought in locations up to 250 km away from the city (van Rooijen et al., 2010). The sanitation sector is no better off: only 62% of the city is connected to the sewerage network (Windrock-Int., 2006). Consequently, a large amount of wastewater is released into the river without treatment. This has serious implications for public health, and also for water bodies as they are becoming polluted.

Hyderabad generates about 1000 million liters per day (MLD) of wastewater (Amerasinghe et al., 2009a). Currently, the main sewage treatment plants (STPs) have a capacity of 602 MLD; the additional capacity projected by 2024 is 556 MLD (STP Amberpet, 2013). These STPs are part of the project, 'Abatement of Pollution in River Musi' (the National River Conservation Plan is an initiative of the Ministry of Environment to reduce contaminant loads in the river). Apart from this, there are about nine small STPs with a total capacity of 40.8 MLD (HMDA, 2013). The preferred technological treatment process is the up-flow anaerobic sludge blanket (UASB; e.g., in Amberpet, Nallacheruvu and Nagole STPs). More advanced treatment processes, such as cyclic-activated sludge technology (C-Tech) are also found (e.g., in Attapur STP). STPs are considered the best option to cope with pollution in rivers. The disadvantage is, however, that they require high capital costs, and the operational and maintenance costs are also high[9].

About 90% of the wastewater generated in Hyderabad is used in agriculture downstream (see van Rooijen et al. (2005) for the estimation procedure) (van Rooijen et al., 2010). Such a high percentage of wastewater being reused is linked to the drainage system (almost entirely discharging in to the river) and the irrigation network (recovering most of the water) (van Rooijen et al., 2010). The wastewater is a mix of treated and untreated effluent, including urban and industrial effluents, and solid waste. The industries include: electroplating, cooking oil, lead extraction/battery units, pharmaceutical, leather, textile, paper, soap and jewelry (Buechler & Devi, 2003). Farmers have no choice but to irrigate with polluted water. The irrigated area is about 12,000 ha. The crops grown include leafy vegetables, para-grass fodder (*Brachiaria mutica*) and paddy (*Oryza sativa*) (Devi, 2006). The river has become perennial due to the city discharges, which has allowed famers to intensify irrigated production by growing crops year round, while in the past they were limited to the rainy season (Ensink et al., 2010).

The Musi River is a reliable source of irrigation, and supports the livelihood of around 150,000 people (Buechler et al., 2002). Irrigation with this water creates employment and income for poor communities, allows production of cash crops, and savings in the cost of fertilizer. The beneficiaries include: landowners, tenant farmers, laborers, transporters, vendors, brokers and consumers (Devi, 2006). Nonetheless, it increases health risks (Ensink et al., 2010), for farmers, laborers and their families in direct contact with wastewater, as well as for consumers. Health risks include diseases caused by the presence of helminths, protozoa, bacteria and viruses (Amerasinghe et al.,

[9] The budget to build STPs is equivalent to USD 40 million, for sewerage about USD 310 million (Anon, 2006).

2009b), and by heavy metals entering the food chain through plant uptake (Chary et al., 2008). The socio-economic impacts include: loss of work days due to bad health and expenses incurred by medication (Devi & Samad, 2008). Next to the health risks, there are environmental risks from groundwater pollution and degradation of soils caused by heavy metals accumulated in the soil. Chary et al. (2008) found high concentrations of lead (Pb) and zinc (Zn) in soils irrigated from the Musi River.

3.3.2 Legal context

There are no separate regulations or guidelines for the safe management and disposal of wastewater in India, nor for the agricultural use of wastewater. Various policies, environmental laws and constitutional provisions on sanitation and water pollution regulate wastewater management: the National Environment Policy (2006), the National Sanitation Policy (2008), Hazardous Waste (Management and Handling) Rules (1989), and municipalities and district acts. Pollution of water is prohibited by the Water Act (1974), by the Water Cess Act (1977) and by the Environment Act (1986) (Kaur et al., 2012).

3.4 Institutional Structure

3.4.1 Water policy

Water policy is the responsibility of the states with the central government advising by issuing a non-binding National Water Policy (NWP). This policy is translated for enforcement in State Water Policies. Each state is responsible for the planning, implementation, funding and management of water resources development (EBTC, 2011). The NWP was revised in 2002 and 2012. The NWP-2002 adopted an Integrated Water Resources Management (IWRM) approach, aiming for multi-sectoral planning according to hydrological units. The following priority ranking is given to water allocation: drinking water, irrigation, hydropower, ecology, agro-industries and non-agricultural industries, and navigation and other uses (Ministry of Water Resources, Republic of India, 2002). Another key aspect was the adoption of the Participatory Irrigation Management (PIM) approach.

Regarding water quality, the NWP-2002 recognizes the need to eliminate pollution from water bodies. Water treatment is required before discharge, and the polluter pays principle has been introduced (Ministry of Water Resources, Republic of India, 2002). Nevertheless, this is not fully enforced, especially for the industrial sector, which is one the main polluters (Chigurupati & Manikonda, 2007). Furthermore, the concept of reuse is acknowledged: ‘measures like (…), recycling and re-use of treated effluents (…) may be promoted (…)’ (Ministry of Water Resources, Republic of India, 2002, p. 6). This is further strengthened in NWP-2012, where it reads ‘recycle and reuse of water, including return flows, should be the general norm’ (Ministry of Water Resources, Republic of

India, 2012, Sec. 6). Overall, more attention is paid to pollution issues in the most recent version of the NWP.

The NWP-2012 recognizes environmental and health hazards caused by pollution, as well as the importance of sanitation. It proposes the development of a third-party system for periodic inspection and punitive actions to be taken against polluters. It encourages reuse of grey water (effluents from kitchens and bathrooms), and gives incentives to industries for recovery of industrial pollutants. Recycling and reuse of water is to be incentivized through a properly planned tariff system (Ministry of Water Resources, Republic of India, 2012). The policy, however, does not explicitly refer to reuse for agriculture. Nevertheless, the 10th Five-Year Plan of the central government identifies the need for research and development on technologies for the treatment of sewage and on health effects of sewage water irrigated agriculture (van Rooijen et al., 2010).

3.4.1.1 State water policy

In consonance with the NWP, AP has its own State Water Policy (SWP) issued in 2008. The policy mandates the state the responsibility for water provision for all sectors and prevention of water pollution. The AP government is responsible for irrigation infrastructure, as well as for the provision of drinking water to the entire population. Water and food security are priorities. The state adopted the PIM approach formulated at the national level. The SWP provides for conserving and protecting water bodies from pollution through regulation, as well as by enforcing the recycling of industrial effluents and wastewater for secondary uses (AP Gov., 2008). Nevertheless, (re)use of wastewater for agricultural purposes is not specifically addressed.

The SWP gives second allocation priority to irrigation, which is the major water user in the state, taking about 67% of the available water (Jairath, 2001). AP pursued a state-wide program for the transfer of management responsibilities of canal irrigation, legally supported by law, to increase farmers' acceptance of water charges to ensure cost recovery (Saleth, 2004). Nevertheless, the level of collection of water fees is low (about 40%, Tirupataiah, 2013) and the state government continues to play a crucial role in the funding. Accordingly, financial returns to invest in irrigation continue to be poor (Jairath, 2001).

3.4.2 Water law

3.4.2.1 Wastewater irrigation: an outlaw?

The AP Water, Land and Trees Act (AP Gov., 2002) and the AP Farmers' Management of Irrigation System Act (AP Gov., 1997) regulate the use of water resources in AP. By law, farmers are organized in Water Users Associations (WUAs). Water rights and access from the canal system is linked to land rights, provided that a person in the command area has land rights, he/she is entitled to use water (AP Gov., 1997). A planned scheme for agricultural wastewater reuse would logically follow the existing configuration. Nevertheless, some aspects, which may influence access, need to be considered: the supply from an STP, for instance would be limited in quantity, affecting the irrigable area (Palanisami, 2013).

Following van der Hoek's (2004) typology, wastewater use in Hyderabad falls under the category of 'indirect use'. This means that farmers use water from the river, which is polluted. It also falls under 'unplanned reuse', because rivers crossing cities become heavily polluted with wastewater, and therefore become de facto sewers (Asano, 1998). (Asano (1998) defines the diversion of water from a river downstream of a wastewater discharge as an incidental or 'unplanned' reuse. Unplanned reuse normally implies indirect reuse.) Concerning the formal character of the practice, formal irrigation would refer to the presence of irrigation infrastructure or a certain level of permission and control from state agencies; in most cases, it would refer to a single point of abstraction (van der Hoek, 2004), while the opposite would refer to informal use. Under this classification, our case would be classified as formal, because the water is running through infrastructure of an existing irrigation system managed by the Irrigation Department. However, the practice infringes what is stipulated in the Hyderabad Metropolitan Water Supply and Sewerage Act (1989) regarding sewage treatment and disposal, which establishes in section 65 that: '[…] no sewage shall be discharged into any water-course until it has been treated in such a manner as may be prescribed in the by-laws […]' (AP Gov., 1989, p. 166). The authorities neither support the practice, nor recognize it (Amerasinghe et al., 2013); however, Musi water runs freely through the irrigation system. From this perspective, the practice is rather 'informal'.

3.4.3 Water administration

3.4.3.1 Organizational framework and management responsibilities

Several players are involved in the sector. The central government, through the Ministry of Water Resources, supervises the planning and development of water resources from policy formulation to infrastructure support. National committees review policy issues and plan long-term development of the sector (Saleth, 2004). The technical support for this ministry is the Central Water Commission, providing infrastructural, technical and research advice for water resources development at state level, and assessment of water resources (EBTC, 2011). The Ministry of Agriculture promotes irrigated agriculture through the Department of Agriculture. Another important stakeholder is the Central Pollution Control Board, which is responsible for water quality monitoring, and for the preparation and implementation of action plans for pollution control (EBTC, 2011). Drinking water and sanitation are the responsibility of state governments. However, the central government allocates funds and ensures that they are provided through Five-Year Plan budgets (Windrock-Int., 2006). In the irrigation sector, the states have transferred management responsibilities to WUAs, with clear responsibilities and powers. Nevertheless, some functions (e.g., the collection of fees) remain under the Irrigation Department (Reddy & Reddy, 2006). Other important institutions are listed in Table 3-1.

Table 3-1 National level institutions related to water resources

Institutions	Responsibilities
Min. of Water Resources	Planning, development of water resources, from policy formulation to infrastructure support
Min. of Urban Development	Urban drinking water provision and sanitation
Min. of Agriculture	Watershed development and irrigation
Min. of Environment and Forests	Water quality
Central Pollution Control Board	Water quality monitoring
Min. of Rural Development	Watershed development, drinking water provision
Min. of Industry	Industrial uses of water
Min. of Power	Hydropower development
Indian Council of Agricultural Research	Development of water management techniques

Source: EBTC (2011).

3.4.3.2 Conflict resolution mechanisms

The NWP provides the general framework to solve inter-sectorial water allocation conflicts through the prioritization of water use (Saleth, 2004). While the NWP-2002 was clear on that, the prioritization of water use is questioned in the latest version (Seth, 2012). Conflict resolution mechanisms in India are still considered ‘ambiguous and opaque’ (Richards & Singh, 2002). Water-related conflicts within a river basin or canal system, as well as conflicts between irrigation and water supply agencies are extensive due to the lack of proper forums for resolving differences. At local level, traditional and informal village level institutions, along with formal local institutions, such as Panchayat and WUAs are regarded as enablers for more effective and accessible conflict resolution mechanisms (Saleth, 2005).

3.4.3.3 State and local level institutions

Amerasinghe et al. (2009b) identified the main institutions for wastewater irrigation planning in Hyderabad. Table 3-2 provides a summary of their functions and responsibilities.

Table 3-2 Functions, responsibilities of state and local level institutions

Hyderabad Metropolitan Development Authority (HMDA): planning, coordination, supervision, promotion and development of Hyderabad metropolitan region, e.g. coordinates activities with municipal corporations, municipalities and other local authorities like HMWSSB (http://www.hmda.gov.in/).
Greater Hyderabad Municipal Corporation (GHMC): Provision of municipal services; regarding water, it manages some lakes (http://www.ghmc.gov.in/index.asp).
Hyderabad Municipal Water Supply & Sewerage Board (HMWSSB): Planning, design, construction, operation and maintenance of water supply systems, sewage disposal and treatment works (http://www.hyderabadwater.gov.in/wwo/UI/about_us.aspx).
Andhra Pradesh Pollution Control Board (APPCB): Statutory authority entrusted to implement environmental laws and rules; responsible for environmental policies and frameworks for waste and natural resources management; design of programs for prevention and control of pollution of water bodies; responsible for pollution standards and monitoring the quality of receiving waters resulting from discharge of effluents, for developing economical and reliable methods for treatment of effluents, and for design of methods of utilization of effluents in agriculture; advising the State Government on these matters (http://www.appcb.ap.nic.in/aboutus/about_us.htm).
Irrigation and Command Area Development Department (ICADD): Supply of irrigation water and development of infrastructure; execution of engineering activities from investigation to final execution, and quality control of infrastructure (http://www.irrigation.ap.gov.in/index.html).
Department of Agriculture: Formulation and implementation of policies and programs to achieve agricultural growth through optimum use of land, water, soil and plant resources; responsible for extension services for farmers and assessment of inputs (e.g. seeds, fertilizers, pesticides), soil testing, soil and water conservation, credit assessment, media production, monitoring and evaluation, disaster management, crop insurance, agricultural mechanization, etc. (http://agri.ap.nic.in/origin.htm).
Panchayat Raj and Rural Development: Planning, execution of programs for rural development, improvement of the coverage and quality of infrastructure facilities in rural areas, provision of clean drinking water, and execution of minor irrigation and poverty alleviation programs (http://www.aponline.gov.in/apportal/departments/PortalListofOrgsbyDepts.aspx?deptdesc=Panchayat%20Raj%20and%20Rural%20Development).
Water Users Associations (WUAs): Monitoring and distribution of water among farmers; involvement in management of irrigation system (http://apcada.cgg.gov.in/josso/signon/apwua.html; http://apland.ap.nic.in/cclaweb/waterusers.htm).

Source: Amerasinghe et al. (2009b). Websites accessed from 15 to 30 April 2013.

3.5 Institutional Assessment

Pagan (2009) identifies five generic institutional design characteristics of key importance (associated with successful management of resources) to evaluate water institutions. In this section, the institutional structure described above, is assessed based on these characteristics.

3.5.1 Institutional objectives

The objectives of the various institutions with respect to wastewater irrigation are rather unclear. The AP Irrigation Department, for instance, is responsible for irrigation water supply. However, it does not have the mandate to deal with 'wastewater'. Provision of drinking water, sewage disposal and treatment for the metropolitan area is the responsibility of the Hyderabad Municipal Water Supply & Sewerage Board

(HMWSSB). The latter should guarantee that sewage is discharged only after treatment, but this is not achieved in practice. The Andhra Pradesh Pollution Control Board (APPCB) is responsible for the prevention and control of pollution of water bodies, and should ensure compliance with the regulation for environmental protection (APPCB 2009). Nevertheless, these responsibilities are not translated effectively in practice. Furthermore, the water quality criteria for irrigation water in AP, currently in force (see APPCB, 2009), lags behind international guidelines such as from the Food and Agriculture Organization of the United Nations (FAO). For instance, for coliform organisms contained in the water for irrigation, the water quality criteria in AP does not stipulate limits, whereas the FAO guideline suggests a maximum level of 1000 FC/100 ml (Pescod, 1992). In practice, the water used for irrigation is almost raw sewage.

Moreover, the Department of Agriculture, whose main objective is to achieve agricultural growth through the use of land and water, and to boost up agricultural production and productivity (AP Department of Agriculture, 2014), is supposed to ensure the supply of quality inputs for agricultural production, yet it is unclear whether this includes the quality of water. As for other institutions, although stakeholders in practice, their objectives are not linked to wastewater irrigation. Clearly, wastewater irrigation lies somewhat in limbo in terms of the responsibilities of various institutions. This makes it problematic to identify the institutions exclusively responsible for 'wastewater irrigation'. Based on usage, it should be the Irrigation Department, but management of pollution does not fall within their mandate of activities. Therefore, under current mandates, providing safe water for irrigation becomes the responsibility of multiple departments.

3.5.2 Interconnection with formal and informal institutions

To change the way a social system operates requires changes in formal and informal institutions (Pagan, 2009). Informal institutions have a key role in society (North, 1990). Cultural values significantly determine the internal values of an organization, and these values rule the organization (Ruys et al., 2000). Pagan (2009) argues that informal institutions determine or constrain the scope of actors with political power to alter the formal ruling institutions. Yet, direct control only exists over formal institutions. The link between formal and informal institutions is rather complex.

Wastewater irrigation in Hyderabad occurs and continues to thrive, despite the lack of formal institutional support. Farmers use polluted water to irrigate crops without any control, despite the risks [water quality improves downstream, see Ensink et al. (2010)]. Both authorities and society are aware of this practice, including the possible risks. But to some extent, the practice is tolerated. It is important to acknowledge that the state government has initiated actions to reduce pollution in the river. The central government also recognizes the consequences of pollution in water and soil, and identifies as a major source of pollution the discharges of untreated wastewater.

Nevertheless, the authorities remain unable to install sufficient infrastructure for the collection and disposal of wastewater, and to guarantee the quality of effluent from the city. Furthermore, the development of new infrastructure for STPs has been unable to keep pace with rapid urbanization and population growth.

3.5.3 Adaptiveness

'Institutions associated with the management of natural resources need to be adaptive because of the inherent complexity of natural systems. […] institutions […] need adaptive capacity because changes in technology, and private and political tastes and preferences will generate pressures for institutional change' (Pagan, 2009, p. 31). Adaptiveness allows continuing management despite complexity and uncertainty (Holling, 1995). Pagan (2009) proposes that institutions that facilitate experimentation and innovation, support clear monitoring and review processes, and incorporate flexibility in how outcomes are achieved are likely to have lower transaction and transformation costs.

Hyderabad faces important challenges concerning pollution of rivers, with implications for farmers in terms of health and agricultural risks. The issue of irrigation with the Musi River has been a concern for over a decade, yet no institutional resolution to address this issue has been taken to date. Furthermore, institutions have not been able to implement policies, such as the 'polluter pays' principle, effectively. On paper, the policy is a step ahead regarding the reuse of water, as it recommends its implementation to be the 'general norm'. But implementation remains weak. Based on this, the institutions involved clearly are still not adaptive enough.

3.5.4 Appropriateness of scale

Spatial (e.g., ecological, political, or social) and administrative scales (e.g., levels of government) upon which institutions are based are fundamental for their success (Dovers, 2001). The establishment of groups around social boundaries is key to sustaining water management groups in the long-run (Curtis et al., 2002). This is because such scale reflects common informal institutional foundations. Both the administrative and spatial scale of a particular institution within an institutional hierarchy affect the transaction costs associated with management decisions, i.e., the more property rights are decentralized, the higher the transaction costs. Conversely, natural resource management institutions that have common social and ecological scales have lower transaction costs (Pagan, 2009).

The development of irrigated agriculture in India based on Command Area Development Authorities, a top-down program, failed to work in harmony with farmers (Crase & Gandhi, 2009). The introduction of the IWRM framework and the PIM approach followed this development. The AP state government showed political will and introduced WUAs across the state; however, the results have been rather discouraging. Reddy & Reddy (2006) found that during the reform process, a significant amount of money was spent on improving irrigation systems rather than strengthening formal institutional structures, and that WUAs were not non-political institutions as they were meant to be. Instead, political involvement dominates their functioning. The experience throughout India is that farmers' involvement in water management is not sustained (Crase & Gandhi, 2009). Decentralization of powers such as assessment, collection of fees, sanctioning of works, do not take place; rather, they remain under the Irrigation Department (Reddy & Reddy, 2006).

In the survey conducted, farmers were asked about WUA membership; 97% of a total 118 farmers interviewed responded that they were not members of a WUA. Based on this figure, WUA membership in the study area is low. Regarding water rights, they remain connected to land rights. This would fall under the category of administrative allocation of water, in contrast with user-managed allocation and market allocation (Meinzen-Dick & Mendoza, 1996). This type of allocation is valid for Musi water. It is rather centralized compared to user-managed and market-based allocation. As for the scale, this remains unclear.

3.5.5 Compliance capacity

Enforcement and compliance are key elements for institutions. Enforcement: to understand how to develop better institutions (although imperfection in enforcement exists in all kinds of institutions; North, 2000); compliance: in designing long-lasting institutions (Ostrom, 1993). Compliance capacity handles violations of contracts (Pagan, 2009). Self-enforcement and third-party enforcement are the two forms of compliance mechanisms (Barzel, 2000); key to enforcement is the ability to punish. The state has a comparative advantage in third-party enforcement, whereas self-enforcement is possible only where a positive value in keeping a contract exists for all parties involved. Compliance capacity gives an indication of the magnitude of the costs and features of institutional design (Pagan, 2009). Pagan (2009, p. 40) proposes the following to evaluate compliance capacity: (1) institutions that have high levels of internal enforcement support will have lower transaction costs when keeping a contract for its full duration is mutually beneficial; (2) institutions that have high levels of external enforcement support have lower transaction costs when keeping a contract disadvantages any party at any time during the life of a contract; and (3) external compliance measures that monitor indirect attributes based on specified production technology have higher transformation costs.

In reviewing the efforts of the national and state government, it is acknowledged that actions have been taken to improve water quality in the river. However, the emphasis is on development of STPs, while the enforcement of regulations lags behind. As to the farmers, they are not sanctioned when using low-quality water to irrigate crops. This reflects the low capacity compliance both from government and the farmers. Saleth

(2005) is of the view that water related acts protect the executives against the consequences of wrong-doing or non-implementation of policies, while no incentives exists for them to be accountable either to the government or to the users.

3.6 Conclusions

Irrigation with wastewater in Hyderabad is indirect, unplanned and informal. The lack of formal recognition of this practice increases health and environmental risks. Current mandates do not consider formal wastewater irrigation. It is problematic to identify institutions responsible for this practice, because it falls under various domains of national and state institutions. Institutions seem to be detached from the practice, and accountability is poor. Unclear objectives, fragmentation among or within institutions (e.g., ill-functioning WUAs) seem to explain much of the current status. Furthermore, enforcement of regulations/policies is missing.

The NWP introduces the 'recycle and reuse' concept. This constitutes a major step for the reuse of wastewater to grow in importance across the country. At state level, however, authorities do not take concrete actions to implement this concept or to remediate issues of water pollution. The concept of formal and planned reuse of wastewater has not been fully explored either, and it seems that wastewater irrigation is not a priority for the institutions involved. Unresolved issues regarding laws and institutions, and the lack of appropriate institutional arrangements might explain this. It might also be that wastewater irrigation is affected by the same obstacles identified for the sanitation sector: a low priority in the domestic budget allocation or a lack of political will to mobilize resources (WSFF, 2013). While sanitation is growing in importance in budgets, it fails to keep pace with the needs of a rapidly growing population. Past experiences show that by the time new infrastructure is in place, the projections have already been surpassed.

In line with Devi & Samad (2008), the absence of organizational capacity (to implement and monitor rules), the poor water and sewerage pricing system, and insufficient attention to environmental issues are the main factors behind the gap between formal and informal use of wastewater in Hyderabad. Considering that food production needs to be secured, and people and the environment protected, institutions should find common goals in order to enhance the benefits of wastewater irrigation primarily that of increasing the availability of good quality water for the agricultural sector. As recommendations, it is fundamental to increase awareness of water pollution and its consequences for public health and the environment. This needs to be translated into actions that would eventually lead to accountability from the authorities. Simultaneously, authorities should understand that irrigation with wastewater can no longer be ignored, and should turn this practice into a planned and controlled activity in order to guarantee quality of life for the people.

Chapter 4. Institutional analysis of wastewater use in Cochabamba, Bolivia

Abstract

Wastewater is increasingly regarded as an alternative water source. To offset the potential negative effects of wastewater reuse and to fully benefit from this additional water source, it is vital to promote planned and regulated use. To this end, it is central to focus on the institutional arrangements governing this practice, creating the need for an institutional analysis. This study explores the engagement in a process of formalization of wastewater reuse for agricultural irrigation. It takes as a case study the community of Huerta Mayu in the Department of Cochabamba, Bolivia. The findings suggest that there is a need to move from the status quo regarding wastewater use, and the current political atmosphere can facilitate this process. This case study offers interesting lessons for the formalization of wastewater reuse in agriculture.

Keywords: wastewater (re)use, agriculture, institutional analysis, Bolivia

4.1 Introduction

Despite the health and environmental risks of wastewater use, the agricultural use of wastewater is a reality in many developing countries, mainly due to the pollution of rivers and the lack of alternative water sources. These risks can be addressed if the practice is planned and regulated. On the other hand, wastewater constitutes an alternative water source which reduces pressure on water resources. This study explores the process of formalization of the use of treated wastewater for irrigation in Bolivia. The case study is the community of Huerta Mayu, in the Department of Cochabamba. There, a plan was developed to utilize treated wastewater for irrigation. The purpose of this study is to gain insight in the institutional arrangements that trigger the inclusion of this measure in the national and departmental policies. To this end, the Institutional Analysis and Development (IAD) framework was applied. An institutional analysis allows understanding the functioning of institutions and the processes of interaction. The added value of such analysis is that it allows identifying the elements that function and those which need adjustments. This is important for designing policies for safe wastewater reuse.

The next section presents an overview of the IAD framework, and it describes the methodology applied. In sections three to six, the research findings are grouped according to the four main components of the IAD framework. Finally, conclusions are presented in the last section.

4.2 Analytical framework

Within 'new institutionalism', the IAD framework proposed by Ostrom (2005) is widely used for institutional analysis (Caves et al., 2013). The framework integrates research from various disciplines to study the formation and change of institutions (Ostrom, 1990). It is a tool to understand the ways in which institutions function and change over time. Through the IAD framework relevant explanatory factors and variables are identified and assigned to categories or components. These components are located within a foundational structure of logical relationships (McGinnis, 2011).

The framework has been applied in various situations to analyze policy and management issues regarding common-pool resources (Caves et al., 2013). The analysis begins with definition of the problem. Here the purpose is to identify the main drivers for the process of formalization of wastewater reuse and reveal what factors are influencing this process. The focus of the analysis is on the patterns of interactions and outcomes in the action arena, which is constituted by the action situation and the actors. This requires identifying exogenous variables that influence the behavior of the actors in a situation (Polski & Ostrom, 1999). Accordingly, as indicated in Figure 4-1, one aspect of this framework is the context in which local actors interact to create the institutional arrangements that shape both collective decisions and individual actions. Actors will interpret situations (e.g., interest in managing water) according to their own context. The IAD framework requires careful examination of this context, i.e., exogenous variables, which comprise biophysical conditions, community attributes and rules-in-use. These encompass all aspects of the historical, social, cultural, institutional and physical environment that set the context within which an action situation is situated (McGinnis, 2011). These variables will influence the second and third components: the structure of the action arena, and in turn the patterns of interaction and outcomes (Caves et al., 2013). The latter two are evaluated in the fourth component. The criteria used commonly, and in this chapter, to evaluate institutional arrangements include economic efficiency, equity, accountability and adaptability (Ostrom, 2005).

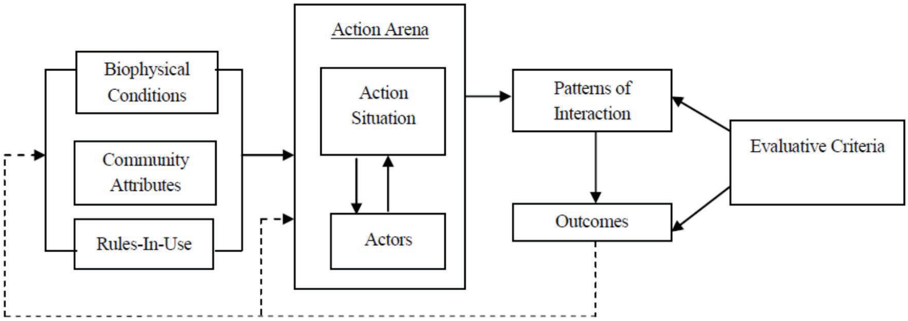


Figure 4-1 Components of the IAD framework

Source: Ostrom (2005)

The components have been explained extensively in other works (e.g., McGinnis, 2011; Ostrom, 2011). Therefore, research findings will be presented below according to the respective components, with only brief descriptions of these.

4.2.1 Methodology

This study applies a qualitative approach to explore and gain understanding of the process of formalization of wastewater reuse. The unit of the analysis is a case study. The advantage of using case studies is that they are anchored in real-life situations and offer rich understanding of particular phenomenon (Merriam, 2009). The sources of data for the analysis include official documents and gray literature. This was complemented with semi-structured interviews, conducted from January to March 2015, with key informants from the Departmental River Basin Service (SDC), as well as with experts of the water sector in Cochabamba and farmers in the study area.

4.3 The context

4.3.1 Biophysical conditions at the national level: economic water scarcity, water pollution

At the national level, Bolivia ranks among the top 20 countries in terms of water availability per capita, with an average of 74,743 m^3 per year (AQUASTAT, 2002). Paradoxically, a significant percentage of the population still does not have access to clean water. By 2010, 75.2% of the population had access to drinking water (88% in urban and 52% in rural areas). The sanitation sector is not better off, only 50% of the population had access to sanitation (55% in urban and 38% in rural areas) (Ministry of Environment and Water, Plurinational State of Bolivia, 2011). Insufficient water and poor sanitation have consequences for the health and well-being of the people, and for the socio-economic development (WWAP, 2012).

Although population growth and climate change are factors putting pressure on water resources, certainly Bolivia is one of the countries that mostly suffer from 'economic water scarcity' (see IWMI, 2007). This concept denotes that water scarcity is caused by "a lack of investment in water or a lack of human capacity to satisfy the demand for water. […] scarcity is due to how institutions function; favoring one group over another […]" (IWMI, 2007, p. 11). The symptoms are limited infrastructure development, so people find it difficult to have enough water for either agriculture or drinking, and where infrastructure exists, water distribution may be inequitable (IWMI, 2007).

Furthermore, water quality is just as important as water quantity for satisfying human and environmental needs, however, this aspect has received far less attention than water quantity (WWAP, 2012). Pollution of water sources is a concern for environmental sustainability in Bolivia (FSD, n/d). A study conducted in the country for 105 cities in the arid and semi-arid zones, indicates the presence of wastewater treatment plants

(WWTP) in 74% of these cities. About 11% of the cities studied have a population larger than 50,000 people (Ministry of Environment and Water, Plurinational State of Bolivia, 2013). The technology used include stabilization ponds, Imhoff tanks, anaerobic reactors, filters, septic tanks, wetlands, and mixed systems such as tanks or reactor with lagoons (Ministry of Environment and Water, Plurinational State of Bolivia, 2013). Although the presence of WWTPs seems encouraging, the evidence suggests that the performance in such WWTPs is rather questionable; and often wastewater is simply discharged in the rivers, which function *de facto* as sewers. Only about 5% of the WWTPs have a removal efficiency larger than 75%, which suggests large insufficiencies and problems in different WWTPs. Furthermore, the malfunctioning of WWTPs often generates bad odors; this aspect has caused people to reject them (Ministry of Environment and Water, Plurinational State of Bolivia, 2013).

Accordingly, farmers have ended up using low-quality water for irrigation. The irrigation sector accounts for 85% of the water used at country level (WLP, 2007). Irrigation with wastewater is found around many large cities in Bolivia, e.g., the Rocha River in Cochabamba, the Choqueyapu River in La Paz, and the Pallina River in El Alto, to name a few. About 5000 ha are irrigated with low-quality water (about 53% in cities of the Department of Cochabamba) (Marka, n/d). This practice remains informal and unregulated, and presents high risks for the people. About 80% of diseases reported in the country are linked to polluted water (La Patria, 2012).

4.3.2 Biophysical conditions at the regional level: water scarcity and pollution in the river

The Rocha River Basin is located in the Department of Cochabamba. This basin is divided in three regions: Sacaba Valley, Central Valley and Lower Valley. It covers an area estimated at 1606 km^2; where the altitudinal variation is from 4160 to 2550 m above sea level. The climate is characterized as semi-arid. The average annual rainfall is 480 mm (Saravia, 2013), mainly occurring during summer, from December till March. For about eight months a deficit of rainfall exists in this area, whereby irrigation is vital for agricultural production (Ampuero, 2009). Administratively, the Rocha River originates in Sacaba municipality (Chapare Province). Downstream, it passes through Cochabamba (Cercado Province), Colcapirhua, Quillacollo, Vinto and Sipe Sipe municipalities (Quillacollo Province) (Figure 4-2).

The Rocha River Basin is a water scarce region, due to its climatic and hydrological conditions but mostly because of an increase in population, which is mainly concentrated in the metropolitan area. Over one million people live in this basin, which represents more than half of the total population of the Department of Cochabamba (SDC-DGIA, 2014). Only Cochabamba, the capital city of the Department, has a population of about 630,587 inhabitants, which represents a 58.8% increase in a decade (INE, 2014). Considering this trend, more wastewater will be generated in urbanized areas, which unfortunately is not appropriately collected and treated. The discharge of wastewater in the city of Cochabamba is estimated at 500 l/s (Román, 2009) or about 43.2 million liters per day (MLD). The municipal sewer collects only about 65% of the wastewater generated in the city (Zabalaga et al., 2007). In effect, the lack of sewerage networks – about 30% of the households in the Department of Cochabamba do not have access to sanitation services (INE, 2012), the absence of WWTPs, the growing effluents from industries, and the lack of solid waste management have caused a drastic deterioration of the water quality in the river. As farmers use this water for irrigation, such quality of water is a threat to public health (SDC-DGIA, 2014).

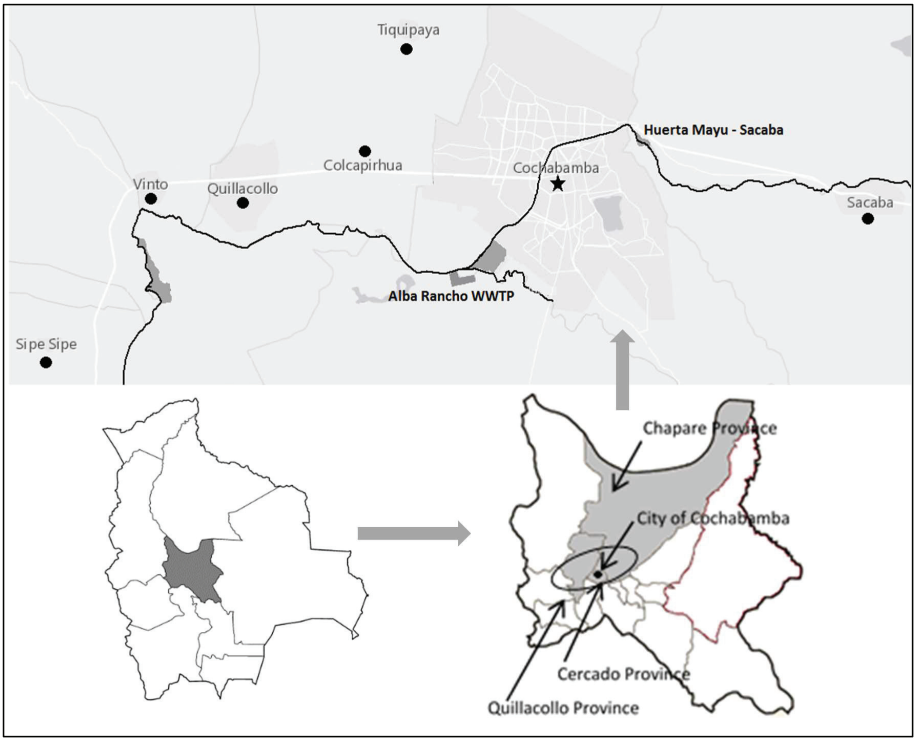


Figure 4-2 Location of the study area

By 2015, only one WWTP operates in the metropolitan area of Cochabamba: the Alba Rancho WWTP, which constitutes one of the most critical sources of pollution. This plant treats part of the effluents generated in the City of Cochabamba. It consists of stabilization ponds and was designed to treat 380 l/s, but it receives an average rate of more than 500 l/s. The plant works mostly as a by-pass and the effluent often does not meet the minimum standard set in the Regulation on Water Pollution [Environment Act N° 1333 of 1992 (Republic of Bolivia, 1992)]. The lack of personnel to operate the plant is identified as one of the main reasons to have inefficient treatment (Lizarazu, 2014). Despite of this, the effluent from the Alba Rancho WWTP is used for irrigation of crops, and aquifer recharge in the Lower Valley, which in turn supplies water wells for human consumption (SDC-DGIA, 2014).

There are plans to update the Alba Rancho WWTP and to construct eleven additional WWTPs in various municipalities located along the Rocha River. The purpose is to improve water quality, and therefore restore its function as a river (e.g., source of water for irrigation) (Salazar, 2014). The plans foster the possibility to integrate reuse of wastewater for agricultural irrigation in response to an increasing water scarcity. They are also a response to the environmental audit conducted by the Comptroller General of the State Office (Contraloría General del Estado) in 2011 (Plurinational State of Bolivia, 2011), which classified the Rocha River as 'highly polluted', and the water quality as 'bad' to 'very bad', thus its use is not suitable for irrigation, as it can cause salinity in soils and crops irrigated with this water can cause gastrointestinal diseases (SDC-DGIA, 2014).

4.3.3 Community attributes at the local level: cropping patterns and irrigation water

Cochabamba was formerly known as the "Bolivian breadbasket". Traditionally, agriculture has been an important activity in the Department of Cochabamba. Although the sector remains a major employer, its contribution to the regional economy has dropped from 18.4% (1988) to 8.7% (2012) (Encinas, 2013). The expansion of the cities puts pressure on rural communities, which turned into peri-urban areas, ultimately promoting land fragmentation (CDI–IMG Consulting, 2006).

Farmers in Cochabamba are organized in communities; some of these communities are also OTBs (local territorial organizations). Water either for drinking or irrigation is an issue of the community; therefore, the community itself is responsible for matters concerning that. Communities are represented by their leaders, who interact with different organizations and institutions at various levels.

This study focuses on Huerta Mayu community, which belongs to Sacaba municipality. Members of this community are organized in an OTB and in an Association of Producers. This community can be considered as peri-urban due to its proximity to the City of Cochabamba. Farmers of this community might not be considered subsistence farmers. They grow vegetables, mainly lettuce, onions, carrots, and beetroot. These are cash crops commercialized in local markets through intermediaries. The average land size is about 1400 m^2 (max. 2500 m^2; min. 400 m^2).

Agricultural production is intensive and highly dependent on irrigation. The Rocha River remains the main water source for irrigation in this community. Farmers use water from the river and from wells, which are indirectly fed by the river (though this process is dynamic). Wells are private, which means that farmers can dig their own well in their land, but it is common for farmers to share the water from this source between neighbors; this is based on internal agreements. There are also two deep wells (100 m and 65 m depth), which are accessible to all members of the community. Water is extracted from the river or wells by means of water pumps, and is distributed through lined irrigation canals. Most farmers own water pumps (fueled by gasoline). Water from the river is mainly used for land preparation; during the growing period farmers prefer water from wells and deep wells. This practice corresponds to an internal agreement whose purpose is to protect the crops from pollution. In times of severe water scarcity, however, farmers are forced to use water from the river, in order to sustain the production. About 67% of the farmers interviewed (from 21 farmers) are satisfied with the water quality. They certainly make a distinction between water from the river and from wells.

The irrigation method used is flood (furrow); this method is neither efficient in terms of water used, nor safe considering the water quality. Although there is not sufficient information about the soils in Huerta Mayu; communities located downstream in La Maica have experienced increased salinity in soils at a ratio of 7 ha per year (this represents some 0.2% of land affected by salinity every year), which results from applying wastewater – high in salt content and using flooding as irrigation method (Román, 2009). The water there is also high in organic matter and other chemical and biological pollutants (Agreda, 2000). In those communities the crops cultivated (alfalfa, ryegrass and maize) and the land use provide a snapshot of the conditions of soil salinity, i.e., salt tolerant crops are found in areas where salinity in the soil is higher (Román, 2009). This aspect suggests that farmers have the ability to adapt the crop pattern to soil and water conditions, however, soil salinity might influence their perceptions towards wastewater.

4.3.4 Rules-in-use: formal rules at the national level

The only water law in Bolivia dates back to 1906 (Quiroz et al., 2007). Water resources management in Bolivia is essentially communal, place-based, and adjustable in time and space (Perreault, 2008). Irrigation systems in particular are community-managed based on customary laws, which responds to the lack of formal legal framework for water management at the national level (Perreault, 2005). Nevertheless, the irrigation sector is regulated by the Irrigation Act N° 2878 of 2004 (Republic of Bolivia, 2004a), which provides the formal recognition of the use of irrigation water. This act stipulates the registration of water rights for indigenous people, peasant communities, associations and peasant unions, based on 'customary practices' (Saldías et al., 2012). A key feature of this act is that it embraces the concept of integrated water management, which anticipates the management processes, planning and implementation within a river basin unit (Republic of Bolivia, 2004a). The National Irrigation Service (SENARI) – dependent of the Ministry of Environment and Water – is the participatory decision-making agency, responsible for regulating, planning, and promoting investment and governance for the development of irrigation, and for agricultural and forestry production under irrigation (http://www.senari.gob.bo).

On the other hand, the provision of drinking water and sanitation services is regulated by the Supply and Use of Water and Sanitation Services Act N° 2066 of 2000 (Republic of Bolivia, 2000). This act regulates the supply of drinking water and sanitation services at the national level, including the process of granting concessions, licenses and registrations for the provision of the service, and rights to fix prices, tariffs and fees, as well as decisions on offenses and penalties. This act applies to the entire sanitation sector which comprises drinking water, sewerage, excreta disposal, solid waste and storm drains (Republic of Bolivia, 2000). Furthermore, under this act, the provision of drinking water and sanitation is the responsibility of the municipal governments, directly or through third parties, depending on whether the area is 'grantable' or 'non-grantable'; if it is 'grantable' then is done compulsory by an EPSA (public-social enterprise for water and sanitation). The agency regulating the sector is the Authority of Supervision and Social Control of Drinking Water and Sanitation (AAPS, ex-SISAB), whose responsibility includes reporting the competent authorities of infringements related to environmental protection in the development of the activities for drinking water and sanitation (Republic of Bolivia, 2000).

The Supply and Use of Water and Sanitation Services Act N° 2066 (Republic of Bolivia, 2000) establishes that water and sewerage service providers are obliged to protect the environment in accordance to the Environment Act N° 1333 of 1992 and its regulations (Republic of Bolivia, 1992). Furthermore, they must "promote the efficient use and conservation of water, by using equipment, materials and construction techniques that do not degrade the environment and contribute to water conservation, promoting the use of water-saving devices and guidance to users for reducing leakage in drinking water systems, as well as appropriate treatment and wastewater disposal" (Art. 23, Republic of Bolivia, 2000).

Meanwhile, the Environment Act N° 1333 aims to protect and conserve the environment and natural resources, by means of regulating the human actions in relation to nature, as well as promoting sustainable development in order to improve the quality of life of the people (Art.1, Republic of Bolivia, 1992). This act stipulates that it is the state that sets norms and controls discharges of any substance (liquid, solid or gaseous) which can cause pollution of water or degradation of the environment (Art. 39, Republic of Bolivia, 1992). Furthermore, it establishes sanctions and penalties for those who discharge wastewater (untreated), chemical or biological effluents, waste of any kind, in watercourses, riverbanks, aquifers, watersheds, rivers, lakes, water ponds, which can pollute or degrade the water, exceeding the limits established in the regulations (Art. 107, Republic of Bolivia, 1992). According to this article, discharges of untreated wastewater are penalized but not prohibited; this reflects an environmental regulation approach based more on economic incentives, in contrast to a command and control approach.

The two sets of regulations of the Environment Act N° 1333 related to the use of wastewater are: the Regulation of Prevention and Environmental Control, and the Regulation on Water Pollution. The first provides the rules in relation to the Environmental Impact Assessment (EIA) and the Environmental Quality Control (CCA) within a framework of sustainable development. The second provides the rules for prevention and control of water pollution; it specifies water quality standards (in Annex A), administrative and technical procedures, effluent discharges to sewers and water bodies, monitoring and evaluation of water quality, water use according to water quality, prevention and control of pollution, and resource conservation (Ministry of Environment and Water, Plurinational State of Bolivia, 2013).

Although a specific act regulating the use of wastewater still does not exist in Bolivia – and sectorial acts determine the use of water and environmental protection at the national level (Ministry of Environment and Water, Plurinational State of Bolivia, 2013) – a shift has occurred in recent years with the introduction of the concept of 'wastewater reuse' in the planning of water resources. In effect, the Irrigation Agenda 2025 incorporates as part of its strategies for 'more water for irrigation', the use of treated wastewater in agriculture (VRHR, 2013). This action is a response to an increasing water scarcity due to factors such as: surface water and groundwater pollution, increasing water demand, and effects of climate change, for which wastewater reuse is considered an adaptation measure (Marka, n/d).

This shift in the paradigm acknowledges the fact that under current trends more wastewater is generated in urban centers, and that this should be managed appropriately in order to protect public health and the environment. In effect, the National Development Plan 2006 (Ministry of Development Planning, Plurinational State of Bolivia, 2006) identifies as main problems in the sanitation sector: low and inadequate coverage of drinking water and sanitation, legal uncertainty, and pollution, including water pollution (Marka, n/d). Nevertheless, the national government has made its interest in increasing the number of people with access to safe drinking water and sanitation under the framework of 'vivir bien' (to live well) explicit. This is in compliance with the State Constitution in Art.16 and Art.20, which establishes the right to water and to universal and equitable access to basic services of drinking water and sanitation (Plurinational State of Bolivia, 2009). This is also reflected in both the National Development Plan 2006 (Ministry of Development Planning, Plurinational State of Bolivia, 2006) and the Sectorial Development Plan of Basic Sanitation 2011-2015 (Ministry of Environment and Water, Plurinational State of Bolivia, 2011).

Finally, in line with the framework of 'vivir bien', the Mother Earth and Integral Development to Live Well Act N° 300 of 2012 (Plurinational State of Bolivia, 2012) provides the guidelines for sustainable use of water; and encourages the adoption of 'recycle and water treatment' (Art.27, Plurinational State of Bolivia, 2012). The latter can be interpreted as the formal introduction of wastewater reuse in the framework of water resources management in Bolivia. In effect, in order to offset the problems related to the use of untreated wastewater – and the fragmentation of the different sectors in relation to agricultural wastewater use – a Joint Committee has been created. This is an inter-sectorial platform to coordinate actions to establish control mechanisms, strategies and development of capacities for the efficient use of wastewater (Marka, n/d). An important outcome of this is the Technical Regulations for Treated Wastewater Use and Sludge of Domestic Origin. This document – under revision – is the regulatory tool in reference to agricultural wastewater use (Ministry of Environment and Water, Plurinational State of Bolivia, n/d).

4.3.5 Rules-in-use: formal rules at the regional level

Water management at the regional level is subscribed to the same policy framework and regulations established at the national level.

The Rocha River Basin is vital for the region and constitutes an important space for economic development. Nevertheless, the current state of the river in terms of water quality presents high risks for public health and the environment. This situation triggered the enactment of specifics acts to address the Rocha River recovery and restoration:

- Act N° 2256 of 2001 (Republic of Bolivia, 2001), declares the Rocha River Basin an 'emergency area', and creates a management unit – technical assistance agency – to elaborate and execute an Emergency Plan aiming to clean and recover the Rocha River Basin, constituted by representatives from the departmental government, the Cochabamba municipality, 'Low Valley' municipalities, Sacaba municipality and the Committee for Environmental Defense Cochabamba (CODAC). The Executive Power is entitled to assign funds for the purpose of this act (Republic of Bolivia, 2001).
- Act N° 2866 of 2004 (Republic of Bolivia, 2004b), declares an emergency zone the Rocha River, its safety belts and areas of influence, in the territory comprised between the municipalities of Sacaba, Cochabamba, Colcapirhua, Quillacollo, Vinto and Sipe Sipe, which suffer a high degree of pollution. This act authorizes the Executive Power to utilize financial resources to take actions in order to avoid an 'environmental disaster'. The management of the river basin is priority and share responsibility of the departmental and municipal governments (Republic of Bolivia, 2004b).
- Act N° 3175 of 2005 (Republic of Bolivia, 2005), declares departmental and national priority the channeling of the Rocha River, including the municipalities of Cochabamba, Colcapirhua, Quillacollo and Vinto. The Executive Power and the departmental government are responsible for managing the financial resources necessary to ensure the channeling of the river and additional works (Republic of Bolivia, 2005).

None of these provisions were implemented. Furthermore, three studies were conducted that concluded that the Rocha River is polluted (SDC-DGIA, 2014). In 1998, the "Study on organic pollution in the Rocha River" indicated that the river became a sewer receptor of domestic effluents from large and small cities, which ultimately do not have adequate WWTPs. In 2005, the departmental government commissioned the "Basic studies of the Rocha River Basin". This study defined the river basin from the High Valley up to the Low Valley, and established the effects of pollution on health, soils and groundwater. The study recommended the implementation of WWTPs in Sacaba, Vinto and Alba Rancho; and control of solid waste and industrial effluents (SDC-DGIA, 2014). In 2007, the departmental government commissioned the elaboration of the "Integrated Management Plan for the Rocha River"; the objective of the plan was to generate sustainable environmental conditions, integrated to the socio-economic development, to increase peoples' well-being in the basin (Ampuero, 2010). Furthermore, this study redefined the area of influence of the basin, and included only the municipalities of the metropolitan area, from Sacaba up to Sipe Sipe (SDC-DGIA, 2014).

A milestone of this process is the environmental audit, conducted by the Comptroller General of the State Office (Plurinational State of Bolivia, 2011), which recommended developing an emergency plan that includes specific actions to 'save' the Rocha River, in coordination with municipalities and other stakeholders (e.g., industry) (SDC-DGIA, 2014). In response to this, the departmental government joined the municipalities involved to sign an Inter-institutional Agreement in order to commission an Integrated Management Plan of the Rocha River Basin. This agreement defined responsibilities and share benefits among the national government (represented by the Ministry of Environment and Water, and the Vice-Ministry of Natural Resources and Irrigation), the departmental government and municipalities involved. It also established the amounts of money that each municipality shall contribute to the project. Unfortunately, the plan was not commissioned after three failed attempts due to the complexity of such plan (SDC-DGIA, 2014).

The Integrated Management Plan was substituted by the Director Plan of the Rocha River Basin. The institution responsible for the development of this plan is the SDC (SDC-DGIA, 2014). Such plan takes into consideration six main strategies. One of these is the 'recovery and sanitation of the Rocha River', which includes in the strategic programs the 'Rocha River decontamination'. Construction of the eleven WWTPs is fundamental for the latter. Another key strategy is 'irrigation and wastewater reuse'. The purpose of this strategy is to meet the demands for irrigation water, in terms of quantity and quality. This program is relatively new; therefore there is little progress compared to other programs (SDC-DGIA, 2014).

To this point, the biophysical and socio-economic context, and the regulatory and policy framework have been described, which allows to continue with the second component of the IAD: the action arena.

4.4 Action arena: the action situation and the actors

4.4.1 Action situation

The IAD framework requires the establishment of the boundaries of the action arena. In this study, the action arena is delimited by the water sector, constituted by the irrigation sector, and the water and sanitation sector in the Department of Cochabamba.

The action situation is the engagement of the stakeholders in a process of formalization of wastewater reuse, particularly the use of wastewater in agriculture. This initiative has been influenced by the realization that the lack of - or poor - sanitation services have serious implications for people and the environment, ultimately deteriorating the quality of life. The increasing water demand has forced different actors to look for alternative water sources, which are both reliable and safe. The formulation of policies for agricultural wastewater reuse will certainly have implications on the ground regarding water management, which is of interest for the sustainability of such endeavor.

In order to learn about the impacts on the ground, this analysis includes the community of Huerta Mayu. This community uses untreated wastewater from the Rocha River to irrigate crops. This practice is indirect and unplanned. Huerta Mayu aspires to receive treated wastewater from El Abra WWTP. Reuse of wastewater is part of the plan conducted by the departmental government and the municipalities involved aiming to recover and restore the Rocha River.

4.4.2 The actors

The main actors identified are: the Ministry of Environment and Water (representing the national government), the SDC (representing the departmental government), the water and sanitation provider: EMAPAS, and the farmers in Huerta Mayu. The main characteristics of these actors, as well as their interactions are described in the next section.

4.5 Patterns of interaction and outcomes

Patterns of interaction and outcomes constitute the third component of the IAD framework. The following main patterns of interaction and their outcomes are analyzed:

1. *Actors: The national government (represented by the Ministry of Environment and Water) and the departmental government (represented by the SDC).*

Patterns of interaction: The national government aims to realize the human right to water and sanitation, for which it embarked in a process of increasing water and sanitation coverage – by 90% and 80%, respectively – including 80% coverage in WWTPs, by 2015 (Ministry of Environment and Water, Plurinational State of Bolivia, 2009). The national government is aware that most wastewater generated in urban centers is not treated, and in most cases WWTPs do not comply with the environmental norms, which ultimately causes pollution in rivers. At the same time, the use of untreated wastewater in agriculture is a threat for public health because it exposes the population to multiple diseases. Ascaris lumbricoides infection and diarrheal disease are common among farmers or those living near the land where wastewater is used (see Siebe & Cifuentes, 1995; Ensink et al., 2008). Other human pathogens such as *Shigella* spp., norovirus, hepatitis A virus, *Cyclospora cayetanensis*, and zoonotic pathogens including verocytotoxin-producing *E. coli*, *Salmonella* spp., *Yersinia enterocolitica*, and *Cryptosporidium* can also be present in the wastewater and hence enter the food chain. Products contaminated by the wastewater use may infect humans or animals through consumption or handling (Uyttendaele et al., 2015).

The national government aims to find solutions to these problems, a main drawback, however, is the lack of national policies and programs for wastewater reuse (Ministry of Environment and Water, Plurinational State of Bolivia, 2009). Furthermore, while the demand for water increases, water availability decreases due to water pollution. In this respect, treated wastewater is regarded as a potential water source, particularly for the agricultural sector; at the same time reuse of wastewater is considered an adaptation measure to cope with climate change (Marka, 2011).

Meanwhile, the departmental government, represented by the SDC, has the mandate to restore and recover the Rocha River. This is supported by the national government. In this line, the departmental government has engaged in various actions to realize the mandate. The Director Plan of the Rocha River Basin provides the guiding strategies. Although wastewater reuse is not the main objective of this plan, the inclusion of treated wastewater reuse for agricultural irrigation, as part of the strategies, is regarded as an important incentive for the irrigation sector and it provides the framework for a formal use of treated wastewater at the departmental level. Additionally, considering wastewater as a potential irrigation source allows reconfiguring the entire water resources management. While this needs more research, it will certainly open windows of opportunities for the irrigation sector.

Outcomes: The departmental government has the support from the national government to address the problems of water pollution in the Rocha River. The specific acts for the Rocha River are examples of this. Furthermore, the Director Plan of the Rocha River Basin provides the guides to manage the river in an integrated way, which aims to guarantee an equitable access to water both in terms of quantity and quality. The inclusion of wastewater reuse as part of the strategies can be regarded as a step towards the formalization of the practice. The problems affecting the Rocha River are not exclusive of this river, instead they are also found in many other rivers of main cities across the country; therefore, the strategies applied in this case can serve as 'good' examples for other cases.

2. *Actors: SDC – Unit Rocha River Basin (representing the Managing Committee for the Director Plan of the Rocha River Basin) and the water and sanitation provider EMAPAS*

Patterns of interaction: The Managing Committee for the Director Plan of the Rocha River Basin – first level institution – is to be established to continue the ongoing processes. This committee will be a policy-advisory body to develop, define and adjust the Director Plan: strategies, programs, and projects. This committee has the SDC (Unit Rocha River Basin) as operating arm (SDC-DGIA, 2014). The committee is to be integrated by the Ministry of Environment and Water (Vice-Ministry of Water Resources and Irrigation); the departmental government (Departmental Secretary for the Rights of Mother Earth and other units related); the SDC; the Planning and Integrated Water Management Directory (part of the departmental government); the Management Recovery Unit for the Rocha River Basin (Act N° 2256 of 2001); members of the Inter-institutional Agreement (municipalities of Sacaba, Cochabamba, Colcapirhua, Quillacollo, Vinto, Sipe Sipe and Tiquipaya, the Ministry of Environment and Water, the departmental government); and the "Valle Alto" Commonwealth (SDC-DGIA, 2014).

The SDC is expected to provide technical support and execute actions which are its competency in the Director Plan. The SDC has become the leading institution of this process in the department, mainly because it is the most experienced institution for river basin management. It is responsible for the elaboration of the Director Plan of the Rocha River Basin, and for the coordination and articulation of actions among the operational bodies (second level institutions) proposed in the Director Plan (SDC-DGIA, 2014). Other responsibilities of the SDC include:

- Implementation and enforcement of plans, programs and policies;
- Evaluation and monitoring of the project: Development and Conservation of the Rocha River Basin; and projects and activities under the integrated management of the Rocha River Basin;
- Collection and analysis of data;
- Coordination, information sharing and advice to municipalities and beneficiary communities;
- Articulation of strategic planning, territorial development and participation;
- Planning of services, activities and projects;
- Relationship management with social organizations, municipalities, associations and other stakeholders within the Rocha River Basin (SDC-DGIA, 2014).

According to the Director Plan, the SDC coordinates actions involving the river, directly with the municipalities and other stakeholders. EMAPAS is the service provider responsible for the provision of drinking water and sanitation in Sacaba municipality, as well as for wastewater collection, treatment and disposal. The SDC is to coordinate with EMAPAS the issues concerning wastewater management in relation to the Rocha River.

EMAPAS is, at present (2015), constructing the El Abra WWTP and another WWTP (Pucara-Esmeralda) is to be constructed. These plants are part of the elven WWTPs proposed in the strategies to 'save' the Rocha River. The construction of these plants had strong opposition from dwellers living close to where the facilities were to be located. Overall, people are reluctant to WWTPs because of the negative experience in the Alba Rancho WWTP. People mostly complain about bad odors, which can be generated in WWTPs, and they consider that the establishment of a WWTP can increase pollution in the area (see Opinion, 2011). Besides this nuisance, WWTPs can also have an impact on land value. Therefore, people may see WWTPs as threats to their neighborhoods. In this regard, it seems that the SDC has played an important role during the negotiation process for El Abra WWTP.

Outcomes: The main outcome of this interaction is the coordination with different stakeholders in the process of saving the Rocha River, thanks to the centralized decision-making agency: the SDC. Certainly, this institution has too many responsibilities. However, the possibility to act as the umbrella agency facilitates the involvement of EMAPAS in the process. While the Plan Director provides the guidelines, the SDC coordinates with the institutions involved, in this case the provider, on the measures and actions to follow.

3. *Actors: EMAPAS, SDC, and farmers of Huerta Mayu*

Patterns of interaction: One of the main problems that EMAPAS faces is water shortage. This provider has difficulties in finding new water sources, and those available are committed to agricultural irrigation. Therefore, although households are connected to drinking water, they receive minimum amounts of water. On the other hand, Sacaba municipality still does not have operating WWTPs, which means that the water used is disposed untreated to the river.

Despite the opposition to WWTPs in the municipality of Sacaba, El Abra WWTP is to be realized, which means that treated wastewater will be available. This WWTP has a projected capacity to treat 178 l/s (or about 15.4 MLD) by 2036.

In order to comply with the national policy to reduce water pollution and increase water for the irrigation sector, and the departmental strategy to 'save' the Rocha River, the SDC and EMAPAS are working in coordination to implement a planned irrigation system where treated wastewater is to be used. Huerta Mayu community is the candidate to receive treated wastewater from El Abra WWTP. In this community, wastewater from the Rocha River has been used indirectly. Farmers, however, are aware that this practice can cause health problems and they are willing to engage in the use of treated wastewater. While awareness of health implications may be an important issue, the main reason why these farmers are interested in using treated wastewater is that this option is a reliable water source. With more water available, farmers can guarantee intensive production of vegetables in this area.

Outcomes: The outcome of this interaction is the realization of, maybe the first, irrigation system in Bolivia that foresees the use of treated wastewater. Certainly, the SDC has played a major role in the negotiation process. Although it has not been established yet the details on how water will be distributed and other aspects of water management (rights, quantities, etc.), the progress so far is important.

Another important outcome is that farmers in Huerta Mayu will be able to secure access to irrigation water. This water will be safer in quality terms compared to other water sources. The access to safe water will allow guaranteeing agricultural production, if other production factors are considered constant. Ultimately, this will have a positive impact on the livelihoods of the community.

Finally, the establishment of El Abra WWTP will certainly have a positive impact on reducing pollution in the Rocha River. However, it is important to consider that the success of this depends on the operation and management of the WWTP. At the moment the experience of EMAPAS in operating and managing WWTPs is rather limited. The experience in Alba Rancho WWTP suggests that the main obstacle in operation of WWTPs is the lack of trained personnel and the excessive bureaucracy to assign personnel. This will certainly be a challenge for EMAPAS.

4.6 Evaluation

Evaluative criteria can help to determine aspects of the outcomes that are satisfactory or need improvement (McGinnis, 2011). Economic efficiency, equity, accountability and adaptability are the most commonly used evaluative criteria (Ostrom, 2005). Efficiency in use of resources; equity in distributional outcomes and processes; accountability to direct users of resource; adaptability or a system's capacity to suffer disturbance and continue to function, without losing functional integrity. Participation can also be included, as it tends to increase legitimacy (McGinnis, 2011, p. 176).

4.6.1 Efficiency

It has been identified that – among others – the lack of institutional capacity in management and operation of water systems, and an incomplete and incongruent institutional framework are major problems facing the water sector in Bolivia (Ministry of Environment and Water, Plurinational State of Bolivia, 2009). In effect, weak institutions and a lack of urban planning are main restrictions to wastewater management in Cochabamba (Huibers et al., 2004).

The process, leaded by the SDC, to implement concrete actions, translated in the Director Plan for the recuperation and restauration of the Rocha River can be considered efficient; if one takes into account that this issue dates back to at least 15 years ago. An important factor that may have pushed this process forward is the support from the national government, which is interested in making effective the human right to water and the concept of ‘vivir bien’, at least in theory.

Furthermore, despite strong opposition to WWTPs, the way in which the SDC, the departmental government and EMAPAS are dealing with this issue can be considered as efficient. The execution of El Abra WWTP is an illustration of this. The realization of the WWTP will have positive impacts on the river’s water quality; this is also an example of efficiency of the process. However, there might be some issues that still need to be addressed, in particular regarding information sharing and awareness campaigns to educate people about the benefits of having WWTPs. This case will be the first irrigation system that uses treated effluent; therefore, it can provide important lessons.

In water management, water use efficiency has been assessed from different perspectives (see Perry, 2007). However, the use of treated wastewater for agricultural irrigation is a way to increase efficiency in the sector. This is because additional water is re-entering the hydrological system, which decreases the need to use other sources of water. Competition among sectors is strong within the basin; therefore efficient use of water is important. Perry (2007) suggests that once there is competition, all uses primarily irrigation must be analyzed in its broader hydrological context. In this respect, it is foreseen that the El Abra WWTP will provide additional water of improved quality; this can be considered as efficiency of this process, and overall in wastewater management and protection of water resources.

In terms of agricultural production, the challenge for the farmers is to make agriculture economically viable, while improving efficiency. Water use efficiency – in terms of water losses – is rather poor in this area. In general, water use efficiency in rural communities in arid and semi-arid regions in Bolivia is less than 50% (see VRHR, 2013), which means that some 50% of the water is lost (through infiltration, evaporation) before it reaches the plant. Farmers continue using conventional irrigation methods such as flooding (furrow), which have great water losses. Certainly, this is no longer sustainable in water scarce regions and needs to be changed. The adoption of high-efficiency irrigation methods such a drip is an alternative. Of course, this will require the support from the departmental and the national government. There is some advance in this respect, for instance, the Irrigation Agenda 2025 (VRHR, 2013) considers the introduction of modern technology: drip and sprinkle, in 40,000 ha, benefitting 35,000 families in the highlands and valleys; this has a budget of USD 200 million.

Since irrigation with wastewater implies health risks, the selection of appropriate irrigation methods is important, but most of all the selection of suitable crops. Little has been done in this respect. However, famers will need advice and guidance on this issue in order to make the most out of treated wastewater.

4.6.2 Equity

The Director Plan of the Rocha River Basin aims to guarantee an equitable access to water both in terms of quantity and quality. Nevertheless, equitable access to water in the Bolivian context is often not in place, mainly due to a limited infrastructure development and water distribution rules, which are dictated by the users themselves in the case of irrigation systems. It is unknown how Huerta Mayu became the community selected to receive treated wastewater from El Abra WWTP. It is assumed that its location had been influential. It is also possible that these farmers are willing to engage in this process in contrast to other communities. Although there is little experience on how to allocated and distribute treated wastewater, it is a fact that water resources management in the Andean context remains a highly political process (see Boelens, 2014).

In terms of the overall outcome of this process of formalization of treated wastewater use, a win-win situation is foreseen, especially for the SDC, EMAPAS, as they comply with their mandates. And for the farmers, since they can benefit from this water source. Health risks can also be reduced both for farmers and the consumers of the crops.

4.6.3 Accountability

EMAPAS is responsible for wastewater treatment. They shall comply with the regulations for water quality standards. Nevertheless, despite the mandates, it is difficult to make them accountable to the general public or the farmers. This argument is based on the experience of Alba Rancho WWTP, where the service provider SEMAPA remains unable to properly treat wastewater. This is a major source of pollution in the river. And yet this happens in the eyes of the authorities, who are unable to react. It seems that there is little accountability from EMAPAS towards the farmers. This issue needs to be addressed in order to guarantee performance as well as sustainability of the system. But most of all, to guarantee that wastewater is properly treated and then supplied to farmers, which will ultimately protect the general public.

Farmers' accountability to consumers of the crops is also missing. It is quite difficult to track the origin of crops in the local markets. And it is almost impossible to prevent farmers from using untreated wastewater. The general public is aware of this issue; however, they also remain passive in this respect.

4.6.4 Adaptability or sustainability

The Director Plan is central in terms of adaptability or sustainability in the process of formalization of wastewater reuse, as it works as the guiding tool to make the actions required effective. This tool is broad and aims to cover various aspects for the restauration and recovery of the Rocha River. On the other hand, it seems that the SDC has been determinant in the progress. This raises the question about whether the process will continue without the SDC. Are other stakeholders involved enough to guarantee that this process will continue? This is unknown, but it shows that the sustainability of this process depends greatly on the SDC.

In terms of sustainability of using treated wastewater in irrigation, this will certainly depend on how the rules are established. Irrigation systems in Bolivia function independently. There is little intervention from the state in water allocation and management of irrigation systems. Users determine the rules of the game. However, when dealing with treated wastewater, other aspects are important to consider which should not be left unregulated; for instance, irrigation methods, type of crops, use of protective equipment for farmers, handling of crops, etc. And then the question is: who is to be responsible for monitoring that this is done appropriately? These are some of the issues that still need to be solved in order to guarantee sustainability of the system.

4.6.5 Participation

Participation of different institutions is, without doubt, a major feature of this process; and is central to legitimate it. The process has received support from different levels of institutions: national, departmental, municipal and local. This is regarded as positive. Nevertheless, it is important to highlight that participation of the industry sector is missing. This sector is important for two reasons: first, is the major water polluter, and should be accountable for this, and second, is a potential user of treated wastewater. This aspect needs further insight.

4.7 Conclusions

This study explored the process of formalization of the use of wastewater in agricultural irrigation in the Department of Cochabamba, Bolivia. The main drivers of this process and the factors influencing it were identified. This was done applying the IAD framework, which allows understanding the functioning of institutions, identifying the interactions among actors involved, as well as the contextual elements facilitating the process.

The most important aspect of this process is the realization that current practices regarding wastewater reuse shall change, because it poses risks for people and the environment. Next, is the realization that wastewater is a potential water source – to cope with increasing water scarcity – and needs to be exploited safely. And that it should be incorporated in the planning of water resources management. There are implicit risks in reusing wastewater; however, a formalization of this practice provides the tools to do it safely. This is certainly a gain compared to the status quo.

Furthermore, the analysis reveals that institutions of the water sector – in Bolivia in general, but in Cochabamba in particular – are willing to engage in direct and planned reuse of wastewater for agricultural irrigation. This is a milestone for the water sector and shows a change in the mindset of the institutions involved. Although the process of supplying farmers with treated wastewater is in its infancy, it is important to recognize the advances so far. For instance, in this particular case is the inclusion of reuse of wastewater in the irrigation policy, or the engagement in a negotiation process to supply water to farmers or the construction of the first WWTP meant to supply treated wastewater. These are important achievements to consider.

The use of treated wastewater is promising, as it increases availability of clean water. Nonetheless, it requires doing things carefully to make the most out of it. A regulatory framework guiding the practice (e.g., the Technical Regulations for Treated Wastewater Use and Sludge of Domestic Origin) will definitely have benefits. Although these guidelines need to be implemented, a worst case scenario would be not having such guidelines. Nevertheless, there are issues that need to be addressed, for instance, defining responsibilities for monitoring and control of irrigation practices; or establishing mechanisms for accountability for service providers and farmers; or defining water allocation and rights for the users.

For farmers, treated wastewater will certainly be beneficial: it represents additional water with improved water quality for agricultural production. This option is attractive to them because water demand exists. An aspect that has not been discussed is the costs of this intervention, since there is little information about this. But it is important to consider cost sharing; this aspect needs further insight. Lastly, educating farmers in the use of treated wastewater is an aspect that needs to be considered. This will allow them to make informed decisions for the development of agricultural production with treated wastewater. Ultimately, this will protect people and increase the quality of life in line with the concept of 'vivir bien'.

Chapter 5. Institutional arrangements for the use of treated effluent in Western Cape, South Africa[10]

Abstract

Wastewater is increasingly regarded as a valuable resource, but to fully and safely exploit the potential, sound institutional arrangements governing its reuse are crucial. This article presents a case study of a self-managed irrigation scheme in Western Cape, South Africa that uses treated effluent directly, formally and safely. By applying the Institutional Analysis and Development framework, the variables within the context, action arena and patterns of interaction that have enabled this outcome are systematically identified and evaluated. Key variables include: water scarcity; an effective policy and regulatory framework; public pollution prevention awareness; self-organization; and capital-intensive water use linked to profitable markets.

Keywords: wastewater reuse; agriculture; financing; institutional analysis; South Africa

5.1 Introduction

Water reuse for various purposes, including agricultural irrigation, has been growing in importance in recent years. This practice is regarded as a measure that can help reduce pressure on water resources. However, there are environmental and health risks linked to using wastewater. Hence, a crucial question is whether and how these risks can be addressed, and what role institutional arrangements, including formal planning and regulatory frameworks, play in the reuse of wastewater.

South Africa can offer important lessons in this regard. With growing competition for water, the reuse of wastewater has been recognized since the 1970s as a vital strategy to ensure that more water resources remain available for the range of uses. Treated wastewater reuse is increasingly applied. At the same time, regulatory frameworks have been further developed and enforced.

This study analyzes an example of such use of treated wastewater, considering a self-managed irrigation scheme in Western Cape where treated effluent from one of the municipal treatment plants of the City of Cape Town (CCT) is used. The objective of this study is to explore, within a context of increasing competition for water resources, the institutional arrangements of water reuse for irrigation that both drive its uptake and ensure that water reuse meets health and safety criteria as stipulated in the formal

[10] This chapter has been published as: Saldías, C., Speelman, S., van Koppen, B., & van Huylenbroeck, G. (2015). Institutional arrangements for the use of treated effluent in irrigation, Western Cape, South Africa. *International Journal of Water Resources Development*, (ahead-of-print), 1-16.

regulatory frameworks. This provides a basis for drawing lessons for policy and regulation elsewhere in South Africa, and internationally.

For this institutional analysis, the Institutional Analysis and Development (IAD) framework is applied (see Ostrom, 2005).

The next section defines the analytical framework and it describes the methodology used. Sections three to six present the research findings, grouped according to the four main components of the IAD framework. Conclusions are formulated in the last section.

5.2 Analytical framework

This study applies the same analytical framework than Chapter 4, therefore, to avoid repetition, refer to the chapter indicated for a more detailed description of the IAD framework.

When applying the IAD framework, the analysis begins with definition of the problem. In this study this is the question: Which institutional arrangements drive the reuse of water, while also ensuring that health and environmental requirements are met? The research findings will be presented below according to the respective components of the IAD framework (Figure 4-1), with only brief descriptions of these.

5.2.1 Methodology

This study applies a qualitative approach to explore and gain understanding of a particular case (Creswell, 2007). A case study is anchored in real-life situations and offers rich understanding (Merriam, 2009). The case selected is Scheme A of a group of farmers in the agricultural region north-east of Cape Town, in Western Cape Province, South Africa, constituting a clear example of treated wastewater use. Semi-structured interviews were conducted with key informants from various institutions, as well as with farmers in the study area, in April–July 2014. In addition, a literature review was conducted. Relevant official policies, laws and regulations, as well as reports, were studied.

5.3 The context

5.3.1 Biophysical conditions at the national level: growing competition for water

South Africa is characterized as a water-scarce country. Agricultural production is highly dependent on rainfall, which is expected to decrease and be erratic (UNEP-FI, 2009)[11]. De Wit & Stankiewicz (2006) estimated a 10% reduction in average rainfall by the end of the twenty-first century, and significant losses of runoff. This will clearly

[11] The term 'erratic' refers to spatial and temporal variability in the rainfall pattern.

affect water availability, which itself has been recognized as the most important limiting factor for agricultural production in the country. This situation is expected to further worsen due to increasing demand for water from other sectors (Goldblatt, 2012). Moreover, new water demands by historically disadvantaged individuals are to be met in order to overcome the gross inequities in the distribution of water from the past. The national government has engaged in various strategies to deal with this (DWA, 2013a). Overall, awareness about water scarcity is strong; it is often mentioned as a major problem affecting the country. Related factors such as deterioration of water quality and ecosystems due to pollution (by means of e.g., eutrophication, salinization, mine drainage and microbiological contamination), as well as developmental impacts on water habitats are also recognized as major challenges for water management in South Africa (DWA, 2013a). These elements have created a vivid awareness of the need to improve water management, at least in theory.

5.3.2 Biophysical conditions at the provincial level: water scarcity requiring new sources

Western Cape has a Mediterranean climate, with cool wet winters (May–July) and warm dry summers (October–February). The average annual rainfall in the study area is about 350–400 mm, but this varies across the peninsula, with some areas receiving up to 1500 mm (Midgley et al., 2005). Overall, the area is becoming even more water-scarce because of the fast-growing urban population, the growing water demand for irrigation, and variability in climate (Midgley et al., 2005; Louw, 2007).

Agriculture is mainly rain-fed. Farmers usually store rainfall in on-farm dams to use in summer for irrigation. To a lesser extent they rely on groundwater from boreholes. The main irrigated crops are grapevines, olive trees and vegetables. The dryland crops are predominantly grains (wheat, oats and canola). Grapevines are preferred partly because of the climatic conditions but also due to the good market opportunities offered by a long-established wine industry. Many farmers grow grapevines to produce their own wine; others supply to wholesale wine producers with whom they have contracts. Although vineyards can grow under dryland conditions, irrigation is fundamental to increase yields. Experience in the area indicates that compared to dryland conditions irrigation raises yields by 30% (based on interviews with farmers in the area).

Thus, securing water for irrigation is fundamental for productive sustainable farming. In this context of increasing scarcity and the search for alternative sources of water for irrigation, in particular for grapevines and grazing paddocks, treated wastewater emerged as an option.

5.3.3 Community attributes at the provincial level: self-management in agribusiness

The farmers in Scheme A are white farmers. They are part of an agribusiness which historically grew profitable but is socially skewed. Western Cape, where the scheme is situated, is culturally diverse. Colored people constitute the largest group, followed by black Africans and whites. The last group represents about 15.7% of the population (Census, 2011b). During the apartheid era, restrictions existed on land ownership for nonwhites outside of the homelands. This allowed the white population to dominate commercial agriculture, particularly in Western Cape, which is regarded as the "historical hearth of white farming" (Moseley, 2007). In effect, agriculture in Western Cape is the most commercialized and export-oriented in the country (Moseley, 2007). The agricultural sector in the province is responsible for 23% of the sector's contribution to the national GDP and for about 60% of agricultural exports, and it is a major employer (Wesgro, n/d in Elsenburg, 2014).

White farming is a male-dominated agribusiness. The farmers are well educated – around 76% of the surveyed farmers have completed higher education – and they are well organized, e.g. in study groups, agricultural associations, etc. Furthermore, they have good access to information and resources. Average household income is estimated at USD 3792 per month[12]. The strong entrepreneurial initiative in this sophisticated agribusiness appears to have been key for the uptake of treated wastewater.

5.3.4 Rules-in-use: formal rules at the national level

Water resources are well regulated in South Africa, by the National Water Act (NWA) of 1998 (Republic of South Africa, 1998) and the Water Service Act of 1997 (Republic of South Africa, 1997). The acts are complementary and provide the framework for water resources management in the country (DWAF, 2004b). Key features of these acts include, first, the recognition of the state, on behalf of the South African people, as the custodian of water. This dissolves the concepts of private water ownership and water rights. Instead, rights of access to water have to be secured through fixed-period water use licenses. Second, they describe a water governance regime based on decentralization, with catchment management agencies as managing authorities. Third, the acts embrace the concepts of water conservation and demand management as drivers for efficient use of water (Naidoo & Constantinides, 2000).

The NWA emphasizes water as a scarce resource that forms part of a unitary, interdependent cycle that should be managed in an integrated manner and in which protection of quality of water resources is fundamental to ensure sustainability for the benefit of all users. Sustainability and equity are fundamental principles in protection, use, development, conservation, management and control of water resources (Republic of South Africa, 1998). The strategies for implementing the NWA provisions are stipulated in a National Water Resource Strategy (NWRS), which is regularly revised (DWAF 2004b; DWA, 2013a). An important component of the NWRS is water quality management. Deterioration of water quality is a major threat to South Africa's ability to

[12] Exchange rate USD 1 = ZAR 10.13

provide sufficient and appropriate quality water to meet people's needs and to ensure sustainability (DWAF, 2004b; DWA, 2013a). The major sources of pollution identified are: agricultural drainage and wash-off (irrigation return flows, fertilizers, pesticides and runoff from feedlots); urban wash-off and effluent return flows (bacteriological contamination, salts and nutrients); industry (chemical substances); mining (acids and salts); and insufficient sanitation services (microbial contamination) (DWA, 2013a).

The NWRS considers reusing water an important strategy to increase availability and to meet water demand: "greater re-use could therefore be a substantial source of water (…). Where return flows are re-used directly, sophisticated treatment processes and proper management may be required, depending on the quality of the return flow and its intended applications" (DWAF, 2004b, p. 44). The second edition, NWRS-2 (DWA, 2013a), recognizes that reuse of water has become even more acceptable and feasible due to increasing water scarcity, improved treatment technology and decreasing treatment costs. According to the NWRS-2, about 14% of the water is reused indirectly through wastewater return flows in rivers. Direct reuse is subject to regulatory authorization and control. Since direct reuse of treated effluent can pose risks for public health, it must be managed carefully and be subject to water quality controls (DWA, 2013a). These controls include not only provisions in the mentioned NWA and Water Services Act but also the Mineral and Petroleum Resources Development Act (Act 28 of 2002), the National Environmental Management Act (Act 107 of 1998), the National Environmental Management: Waste Act (Act 59 of 2008), the National Environmental Management: Integrated Coastal Management Act (Act 24 of 2008), and municipal bylaws.

The NWA introduced a water-use authorization system. In this system water users have to apply for a water-use license. Exemptions from this application procedure are foreseen in the act for large quantities from specific water sources and for specific people under the system of General Authorizations (van Koppen & Schreiner, 2014). General Authorizations can still serve as a regulatory tool. Accordingly, a specific General Authorization exists for wastewater use. The Revision of General Authorizations in terms of Section 39 of the NWA (Government Gazette, 2013) is now the legal instrument for wastewater use, applicable nationwide, which allows irrigation with wastewater if certain quality parameters and conditions are met (DWA, 2013b).

5.3.5 Rules-in-use: formal rules at the provincial level

At the provincial level, the CCT already promulgated its Treated Effluent By-Law in July 2010 (City of Cape Town, 2010). This by-law controls and regulates the use of treated effluent in its jurisdiction and matters connected therewith. This legal instrument for treated effluent in the jurisdiction of the CCT binds all the organs of state. Any provision in any other by-law concerning treated effluent is subject to the provisions of this by-law (City of Cape Town, 2010). Under this framework individuals can apply for supply of treated effluent through a signed agreement: "Treated effluent from the treated effluent supply system of the City will not be supplied to any premises unless the consumer, with the consent of the owner, has applied to the City for a supply and such application has been agreed to, subject to such conditions as may be imposed by the Director: Water and Sanitation" (City of Cape Town, 2010, p. 1271).

The application includes: a declaration that the applicant is aware of and understands the contents of the agreement; acceptance of liability in terms of the by-law for the cost of the supply of treated effluent until the agreement is terminated; the purpose for which the treated effluent is to be used; the plumbing layout; etc. (City of Cape Town, 2010, Section 12). Furthermore, this by-law stipulates the use of treated effluent for irrigation purposes under various categories of sewage purification works. In summary, it allows irrigation of crops with treated effluent depending on the level of treatment that the wastewater has received. For advanced purification (including primary, secondary and tertiary treatment), the final effluent complies with Special Standards, and the quality is comparable with that of drinking water. In that case, fruit trees and vineyards may be irrigated (see City of Cape Town, 2010 for other levels).

Now that the context of growing water scarcity, the sophisticated and profitable agribusiness, and the advanced regulatory tools at the provincial level (supported by national policies and regulations) have been described, we turn to the relevant action arena of the action situation and to the actors.

5.4 Action arena of action situation and actors

5.4.1 Action situation

The second component of IAD regards the analysis of the boundaries or 'action arena' of an action situation and the actors. So, this consists of those parts of the water and agricultural sector in Western Cape dealing with the use of treated effluent for agricultural irrigation[13]. "The action situation is the core component of the IAD framework, in which individuals (acting on their own or as agents of organizations) observe information, select actions, engage in patterns of interaction, and realize outcomes from their interaction" (McGinnis, 2011, p. 173).

The action situation here is the uptake of treated effluent for irrigation by the actors: the farmers who decided to organize and establish Scheme A, seeking to respond to the lack of alternative water sources for irrigation in the area.

Around 2003, when the farmers' initiative to use treated effluent started, one of the municipal wastewater treatment plants of CCT, the Potsdam Wastewater Treatment

[13] Abandoning the distinction between action situation and arena has been recommended (McGinnis, 2011); however, the action arena is made explicit here to facilitate the analysis.

Works (WWTW), supplied treated effluent. The main users of the effluent include golf courses, industry, schools and sport fields. At that time, there were severe problems of pollution in the Diep River, the receptor for Potsdam WWTW effluent.

The Diep River is 65 km long. It originates in the Riebeek-Kasteel Mountains and flows south-westerly through Malmesbury, passing through the Rietvlei Wetland Reserve, and ending in Table Bay. This river is a major freshwater ecosystem in Western Cape. Various sources of pollution exist in the river basin, such as an oil refinery, industries, sewage treatment plants and a landfill site (River Health program, 2003; Shuping, 2008; Jackson et al., 2009). According to the State of Rivers Report (River Health program, 2003), water quality, habitat integrity and flow have been severely altered in this system, mainly through the cumulative effects of farm dams and abstraction, removal of the natural riparian vegetation, riverbed modification, treated wastewater discharges and agricultural runoff, as well as through the introduction of alien fauna and flora.

A local environmental NGO put particularly strong pressure on the municipality to address the issue of pollution. The ecological impact of pollution on the Rietvlei Lagoon was widely known, as it has been followed by the media[14]. For instance, in December 2006, a drop in oxygen levels in the water caused the death of thousands of fish and small crabs in the lagoon. This event was described by the locals as an ecological disaster (Steenkamp, 2006). Meanwhile, Friends of Rietvlei had been established to act as a support group for the Rietvlei conservation area and its surroundings; the area included the Rietvlei Wetland Reserve, the Diep River conservation area north of the Blaauwberg road bridge, and the Diep River estuary. Their activities include assisting the Blaauwberg administration in the management of Rietvlei, and advising on various other environmental committees in the area (Friends of Rietvlei, 2015).

In this situation, the CCT was looking for any opportunity to give the effluent another use instead of discharging it into the river. This would partially solve the problem of pollution that was in the spotlight at that time, and at the same time it would help the municipality meet water demand – a constant problem mainly due to rapid urbanization. The CCT already had some experience with the use of treated effluent on an *ad hoc* basis, driven by private-sector initiatives (DWAF, 2007). Furthermore, reuse of treated effluent was regarded as a potentially large water source, and further research was recommended in the Internal Strategic Perspective for the Berg Water Management Area (DWAF, 2004c). Reuse would also comply with the government's general objectives regarding water conservation and demand management, of which water reuse is a fundamental component. In this action situation of growing public pressure on the CCT managers to avoid discharge from Potsdam into the river, the farmers of Scheme A expressed their interest to take up and pay for effluent.

---

[14] See http://www.iol.co.za/news/south-africa/milnerton-lagoon-a-shadow-of-former-self-1.382218 and http://westcapenews.com/?p=1056

5.4.2 The actors: characteristics of the irrigation scheme

The two main actors in this situation are the group of farmers of Scheme A, proposing to use treated effluent, and the CCT, supplying the water, as discussed below. Other actors who are indirectly involved are the Department of Water and Sanitation (DWS, represented by its regional office in Western Cape) and the wine industry in the region. The characteristics of the farmers and the irrigation scheme are presented in detail here, while the other actors will be addressed in the next subsection.

The farmers and their irrigation scheme have very specific characteristics. The scheme was mainly a private initiative, funded entirely by the users. Farmers in the area of the project (see Figure 5-1) were invited to become members, but strict membership conditions were set. These included: (1) location of the farm within the proposed command area; (2) the willingness to use treated effluent, which means that the user accepts the risks as well as the benefits implied; and (3) the financial capacity to contribute to the investment in constructing the irrigation scheme. The latter was crucial in determining membership.

The beneficiaries of the scheme are 38 farmers that invested in the infrastructure. New farmers cannot join the scheme. The total irrigated area is about 3000 ha. Water is mainly used during summer (October–February), when the demand is high. The main crop irrigated is grapevines, and to a lesser extent olive trees. The technology used is drip irrigation. In order to guarantee the quality of the supply, farmers appointed their own engineer to run the scheme, from the WWTW to the final user. Farmers initially formed a joint venture, which by 2014 is to be transformed into a water user association.

Figure 5-1 Location of the scheme (schematic only)

The infrastructure to supply treated effluent to farmers has two parts. The first part, which is under control of the CCT, consists of:

– The Potsdam WWTW, which consists of an old and a new facility that run in parallel and treat the same raw wastewater. The old works include primary sedimentation, biological filtration, and maturation ponds. The new works include primary sedimentation, activated sludge, maturation ponds, denitrification and biological phosphorus removal (DWA, 2009). The total combined capacity is 47 million liters per day (MLD). Of this, about 36 MLD (77%) is reused and about 5–6 MLD is permanently discharged into the river as environmental flow. The effluent supplied is a mix of effluents from both works.
– The water completes the treatment process with a final UV disinfection treatment. Water quality is under the responsibility of Potsdam WWTW, and this is subject to the Green Drop Report (DWS, 2011). This instrument aims at improving wastewater management in municipalities across South Africa.
– A pump station located at the WWTW premises (three pumps, each with capacity of about 800 m^3/h).
– The main pipeline, to convey water up to a reservoir with storage capacity of 20,000 m^3. The municipality supplies farmers with water through the municipality's existing conveyance infrastructure, which also serves other users (industries, golf courses and sports fields) with treated effluent. The reservoir is located on private premises. It is covered with isolation material to avoid infiltration of water into the soil. The surface is also covered, to prevent people from entering the reservoir.

The second part is the irrigation scheme. It covers areas in Durbanville and part of Philadelphia. It starts at the reservoir and consists of:

– A main pump station, with four pumps, each with a capacity of 300 m^3/h, including a high-efficiency pump. It is an automated system. The maximum capacity is equivalent to 20,000 m^3 per day, pumping at 830 m^3/h.
– An ozone system at the main pump station, providing a final disinfection treatment to reduce *E. coli*.
– About 40 km of pipeline to distribute water. Part of the line runs parallel to the road, and then splits into a north line (to serve Philadelphia) and a south line (to serve Durbanville). The diameter of the main pipeline is 450 mm.
– Four boost pump stations to maintain pressure in the scheme. Each station has two pumps, with different capacities depending on the requirements.

The pipelines (to convey water to the fields) were designed for the 38 users who invested in the scheme. At present (2014), the pipelines are used at maximum capacity, and an upgrade is not possible; nor are there plans to upgrade the network in the future.

Each farmer has his own take-off point to extract water at a certain rate and pressure. The volumes of water are metered. Farmers are billed monthly based on usage. The payment has two components. The first is the water fee for treated effluent, established by the CCT at about USD 0.08/m^3. The second component covers operation and maintenance costs. Five rates (USD 0.15/m^3 is the lowest, and USD 0.17/m^3 the highest) exist depending on the pumping cost, which is influenced by farm location. Another rate of USD 0.56/m^3 applies to those who did not cover full capital costs. Finally, there is a yearly administration fee, based on the area of each farmer, and established at about USD 18.27/ha. This must be paid even if the farmer does not use the water. It covers expenses of the joint venture and technical personnel. So, part of the fees collected goes to the municipality for the treated effluent; the rest covers the operation and maintenance of the scheme. In summary, treated effluent costs USD 0.23–0.64/m^3. This is less than the cost of fresh water, which is estimated at USD 0.79/m^3 in the study area.

With this information the interactions between actors and their outcomes can now be analyzed.

5.5 Patterns of interaction and outcomes

Patterns of interaction describe the relationships among actors influencing decisions. The outcomes are the results of the interactions. Mapping interactions among actors and rules in a given action situation is essential to identify and understand the outcomes of the action arena (Smajgl et al., 2009). Three key patterns of interaction and their outcomes were identified.

1. *Actors: CCT and farmers*

Patterns of interaction: The CCT had received pressure from civil society to address issues of pollution in the Diep River caused by, among other factors, the low-quality water discharges from the Potsdam WWTW. In addition, water was scarce for farmers. Therefore, farmers saw the opportunity to use treated effluent from the WWTW to secure irrigation water. The municipality in turn saw the opportunity to make a reuse scheme feasible as the potential users were there.

Farmers use treated effluent based on a specific agreement between them and the CCT (one agreement for the joint venture that includes the whole group). This agreement was for a fixed period of time (20 years). During this period, farmers are entitled to use the effluent from Potsdam WWTW, up to 20,000 m^3 per day, if water is available.

Farmers are seasonal users, mainly during the summer, although they can withdraw year round; some farmers also withdraw in winter. Nevertheless, the CCT does not guarantee a supply of water, because it depends on what is available from the WWTW. Additionally, other users of treated effluent, using the water the entire year, may have certain priority. In practice, therefore, farmers struggle to make sure that water is available to them. The success of the scheme greatly depends on management in order to secure the supply of water and the quality of the effluent. There is a strong link between farmers and the CCT through the manager of the scheme, who rigorously follows the effluent from the WWTW to the end users. Worth mentioning is that farmers express trust in this relationship.

Since farmers receive the treated effluent from a local authority, in this case the CCT, they are not expected to obtain a registration for their water use (DWS, 2015). The underlying idea is that the CCT is entitled to a water use license for Potsdam WWTW issued by the DWS, and it is through this license that farmers can use the water.

Moreover, the CCT can prevent individuals from consuming the water, if they fail to pay their bills. Although this might not happen in practice, the CCT can act as the 'owner' and stop water supply when the agreement is not complied with. This implies a 'low cost of exclusion' (McGinnis, 2011).

Outcomes: The municipality benefits from supplying the water for a service fee instead of discharging it into the river, which in theory improves the quality of the river. Simultaneously, it helps in meeting water demand, as they do not have to supply fresh water to other users in the entire scheme such as industries, golf courses and sport fields. Farmers benefit from having a reliable source of water for irrigation. With irrigation available, farmers can increase crop yields or guarantee quality, and at the same time increase the value of their property as they have access to important resources, both land and water.

2. Actors: DWS and CCT

Patterns of interaction: The CCT interacts with the DWS in relation to water supply and wastewater management.

The CCT is responsible for supplying water to the city for uses such as drinking and industry. The city faces a water shortage, mainly due to population growth leading to higher water demand and irrigation expansion. The CCT is also responsible for wastewater management. They face problems of pollution due to discharges of low quality water in natural flows, resulting from their lack of capacity to operate and manage treatment plants. The use of treated effluent is an opportunity for the municipality to meet water demand and simultaneously improve wastewater management, as they have the regulatory incentives to do so – see e.g. the Green Drop Report (DWS, 2011). On the other hand, the DWS has the mandate to lower water demand through various strategies. Reuse of water is one of these. The inclusion of such measures in the NWRS is an important incentive for the sector, as it provides the regulatory framework.

Outcomes: The support from the DWS to formalize the use of treated effluent through the NWA and both NWRSs is an important incentive for the CCT. This has enabled the municipality to promulgate a by-law which provides the legal framework for reuse of treated effluent for different purposes, including agricultural irrigation. It seems that this by-law is the formalization of a practice which had already been taking place for some years. It might be also related to the engagement of the municipality in water demand management.

As for the recently updated General Authorization for the use of wastewater in irrigation, it is unknown whether it has been used; however, this instrument can facilitate the formal use of wastewater in other regions, where such by-laws do not exist.

3. Actors: Farmers and wine industry

Patterns of interaction: The wine industry is a powerful actor that certainly influences agricultural production in the area. It is one of the fastest-growing and economically most lucrative agribusinesses in Western Cape (Cape Wine Academy, 2002). Wine exports as a percentage of domestic sales increased from 13.8% to 81.6% in the period 1994–2005 (McDonald et al., 2006). Furthermore, the economic trade has led to an increase in plantings and production of premium cultivars (Fairbanks et al., 2004). The interaction between farmers and the wine industry is dictated by the price and production of grapevines. Yields of grapevines increase with irrigation. Some farmers in the scheme have partially shifted from wheat to vineyards. This was mainly motivated by the possibility of using treated effluent from Potsdam WWTW. Clearly, securing irrigation water is important in the development of viticulture in the area, and a clear incentive for farmers to opt for the treated effluent option.

Farmers (and the CCT) refer to the water as 'treated effluent', which implies that it is no longer sewage. This has a positive impact on people's perceptions regarding this activity. Furthermore, the fact that the wine industry is governed by several norms and regulations in terms of quality issues, including food safety, safe production practices, irrigation methods, etc., gives a sense of trust to consumers. Nevertheless, the current labelling of wine does not require indicating the source of irrigation water (Wines of South Africa, 2009). Furthermore, a study on irrigation with winery wastewater suggests that using augmented winery wastewater does not affect grapevine performance or wine quality substantially and thus might be regarded as a possible alternative source for irrigation of vineyards (Schoeman, 2012). Different irrigation strategies can increase yields of certain varieties of grapevines without compromising wine quality (see Myburgh, 2011).

Outcomes: The main outcome of this interaction is increased yields and overall production of grapevines due to secured access to irrigation water, the quality of which is seen as safe for health.

5.6 Evaluation

Evaluation criteria serve to determine aspects of the outcomes that are satisfactory or need improvement (McGinnis, 2011). The commonly used criteria include economic efficiency, equity, accountability and adaptability (Ostrom, 2005). Efficiency in use of resources captures the productivity of resource use and reuse. Equity regards distributional outcomes and processes. Accountability is considered especially with respect to direct users of the resource. Finally, adaptability is defined as a system's capacity to suffer a disturbance and still continue to function, without losing functional integrity (McGinnis, 2011).

5.6.1 Efficiency

Farmers use water quite efficiently, for instance by harvesting runoff and rainfall (i.e. harvesting water that would otherwise be lost); by using drip irrigation (reducing water loses through infiltration and evaporation) and high-tech soil moisture monitoring systems (to apply the necessary amount of water to the plant); by adjusting their production to water availability; and by the selection of crops. Water use efficiency - in terms of yield per unit of water – for grapes varies regionally, however, overall it is high across Western Cape (AGRIPROBE, 2007). A study conducted in nearby areas estimates grapevine water-use efficiency at 3.3-4.8 kg/m^3 for 2005/06 (WaterWatch, n/d). Within the basin, competition for water among sectors is strong. Irrigated agriculture uses about 43% of the surface water, so efficient irrigation is essential (AGRIPROBE, 2007). Furthermore, the use of treated effluent increases the efficiency of water use in the sector – because water is re-introduced to the system, while raising the productivity of the farmers. The CCT is forced to improve the treatment system to provide higher-quality water; part of this water is reused, and the rest improves the water quality in the river. This is a way to achieve efficiency in terms of wastewater management and protection of water resources.

5.6.2 Equity

Equity is a central principle of the NWA in the protection, use, development, conservation, management and control of water resources in South Africa. This principle recognizes the basic human needs, the need to protect water resources and the need to promote social and economic development that redress inequities from the past (Republic of South Africa, 1998). Equity in the South African water law and context means access to water for all groups, in particular historically disadvantaged communities. The type of scheme described in this article requires large capital investments from the users of the treated effluent, strong self-management, and historically grown relations to profitable global markets. While more employment would be created, taking up treated water may not be an option for small or emerging black farmers under current conditions.

5.6.3 Accountability

Although the municipality is responsible for treatment of wastewater, it seems that they are not accountable to farmers in aspects such as purity of the effluent, suitability, or damages arising from the use of the effluent. In this respect, the municipal by-law reads as follows (Section 32):

> (1) The City does not warrant, expressly or impliedly, the purity of any treated effluent supplied by it or its suitability for the purpose for which the supply was granted. (2) The quality of the treated effluent may vary and the consumer must take this into account. (3) The use of treated effluent is entirely at the risk of the consumer and the City is not liable for any consequential damage or loss arising directly or indirectly therefrom. (4) The City is under no obligation to test the quality of the treated effluent. (5) Should a consumer require the quality parameters, he or she must have it analyzed at own cost and the onus is on him or her to monitor the quality of the water supplied. (City of Cape Town, 2010, p. 1274).

Furthermore, as farmers indicate, under the current agreement there is no guarantee of supply. This aspect is subject to water availability. Basically, there is little formal accountability of the municipality to the users. This is an issue that certainly needs to be addressed for the sustainability of the scheme.

5.6.4 Adaptability or sustainability

The realization of the scheme indicates that under the given conditions such a scheme is feasible and economically sustainable. Clearly, there are implicit risks when irrigating with treated effluent, both in environmental and health terms. However, the greatest strength of the scheme is the fact that it is privately funded and self-managed, which has allowed farmers to react rapidly in times of emergency. Independence from the municipality in operating the scheme (downstream from the reservoir) allows them to make their own decisions for safe use of treated effluent. On the other hand, such self-management may explain why the municipality relaxes when it comes to securing good quality water at all times. Farmers have done well so far in managing treated effluent (e.g., installation of an additional ozone system, periodic monitoring of water quality). However, it is important for the scheme's sustainability that the municipality takes care of this aspect in more detail. The Green Drop Report (DWS, 2011) may serve this purpose. Furthermore, the fact that the river is less polluted, because the effluent is not discharged, can be considered an increase in sustainability, as is the general perspective of water reuse. Finally, another aspect to consider is the institutional framework, which encourages such initiatives. This is fundamental in that it provides the regulatory foundations required to make such schemes possible.

5.7 Conclusions

The South African water policy is trying, through different strategies, to address the growing competition for water. One of these is the reuse of wastewater in response to increasing water scarcity. The analysis in this chapter shows that direct and planned reuse of wastewater for agricultural purposes can be successful under certain conditions.

First, awareness regarding water scarcity should exist. This helps the government, the municipalities and the users to see water reuse as a real option. This element is linked to a second element: pollution of rivers. The growing public awareness with respect to this issue has triggered various initiatives aiming at improving water quality in the rivers; this includes water reuse.

The third element is the formalization of water reuse through policies and regulatory frameworks. This can be regarded as a consequence of water scarcity. Certainly, there are implicit risks in using wastewater, whatever the purpose. However, a formalized practice provides the necessary elements for a safe practice. This example shows that reuse of water is possible thanks to a strong guiding policy, which reflects the needs of the country in terms of water management. This latter spawned in a framework that provides the mandates for reuse of water at the local level (the by-law). Although there are still unresolved issues, for instance in terms of accountability, it is possible to see the benefits of having a regulatory framework guiding the practice (e.g., water quality standards, treatment processes, crop restrictions, and categories of types of uses), as it gives certainty to public agencies but also to users. Of course, guidelines can always be improved and adjusted to local needs; however, a worst-case scenario would be having no such guidelines.

Fourth, a demand for water exists. This is linked to the agricultural markets. Farmers would not consider the reuse option if alternative sources were available. It only makes sense if making such an investment provides benefits for their production. Thus, demand, generated from access to agricultural markets, is fundamental for the sustainability of the scheme but also for its realization. A secure market is essential to engage in the high capital costs of such schemes.

Fifth, in terms of management, the most important features of the scheme are self-management and self-funding. In line with the benefits identified for irrigation schemes under the framework of irrigation management transfers, these elements are of key importance for the sustainability of the scheme. The underlying assumption is that in such schemes users will behave as ‘owners’. In this case, the benefit is mainly in terms of safe use of the effluent, as there are issues of water quality involved, but also in terms of guaranteeing a well-functioning scheme, where users are satisfied with performance. On the other hand, when quality issues are involved, a scheme requires monitoring from regulatory agencies. This issue needs to be further explored.

Last but not least, an important aspect is the farmers' capacity to bring together knowledge, skills, and technical and capital resources. These aspects are probably the most fundamental for the success of water reuse for agricultural irrigation under the conditions of Western Cape.

Chapter 6. Institutional analysis of the agricultural use of treated wastewater in Israel

Abstract

The use of wastewater is gaining momentum worldwide. Increasingly wastewater is regarded as an alternative source to cope with water scarcity. With some 70% of treated wastewater being reused in agriculture, Israel is the leader in this practice. Moreover, the practice is planned, regulated and implemented by the State. Important institutional arrangements include the recognition of the potential of wastewater and taking care of health and environmental risks. The identification of clear objectives, as well as technological advancements, has enabled the implementation of water reuse. But even more important is the political will to address issues of water scarcity, water conservation and pollution prevention. The purpose of this study is to untangle the institutional arrangements set up in Israel and to learn from them, in order to understand what is needed for a safe use of treated wastewater in agriculture.

Keywords: treated wastewater (re)use, irrigation, agriculture, institutional analysis, Israel

6.1 Introduction

Water availability is essential to the success of agricultural production. About 60% of all the world's freshwater withdrawals are used in irrigation; consequently today's food production is highly dependent on adequate irrigation (Kenny et al., 2009). The rising population will not only demand more food, but also more water. In searching alternative water sources to meet demand, treated wastewater[15] from municipal sources provides many advantages: it is highly reliable and supply normally increases with population growth; the costs of treating wastewater to secondary (or even tertiary) level is generally lower than the costs of unconventional water sources such as desalination; the option of allocating treated wastewater to irrigation is less expensive compared to other uses, therefore preferred by service providers; treated wastewater reduces the use of freshwater in irrigation; in some cases, treated wastewater can be a source of nutrients; and in many cases it will be the highest quality water available to farmers (USEPA, 2012).

Across the world the use of treated wastewater is growing in importance. Developed countries such as the US reuse about 7 to 8% of their wastewater; Australia uses about 8% and plans to increase reuse up to 30% by 2015; Singapore uses about 30% and has long-term planning to diversify its water supply; Saudi Arabia reuses some 16% and

[15] The terms: treated wastewater, effluent and reclaimed water are used interchangeably.

plans to increase up to 65% by 2016; yet the leader in wastewater reuse is Israel with some 70% of treated wastewater being reused in agriculture (USEPA, 2012).

Israel faces severe water scarcity, at the same time it is the leader in advanced water technology. It has an ambitious water program to address water scarcity, which includes investing in desalination (it already has over 30 seawater desalination plants operating through reverse osmosis); fixing water quotas; supporting water-efficient practices and upgrading wastewater treatment capacities in order to increase the recycling of wastewater (Moilanen & Mroueh, 2010).

The purpose of this study is to untangle the institutional arrangements that facilitated the use of treated wastewater in Israel, and to understand the drivers, the challenges and the gaps. Ultimately, the purpose is to learn from this case and to draw lessons for other countries. The chapter is organized as follows: the next section presents the analytical framework, constituted by three parts or components: the institutional environment, the institutional structure, and the institutional assessment. The first two components are addressed in section three and four, respectively. Section five presents the institutional assessment of the institutional environment and the institutional structure. Finally, conclusions are presented in the last section.

6.2 Analytical framework

The analytical framework used to analyze the institutional settings of wastewater reuse in Israel is the same as the one used for the Indian case. Therefore, to avoid repetition, refer to Chapter 3 for a detailed description of the analytical framework.

Note that the purpose of assessing the institutional structure and environment (second part of Figure 3-1) is to identify positive outcomes, to find where there is room for improvement, and ultimately learn from the Israeli experience.

6.2.1 Data collection

The study applies a qualitative approach to explore and to gain understanding of the case study, and is based on a literature review. The main sources of information were policy documents, acts, reports, and official websites of Israeli institutions; as well as reports, chapter books and gray literature available online.

6.3 Institutional environment

6.3.1 Biophysical context: limited water resources

The State of Israel is located in the southeastern shore of the Mediterranean Sea (Figure 6-1). Various climatic conditions are found in the country, from subtropical to arid, due to the altitudinal variation from 400 m below sea level up to 1000 m above sea level (Ben-Gal, 2010). The region is characterized as water scarce. In effect, Israel ranks among the most water scarce countries in the world, where water availability per capita was estimated at 276 m^3 per year (AQUASTAT, 2002). Variation in rainfall is significant across the country in a distance of 300 km from North to South. The northern part (near the Lebanese and Syrian border) receives on average +800 mm per year, whereas the southern part (Gulf of Aqaba) gets on average around 50 mm per year. About 80% of rainfall occurs in the northern part during winter time from November to April (Tal, 2010). This region has always been susceptible to droughts; however, due to climate change drops in rainfall are expected (Tal, 2010; Kislev, 2011).

Figure 6-1 Map of Israel

Source: http://www.imagekb.com/israel-map

Rainfall constitutes the main natural water source: winter rainfall is stored to be used during summer (dry season). The main water reservoirs are: the Sea of Galilee, the Costal Aquifer, and the Mountain Aquifer. Furthermore there are also smaller regional sources in Upper Galilee, Western Galilee, Beit Shean Valley, Jordan Valley, the Dead Sea Rift, the Negev, and the Arava (Tal, 2010).

Considering the geographic variation in rainfall, water transfers from North to South do occur, especially to the center of the country, which is most populated, and to the Negev, where agricultural production depends on irrigation (Kislev, 2011). The National Water Carrier[16] – first operated in 1964 – was constructed to supply water to the agricultural sector; this is no longer the case, a great share of the water is now diverted to the urban sector – the largest fresh water user. The National Water Carrier transfers water from the Sea of Galilee towards the west and southern parts; other systems, also linked to the National Water Carrier, supply water to Upper Galilee, Western Galilee, the main cities, and the Negev (Kislev, 2011).

6.3.2 Historical and socio-economic context: water and agriculture

Historically the role of agriculture in Israel's economy is important. For early settlers farming was an ideology, which was needed to transform the occupational and social structure of Jews (Ben-Gal, 2010). In early years of the State of Israel, large numbers of immigrants arrived, who were settled in agricultural-based communities. Many of these communities were located at the arid borders of the territory, and they were conceived as vehicle to take up land ownership (Ben-Gal, 2010). At the same time, the state needed to feed the growing population and create low skilled-jobs for immigrants (OECD, 2010). These agricultural communities became the core of the country's spirit. Furthermore, 'making the desert bloom' was the national goal, which positioned agriculture beyond the mere production of food (Ben-Gal, 2010).

The expansion of agriculture in Israel was possible thanks to irrigation. The state strongly supported this sector: water was subsidized, price support for basic crops was offered, disaster relief was provided, extension agents supported farmers' practices, and there was a substantial support for research and development (OECD, 2010; Ben-Gal, 2010). Nevertheless, in recent years the support of the state has declined; water prices have increased – mostly to cover investments in water supply – and subsidies for irrigation water have decreased. New policies allow farmers to change the zoning of their land or to rent land to large agribusiness, which was almost impossible in the past. The trend for agriculture now is that of economy of scale where farms have to grow to stay competitive. The share of the agricultural sector in the gross national product (GNP) is some 2.5% and it represents about 3% of the exports (Ben-Gal, 2010).

In the period 1948 to 2001, the total area of arable land has increased from 160,000 ha to about 420,000 ha. In the same period, irrigated land has increased from 30,000 ha to 186,600 ha (Inbar, 2007). The climatic, topographical and soil conditions allow a wide

[16] The National Water Carrier is the largest water project in Israel. It consists of a system of pipes, open canals, tunnels, reservoirs and large scale pumping stations built in order to transfer water from the Sea of Galilee to the highly populated center and the arid south. This system constitutes a single network linking most of the regional water projects throughout the country. It has a capacity of 1.7 million m^3 per day (Kantor, n/d; Waldoks, 2008).

range of agricultural production (Ben-Gal, 2010). A variety of crops are produced. Irrigated-crops include fruits (citrus, avocados, kiwis, mangos, bananas, dates, apples, pears, and cherries); vineyards (table and wine grapes); flowers and ornamental plants; vegetables; maize, cotton, groundnuts and potatoes. Rain-fed winter crops (some 35.8% of the land) include wheat, hay, legumes, and safflower (Ben-Gal, 2010).

Nonetheless, water shortage is the main limiting factor for agriculture development in Israel (Inbar, 2007). Water consumption – from all sectors – has increased from 230 to 1997 million m^3 in the period 1948 - 2002[17]; only 82% of the latter is renewable (Ben-Gal, 2010). Considering these facts, Israel has decided to increase wastewater reuse. Over the years, fresh water allocated to agriculture will be replaced by marginal water, e.g., treated wastewater or desalinated water (Kislev, 2011; OECD, 2015). Treated effluent is expected to reduce fresh water allocation to irrigation while preserving the scope of agriculture (Tal, 2010). The agricultural sector remains the largest water user, with some 58% of the water consumed. However, marginal water (incl. treated wastewater, brackish and desalinated) accounts for about 62% of the water used by this sector (see Table 6-1).

Table 6-1 Water consumption in Israel in 2013

Sector	Potable water (million m^3)	Marginal water (million m^3)	Total (million m^3)	(%)
Industry	91.5	48.8	140.3	6.8
Domestic	717.8	15.4	733.2	35.3
Agriculture	460.6	744.0	1204.6	58.0
Total	1269.9	808.2	2078.1	

Source: Water Authority (2015a).

6.3.3 Socio-economic context: treated wastewater as a new water source

Israel has limited water resources to develop a number of activities, including agriculture. This has been recognized early in the establishment of the State; therefore water shortage was partially addressed by improving water use efficiency in agriculture and by the promotion of water conservation. Nevertheless, the key of Israel's management strategy was to create policies to develop new sources of water such as brackish water, treated wastewater and desalination (Tal, 2010; Ben-Gal, 2010). In effect, water management in Israel was characterized as the pursuit of expanding resources (Tal, 2010).

Furthermore, Israel was among the first countries to recognize the potential of recycled municipal effluents as a water source. Water managers approved – in 1956 – a strategy for wastewater reuse and made it a central component of the water management strategy

[17] In 2013, the total water consumption was estimated at 2187 million m^3 (Water Authority, 2015a).

(Tal, 2010). This strategy envisioned recycling of 150 million m^3 of wastewater to be used in agriculture. About 50 projects were developed to connect farms to municipal wastewater treatment facilities (Ben-Gal, 2010; Tal, 2010). In 2010, about 350 million m^3 of wastewater were recycled, which represents about 77% of all wastewater produced, and about a fifth of the country's water supply (Tal, 2010). For the agricultural sector, treated wastewater represents about a third of the supply (see Table 6-2), and is expected to increase (Ben-Gal, 2010; Tal, 2010).

Table 6-2 Supply of water and treated wastewater to agriculture

Year	Total water supply (million m^3/yr.)	Agricultural supply (million m^3/yr.)	Reused wastewater (million m^3/yr.)	% of total supply	% of supply to agriculture
1965	1329	1075			
1970	1564	1249			
1980	1700	1235	80	4.7	6.5
1990	1804	1216	159	8.8	13.1
2000	1924	1138	269	14.0	23.6
2005	1961	1126	335	17.1	29.8

Source: Central Bureau of Statistics in Ben-Gal (2010).

However, the incorporation of treated wastewater reuse in the national planning came along with the realization that wastewater generation is to increase in urban centers and that if this is not managed properly, it can create problems for public health and the environment. During the 1950s, only a few centralized sewage collection systems existed in Israel, and virtually no treatment facilities were in place, which resulted in pollution of valuable water sources and the sea, and the outbreak of epidemics – cholera in 1970 and polio in 1988. This situation raised awareness of the risks of wastewater and the need to establish sewage systems and treatment facilities (Tal, 2010; Kislev, 2011). On the other hand, it pushed forward wastewater reuse, conceived to be used in agriculture (Tal, 2010).

Wastewater is managed at the local level. By law, local authorities are responsible for the treatment of wastewater (Inbar, 2010). While cities collect and treat their wastewater; farmers in the vicinity build recycling facilities and use treated wastewater. Local governments are responsible for the costs of treatment. A large share of the State budget is committed to support wastewater and recycling systems (Kislev, 2011). In the period 2000-2010, the annual average State support for investment in sewage treatment plants was ILS 367 million (or some USD 95 million[18]) and ILS 128 million (or USD 33 million) were spent in recycling facilities. They represent about 61 and 21%, respectively, of the total State budget spent in development for the sector – amounted to ILS 604 million (or USD 157 million) (Kislev, 2011).

[18] Value estimated at an exchange rate: USD 1 = ILS 0.26.

The largest treatment facility is the Dan Region Wastewater Reclamation Project, located in Shafdan. This plant was constructed during the 1970s to treat, at tertiary level, sewage from Tel Aviv metropolitan area, which includes some 15 cities. About 130 million m^3 per year of high-quality water is produced and used by farmers in Negev, after it is injected into aquifers, where it undergoes an additional filtration process (Tal, 2010). Effluents from other facilities are more restricted for two reasons: health risks to farmers and their produce, and high salinity that can damage reservoirs. The second largest plant is Kishón, which treats wastewater from Haifa and surroundings, and supplies treated effluent to the Jezre'erl Valley, the Harod Valley and Lower Galilee (Kislev, 2011).

6.3.4 Legal context: rules-in-use for wastewater reuse

From the point of view of public health, wastewater reuse raised questions about the quality of the effluent (Tal, 2010). Nevertheless, one of the criteria for successful use of treated wastewater was that the treatment level is high enough to guarantee safe use of the effluent (Ben-Gal, 2010). In 1953, the Ministry of Health recommended one of the world's first wastewater irrigation standards, which excluded raw sewage as irrigation water; and limited the crops that would be irrigated with treated effluent to cotton, fodder, and those which are not consumed raw (Tal, 2010).

The decision of Israel to increase the use of treated wastewater required standards that allows the effluent to be used unrestricted in irrigation without risks to soils and water sources (Inbar, 2007). Furthermore, this would also allow treated wastewater to become the main source for irrigation (Ben-Gal, 2010). Accordingly, in 2001 the Ministry of the Environment proposed to review and upgrade the water quality standards for the agricultural use of treated wastewater and its disposal into receiving water bodies. The new standards – for unlimited use of treated wastewater – were approved in 2005 (Tal, 2010). They are more stringent to minimize potential damage to water, flora and soil; therefore they require higher treatment levels (Inbar, 2007; Tal, 2010). Some aspects of the regulation are based on European standards (e.g., to limit the discharge of heavy metals); others are developed to address the unique conditions of Israel (e.g., regulations prohibiting discharges of brines into municipal sewage systems). Special attention is given to salinity of municipal sewage, which is an issue of importance in Israel (Inbar, 2007; 2010). It is expected that the new standards will facilitate the reallocation of about 50% of freshwater (500 million m^3) from agriculture to other sectors: domestic and industrial (Inbar, 2010).

Table 6-3 presents different standards for agricultural use of wastewater. The standards from Israel are comparable to those from the US and Australia.

Table 6-3 Water Quality Standards for agricultural wastewater reuse

Parameters	Units	US EPA (*)	WHO 1989 (**)	Australia, NSW (***)	Israel (****)
Fecal coliforms	Unit/100 ml	No detectable fecal coliform[a]	<1000 [c]	<10	10
Intestinal nematode egg	larva/L		<1[d]	<1	
Electric conductivity	dS/m	<0.7[b]			1.4
pH		6-9		6.5-8.5	6.5-8.5
TSS	mg/l				10
BOD	mg/l	≤10		40-1500 [e]	10
COD	mg/l				100
Dissolved oxygen	mg/l				>0.5
Total nitrogen	mg/l	Varies according to state		50-100 [e]	25
Total phosphorus	mg/l			10-20 [e]	5
SAR	$(mmol/l)^{0.5}$				5
Arsenic	mg/l	0.1		0.1 [f]	0.1
Boron	mg/l	0.75			0.4
Cadmium	mg/l	0.01		0.01	0.01
Chromium	mg/l	0.1		0.1	0.1
Cobalt	mg/l	0.05		0.05	0.05
Copper	mg/l	0.2		0.2	0.2
Iron	mg/l	5		0.2	2
Lead	mg/l	5		2	0.1
Manganese	mg/l	0.2		0.2	0.2
Mercury	mg/l			0.002	0.002
Nickel	mg/l	0.2		0.2	0.2
Selenium	mg/l	0.02		0.02	0.02
Zinc	mg/l	2		2	2
Sources:		USEPA (2012)	WHO (1989)	DEC (2004)	Inbar (2010)

(a) Number of total or fecal coliform organisms (whichever one is recommended for monitoring in the table) should not exceed 14/100 ml in any sample.

(b) Adapted from FAO 1985 in USEPA (2012).

(c) For unrestricted irrigation.

(d) For restricted or unrestricted irrigation; unrestricted irrigation refers to irrigation of trees, fodder and industrial crops, fruit trees and pasture; restricted irrigation to irrigation of edible crops, sport field and public parks.

(e) For medium strength.

(f) Trigger values for metals in irrigation effluent for long term use on all soil types (up to 100 years); this applies to all metals listed.

(*) For food crops intended for human consumption, eaten raw; use of treated effluent in surface or spray irrigation.

(**) The new guidelines – WHO 2006 – provide guidance on health protection measures for safe use of wastewater. They are based on: scientific consensus and best available evidence; health based targets; good practices and a multiple-barrier approach; to be adapted local social, economic, and environmental factors; striving to maximize overall public health benefits and the beneficial use of scarce resources; considering different exposed groups: consumers, farmers, nearby communities (Rousseau & Hooijmans, 2010).

(***) For raw human food crops in direct contact with effluent, e.g., via sprays; and irrigation of salad vegetables

(****) For unrestricted irrigation

6.4 Institutional structure

6.4.1 Water law

The water sector in Israel is governed by numerous laws, dealing with planning and building, health and environmental protection (Kislev, 2011). However, the Water Law of 1959 (State of Israel, 1959) provides the regulatory framework only for water.

6.4.1.1 Water rights and allocation

The Water Law establishes that water sources in Israel are the property of the public and they are controlled by the State, in order to fulfill people's needs and the development of the country (Sec.1, State of Israel, 1959). Under this law, "any individual is entitled to receive water and to use it, in accordance with the provisions of this law" (Sec.3, State of Israel, 1959, p. 1). Furthermore, the law explicitly states that a person's right to receive water is valid as long as it does not lead to salinization or depletion of the water source (Sec.5, State of Israel, 1959). Any right to water is linked to a purpose, these are: domestic, agriculture, industry, labor, trade and services, public services, and protection and restoration of nature and landscapes. The right to water ceases upon the cessation of the purpose (Sec.6, State of Israel, 1959).

The law does not recognize private ownership of water or its use; it is the state that manages all water sources (Kislev, 2011). In this respect, the law reads as follows: "a person's right in any land does not confer on him any right over a water source that is situated in that land, or that passes through it or in its borders, but the provision of this section does not derogate from the right of any individual under Section 3" (Sec.4, State of Israel, 1959, p. 1).

Water supply for all uses is done through the regional water corporations. The municipal and regional water corporations are responsible for delivery and quality of water, as well as for wastewater treatment. They do not own water rights, but entitlements to use water are defined by law. Water corporations purchase water entitlements from the central water company: the Mekorot. The period granted for the entitlement is in perpetuity, but conditional upon beneficial use (OECD, 2015).

By law, the agricultural and manufacturing sectors receive water quotas, which are determined administratively. In contrast, there are no quantity restrictions for the domestic sector, which can use water on demand, as long as users pay for it (Kislev, 2011). Water is allocated to the agricultural sector by the Water Authority – this has replaced the Water Commissioner since 2007 – which is responsible for safeguarding water quantity and quality, issuing abstraction licenses and allocations to users (Shevah, n/d). Water use entitlements are based on an assessment of the land size, type of crop and other agricultural needs. If an entitlement was not used for a period of time, it remains in place for the period granted. Farmers can apply to the Ministry of Agriculture and request reallocation of quotas (OECD, 2015).

6.4.1.2 Regulations of water use

Regulations include three main areas: regulation of natural sources and water withdrawal; allocation of water to end users; and economic regulation of the supplier and its activity (Kislev, 2011).

A strong emphasis is put on the preservation of water: water should be handled efficiently; water facilities should be maintained in proper conditions to prevent wasteful use of water; and blockage and depletion of water sources should be refrained (Sec.9, State of Israel, 1959). When a water source is becoming depleted, the production of water from that source should be reduced or regulated in order to guarantee water supply (Sec.19, State of Israel, 1959). Moreover, an obligation to meter water was imposed; water abstraction by permit only was established; and water allotments may be reduced in drought periods in rationing districts (Kislev, 2011). All sectors are monitored for water withdrawals; these include: agriculture, domestic, industrial, environment and transfer to the sea or another system. Nevertheless, sanctions only exist for the agricultural sector, where high levies are imposed for overconsumption of water (treated effluent and fresh water) (OECD, 2015).

6.4.1.3 Economic regulation of water supply

The Israeli government uses a number of rules for calculating the costs of water supply and determining water tariffs. Calculation of the costs is based on real costs of the water supplier; however, tariffs may vary according to the purpose of the use and users' ability to pay (Kislev, 2011). At the national level, water tariffs are set for the Mekorot only; other water suppliers, private or regional cooperatives, set their own tariffs and the State does not intervene. For the domestic sector, the regulation establishes the tariffs that Mekorot customers shall pay, as well as the tariffs for local suppliers. Setting water tariffs is the responsibility of the Water Authority Council (Kislev, 2011).

The tariffs will depend on the water source. For instance, for treated wastewater, tariffs for the industrial and agricultural sector are planned to gradually increase, until they reflect the full cost of water; then the subsidies – currently supported by the domestic sector – can be removed. For large scale desalination, water consumption of the domestic sector is set in quotas, based on the size of the household and other socio-economic variables; once the quota is surpassed, the tariff for surplus consumption applies. For the agricultural and industrial sector, tariffs are planned to increase gradually, as in the previous case (OECD, 2015). See Kislev (2011) for an extended analysis of water tariffs.

6.4.1.4 Prevention of water pollution

Replacing scarce water resources, which have been polluted, with expensive alternatives such as desalination is a reminder – for Israel – of the importance to protect water quality (Tal & Rabbo, 2010).

Water pollution is prohibited in Israel. The Water Law establishes that: “a person must refrain from any action that causes or may cause water pollution, whether directly or indirectly, immediately or after some time; and it shall be immaterial whether or not the water source was already contaminated prior to this action” (Sec.20B-a, State of Israel, 1959). Moreover, discharges of any substance (liquid, solid or gaseous) in water sources are not allowed (Sec.20B-b, State of Israel, 1959).

To prevent water pollution and to protect water sources, the Minister of Environmental Protection may, in consultation with the Council of the National Authority and in collaboration with other ministries, set regulations that determine restrictions, prohibitions, conditions and other provisions regarding: location and establishment of polluting factors; use of substances or methods during production processes, operation and use of the polluting factor; and the production, import, distribution and marketing of certain substances and products (Sec.20D, State of Israel, 1959). For sewage disposal from a polluting factor, a plan must be submitted to the National Authority, which specifies the manner of disposal, water quality (chemical, physical and biological composition) and quantity. When the sewage disposal plan is approved, it must be followed (Sec.20E, State of Israel, 1959).

When water pollution is caused, the National Authority may order whoever caused the pollution to do everything necessary to stop pollution of water, to restore the prior conditions, and to prevent the recurrence of water pollution (sec.20G-a, State of Israel, 1959). When the person responsible fails to comply with the provisions ordered, it shall be liable to double expenses incurred (sec.20G-b, State of Israel, 1959). Furthermore, if the person responsible for the pollution of water does not comply with the provisions given (to restore water conditions), or violates any provision or regulation, the National Authority may order to cease the production, supply or consumption of water or to reduce or to refrain from allocating it (drinking water shall not be denied) (Sec.20H, State of Israel, 1959).

6.4.1.5 Provisions regarding water quality

The Ministry of Environmental Protection is responsible for the development of regulations regarding water quality for different purposes, including flood water and sewage, but excluding drinking water quality, which is under the responsibility of the Ministry of Public Health (see Sec.20M, State of Israel, 1959). The National Authority shall guarantee the compliance with the regulations.

6.4.1.6 Reforms of the law

In the last decade, the Water Law has undergone two important structural reforms. In 2001, the transfer of the domestic water supply from municipal water departments to independents companies (or corporations). In 2006, an amendment centralized the Water Law regulation activity in the Water Authority (Kislev, 2011).

6.4.1.7 Other laws related to water

Following other laws complete the regulatory framework for water management in Israel:

- The Water Measuring Law of 1955 provides for the measurement of water supplied. The Minister may order the owner of a water resource to measure water consumed. Non-measured supply is allowed under certain conditions (Sec.5-6). Price and quantity of water shall be fixed between parties or in accordance to the provisions of the law in Sec.7-8. The Director of the Authority is empowered to inspect and supervise compliance with the provisions of the law. Offenses and penalties are stipulated in Sec. 10-12. The Minister of Agriculture is responsible to make provisions as to the installations, maintenance of water meters, duties and rights for suppliers and consumers, separate measuring for categories of consumption, reports submission, and fees (State of Israel, 1955a).
- The Water Drilling Control Law of 1955 provides that no well may be drilled and water abstracted without a license issued (Sec.4). The law empowers the Water Authority (former Water Commissioner) to refuse a license request if a new well can harm groundwater or interfere with household water supply (Sec.5). Other provisions deal with supervision and inspection, corrective actions, offenses and penalties (State of Israel, 1955b).
- The Drainage and Flood Control Law of 1957 created a national drainage board and regional drainage boards. The national drainage board advises the Minister of Agriculture, which is responsible for implementation of the law and approving of regional drainage plans. Regional drainage boards are independent bodies, constituted of representatives of local and national government, entrusted with power to prevent soil erosion and promote drainage (Laster & Livney, 2009). The law provides for operations aimed at concentrating, storing, conveying or removing water (surface or other) harmful or likely to be harmful to agriculture, public health or to the development of the country and maintenance of regular services, drying of marshes, and protection and prevention of flooding. However, this law does not regulate wastewater treatment (State of Israel, 1957).

6.4.2 Water policy

6.4.2.1 Overview of the national water policy

Israel has successfully implemented water policies that have enabled the development of an advanced economy, and the supply of high-quality water for the people and for an advanced agricultural sector, all this within a context of scarce and contested water resources. The same policies, however, have been strongly criticized and labeled as outdated, inefficient, environmental detrimental, and have been called for a revision (Feitelson, 2013).

Certainly, in order to achieve the national goal to ensure supply of water of suitable quality, quantity and reliability, and with economic efficiency, for the sustainable welfare of the consumers, Israel needs innovative plans and initiatives (Water Authority, 2011). On the demand side, the water policy emphasizes water-use efficiency in all sectors. It includes economic tools and incentive mechanisms such as water tariffs, regulations, and penalty mechanisms for reducing water losses; as well as water saving education and training, and effective awareness campaigns about water scarcity and water conservation (OECD, 2011; Shevah, n/d). On the supply side, the water policy embraces the use of alternative water sources such as desalination, treated effluent and brackish water. These alternative water sources make an important contribution to ensure sustainable long-term consumption of natural supplies (Water Authority, 2011).

In relation to irrigation water, the national water policy establishes that agricultural production is a national goal that incorporates community development, and is of social and environmental importance. Therefore, the water sector has to adapt in order to promote this goal. The quantities of water supplied to the agricultural sector shall be stable over time and accordance with the government resolutions and the "water arrangement with the farmers". Additional quantities will be supplied, based on covering full costs (Water Authority, 2012).

In relation to sewage and effluent, the national water policy designated agriculture as the main user of treated wastewater, followed by nature with small quantities assigned. In certain cases, where there is no designation to agriculture for treated wastewater, 'grey water' projects will be promoted. All efforts will be made to connect sewage producers to treatment plants; collection and treatment of wastewater will be prioritized taking into account reclamation programs. Quality of treated wastewater will be improved to meet the new standards, and will be tailored to the needs of the water sector, subject to a cost-benefit analysis considering the existing regulations and the implications of reclamation (Water Authority, 2012).

Some of the national plans for improvement in water-use efficiency for the period 2010-2050 include:

- Increase the use of treated wastewater in the agricultural sector and decrease reliance of the sector on fresh water from 42% currently to 26% by 2050.
- Increase water recycling in the industrial sector by approximately 10% by 2035.
- Replace fresh water with alternative water sources (e.g., desalinated sea water, effluent and brackish water). Supply more than half of the country's water requirements by 2015 with alternative water sources and increase reliance on these sources.
- More than double the contribution of desalinated water to the national fresh water supply from 20% (307 million m^3) in 2010 to 46% (809 million m^3) in 2020.
- Maintain natural fresh water consumption rates at or below the average natural supply rate and maintain or decrease the domestic per capita water consumption at or below 100 m^3 per year.
- Continue national investments in research, development, training, and demand management incentives to increase conservation and use-efficiency in the agricultural sector (Water Authority, 2011).

6.4.2.2 Water pricing for irrigation and cost-recovery policies

Water tariffs are based on quantitative allocation to groups of users: towns, local councils and water users associations. Water prices for the various users are fixed by a parliamentary committee based on recommendation made by the Ministry of Finance and the Water Commission (Shevah, n/d).

The Water Law distinguishes between cost of water and water fees. Cost of water refer to the costs of extraction and supply (on the production side) and is the responsibility of the Water Authority – it was set in the past by the Ministry of Agriculture. Water fees are prices paid by the users, which are based on various considerations such as the users' ability to pay – though the government has recently adopted a policy of cost-recovery prices. The law also sets extraction levies that are meant to reflect water scarcity which differ from place to place (Kislev, 2011).

Formerly, water prices were determined without taking into account the costs of provision. When the Water Authority was established, in 2006, it was assigned to set prices for agriculture, based on the average Mekorot costs of water supply to the sector, including agriculture's share of desalinated water. This was agreed with farmers' representatives (Kislev, 2011).

Mekorot supplies water to most users in Israel (about 60% of the total consumption), including agricultural users (Shevah, n/d). The Mekorot tariffs for fresh water to agriculture are block-rate prices. Farmers, either Mosháv, Kibbutz or individual farmers, have a basic water quota and the prices paid are set according to demand relative to the quota (see Table 6-4) (Kislev, 2011). A single level is imposed on all crops. A penalty is levied on users exceeding their quotas (Shevah, n/d).

Table 6-4 Water tariffs for fresh water in the agricultural sector

Block	Quantity	Price per m³	
		ILS	USD (*)
I	A: 50% of quota	1.65	0.43
II	B: 30% of quota	1.90	0.50
III	C: 20% of quota	2.41	0.63

Source: Kislev (2011)

Prices do not include value added tax.

*Exchange rate USD 1 = ILS 0.26, as of June 2015.

By 2016, the prices for all blocks will raise by ILS 0.60 (or USD 0.16) per m^3 (Kislev, 2011). A discount rate of 10-40% is applied on rates for brackish water with chloride content between 600-1500 mg/l or above (Shevah, n/d). For treated effluent supplied by Mekorot: the price of effluent from Shafdan is set at ILS 0.93 (or USD 0.24) per m^3 as allotment and incremental payment for extra consumption. For other effluents for unrestricted irrigation, the price is ILS 0.80 (or USD 0.21) per m^3. Prices for effluents are also expected to increase (Kislev, 2011).

By law, water tariffs for the domestic and industrial sector are cost-recovery rates, and user payments will cover the cost of the corporations' services (Kislev, 2011). For the agricultural sector, current water fees are still subsidized. The average tariff for irrigation covers about 82% of the average cost (Shevah, n/d). Although water tariffs for the agricultural sector have increased and will continue to increase, the agricultural sector has been the main beneficiary of Mekorot water prices and of the investment in recycling facilities. Another form of support to this sector is by compensations for reductions in water supply during droughts. Compensations are paid indirectly as aid to investments in improvements of infrastructure, replanting of orchards, advancement of summer fruit exports or support to regional wheat (Kislev, 2011).

6.4.2.3 Costs of fresh water and treated wastewater

The water system in Israel is characterized by substantial investments in water elevation, large conveyance systems and treatment plants. The average cost of water, as indicated by Mekorot, is USD 0.31 per m^3. It includes capital costs (41%), fixed costs (26%) and variable costs (33%). The marginal cost of water supply to distant and elevated areas is higher (Shevah, n/d).

Treated wastewater is heavily subsidized by the domestic sector (Lavee & Ash, 2013). Treated wastewater from the domestic sector constitutes the effluent that is reclaimed for irrigation in the agricultural sector. Roughly 508 million m^3 of domestic wastewater is treated, and about 450 million m^3 of treated wastewater is transferred to the agricultural sector (Water Authority, 2012). The operational cost of reuse of treated wastewater includes pipe conveyance costs from the treatment facilities to the agricultural plots. The cost of effluent reused is estimated at USD 0.23 per m^3 (Table 6-5). The treatment process is not considered to be a direct cost of reuse, as stringent wastewater treatment procedures are necessary for environmental preservation, irrespective of whether or not the effluent is reused (Water Authority, 2011). The costs of wastewater treatment are presented in Table 6-5.

Table 6-5 Estimated costs for wastewater treatment and reuse

	2010	2015	2020	
	Millions USD/year			USD/m^3
Effluent reuse: conveyance from treatment facilities to agricultural plots and nature	113	129	143	0.23
Transport to treatment facilities	117	122	128	0.45
Wastewater treatment operation (running)	454	514	573	0.91
Upgrade existing secondary treatment facilities to tertiary treatment		52		0.17
Construction of new treatment facilities		42	41	3.37
Construction of new piping system		39	38	3.11
Class A treatment and sludge transport: disposal or use as fertilizers	6	6	7	61.09
Total	690	903	931	

Source: Water Authority (2011).

6.4.3 Water administration

6.4.3.1 Organizational framework and management responsibilities

The national water resources administration is constituted by the Water Authority and Mekorot, as the main organizations responsible for executing and implementing the policies formulated by the Ministry of Energy and Water Resources and the government's resolutions concerning Israel's water resources (see Table 6-6) (Ministry of National Infrastructures, Energy and Water Resources, State of Israel, 2015). Water pollution prevention (protection of water quality, prevention of water pollution and regulations on these issues) is under the responsibility of the Ministry of Environmental Protection (Ministry of Environmental Protection, State of Israel, 2012).

The Water Authority is the government's executive branch, responsible for the administration, operation and development of Israel’s water economy, including preservation and restoration of natural water resources, development of new water resources and the oversight of water users and producers, so as to allow high quality water and sewage services of optimal reliability, while increasing the sustainable welfare of Israeli citizens (Ministry of National Infrastructures, Energy and Water Resources, State of Israel, 2015). The Water Authority centralizes, under one administration, responsibilities for the entire system, including pumping to sewage treatment and reclamation plants (OECD, 2010).

Table 6-6 Main water institutions and responsibilities

Institution	Scale	Main responsibilities
Ministry of Energy	National	Policy and planning
Water Authority	National	Policy, planning, and allocation
Municipal and regional water companies	Local (Municipal)	Water supply and wastewater treatment; monitoring
Drainage and river authorities	Basin	Management of ecosystems

Source: OECD (2015).

Mekorot is the national water company, which operates under the supervision of the Minister of Energy and Water Resources. Mekorot was defined by the Water Law as the National Water Company and is accountable to the Water Authority – the regulator that supervises Mekorot's activities on behalf of the State (Mekorot Website, n/d). Mekorot has supplied water to the Israeli population for more than 75 years. About 70% of all the water consumed in the country is supplied by Mekorot, about 80% of which is drinking water. Mekorot's water supply system unites most regional water plants, the National Water Carrier System and the Yarkon Negev Facility, and integrates waters from the Sea of Galilee, the coastal and mountain aquifers, drilling waters, seawater and desalinated waters (Ministry of National Infrastructures, Energy and Water Resources, State of Israel, 2015).

In relation to the wastewater sector, collection and treatment of wastewater is responsibility of the water corporations or local authorities. Wastewater reuse plants are established by the private sector. The role of the Water Authority is to ensure removal of wastewater and optimum use of treated wastewater, as well as to promote development of infrastructure, upgrading the infrastructure to improve reclaimed water's quality and widen its range of applications, managing inter-ministerial committee for approval of projects, statutory and political accompanying of project entrepreneurs, project budgeting, engineering and accounting accompaniment of projects and defining regulation requirements in the wastewater sector (Water Authority, 2015b). Permits for users of treated wastewater and the control of freshwater quality are the responsibility of the Ministry of Health (OECD, 2008).

6.4.3.2 Other institutions in agricultural water supply

Besides Mekorot, water is supplied to agriculture by Agricultural Water Associations (OECD, 2010). Especially in the northern region and the Sea of Galilee, water supply to agriculture is the responsibility of water associations, which are regional cooperatives. Members of these cooperatives are kibbutzim and moshavim. These associations also serve as political platforms for negotiations with public official about the needs of their members. In this regard, the agricultural sector in Israel has important political power. In contrast, farmers in the national system are not organized, and they are mainly costumers of the Mekorot (Kislev, 2011).

6.4.3.3 Conflict resolution mechanisms

Water users of the agricultural sector may apply to local water corporations to resolve any conflict. If a given conflict is not resolved, they can apply to the Water Authority (OECD, 2015).

6.5 Institutional assessment

In this section, the institutional arrangements for the reuse of treated wastewater in Israel, which have been described above, are evaluated based on five generic design characteristics proposed by Pagan (2009). These characteristics are associated with successful management of resources; they include institutional objectives, interconnection with formal and informal institutions, adaptiveness, appropriateness of scale, and compliance capacity.

6.5.1 Institutional objectives

A fundamental aspect of the institutional structure of the water sector in Israel is that the objectives of the institutions are clear. Furthermore, specific objectives for planning, implementation and management of water and wastewater are set, which take into consideration the socio-economic and biophysical environment. The law is clear in respect to water rights, which are linked to a purpose. A main characteristic of the law is that it does not recognize private ownership of water or its use; therefore it is the state that controls all water sources. The principles of public domain, state control, preservation of resources, and water's objectives constitute the foundation for the regulations that are derived from the law (Kislev, 2011). This is important because decisions regarding water allocation, priorities of use, quality issues, interventions, etc. are controlled by the state. In this respect, Kislev (2011) argues that thanks to the 'public ownership of water', Israel's Water Law is simpler and its allocation framework is efficient.

At the same time, the establishment of a Water Authority responsible for all aspects of decision-making – safeguarding water quantity and quality, issuing abstraction licenses and allocation to users – is central for integrated water resources management. The role of this institution in relation to treated wastewater reuse is crucial, because it allows controlling and guaranteeing the safe production and application of effluent. Water supply to the agricultural sector is done through regional water corporations or water association, which are accountable for the delivery of quality water. In summary, the institutional arrangements for treated wastewater reuse in Israel are clear and more importantly the use is regulated, controlled and monitored by the state.

6.5.2 Interconnection with formal and informal institutions

The interconnection between formal and informal institutions is not straightforward; this happens in complex ways. Nevertheless, the importance of informal institutions for society (North, 1990) is that they foster and reflect cultural values, which in turn determine the internal values of an organization (Ruys et al., 2000). Although direct control only exists over formal institutions, informal institutions can determine or constrain the scope of actors with political power to alter the formal ruling institutions (Pagan, 2009).

Based on that, the role that the State plays in water management in general, and wastewater reuse, in particular becomes evident. The strong position of the State in the water sector in Israel echoes the importance of water for the national economy. The use of wastewater is a response to water scarcity, therefore this activity is well planned and regulated, and more important is steered by the national agencies. This reflects the formal institutional support to such practice. On the other hand, a high-level of awareness in relation to water scarcity and water conservation exist among all water users. This is reflected in various ways, for instance, a reduction in the per capita supply in all sectors. Remarkably is that agriculture continues to produce food for a growing population despite of the relative reduction in water availability (Kislev, 2011). Furthermore, the country has achieved food self-sufficiency and has effectively promoted exports of fruits and vegetables (OECD, 2010). Farmers, on their side, are committed to water-use efficiency. The use of drip irrigation and other pressurized irrigation systems (i.e., sprinklers, micro-sprinklers, micro-jets) is widely spread, and flood irrigation is no longer used (Ministry of Economy, State of Israel, 2012). Israel is world leader in agricultural technology in arid environments, which resulted from high investment in research and development; well-developed education systems; and high-performing extension services (OECD, 2010).

The quantity of treated wastewater used is expected to increase in the agricultural sector. This is only possible thanks to regulations and standards, which take into account the safety of people. In effect, agriculture in Israel “relies not so much on a ‘natural’ comparative advantage in farming, but on an ‘induced’ comparative advantage built on technological progress” (OECD, 2010, p. 12).

6.5.3 Adaptiveness

Institutions dealing with natural resources need to be adaptive because of the inherent complexity of natural systems and because changes in technology generate pressure for institutional change (Pagan, 2009). Capacity to adapt is important because it facilitates management – of natural resources – despite complexity and uncertainty (Holling, 1995). Pagan (2009) argues that those institutions that can facilitate experimentation and innovation, support monitoring and review processes, and add flexibility in reaching the outcomes tend to have lower transactions and information costs.

Israel faces severe water scarcity and yet it has been able to continue, by looking at alternative water sources such as treated wastewater and desalinated water. Certainly, planned and regulated use of treated wastewater in agriculture is an evidence of the adaptive capacity of water institutions in Israel. To think out-of-the-box seems to be a characteristic of the success of the water sector in the country. This is supported by clear regulations and implementation systems, which make the reuse of treated wastewater possible. At the same time, a strict regulatory framework is set to reduce the risks for both farmers and consumers, and so offset the negative effects of wastewater. Not less important is the support given to research and development for water technology. Water institutions in Israel have been able to implement policies effectively, which might be related to the strong participation of the State in decision-making. These aspects highlight the adaptiveness of water institutions in Israel.

6.5.4 Appropriateness of scale

Essential for the success of institutions is the spatial (e.g., ecological, political or social) and administrative scale (e.g., government levels) (Dovers, 2001). It is argued that administrative and spatial scale of a particular institution, within an institutional hierarchy, affect the transaction costs associated with management decisions, i.e., the more property rights are decentralized, the higher the transactions costs. Furthermore, natural resources management institutions that have common social and ecological scales have lower transaction costs associated; this is because such scale reflects common institutional foundation (Pagan, 2009).

Israel is rather a small country in terms of land size, located in a particularly arid zone; despite of this it presents some variations in terms of ecological characteristics, from North to South. In terms of the social scale in relation to agriculture, about 94% of the land is state-owned and administrated by the State, which distributes land use rights to farmers for varying periods. Agricultural production is dominated by cooperative communities, mainly the kibbutz and moshav. These communities accounts for about 80% of agricultural output (OECD, 2010). This is a unique characteristic of Israel, and added to the hierarchical and centralized institutional framework, explains much of the way in which water resources are managed. It seems to be a correspondence between the spatial and administrative scale, which facilitates management of resources, in this case: water.

6.5.5 Compliance capacity

Two important aspects of successful institutions are enforcement and compliance capacity. Although imperfections in enforcement exist in all institution, it helps understanding how to develop ‘good’ institutions (North, 1990). Moreover, compliance supports the designing of long-lasting institutions (Ostrom 1993) and handles violations of contracts through punishment (Pagan, 2009). Two forms of compliance mechanisms include self-enforcement and third-party enforcement (Barzel, 2000). The state has advantage in the latter, while self-enforcement happens where there is an added value in keeping a contract for all parties involved. Compliance capacity offers an indication of the costs and features of institutional design (Pagan, 2009). For instance (1) institutions that have high levels of internal enforcement support will have lower transactions costs when keeping full duration of a contract is mutually beneficial, (2) institutions that have high levels of external enforcement support have lower transactions costs when keeping a contract disadvantages any party at any time during the life of a contract, and (3) external compliance measures that monitor indirect attributes based on specified production technology have higher transformation costs (Pagan, 2009).

Perceptions on centralized modes of governance – applies to all sectors – is that they raise high levels of rent-seeking, corruption and lack of accountability of government officials (Bardhan & Mookherjee, 2005). While centralization can generate problems of accountability, there are also advantages of having a strong water institution centralizing most aspects of the sector. In this respect, a series of events (e.g., increase of water demand, overexploitation of water resources and consequently environmental problems, severe droughts, degradation of water quality) generated criticism towards the water sector in Israel. The response from the State was augmenting supply through large-scale desalination and reuse of treated wastewater; reducing amounts of water allocated to agriculture and limiting agriculture's consumption almost exclusively to treated wastewater; promoting water saving education and technologies; and more important changing institutions and governance (Tal, 2006).

The water sector effectively monitors water withdrawals, including all water users. Nevertheless, sanctions only exist for the agricultural sector for overconsumption of water, regardless the source (OECD, 2015). On the other hand, great efforts have been made in relation to improvements of water quality, however, not all wastewater (from households and industry) is collected and treated; some untreated wastewater still flows into streams, causing environmental problems (Megdal, 2012), which suggests that there is room for improvement in this respect.

The institutional reforms aimed at fostering more accountability. The most important aspect was to empower and increase independence of the Water Commissioner, which was transformed into the Water Authority (World Bank, 2007). The Water Authority has obligations to ensure supply of water – of good quality, quantity and reliability, provide sewage services and management of treated wastewater, and manage water drainage and runoff (Water Authority, 2012). It controls all aspects regarding water allocation and is also responsible for resolving conflicts. Certainly too many responsibilities are under the umbrella of the Water Authority. Becker & Ward (2014) argues that in order to achieve its objectives, the Water Authority will require integrating external factors, constraints, policy instruments and targets. Nevertheless, the water sector in Israel will remain at the center of the scene, considering the international conflicts with neighboring countries.

6.6 Conclusions

It is only fair to recognize the achievements of Israel regarding water management and agricultural development. A key element of this success was making water resources a public property, therefore having the State to control and regulate all aspects of water management, including water exploitation, allocation, pollution control prevention and water conservation. This aspect does not stand alone; a strong institutional and legal framework, priorities in public expenditure, support in research and development, and clear action plans facilitate water management in Israel. Accountability is also an important aspect for the success.

Regarding the use of treated wastewater in agriculture, the most important aspect is the realization that water is a scarce resource and can no longer be wasted. Israel was able to see this and more important to understand the potential of wastewater reuse. Clear objectives incorporating treated wastewater as potential water source; taking into consideration health risks, for which strict norms were formulated, accompanied this process. The role of the State in planning, implementing and controlling wastewater reuse is central for the success.

The main lesson to be learned from Israel is that uncontrolled raw wastewater use is not an alternative. There are just too many costs involved in this practice in relation to public health and the environment. And there is a social and environmental responsibility to ensure that wastewater is properly collected, treated and disposed. Next, Israel shows the importance of increasing awareness about issues related to water pollution, as well as water conservation practices. It demonstrates that these aspects need strong support from the state. In consequence, it is essential to spawn political will to mobilize resources for wastewater management, including collection, treatment, and reuse. Israel also illustrates that with the technology available is possible to treat wastewater to higher-quality levels, taking into account the end-use of effluents. Also the case shows the importance of having guidelines and quality standards for wastewater reuse. This case validates the many advantages of wastewater reuse, especially for the agricultural sector, which can benefit enormously, while preserving fresh water sources for other uses.

Chapter 7. Towards formalization of wastewater reuse in agriculture: A discussion comparing institutional settings in Israel, South Africa, Bolivia and India

Abstract

This chapter compares the institutional settings of wastewater reuse in agriculture in four countries which differ in socio-economic development: Israel, South Africa, India and Bolivia. The purpose of this comparison is to gain insight in the process of formalization of wastewater reuse in different settings, therefore, identifying the drivers, constraints and institutional arrangements influencing the process. Key variables of formalization include: water scarcity, public pollution prevention awareness, an effective policy and regulatory framework, and a capital-intensive water use linked to profitable markets.

Keywords: wastewater reuse, agriculture, institutional arrangements, Israel, South Africa, Bolivia, India

7.1 Introduction

Water has become scarcer almost everywhere, especially in semi-arid and arid regions. As water scarcity grows, so does the competition among water users. Consequently, in many regions, wastewater has become too valuable to be wasted (Mara, 2004). While the urban sector has priority for fresh water, the water used by this sector returns to the water cycle as wastewater. With rapid urbanization it is expected that more wastewater will be generated in urbanized areas, which can benefit the agricultural sector. In such context of water scarcity and competition, wastewater reuse[19] has grown in importance in recent years and is considered a measure to reduce pressure on water resources. Even in some cases, wastewater is regarded as a low-cost alternative to conventional irrigation water (Scott et al., 2004a).

In developing countries, however, wastewater reuse occurs within the informal arena, which means that untreated wastewater is used for irrigation as a consequence of the lack of proper collection, treatment and disposal of wastewater (Drechsel & Evans, 2010). This type of practice represents risks for the health of the people (farmers and consumers) and the environment. In contrast, more developed countries have recognized the importance to address such risks and have developed formal institutional arrangements for wastewater reuse in agricultural irrigation. The formalization implies planned and controlled use of treated wastewater. It helps to reduce the risks and to benefit from additional water that would otherwise be discarded. Wastewater reuse – a multi-disciplined and central element of water resources development and management, can help to close the loop between water supply and wastewater disposal (Asano, 2001).

[19] The terms ‘water reuse’, ‘wastewater reuse’ or ‘wastewater use’ are used interchangeably.

This chapter discusses the main aspects of the institutional arrangements for wastewater reuse and the role that they play in countries with different socio-economic development levels, but which are involved in wastewater reuse either formally or informally. Four countries were considered for this analysis: Israel, South Africa, Bolivia and India. Each one of these represents one step in the ladder towards the formalization of wastewater reuse, with a focus on irrigation. Israel is the world leader in water reuse; it has established policies and regulations for water reuse since the mid-1950s and currently uses about 70% of treated wastewater in agriculture. Similarly, in South Africa the reuse of wastewater has been recognized since the 1970s as a vital strategy to ensure that more water resources remain available for the range of uses. Treated wastewater reuse is increasingly applied and the regulatory framework has been further developed and enforced. Along the same line, Bolivia has recently formally recognized the importance of wastewater as alternative water source to cope with increasing pressure on water resources. Nevertheless, wastewater reuse remains informal and unregulated; therefore it presents high risks for the people. Pollution of water sources is a main concern for environmental sustainability in Bolivia. India has also introduced water reuse in its water policy, but the focus is not agriculture. As in the case of Bolivia, however, the practice occurs and thrives in an informal way, with high risks for the population as well as for the environment.

The drivers behind formalization of wastewater reuse are presented in section two. The institutional settings of the countries of comparison are described in section three, including policy frameworks and levels of risk awareness. The need for institutional change is discussed in section four, while the role of guidelines is discussed in section five. Section six discusses other important factors of the formalization of wastewater reuse. Finally, in the last section, the conclusions are presented.

7.2 Drivers behind the formalization of wastewater reuse

The extended use of wastewater in irrigation in countries such as Israel, South Africa, Bolivia and India is mostly related to water scarcity. Essentially, wastewater is reused because there is no alternative water source. Next to the notion of water scarcity, there are concerns about water pollution. This aspect is important since water pollution increases water scarcity. In effect, water pollution, due to discharges of untreated wastewater in rivers and lakes, is a major problem in most countries around the world (Asano, 2001).

Israel is one of the most water scarce countries in the world. Aware of its limitations in terms of water resources availability to meet water demand, Israel had early realized the potential of wastewater, particularly for the irrigation sector. But at the same time, pollution of valuable water resources and outbreaks of epidemics raised awareness of the risks of wastewater and the need to establish appropriate sewage systems and treatment facilities (Tal, 2010; Kislev, 2011). Water conservation and pollution prevention were identified as important components of water resources management in the country, which pushed forward wastewater reuse for agricultural irrigation (Tal, 2010). These aspects were accompanied with an effective campaign to raise people's awareness regarding water scarcity and water conservation issues (OECD, 2011).

South Africa is also characterized as a water scarce country. The country faces difficulties to supply safe water to its population. The challenges and concerns include security of supply, environmental degradation and water pollution, and inefficient use of water (DWA, 2013a). As a response to the water crisis in South Africa, water reuse has been introduced in the water policy as one of the key strategies to reduce pressure on water resources. This measure is growing in importance; however, it is still not fully implemented across the country. There are few examples where wastewater is reused in agriculture, such as the case of a small group of farmers in Durbanville in Western Cape Province; a private initiative where farmers use treated wastewater from a municipal treatment plant. This experience, however, has been perceived as positive and serves as example to be replicated elsewhere.

In most parts of Bolivia and India, the use of wastewater is mostly a consequence of water scarcity and water pollution. In both cases, water scarcity is largely affected by deterioration of water sources, which compels farmers to use polluted water for irrigation. Degradation of water sources is linked to inadequate wastewater management, including lack of infrastructure and institutional support. Bolivia has recently incorporated the concept of water reuse in its water policy framework, which responds to the need of improving water quality in rivers and lakes, whereas the ultimate objective is to increase overall water availability. This was triggered by the realization that wastewater is a potential water source – to cope with increasing water scarcity – and needs to be exploited safely. In India water degradation is a main concern. Considering the limited water resources for such large population, more attention has been given to water quality issues. Water recycling and reuse have been introduced in the water policy framework. Again, the rationale behind this is to reduce the pressure on water resources.

7.3 Working institutional settings

7.3.1 Policy frameworks for wastewater reuse

How wastewater is included in water resources management varies in the countries of analysis. In Israel, for instance, water sources are public property and are controlled by the state. Water resources management is centralized in one Water Authority that overlooks all aspects related, including water allocation for all users. Wastewater is an integral component of the overall water resources planning and development. It is included in the national water policy as a main source for agricultural irrigation. This is explicit in the water policy and the subsequent measures are in consonance with this initiative. The state has been able to implement large water reuse systems, which provide treated wastewater to the agricultural sector. The water and sanitation sector is responsible for wastewater treatment; the health sector looks after quality issues; and the agricultural sector uses the treated wastewater. Even if wastewater would not be reused in agriculture, it undergoes treatment in order to protect the environment as well as other water sources. Protection of water quality is essential for the sustainability of water resources in Israel. In these arrangements there is transparency and accountability.

In the same way, water resources are public property in South Africa, which dissolves the concepts of private water ownership and water rights. Instead, rights of access to water exist through fixed-period water use licenses. Furthermore, water governance is based on decentralization with catchment management agencies as managing authorities (Naidoo & Constantinides, 2000). In contrast to the traditional approach, which focused primarily on supply management; the water policy seeks for a smart water management approach. The latter includes water conservation and demand management as drivers for efficient use of water; effective and sustainable use of water, local resource optimization, water systems management and control, desalination and water reuse. Through different strategies, the South African water policy tries to address the growing competition for water. In addition, water pollution and resource quality are priorities due to their implications for society, the economy and the environment (DWA, 2012a). Although, water reuse is formally introduced in the water policy, the development of state projects for water reuse is almost inexistent. The initiatives for water reuse in agriculture come mainly from the private sector. This is done primarily on an *ad hoc* basis. Unfortunately, the public sector lacks people's trust regarding the provision of water services, especially for wastewater management.

In Bolivia, water resources management is mainly communal, place-based, and adjustable in time and space (Perreault, 2008). Water for irrigation is basically managed by the users' community based on customary laws, which denotes the lack of formal legal framework for water management in the country (Perreault, 2005). The state's participation in water resources planning and development, for the agricultural sector, is limited to the development of infrastructure, i.e., construction of storage, conveyance and distribution infrastructure. Management of water in irrigation systems is done entirely by the users. Wastewater use remains highly informal, resulting from pollution of water sources. With the introduction of water reuse in the water policy framework, Bolivia also aims to reduce pressure on water resources and address the concerns on water pollution. The development of formal water reuse projects, however, is still in infancy. It is not clear how this will be incorporated in the overall water management. However, considering the risks of wastewater, it requires careful planning, control and monitoring, which are essential for the sustainability of such endeavor. This calls for more involvement of the state in water management.

In India, each state translates the national water policy into state water policies. States are responsible for the planning, implementation, funding and management of water resources development (EBTC, 2011). The national water policy adopted an Integrated Water Resources Management (IWRM) approach for multi-sectoral planning according to hydrological units, and the Participatory Irrigation Management (PIM) approach. The latter aimed for sustainability of irrigation systems through water users' participation. Water quality is an important component of the national water policy, which recognizes the need to eliminate pollution of water bodies (Ministry of Water Resources, Republic of India, 2002). A key element of this policy is the polluter pays principle, and it proposes the development of a third-party system for periodic inspection and punitive actions to be taken against polluters. This principle, however, is not enforced on the ground (Chigurupati & Manikonda, 2007). Furthermore, although the concept of water reuse is acknowledged in the water policy, encouraging reuse of grey water and giving incentives to industries for recovery of industrial pollutants, it does not address agricultural irrigation. Therefore, current use of wastewater in agricultural irrigation is done primarily indirectly and unplanned. Again, this is due to the lack of adequate infrastructure to collect and properly treat wastewater. The practice represents health risks for the farmers and consumers of raw crops.

7.3.2 Importance of risks awareness

Generally, people can identify that untreated wastewater embodies risks, especially for the health. This is basically because untreated wastewater is dirty, malodorous and often carries solid waste. These elements serve to indicate people that there is something wrong about the water, which may be harmful, even though they do not know what. Then, why is untreated wastewater used in spite of this? The answer is water scarcity. In the case of agriculture, famers depend on water to sustain agricultural production and their livelihoods. In most developing countries, like Bolivia and India even parts of South Africa, where untreated wastewater is used informally, farmers are uneducated and they struggle to survive from the land.

Nevertheless, for policy-makers, public servants and the general public the story is somehow different, as their livelihoods are not at stake. Then, why do some countries accept that untreated wastewater is used indiscriminately despite health and environmental risks? And other countries do not? In this case the answer is not straightforward. One aspect may be the socio-economic development of a country and how this influence people's perceptions and behavior regarding the use of untreated wastewater. Another aspect influencing might be related to specific circumstances in which people live, which will guide people's behavior. Inglehart (1995) found that increased awareness of environmental pollution and increased interest in environmental issues are largely related to a shift from materialist to post-materialist goals. Under this assumption, only when countries have fulfilled their basic material needs, they will focus their attention on satisfaction of higher order needs (post-materialist) such as environmental issues (Anderson et al., 2007) or, in this case, the use of safe treated wastewater [see Maslow (1954) for the Need Hierarchy Theory]. The implication of this argument is that the increase in awareness of environmental problems and the willingness to address them results from rising living standards and levels of education (Anderson et al., 2007). In contrast, Dunlap et al. (1993) argues that there is little difference in levels of environmental concern among people of less developed countries and those from highly developed countries.

The Israeli case shows evidence that formalization of the water reuse is intrinsically related to water scarcity and to a high level of awareness of water pollution and its consequences for health and the environment. Israel has actually experienced in the past outbreaks of epidemics resulting from the lack of proper management of wastewater. This negative experience, supported by effective awareness campaigns, might have catalyzed behavioral change. In addition, pollution of water sources have a great impact on water availability and considering the limited resources that Israel has, this would have had high costs for the country as a whole.

Although awareness might be independent of the level of socio-economic development of a country, as Dunlap et al. (1993) argued, it will certainly influence the country's capacity to effectively formulate policies and measures addressing environmental issues. In other words, economic capital and human capital are essential to formulate sound policies and regulations for water reuse, and more importantly to implement them on the ground through peoples' support. Inglehart (1995, p. 57) argues that "policies designed to solve environmental problems are unlikely to succeed unless they have broad public support, but the motives for public supports are poorly understood". At the same time, people's support will guarantee that accountability exists, as people will be able to ask for it. In countries like Bolivia or India and even parts of South Africa, the environmental problems, in this particular case the use of untreated wastewater, are still underestimated. The unwillingness to address these issues can be explained by a lack of human capital more than economic capital only.

7.4 The need for change in institutional settings

7.4.1 Is there a need for changes in institutional settings?

Undoubtedly there is a need for changes in the institutional settings regarding the use of wastewater and its management. This is because of the risks that wastewater represents, as well as the benefits that it offers mainly in terms of additional water. Wastewater is a transversal component for various subsectors of the water sector. As sub-product of urban and industrial users, wastewater is directly related to the water and sanitation sector. Next, untreated wastewater represents potential risks for the environment. It degrades water sources affecting life in aquatic systems; it can also affect the soils negatively, as it may add components which reduce the soils' adequacy for agricultural production. Furthermore, untreated wastewater is a potential risk for public health. It contains pathogens that cause illness. Diarrhea – caused by water-borne diseases – is responsible for 4% of all deaths and 5% of health loss to disability; and it kills some 2.2 million people globally each year, mostly children in developing countries (WHO, 2015). On the other hand, wastewater is a source of irrigation water. Consequently, it should be regarded as an overarching component connecting the several subsectors within water management. Bazza (2003) argues that the large number of institutions involved and the complexity of wastewater production and reuse requires the establishment of sound institutional frameworks to coordinate among agencies.

Although there is still so much to do regarding wastewater management, the general perception regarding treated wastewater is positive. The potential of additional water is the main benefit perceived of wastewater, especially in water scarce regions. Some countries already realized that wastewater has to be included in the broad water management framework. For instance, this is the case in the four countries of analysis; especially Israel is a good example of this. Other countries such as Tunisia and Jordan have also policies in place that address wastewater treatment and reuse through a range of instruments. Their policymakers consider the use of treated wastewater to be an essential aspect of strategic water and wastewater planning and management (Qadir et al., 2010b). South Africa also knows the potential of wastewater; in some parts of the country, such as in Western Cape Province, institutional changes were supported to facilitate wastewater reuse.

However, other countries like Bolivia or India, for instance, still fail to effectively support comprehensive wastewater treatment programs. This is illustrated by the disturbing cases of water pollution and the still large number of people who lack access to appropriate sanitation. The central problem still is the lack of governmental support to engage in long lasting sanitation programs (see Ghneim, 2010). Bazza (2003) argues that institutional arrangements in developing countries are too complex and that conflicts exist among concerned agencies ranging from overlapping of responsibilities to the absence of well-defined mandates. The general rule is that each party wants to benefit without taking responsibility. The role of the international community in water and sanitation programs, including wastewater reuse, is central for the engagement of countries in various activities. The more the issues of water and sanitation are discussed, the more policymakers feel pressure to introduce changes in the institutional settings. The Bolivian case illustrates this aspect.

7.4.2 Advantages of formalization of wastewater reuse and issues restricting the development of formal structures

The main advantage of formalizing the use of wastewater in agricultural irrigation is in terms of additional safe water for the sector. Next, is in terms of public health and environmental protection. Formalization allows for planning and control. In turn, this guarantees protection for the people as well as for the environment. The high risks associated with untreated wastewater give little room for uncontrolled practices. In general, the establishment of a coordinating committee, consisting of representatives of multiple agencies, to formulate clear rules and mandates to ensure development and planning of wastewater reuse is fundamental (Bazza, 2003). Formalization of wastewater reuse in Israel is an example of this. It shows how the sector can benefit from water supply while releasing fresh water for other sectors. In this way, pressure on water resources is reduced. An important component of formalization of wastewater reuse in Israel is the strong role of the state, through a Water Authority, in water resources planning and management. And a strong commitment of the state to transform the water resources paradigm by introducing alternative water sources. In contrast, in South Africa, wastewater reuse is mainly done on *ad hoc* basis. Although wastewater reuse is part of the water policy framework, it is not central to water resources planning and management. Similarly, in countries like India or Bolivia, water reuse remains at large an isolated measure.

The main constraint in the development of formal structures for wastewater reuse is the lack of political will. It seems that countries are unwilling to incorporated formal wastewater reuse unless there is a feeling of severe water scarcity. Similarly to what happens in the water and sanitation sector, the level of risk awareness of untreated wastewater helps to increase political will, but it is not enough to take actions. It might be that other elements are necessary to push governments to address these issues, for instance, a perceived water crisis. This can catalyze change and facilitate formalization of wastewater reuse.

Another element that constrains formal structures for wastewater reuse is in terms of public budgets. Wastewater reuse is far from being a priority in most countries. On the other hand, the costs associated with wastewater collection and treatment remain high, for instance, in conventional centralized systems (Maurer et al., 2005), which might withhold countries from setting up and running wastewater treatment systems effectively. Bazza (2003) argues that high costs of treatment and management of wastewater reuse is one of the major limitations facing weak economies in most countries. In line with Bazza (2003), other constraining issues include unclear policies, institutional conflicts, unclear mandates, and lack of regulatory frameworks for implementing wastewater reuse. In effect, as Angelakis et al. (1999) argue, regulations for wastewater reuse are crucial to protect public health, increase water availability, prevent water pollution and enhance water resources and nature conservation policies.

Although, we do not make a cost-benefit analysis for wastewater reuse, there is enough evidence that supports the socio-economic benefits of moving from informal to formal structures, mostly expressed in terms of having additional water, safe environments (air, land and water), and healthy people. Informal practices of untreated wastewater are a burden for public budgets. Qadir et al. (2010b) draw attention to the long-term health effects of the increasing use of wastewater on public budgets, either directly in the form of public expenditures to protect health and welfare, or indirectly in declining productivity of land irrigated with untreated wastewater. Certainly, these are issues to consider for countries that remain within the informal practice of wastewater reuse.

7.5 The role of guidelines

Guidelines are an important component of the formalization of wastewater reuse. Indeed, there is a real need for the establishment of wastewater reuse guidelines (Bixio et al., 2006). The advantage of having guidelines is that they provide a framework of reference for the agencies responsible for wastewater management. However, there are various types of guidelines going from less to more stringent. The main difference is the level of rigor in terms of water quality. Stringent water quality standards aim for absolute protection of public health, whereas less restrictive water quality standards are more pragmatic and recognize existing wastewater reuse practices (Angelakis et al., 1999).

Some developed countries, with formal use of wastewater, have their own national standards, e.g., USA, Australia, and Israel. The latter is one of the first countries that introduced wastewater irrigation standards, which excluded raw sewage as irrigation water (Tal 2010). The updated version of the Israeli standards (launched in 2005) for unlimited use of treated wastewater are even more stringent to minimize potential damage to water, soil and flora. They require, however, higher treatment levels (Inbar, 2007; Tal, 2010), which for the Israeli case does not seem to be an obstacle. In developing countries, however, stringent water quality standards are difficult to be attained, and they have higher treatment costs (von Sperling & Lemos Chernicharo, 2002). This is often a limiting factor for developing countries. In this regard von Sperling & Lemos Chernicharo (2002) advocate for a gradual improvement of the treated wastewater quality. This approach consists of a stepwise development where countries decide to implement only partial treatment, for which financial resources are available and obtain certain improvement in water quality. In this way, health and environmental risks are reduced, even though the standards have not been satisfied. Standards are treated as target values to be attained whenever possible (von Sperling & Lemos Chernicharo, 2002).

On the other hand, the World Health Organization Guidelines for Wastewater Use in Agriculture (published in 2006) incorporated the concept of risk management. They are based on the principle that there should be no additional cases of disease in the population at risk (Ensink & van der Hoek, 2007). Health targets and tolerable burden of disease is to be achieved by a combination of treatment and non-treatment options for health risk reduction (WHO, 2006). This approach encourages governments to adapt the guidelines to their own socioeconomic and environmental realities (Ensink & van der Hoek, 2007) and provides flexibility even in situations where wastewater treatment still remains a challenge (Qadir et al., 2010a). Ensink & van der Hoek (2007) advocate for the WHO Guidelines as the most appropriate for developing countries, as they are based on actual risks and will not result in unnecessarily strict and expensive treatment technologies to achieve standards. In the same line, Salgot et al. (2006) suggest that risk assessment is useful for reducing the cost of wastewater reuse by avoiding expensive treatments where they are not needed, instead using limited resources where risks are higher. The overall positive effect is due to a reduction in sanitary care derived from a reduced possibility of infections, work-time losses due to illnesses, and overall improved quality of life (Salgot et al., 2006).

Nonetheless, from the countries of analysis, only Bolivia incorporates some parts of the WHO Guidelines in its own wastewater reuse guidelines (under development), whereas India and South Africa do not (Israel has its own national standards as explained above). It is questionable, however, if countries like Bolivia will be able to implement the guidelines because they largely rely on behavioral change in sanitation habits. On the other hand, for policy-makers wastewater treatment still is central for the management of wastewater and the formalization of wastewater reuse. In this regard, Ensink & van der Hoek (2007) indicate that the acceptability, of other measures proposed in the WHO Guidelines for health risk reduction, to farmers, policy makers and consumers remains unknown. Certainly, the implementation of such measures will require strong support for behavioral change through educational campaigns and long-lasting educational programs, which might be one of the main weaknesses in developing countries.

7.6 Other factors to consider in the process of formalization

7.6.1 Water rights

In informal wastewater reuse systems, water rights might exist or not, depending on the local practices for water management. In Bolivia, for instance, customary laws are applicable for irrigation water. They imply that traditional uses of water are recognized by the state. When rivers become polluted, as is the case in most informal systems for wastewater use, the traditional uses of water remain valid. In some cases, however, because of the poor water quality, water rights might be dissolved, but in times of scarcity they might be restored. In countries like India, water rights for irrigation water are associated to land tenancy. River water is normally distributed among the farmers within the command area. Farmers will receive water despite it being polluted.

In formal wastewater reuse systems, water rights are to be created based on the country’s exiting laws. In Israel, for instance, treated wastewater is exchanged for fresh water. Treated wastewater is allocated to farmers in similar way than fresh water is. In Bolivia, which is engaging in the first formal wastewater reuse project, water rights are still not determined for the users of the irrigation system. This is because defining water rights is normally a sensitive issue. One issue to consider, however, is that water rights for treated wastewater should be regarded as rights to access instead of property rights. This is because the quality of treated wastewater can fluctuate and is variable in time. Thus it requires that authorities and operators can decide upon the use and application of treated wastewater, which might not be the case if property rights are in place.

7.6.2 Wastewater reuse in profitable agricultural markets

Wastewater is used in agricultural irrigation because there is demand for it. But to expand the use of treated wastewater in agricultural irrigation requires that this option is cost-effective compared to other alternatives. In effect, current water shortages and the costs associated with freshwater have made wastewater reuse a viable option (Fatta & Kythreotou, 2005). Furthermore, Fatta & Kythreotou (2005) suggest that wastewater reuse, although costly at first, is quite cost-effective in the long run. But this might be applicable mostly to water scarce regions, where wastewater might be the only alternative. In Israel for instance, treated wastewater is more cost-effective than desalination of seawater, therefore it has been chosen to substitute fresh water in the agricultural sector. Another example is the group of farmers in the hinterland of Cape Town, in South Africa, whom decided to go for treated wastewater reuse because other water alternatives became too expensive compared to treated wastewater. In both cases, however, agriculture is linked to profitable markets. Consequently, implementation of treated wastewater irrigation systems might be justifiable when agricultural production is linked to profitable markets. Asano (2001) suggests that wastewater reuse is usually too expensive for traditional agricultural irrigation in most countries and only landscape irrigation and other urban application can afford to pay for the water.

In other cases, where subsistence agriculture is practiced, planned wastewater reuse systems might be too expensive for the users, if they are to share the costs. The evidence from the group of farmers in South Africa suggests that the most expensive part of the reuse system is the conveyance infrastructure (pipes, pump stations, meters, etc.). Asano (2001) has acknowledged this fact and indicates that conveyance and distribution systems represent the principal cost of most wastewater reuse projects around the world. In countries like Israel, however, wastewater reuse systems are still largely subsidized, which decreases the burden on farmers. Subsidies for wastewater reuse systems might be a more suitable alternative in developing countries, at least in the initial phase. In any case, costs associated to wastewater treatment are not considered, since they are usually already included in the national budgets as pollution control costs (Asano, 2001). As a final point, planned wastewater reuse irrigation systems should not be considered as low-cost water supply, unless wastewater treatment facilities are conveniently located near large agricultural areas, and when no additional treatment is required beyond the existing wastewater treatment facilities from which treated wastewater is delivered (Asano, 2001).

7.7 Conclusions

Overall, agricultural wastewater reuse is rather complex, because it falls under various domains of water management. In turn, this impedes that institutions take responsibility. Therefore, a key element for the formalization of wastewater reuse is clarity in the institutional arrangements. It is fundamental that the various sub-sectors of water managements have clear mandates and responsibilities for wastewater management and reuse. The benefits of having a regulatory framework guiding the practice, which includes water quality standards, treatment levels and processes, crop restrictions, categories of types of uses, etc., provides certainty to public agencies and users.

Next, formalization of wastewater reuse should not be an option for countries. This is because the informal practice of wastewater use represents risks for public health and the environment. But also because wastewater reuse is additional water which should be reintroduced in overall water management. As the evidence suggests, in most countries a recognized level of water scarcity is a more powerful driver for the formalization of water reuse, than water pollution. However, public awareness with respect to water pollution is necessary to trigger changes in institutional arrangements and ultimately generate behavioral change. In general, this aspect lags behind in most societies in developing countries, as they fail at generating such changes. Much of this might be related to the overall low levels of education and to tolerance to current conditions.

Wastewater offers a window of opportunities for water resources management, particularly for the agricultural sector. Countries can benefit enormously from this, but formalization of water reuse is required because it will guarantee that people enjoy the benefits while they are protected from the risks of wastewater.

Part 2: Farmers' preferences for wastewater reuse

Chapter 8. Methodological approach

8.1 Understanding farmers' preferences through a choice modelling approach

Understanding farmers' preferences and perceptions concerning the use of wastewater for irrigation can provide important insight knowledge from the users' perspective, which is essential to develop sound policies in water resources management. The relevance of understanding farmers' preferences has been described in detail in section 1.5.

In order to understand the farmers' preferences concerning frameworks of wastewater reuse for irrigation, including their willingness-to-pay (WTP) for changes, a choice modeling (CM) approach was adopted in this study. Moreover, the farmers' preferences were revealed using a choice experiment (CE). Three case studies were considered, namely Hyderabad in India, Cochabamba in Bolivia, and Western Cape in South Africa. Through these case studies a spectrum of different degrees of wastewater reuse was analyzed. It is important to stress that each case study presents unique characteristics in terms of water management, agricultural production, policies and regulations governing water and wastewater.

The theory suggests that understanding consumer behavior can lead to changes in service design, pricing strategy, distribution channels, as well as concepts of public welfare (Louviere et al., 2000). The CE technique is an application of the theory of value (Lancaster, 1966) combined with the random utility theory (Thurstone, 1927), which states that consumers derive satisfaction from the characteristics or attributes of the goods. In other words, consumers' utility derived from goods can be decomposed into utilities from the constituent characteristics of these goods (Hanley et al., 2001; Louviere et al., 2008). This surveyed-based technique captures the preferences for goods, where goods are described based on their attributes that take different levels (Hanley et al., 1998).

CE has gained recognition in the field of environmental valuation (Hanley et al., 2001; Adamowicz, 2004; Hoyos, 2010). It is increasingly applied to value water resources such as wetlands [e.g., Carlsson et al., 2003; Birol et al., 2006a; Milon & Scrogin, 2006] or water services [e.g., Snowball et al., 2008; Kanyoka et al., 2008]. In relation to wastewater, in a study by Birol & Das (2010), CE was applied to estimate the local public's WTP for improvements in the capacity and technology of a sewage treatment plant in Chandernagore municipality, India. Another study by Genius et al. (2012) applied CE to elicit the value of the attributes of a wastewater treatment plant in a rural area in Greece; the attributes included – among others – water quality and irrigation with recycled water. Ndunda & Mungatana (2013) applied CE to estimate the benefits of improved wastewater treatment programs to mitigate the impacts of water pollution in Nairobi, Kenya. Alternatively, some authors also use contingent valuation (CV), Birol et al. (2008) for example, to investigate farmers' preferences for treated wastewater and their WTP; and Alcon et al. (2010) to estimate the non-market benefits derived from the use of reclaimed wastewater for agricultural purposes in Segura River Basin, Spain.

The application of CE with farmers on water management issues, particularly concerning wastewater reuse, in developing countries is rather rare. Most studies applying CE on water issues focus on developed countries. Hence, assessing farmers' preferences for wastewater reuse frameworks for agricultural irrigation, and their WTP for changes, applying a CE is a significant contribution to fill this knowledge gap. Furthermore, most studies focus purely on the characteristics of the water, in terms of quality or quantity, while this study adds to the analysis aspects of the institutional settings. This is based on the premise that besides the characteristics of the water (quality, quantity), the institutional aspects (management approaches, rules and restrictions concerning the use) will also have an effect on farmers' WTP for changes. This aspect is the most innovative part of the application of CE in this study.

Compared to CV, CE has the potential to provide greater information about peoples' preferences. Thanks to the focus on the attributes, it can generate multiple value estimates from a single application (Morrison & Bennett, 2000; Bennett & Blamey, 2001), which is useful for decision-makers dealing with natural resources planning both at the local and national level. As in CV, economic values for any environmental resource, including non-use and use values, can be estimated through a CE. However, in addition to the estimation of the environmental resource as a whole, CE enables estimation of the implicit value of the attributes; their implied ranking and the value of changing more than one attribute at once. CE studies are, therefore, more informative than discrete choice contingent valuation studies and provide multiple opportunities for respondents to express their preferences (Snowball et al., 2008). CE is also more useful when dealing with situations in which changes are multidimensional and trade-offs between these particular changes are of interest (Adamowicz et al., 1998, p. 74; Hanley et al., 2001, p. 448 cited in Snowball et al., 2008). Another advantage is that respondents are more familiar with the choice approach rather than the payment approach (Birol et al., 2006b). Finally, by including price as one of the attributes this survey-based methodology for modelling preferences for goods allows the estimation of WTP (Hanley et al., 2006).

A typical CE exercise is composed of a number of stages, namely (1) selection of attributes, (2) assignment of levels, (3) choice experimental design, (4) construction of choice sets, (5) measurement of preferences, and (6) estimation procedure (Hanley et al. 2001). These stages are explained in the following sub-sections.

8.2 Attributes selection and choice experimental design

In choice experiments (CEs), respondents are asked to choose among different alternative specifications of a good. These alternatives are described in terms of the attributes of the good and the levels that these attributes take (Louviere et al., 2008).

In order to select appropriate attributes of the good, it was important to understand the characteristics of the study site in terms of water management, agricultural production, and policies and regulations governing water and wastewater. Furthermore, the levels adopted had to be "feasible, realistic, non-linearly spaced, and span the range of the respondents' preference maps" (Hanley et al., 2001, p. 437). Taking into account the local characteristics does not only deliver realistic attributes, it also accounts for variability in terms of wastewater reuse practices. This considers that wastewater reuse practices present unique characteristics determined by their localities. The attributes and levels proposed for the different case studies are described in the next sub-sections.

Although it is often the practice in CEs to have focus groups to conclude on the final attributes, this was not done in any of the case studies. Attributes and levels were determined through various discussions with people on the ground, broadly called experts, which included researchers in the field of economics and social science, water resources engineers, and key local actors (e.g., farmers' leaders or representatives). The attributes of interest were assessed in terms of their relevance, and the experts opinions were taken into account. These discussions help to achieve the academic standard and the local fit regarding the attributes. For every case study, the final list of attributes and levels were discussed with the supervisors of this dissertation. The attributes selected responded to the main aspects of interest in terms of wastewater reuse in agriculture in the specific case study area.

Next, once the attributes had been selected, and their respective levels assigned, the next step was the experimental design. This consists of selecting a set of choices from the set of all possible choice sets, which comply with specific statistical properties such as identification and precision, and with non-statistical properties such as realism and complexity (Louviere et al., 2000). This is explained for each case study in the following sub-sections.

8.2.1 Case study: Hyderabad, India

The good to be valued in this case study was the framework for the use of water delivered by the Musi River for irrigation, in the agricultural area of the outskirts of Hyderabad, India. Five attributes were identified based on a literature review and on expert consultation: 'water quantity', 'restrictions', 'health risks', 'nutrient content' and 'price'.

The ‘water quantity’ attribute refers to the amount of water delivered to the farmers by the river. In this case, three levels were proposed: high, medium and low. As there was no information on the quantity of water used by the farmers, this attribute was described in qualitative terms. ‘Medium’ quantity was the reference level; this was understood as the amount of water a farmer would have at present (at the time of the survey) to irrigate his/her entire farm (no specification was made for the size of the land). The other two levels described situations where more or less water was supplied compared to the reference level.

The ‘restrictions’ attribute refers to the measures that farmers should take while using the water. Again three levels were proposed:

- Strict (high): strict restrictions on crops, imply that vegetables eaten-raw are not allowed, there is strict control on irrigation methods (e.g., flooding should be avoided), and there is a strict monitoring of the practice.
- Moderate: restriction on crops exists, but more variety of crops is allowed; control on irrigation methods exists with options for crop-method mix, and there is a regular monitoring of the practice.
- No restrictions: there is no restriction on crops and on irrigation methods; however, farmers are responsible for washing and safe-handling of crops.

The ‘health risks’ attribute refers to the possible health risks that exist for the farmers (expressed by the number of farmers that are exposed to health risks) as a consequence of being in contact with water from the Musi River. For this attribute three levels were proposed:

- Very high: a large number of farmers are exposed to parasites, which can cause skin irritation and other health-related problems, as a consequence of being in contact with wastewater.
- Tolerable: fewer farmers get sick, but it is accepted that still a number of farmers can get sick as a consequence of irrigating with wastewater.
- Reduced: in this case the number of farmers that can get sick is reduced because of an improvement of the water quality in the river resulting from wastewater treatment.

The ‘nutrient content’ attribute refers to the nutrients present in the wastewater, which are beneficial for crop development, but it also considers the existence of pollutants and salts which can harm the plant or decrease the yields. For this attribute, two levels were proposed:

- High: water is high in nutrients, but also high in pollutants or salts that can decrease yields.
- Low: water is treated; therefore the nutrient content is reduced, but also the content of pollutants and salts.

Finally, a price was included as part of the attributes to estimate the respondent's WTP for changes. Four levels were proposed for the price attribute; the reference level was INR 250 and 500 per ha for dry and wet crops, respectively. The other levels were: one below the reference level and two above the reference level (see Table 8-1). The reference level is what farmers should pay in one season as 'water tax' per ha per crop under the command area. Water intensive crops (e.g. sugar cane and rice) are referred to as 'wet crops', whereas less water intensive crops (e.g. cotton and maize) are referred to as 'dry crops' (Tirupataiah, 2013). An informal source suggested that farmers were willing to pay between INR 250 and 500 per ha to treat the wastewater in the river, so they can improve the water quality and go back to grow paddy. In Table 8-1 the attributes and its levels are summarized.

Table 8-1 Attributes and levels for choice sets - Hyderabad

Attributes	Levels			
Water quantity	High	Medium	Low	
Restrictions	Strict (high)	Moderate	No restrictions	
Health risks	Very high	Tolerable	Reduced	
Nutrient content	High	Low		
Price (INR/ha) [(1)]	< 250 ([a]) < 500 ([b])	250 ([a]) 500 ([b])	250 + between 250 and 500 ([a]) 500 + between 250 and 500 ([b])	250 + more tan 750 ([a]) 500 + more tan 750 ([b])

(1) USD 1= INR 54.90

(a) Dry crops; (b) Wet crops

There are two types of CEs: labeled (alternative-specific) and unlabeled (generic). Labeled CEs refer to alternatives where the name of the alternative delivers additional information in addition to the attributes. In contrast, unlabeled CEs refer to experiments where the name of each alternative is generic and the only way to differentiate the alternatives is through the attributes and their levels (Hensher et al., 2005). According to Hensher et al. (2005), labeled CEs have some disadvantages: 1) they require larger samples compared to unlabeled ones; 2) the IID (independent and identically distributed) assumption is more likely to be violated; and 3) respondents may use the labels assigned to the alternatives as proxies for the omitted attributes in the experiment. Conversely, an advantage of assigning labels to CEs is that responses will reflect the emotional context in which preferences are revealed (Blamey et al., 2000). In the case of Hyderabad, an alternative-specific CE design (choice sets have a specific label) was constructed using the software SAS. The reason why a labeled CE was selected for this case study was due to the interest in evaluating specific scenarios or alternatives, i.e. the type of intervention was needed to be emphasized, where a generic CE would have lost the focus. Three alternatives were presented to the respondents labelled as: No Intervention (NI), Restrictions (R) and Water Treatment (WT). Furthermore, a generic full factorial design would produce a total of 216 profiles ($3^3x4^1x2^1$). Because such a large number is impossible to evaluate and not all profiles are realistic under our alternative specific scenario, a fractional design maximizing D-efficiency was constructed. This design had D-efficiency of 96.53%, A-efficiency of 93.02% and G-efficiency of 93.25%. These indicators specify the goodness of the design relative to the hypothetical design (Kuhfeld, 2000).

Simultaneously, the choice sets were constructed grouping the profiles into choice sets to be presented to the respondents. In this case, the profiles were grouped into 12 choice sets, which were divided in three blocks. The purpose of blocking is to reduce response fatigue (Adamowicz et al., 1998). In this experiment, each respondent had to consider four choice sets. Considering that CE is a demanding exercise and respondents could be illiterate, pictograms were used (Speelman & Veettil, 2013). Furthermore, an opt-out option was also included in the choice set. The inclusion of an opt-out option in CEs is considered best practice to try to mimic the real market situation as closely as possible, and to avoid a 'forced choice' by allowing respondents to choose another alternative if they do not prefer any of the hypothetical alternatives presented (Banzhaf et al., 2001). In Annex 4, an example of a choice set and the pictograms are presented.

8.2.2 Case study: Cochabamba, Bolivia

In this case, the good to be valued was the framework for reuse of wastewater in agricultural irrigation in three communities diverting water from the Rocha River, in Cochabamba, Bolivia. The attributes describing this framework were the following: 'water quality and quantity', 'access to water', 'use restrictions', 'farmers' involvement' and 'price of petrol'.

The 'water quality and quantity' attribute refers to the quality of the water and the quantity. There are trade-offs between quantity and quality. This attribute had two levels:

- Treated wastewater: this level implies lower health risks for farmers in contact with water. By means of treatment, the nutrient content in the water is reduced, but also the content of pollutants or salts that can damage plants and soils is reduced. The quantity of water available to farmers is restricted to the capacity of the WWTP, usually less than in the untreated wastewater scenario.
- Untreated wastewater: this level implies high health risks for farmers in contact with the water. It is high in salt content, which can cause salinity in the soil; in the long term this degrades the soil and is no longer apt for agriculture. It is high in nutrient content, which is good for crop growth, but also the content of pollutants or salts is high which can decrease crop yields. The water quantity depends on what is available in the river or sewerage.

The second attribute, refers to the 'access to water' by the farmers. This attribute had two levels:

- Restricted: the access to water is restricted to users of the irrigation system. Usually membership to an irrigation system is determined at the beginning by the future users. The future users are those who are interested in the irrigation system and are willing to take part of it including all responsibilities. Once the irrigation system starts operating, it is atypical that new users are added.
- Non-restricted: the access to water is not restricted, i.e., anybody can use water. In this case, there is no membership required to benefit from the irrigation system.

The third attribute: 'use restrictions' refers to measures to be taken into account by the farmers while using wastewater in order to protect their health; at the same time they also work as protective measures for the consumers. This attribute had two levels:

- High: Strict restriction on crops (e.g., vegetables eaten raw are not allowed). Strict control over irrigation methods (e.g., furrow or flooding is not allowed unless water is not in contact with crops; drip irrigation is recommended). Waiting periods between the last irrigation and harvesting are required. Periodic control on water use practices.
- Low: No restriction on crops. No restriction over irrigation methods. Sporadic control on water use practices.

The fourth attribute refers to 'farmers' involvement' in the irrigation system and the WWTP. Two models of involvement were proposed:

- Model 1: Farmers are responsible for all aspects of the irrigation system. They are the decision makers concerning operation and management of the irrigation system. If there is a WWTP providing water for irrigation, farmers are not involved in any task of the WWTP, i.e., the WWTP operates separately from the irrigation system. The WWTP is operated and managed by the municipality or EPSA (public-social enterprise for water and sanitation).
- Model 2: Farmers are still responsible for all aspects of the irrigation system, namely operation and management. If water is provided from a WWTP, farmers participate in some tasks within the WWTP, e.g., cleaning of the works, gardening, etc. Farmers are involved in decision-making concerning the WWTP and the irrigation system. The WWTP remains operated and managed by the municipality or EPSA.

The last attribute is the 'price of petrol', included as part of the attributes to estimate the WTP for changes in attribute levels. In these communities water is pumped with petrol pumps, therefore the price of petrol served as the price attribute. The purpose of substituting the price of water with the price of petrol was to avoid direct use of water price because these communities are sensitive to water pricing issues, therefore it might have not been well received. The price of petrol (at the time of the survey) was taken as reference price (i.e., Bs. 3.74 or USD 0.54 per liter). The other two levels derived from increasing the price reference by 2 and 5%, respectively. Table 8-2 presents the summary of the attributes and levels.

Table 8-2 Attributes and levels for choice sets - Cochabamba

Attributes	Levels		
Water quality and quantity	Treated wastewater	Untreated wastewater	
Access to water	Restricted	Non-restricted	
Use restrictions [(a)]	High	Low	
Farmers' involvement [(b)]	Model 1	Model 2	
Price of petrol (Bs/L) [(c)]	3.93	3.81	3.74

(a) For the farmers, but they work as protective measures for the consumers
(b) Involvement in the irrigation system and the WWTP
(c) USD 1 = Bolivianos (Bs) 6.96

For this study, a generic CE was constructed, using the software JMP 11.2.0. In a generic CE the alternatives or profiles are unlabeled. In this case the interest was on the information that the attributes could generate without labels. Furthermore, in this case, the full factorial design generated a total of 48 profiles (2^4x3^1). As this remains a large number of profiles to evaluate, a fractional design maximizing D-efficiency was constructed. The indicators to specify the goodness of the design relative to the hypothetical design (Kuhfeld, 2000) are the following: D-efficiency 97.1%, A-efficiency 94.1% and G-efficiency 83.8%.

Next, the profiles obtained from the fractional design were grouped. In this case, the 15 choice sets were divided in three blocks, so each respondent had to consider five choice sets, each comparing two alternatives. An opt-out option was also included, for the same reasons explained in section 8.2.1. Again, in order to reduce the cognitive burden of the exercise, the choice sets were presented to the respondents in pictograms. An example of a choice set and the pictograms used are provided in Annex 5.

8.2.3 Case study: Western Cape, South Africa

In this case, the good to be valued is the framework for water reuse in irrigation in the agricultural region around Cape Town, in Western Cape, South Africa. Four attributes were identified, based on a literature review and on expert interviews: 'water quantity-quality', 'practice restrictions', 'management model' (of the scheme) and 'price'.

The attribute 'water quantity-quality' refers to the access to different quantities of water and the relative water quality standards available. Four levels were proposed:

- A1: limited water quantity – up to 50 m^3/day, strict quality standards and reduced nutrient content.

- A2: limited water quantity – up to 50 m^3/day, general quality standards and high nutrient content.
- A3: maximum water quantity – up to 2000 m^3/day, general quality standards and high nutrient content.
- A4: unlimited water quantity, quality standards less strict than the general standards and high nutrient content.

Note that there are tradeoffs between quantity and quality. The volumes of water specified for these levels were based on information contained in the "Government Notice N°665, Department of Water Affairs: Revision of General Authorizations in terms of Section 39 of the National Water Act, 1998" from 6 September 2013 (Government Gazette, 2013).

The second attribute, the 'practice restrictions' refers to the measures to be taken while using the water to irrigate. Three levels were identified for this attribute, namely:

- High: strict restriction on irrigation of crops for human consumption (e.g., vegetables eaten raw not allowed); strict control over irrigation methods (implies periodic inspections); and strict monitoring of water use (e.g., protective measures, including the use of protective clothes such as rubber boots or gloves, signaling of water pipes and reservoirs, waiting periods between irrigation and harvesting, avoiding direct contact between water and crops, use of drip irrigation).
- Moderate: irrigation of crops for human consumption which are not eaten raw is allowed, including fruit trees and vineyards; moderate control over irrigation methods (implies sporadic inspections); and regular monitoring of water use (e.g., protective measures).
- Low: no restriction on crops; no restriction of irrigation methods; regular monitoring of water use (e.g., protective measures).

The third attribute refers to the proposed 'management model' for the scheme. This refers to models for water supply infrastructure and management. Three levels were proposed:

- Public: financed, operated and managed by a public agency, e.g., the municipality.
- Private: financed, operated and managed by the users; wastewater is pre-treated at the municipality; monitoring of water quality standards remains under the DWA.
- Public-private-partnerships: funding is shared, e.g., users contribute to capital costs for development of the infrastructure, tariffs take into account maintenance and operating costs only, management is by the users, the municipality is only involved in delivering the water to a certain point in the scheme.

Finally, price was included as one of the attributes to enable estimation of the WTP for changes in other attribute levels. In this case, the prices were defined taken as reference the following: 1) water tariff stipulated by the Council for agricultural irrigation schemes, but not under Special Users (ZAR 1 per m^3); 2) water tariff paid by the users in the Potsdam farmers' irrigation scheme (ZAR 2.5 per m^3), this is the highest value in the tariff scale and it is related to the investment made in the conveyance infrastructure by the farmers and the amount of water they will receive; and 3) the highest value in the scale tariff established by the Council, which corresponds to commercial/industrial users (ZAR 4.20 per m^3). Table 8-3 presents the attributes and their respective levels.

Table 8-3 Attributes and levels for choice sets – Western Cape

Attributes	Levels			
Water quantity, quality & nutrient content	A1	A2	A3	A4
Practice restrictions	High	Moderate	Low	
Scheme model	Private	Private-Public Partnership	Public	
Price (ZAR/m^3) (*)	5	2.5	1	

*USD 1 = ZAR 10.5

For this analysis, a generic CE, using the software JMP 11.2.0, was constructed. This implies that the alternatives/profiles were unlabeled. As in the case of Cochabamba, the interest was to generate information without labeling the alternatives. A full factorial design produced a total of 108 profiles (4^1 x 3^3). However, this was still a large number to evaluate. To address this issue a fractional design maximizing D-efficiency was constructed. This design had D-efficiency of 95%, A-efficiency of 89% and G-efficiency of 69%.

Next, in order to construct the choice sets, the profiles were grouped to be presented to the respondents. The profiles were grouped into 12 choice sets and divided into three blocks. Therefore, each respondent had to consider four choice sets. An opt-out option was also included (the justification is the same that in the case of Hyderabad explained in section 8.2.1). This was preferred over the status-quo option because there was no common status-quo for the respondents, with some currently using treated wastewater and some not. The choice sets were presented in pictograms in order to decrease the cognitive burden of the exercise (Speelman & Veettil 2013). An example of a choice set is provided in Annex 6, including the pictograms used.

8.3 Data collection process

The process of data collection involved mainly three steps. A first step consisted in several interviews/discussions conducted with local experts, preceded by a literature review. During this step important information was gathered about the characteristics of the area in terms of water management and wastewater reuse, which also served as input for the design of the CE. A second step consisted in the design of the survey to be asked to the famers, which included the CE, and additional questions on perceptions, socio-economic and farm characteristics. One survey was constructed for each case study, which contained similar questions, but at the same time it varied in other aspects in order to fit the local context. The surveys for the different case studies were elaborated by the author and discussed with experts (from IWMI local offices) and the supervisors in order to obtain feedback and make the necessary improvements. Once all the suggested changes were introduced, a final version of the different surveys was then presented to the supervisors and approved before going to the field. This process was repeated for each case study.

The third step consisted in the implementation of the survey. On the field, the surveys were tested again with the respondents themselves. Strong emphasis was put to make sure that the respondents could understand the questions (through the use of appropriate vocabulary) and that the purpose of the questionnaire was clear to them. The first day of the survey was key to detect if changes were still necessary, different qualitative aspects such as the use of words (in English for Hyderabad and Western Cape, and Spanish for Cochabamba), the length of the questionnaire (to avoid farmers tiredness), the clarity of the questions were checked during this exercise. In the case of Hyderabad, two local assistants provided feedback on the questionnaire during the first round, in the other two cases this was a self-assessment. Farmers surveyed during the first round included: 11 in Hyderabad, 10 in Cochabamba and 1 in Western Cape.

Many farmers in Hyderabad and Cochabamba were illiterate, in contrast to farmers in Western Cape. In all cases the surveys were conducted face-to-face, where every question was read to the respondents, so respondents did not have to fill the form themselves. In the case of the CE, respondents were explained every alternative for each choice set, repeatedly. In addition, respondents were presented with pictograms so they could follow through the explanation of each alternative. Then they were asked about their choice (i.e. to select one of the alternatives) and informed that they could also opt for none of the alternatives presented to them (i.e. to select the opt-out option, but this option was rarely chosen). Each face-to-face interview lasted normally between 30 and 40 minutes. It was important to keep the time to guarantee that farmers would not lose interest. For this reason, the CE was the first set of questions to be asked. Nevertheless, some respondents required more time, which was provided accordingly. Some of the respondents enriched the interviews by providing more information other than what was asked in the questionnaire. Every respondent was asked to participate in the survey voluntarily and informed in advance about the purpose of the survey and the approximate time it would take. If they agreed, then the survey proceeded. The data were analyzed anonymously.

Hyderabad was the first case study to be conducted. More attention was paid in this case in terms of the type of questions to be asked (e.g., socio-economic and farm characteristics, farmers' perceptions) and the whole design and development of the CE (including selection of attributes). It served as a learning experience, where many aspects could be improved during the development of the survey and design of the CE for the next case studies. For instance, in this case a labeled CE was designed, but given the observation that an unlabeled CE might have been more suitable, this approach was taken in Western Cape and Cochabamba. Another aspect learned from the first survey was the use of a Likert-scale to assess the farmers' perceptions instead of direct questions; this was also changed in the other two case studies. On the other hand, this experience also helped to gain confidence in the questions, so there was opportunity to explore other new components to be considered in the other case studies.

For the case study in India, the CE was included in a survey conducted between May and June 2013 with farmers from peri-urban and rural villages located along the Musi River in a stretch of about 25 km from Hyderabad (see Figure 9-1). Based on the findings from Ensink et al. (2010) concerning the improvement of the water quality in the river further downstream, the starting point of the survey was the 1st-weir located nearby Peerzadiguda village[20], then moving downstream up to the 8th-weir located in the proximity of Pillaipalli village[21]. It covered five villages in the peri-urban area, four villages in the peri-urban–rural fringe, and five villages in the rural area. The purpose was to capture possible spatial effects. Respondents were randomly selected. They had to be farmers in the area and minimum 18 years old. Respondents were interviewed on field while conducting their usual farming activities. The survey contained additional questions on socio-economic characteristics, cropping patterns and irrigation practices. The survey was conducted with support of local assistants that were fluent in English and the local language. The assistants were trained before going to the field. A total of 118 respondents took part in the experiment.

For the case study in Bolivia, data collection consisted of a survey carried out with farmers from three communities using water for irrigation from the Rocha River: Huerta Mayu (upstream), Maica Chica (middle zone) and Maica (downstream) (see Figure 10-1). The survey was conducted between February and March 2015. It contained the CE and included additional questions on socio-economic characteristics, cropping patterns, irrigation practices and perceptions on wastewater reuse. The respondents were randomly selected in each community, applying a simple random approach. The conditions were that the respondent had to be above 18 years old and member of the community. In each community, the leader was asked permission to enter the community to conduct the survey. The language of communication was Spanish. The sample size was linked to the experimental design. In JMP 11.2.0, a minimum sample size necessary to generate an efficient design – with a D-efficiency of a desired level – was set. In this case this was 42 respondents. A total of 49 respondents participated in the survey, generating a total of 245 observations for the CM.

[20] Geographical coordinates: 17°23'15.91" N; 78°35'52.23" E.
[21] Geographical coordinates: 17°23' 9.47" N; 78°44'1.97"E.

For the case study in South Africa, the process of data collection consisted of a survey conducted in the agricultural area of the hinterlands of Cape Town, in Western Cape Province (see Figure 11-1), between April and July of 2014. The CE was part of this survey, which also included questions on socio-economic characteristics, cropping patterns, irrigation practices and perceptions on wastewater reuse. The respondents were randomly selected and the language of communication was English. The sample size was linked to the experimental design. In JMP 11.2.0, a minimum sample size necessary to generate an efficient design – with a D-efficiency of a desired level – was set. In this case this was 45 respondents. Finally, a total of 46 respondents participated in the survey. With this sample size 184 observations were generated for the CM exercise. Seventeen of the respondents were part of a group of 43 farmers that currently use treated wastewater for irrigation (38 in Durbanville, and 5 in Malmesbury). This represents about 40% of the total number of farmers using treated wastewater in the area. The remaining 29 respondents were included as a control group. Overall the sample size represents about 6% of the population [the total number of farm units in Bellville/Durbanville, Stellenbosch and Malmesbury amounted to about 795 according to the Census of Agriculture Provincial Statistics 2002 (Statistics South Africa, 2006)].

8.4 Limitations of the data

It is acknowledged that the sizes of the samples for the different case studies are small. This is considered a limitation of this study. However, it is also important to emphasize that wastewater reuse is not uniform at the same scale in every location. The trajectory of the case studies may be interpreted as follows: the access to wastewater is high where regulations are poor, as most peri-urban water bodies are polluted (e.g. in Hyderabad and Cochabamba at different scale, with the difference that in Cochabamba a process of planned wastewater reuse is under development), then it declines as regulations are enforced (e.g. in Western Cape), and finally it peaks up again where regulations strongly promote wastewater reuse (e.g. in Israel) (see Figure 8-1).

This implies that the size of the target population is different in every case study and is connected to the local characteristics. Considering this particular feature of wastewater reuse across the world, namely variability in scale, it is unrealistic to expect uniform and large sample sizes in all case studies. In effect, in Western Cape and Cochabamba the target populations were rather small. In Western Cape the schemes of farmers using treated effluent comprised a total of 43 farmers, and 40% of the farmers using treated wastewater in this area were surveyed. In Cochabamba the target population distributed in the three target communities was about 230 farmers, about 20% were surveyed. In Hyderabad, a proper census is not available on the number of farmers using water from the Musi River (Amerasinghe, 2015). Buechler et al. (2002) estimated that some 250 households use Musi water for agriculture on a total of 100 ha in the urban area along a 5 km stretch of the river. Based on such figures, through extrapolation it is estimated that the target population in Hyderabad ranged between 1250-5450 households. This would mean that between 2 and 9% were surveyed.

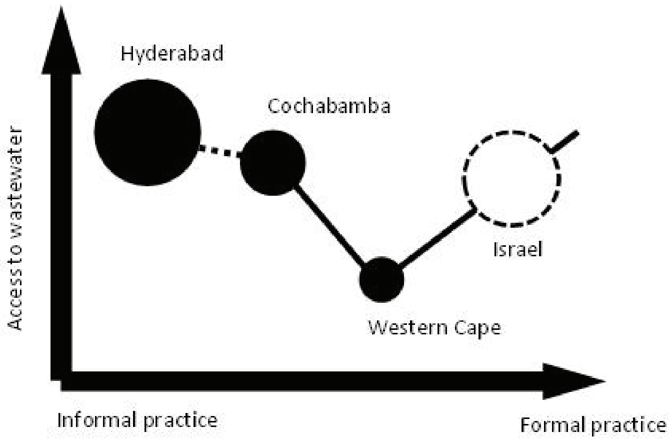


Figure 8-1 Relation between access to wastewater and (in) formality of the practice to illustrate variability in scale of wastewater reuse

8.5 Model specification: conditional logit and latent class model

The last step in the CE consists of the estimation procedure. In this case, this was done in two steps: first a conditional logit model (CL) was estimated and then a latent class model (LC). The specification of the model is presented in this section.

The theoretical foundation of CM is the random utility theory (McFadden, 1974). This theory suggests that individuals make choices based on the characteristics of the good along with a random component. The latter may result from the uniqueness of preferences of the individual or from the analyst's incomplete information about the individual. Then, the utility U_{ij} of an individual i derived from alternative j is decomposed into an observable component V_{ij} and an unobserved random component ε_{ij}:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \qquad (1)$$

V_{ij} can be expressed as a linear function of the explanatory variables as follows:

$$V_{ij} = x'_{ij}\,\beta \qquad (2)$$

Where β is a vector of coefficients associated with the vector x' of explanatory variables, which are attributes of alternative j, including the socioeconomic factors of individual i (Snowball et al., 2008). The underlying assumption is that individual i would choose alternative j over alternative k, if $U_{ij} > U_{ik}$ (McFadden, 1974).

Considering that the explanatory variables are attributes, a CL was applied in this study. CL is suitable when the choice among alternatives is modelled as a function of the attributes of the alternatives rather than (or in addition to) the attributes of the respondent. This particular feature makes CL more suitable for modelling polychotomous choice situations (Hoffman & Duncan, 1988). Compared to the Multinomial Logit (MNL) model, CL models the problems of interest by using a 'characteristics of the alternative' approach. In other words, while MNL focuses on the respondent as the unit of analysis and uses its characteristics as explanatory variables, CL focuses on the set of alternatives presented to each respondent and the explanatory variables are the characteristics of those alternatives (Hoffman & Duncan, 1988). In a CL, it is assumed that the error of disturbances have a type 1 extreme value distribution: $exp\ [-exp(-\varepsilon_{ij})]$. The selection of an alternative is expressed as (McFadden, 1974):

$$U_{ij} > max_k \in_{ci,k\neq j} U_{ik} \qquad (3)$$

The probability of choosing an alternative j among n choices for individual i is given by:

$$P_i\,(j) = P\left[x'_{ij}\beta + \varepsilon_{ij} \geq max_k \in_{ci}\ (x'_{ik}\beta + \varepsilon_{ik})\right] = \frac{\exp(x'_{ij}\beta)}{\sum_{k\in_{ci}}\exp(x'_{ik}\beta)} \qquad (4)$$

The parameters of the CL were estimated applying the maximum likelihood estimation procedure using the software NLOGIT 5.0.

A disadvantage of the CL model, however, is that it assumes homogeneity in preference across respondents, as one single parameter estimate is generated for each choice attribute (Colombo et al., 2009). Accounting for heterogeneity in economic analysis is useful for estimating unbiased models and forecasting demand by including individual characteristics. Moreover, understanding heterogeneity will provide information on the distributional effects of resource use decisions or policy impacts (Boxall & Adamowicz, 2002).

Two approaches have been developed and are often compared for incorporating preference heterogeneity in the analysis: the Random Parameter Logit (RPL) and the Latent Class (LC) model. The RPL accounts for preference heterogeneity using a continuous distribution for individual tastes by assuming that each member in the sample has a different set of utility parameters. The RPL approach holds intuitive appeal to the extent that it recognizes the possibility that two respondents are not alike in their preferences (Provencher & Moore, 2006). But to operationalize this notion of individuality, the RPL approach requires the analyst to choose a particular parametric form for the distribution of parameters. This requirement explains why the RPL approach does not necessarily outperform the semiparametric approach of latent class analysis (Provencher & Moore, 2006). Boxall & Adamowicz (2002) argue that while RPL incorporates heterogeneity, it is not well-suited to explaining the sources of heterogeneity. These sources relate, in many cases, to the characteristics of individual consumers (Boxall & Adamowicz, 2002). In any approach, however, to incorporate heterogeneity into the analysis there must be a priori knowledge of the elements of heterogeneity. Ideally, theory should provide the foundation for possible sources of heterogeneity (Boxall & Adamowicz, 2002).

A LC model has been adopted in this study, in a second step, for the analysis of the farmers' preferences.

McFadden (1986) recognized the opportunity of using latent variables in understanding choice behavior, by integrating information from choice models with attitudinal, perceptual and socio-economic factors through a latent variable system. The LC approach accounts for preference heterogeneity by assuming that the sample of respondents arises from a given number of groups or segments (Boxall & Adamowicz, 2002). Although taste variation is not incorporated within the segments, its intuitive interpretation of variation across segments in the population has made the LC model a convenient tool to obtain useful information about the distribution of welfare effect associated with policy changes (Provencher et al., 2002; Greene & Hensher, 2003). The LC model accounts for heterogeneity in the systematic part of the utility, but differs in the assumptions of the distribution of preferences (Sagebiel, 2011). The model can capture variation in preferences between segments of respondents (Birol et al., 2006a). Usually it outperforms models that assume homogeneity of preferences (Provencher & Bishop, 2004; Birol et al., 2006a; Sagebiel, 2011).

The LC approach tackles the problems presented in the RPL model. It involves characterizing segments from discrete observed measures such as attitudinal scales, or can involve empirically testing whether a theoretically posed typology adequately fits a set of data (McCutcheon 1987, p. 8). When combined with information on preferences relating to consumer choice, this approach offers an opportunity to understand and incorporate preference heterogeneity in consumer analysis (Boxall & Adamowicz, 2002). Compared to RPL model, a LC model proofed to be superior for welfare measures and interpretation (Birol et al., 2006a). Sagebiel (2011) compared RPL and LC, and found that the LC has slight statistical advantage over the RLP. He suggested that LC should be chosen when different groups within the sample are expected, which show within class homogeneity (Sagebiel, 2011). On the other hand, Hynes et al. (2008) emphasize that, based on a number of studies comparing RPL and LC model to modeling heterogeneity in preferences, overall no model is found to be generally superior, and sometimes even a simple CL model does better in out-of-sample forecast than models designed to capture heterogeneity in the population.

The previous paragraphs provided the rationale for the adoption of a LC model over a RPL, to analyze the farmers' preferences for wastewater reuse frameworks. In addition, an important determinant for choosing, in this case, a LC model is that this model requires less observations compared to the RPL to generate results, which in this case was appropriate considering the small samples. It also offers simplicity in the interpretation of results.

In the LC model, heterogeneity in preferences is included through the observable component. Assuming the existence of *s* segments in a population and that individual *i* belongs to segment *s* $(s = 1,\ldots, S)$, the utility function can be expressed as follows (Boxall & Adamowicz, 2002):

$$U_{ij|s} = x'_{ij}\,\beta_s + \varepsilon_{ij|s} \qquad (5)$$

The probability of choice for an individual *i*, considering that the individual belongs to segment *s*, of selecting an alternative *j* in the t^{th} choice set of *n* alternatives, for a particular choice activity is given by (Greene & Hensher, 2003):

$$P_{ijt|s} = \left[\frac{\exp(\beta_S x'_{ijt})}{\sum_{j=1}^{J}\exp(\beta_S x'_{int})}\right] \qquad (6)$$

Then, the probability that an individual belongs to a particular segment is given in equation 7, where Z_i is a vector of individual-specific variables and a_s is a vector of segment-specific parameters to be estimated (Speelman & Veettil, 2013):

$$P_{is} = \left[\frac{\exp(a'_s Z_i)}{\sum_{s=1}^{S}\exp(a'_s Z_i)}\right] \quad (7)$$

The probability that any randomly selected respondent chooses an alternative is obtained combining the conditional probability (eq. 6) with the segment membership probability (eq.7) as follows (Speelman & Veettil, 2013):

$$P_{ij} = \sum_{s=1}^{S}\left(\frac{\exp(a'_s Z_i)}{\sum_{s=1}^{S}\exp(a'_s Z_i)}\right)\prod_{t=1}^{T}\left(\frac{\exp(\beta_s x'_{ijt})}{\sum_{j=1}^{J}\exp(\beta_s x'_{in})}\right) \quad (8)$$

The parameters for the LC model were estimated by applying the maximum likelihood estimation procedure in the software NLOGIT 5.0.

8.5.1 Considerations for Hyderabad

The LC model was run for two, three and four segments. In order to determine the 'optimal' number of segments, following criteria were used: the log likelihood, Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Ruto et al., 2008). The optimal model is the one that presents these criteria with minimum values (Speelman & Veettil, 2013). The goodness-of-fit of the model is measured by the likelihood ratio index (LRI) or pseudo-rho squared (ρ^2). For well-fitted models LRI takes values larger than 0.2 and it is rare to find LRI larger than 0.4 (Hoyos, 2010). In this model, the LRI is 0.26 (see Table 8-4).

Belonging to a segment is probabilistic and depends on socio-economic and attitudinal characteristics of the respondents (Birol et al., 2006a). For the segment membership function a combination of different variables was tested including: 'nutrient content awareness', 'health risk awareness', 'experiences on negative effects on crops', and 'water scarcity'. Socio-demographic variables such as age, gender, location, education, household size, crop type, income, tax payment, etc. were also tested, but these did not generate robust results. The exercise was a trial-and-error procedure, in order to find robust results (see Table 9-3 for the results of the model).

Table 8-4 Criteria to determine optimal number of segments - Hyderabad

N° segments	Log likelihood	LRI (ρ^2)	AIC	BIC
1	-433.8	0.02	1.888	1.950
2	**-380.7**	**0.26**	**1.712**	**1.880**
3	-358.6	0.30	1.668	1.944
4	-344.3	0.33	1.659	2.041

Source: criteria from Speelman & Veettil (2013).

8.5.2 Considerations for Cochabamba

In this case, due to the small sample size, the LC model was run for two segments only. In a pre-test the model was run for three segments, but it was observed that considering the sample size, the number of respondents per segment would become too small. Hence, it was considered not relevant to run the model with more segments, and just run the model for two segments only. This consideration was also taken for the case of Western Cape.

The two segments generated in the LC model are balanced: segment one held 49.9%, whereas segment two held 50.1%. The LRI in the segmented model is 0.54, higher than in the CL model (Table 8-5). The perception on 'irrigation with wastewater reduces the quantity of fertilizers to be applied in the soil' is what differentiated the two segments. This difference is significant at 5% level. The other variables used in the segmentation were not statistically significant (see Table 10-3 for the results of the model).

Table 8-5 Criteria to determine optimal number of segments - Cochabamba

N° segments	Log likelihood	LRI (ρ^2)	AIC	BIC
1	-86.25	0.49	182.5	200.0
2	-77.76	0.54	185.5	238.0

Source: criteria from Speelman & Veettil (2013).

8.5.3 Considerations for Western Cape

Given the size of the sample, it was considered sufficient to run the LC model for two segments only. As it was explained in the previous section for the case of Cochabamba, more segments would have small number of members due to the small sample size. In this model the LRI is 0.26, which is above 0.2 recommended for well-fitted models (see

Table 8-6). For the segment membership function, different combinations of variables were tested. As in the previous cases, this was a trial-and-error procedure until robust results were found. The combination of variables that generated results included: the ‘perception on health threats of irrigation with treated effluent’, the ‘perception of the environmental threats’ and the ‘current use of treated effluent’ (see Table 11-3 for the results of the model).

Table 8-6 Criteria to determine optimal number of segments – Western Cape

N° segments	Log likelihood	LRI (ρ^2)	AIC	BIC
1	-170.82	0.15	1.944	2.083
2	-149.91	0.26	1.847	2.196

Source: criteria from Speelman & Veettil (2013).

8.6 WTP estimation

In CM, it is possible to estimate WTP by including price as an attribute of the good (Hanley et al., 2001). The marginal utility estimates (coefficients) can be transformed into estimates for changes in attribute levels. By combining different attribute changes, welfare measures can be obtained (Hoyos, 2010). WTP for changes in attribute levels or the marginal rate of substitution (MRS) is done by taking the ratio between the coefficients of individual attributes and the price attribute (Speelman & Veettil, 2013):

$$WTP = \frac{\beta_k}{-\beta_m} \quad (9)$$

β_k is the attribute’s coefficient and $-\beta_m$ is the price attribute coefficient. WTP values for attribute changes and 95% confidence intervals were estimated through the use of the Wald Procedure (Delta Method) in the software NLOGIT 5.0.

Chapter 9. Discussion of the results of the choice experiment in Hyderabad

Abstract

Most cities in developing countries fail to treat their wastewater. As a consequence farmers downstream use low-quality water for irrigation. This practice implies risks for farmers, consumers and the environment. On the other hand, this water supply supports the livelihood of these farmers. Linking wastewater treatment to irrigation could be thus a win-win solution: removing the risks for society and maintaining the benefits for farmers. However, certainly in developing countries the high investment costs required are problematic and the preparedness of farmers to contribute to cost recovery is questioned. Using a choice experiment, this chapter provides insight into farmers' preferences for wastewater use scenarios, quantifying their willingness-to-pay. The case study is Hyderabad, India. Farmers in this region are found to prefer a water treatment option and they are prepared to pay a surplus for treated wastewater. In the light of the cost-recovery problem this information is valuable for policy makers.

Keywords: wastewater use, agriculture, choice experiment, latent class model, India

9.1 Introduction

Despite the provisions in the national water policy (Ministry of Water Resources, Republic of India, 2002, 2012) to improve water quality, pollution of water bodies across India is alarming, especially nearby cities. This results from the lack of infrastructure, poor enforcement of the regulatory framework and dysfunctional institutions. As cities grew, so did the demand for drinking water and sanitation. Most cities are unable to safely dispose wastewater. According to the Joint Monitoring Program (2012), about 92% of the population has access to an improved water source, whereas only 34% has access to improved sanitation facilities. Moreover, the municipal wastewater treatment capacity covers only about 31% of the wastewater generated (Kamyotra & Bhardwaj, 2011). These figures suggest that water returns to the system with hardly any treatment after use. This has implications not only for public health, but also for the environmental status of water resources as they are being polluted. Discharging wastewater without treatment is forbidden in India; in practice however this is not complied. The implication for farmers is that they will not have other choice but to irrigate with low-quality water.

The agricultural sector can benefit enormously from wastewater (Scheierling et al., 2011). But this implies a shift from informal to formal use (towards treatment) in order to reduce threats associated to the practice. In developing countries, the high investment costs required for this are problematic (Leas et al., 2014) and the preparedness of farmers to contribute to cost recovery is questioned. Therefore, more studies about the willingness-to-pay (WTP) by farmers are necessary. This chapter contributes to this lack in literature by a case study for India, more precisely the peri-urban region in Hyderabad. This case study is exemplary for many similar situations around large cities in developing countries. The purpose of the study is to get insight in the current practice of 'wastewater' irrigation, to identify farmers' preferences in this regard, including the factors influencing these preferences, and to quantify their WTP for different use scenarios. The study applies a choice experiment (CE) considering three hypothetical scenarios for wastewater irrigation, namely, 'No intervention' (NI) or business as usual, 'Restrictions' (R) and 'Wastewater Treatment' (WT). A conditional logit (CL) model is first applied, and then a latent class (LC) model is estimated to capture the heterogeneity in preferences within respondents.

9.2 The study area

The case study is the Musi River in Hyderabad, the capital city of the former state of Andhra Pradesh. Hyderabad is located in the semi-arid region of the Deccan Plateau about 540 m. above sea level. The average annual precipitation is 700-800 mm. Rainfall occurs during the monsoon season from June to October (Buechler & Devi, 2003). Like other cities in India, Hyderabad has experienced a rapid growth; its population accounts for 6.8 million people (Census, 2011a). The Musi River was in the past a seasonal river that provided farmers downstream with irrigation water (Ensink et al., 2010). Nowadays, it became perennial due to discharges of low-quality effluents from the city. According to van Rooijen et al. (2010), about 90% of the wastewater generated in Hyderabad is used for irrigation; the area irrigated is about 12,000 ha (Devi, 2006). The crops grown include vegetables, para-grass fodder, and paddy. Wastewater irrigation contributes to livelihoods and food security of the urban and peri-urban poor (Devi, 2006).

The study site is located in the peri-urban and rural fringes along the Musi River (Figure 9-1). Farmers there are mainly smallholders (average land size 1 ha). Musi has enabled them to grow para-grass throughout the year and to have two harvests of paddy per year (van Rooijen et al., 2010).

Several studies were conducted in the Musi River to determine the water quality and its effects on public health and economic development (e.g., Amerasinghe et al., 2009a, 2009b; Ensink et al., 2010; Cheepi, 2012). Ensink et al. (2010) found that three species of helminths eggs were present in the water: hookworm, Ascaris and Trichuris. Moreover, in the proximities to the city concentrations of *E.coli* were comparable to those of raw sewage. The quality of the water however improves significantly downstream. Despite this improvement, the above mentioned problems impose health risk upon farmers (Ensink et al., 2010). Furthermore, another study indicated that salinity induced reduction of yields are to be expected due to the high Electric Conductivity in the soil. It reported presence of cadmium (Cd) in the soil exceeding the

EU maximum permissible level in 47% of the samples. Nevertheless, risks to human food chain were considered negligible (Amerasinghe et al., 2009b).

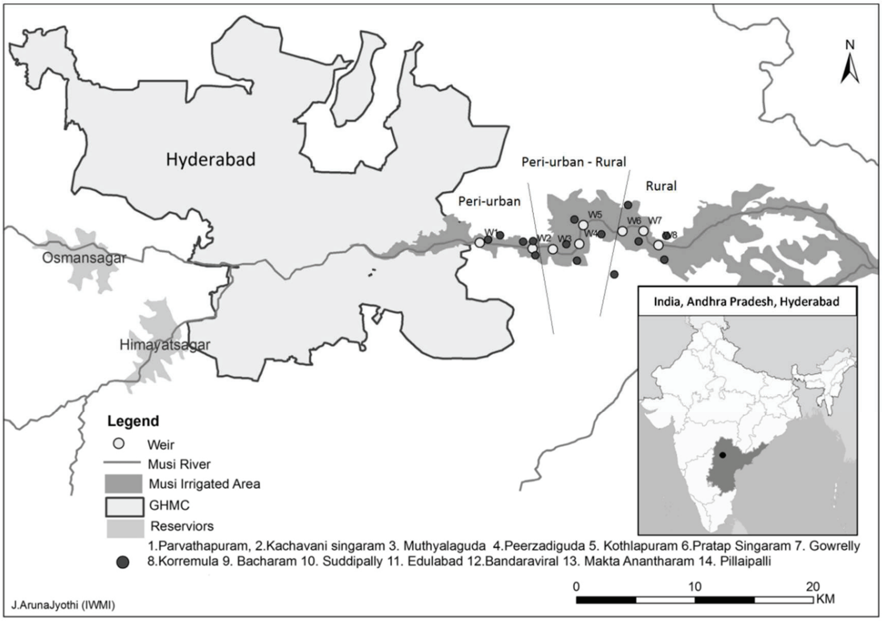


Figure 9-1 Location of the study area – Hyderabad

Source: ArunaJyothi, IWMI (2013).

9.3 Results and discussion

A conditional logit (CL) model was first used to analyze the data. However, a latent class (LC) model was used in a second stage to reveal possible variations in preferences that may result from heterogeneity among respondents, which is of interest for the analysis. The socio-economic and farm characteristics, the farmers' perceptions regarding wastewater as well as the results of the two models are discussed in the next sections.

9.3.1 Socio-economic and farm characteristics

The socio-economic characteristics of the sample are summarized in Table 9-1. The table also reports the socio-economic characteristics of the segments of respondents, but they will be discussed in the last part of section: farmers' preferences for wastewater reuse scenarios.

The sample consists predominantly of male, full-time farmers, where the average age is 47 years. The average household size consists of 4 members. Most respondents were illiterate. Concerning geographical location, the area was divided in three subareas:

peri-urban, peri-urban-rural and rural. Most respondents belonged to the peri-urban – rural group, followed by the rural and peri-urban groups, in that order. In other words, more farmers surveyed came from the transition between peri-urban and rural (see Figure 9-1).

The average household income from irrigated farming was estimated at USD 77.9 per month. Considering other farming activities and other activities not related to agriculture, the average household income was estimated at USD 142.3 per month. Concerning the land ownership, most respondents stated that they lease the land (about 45%); some 38% of respondents own the land and the rest do a combination of both, i.e. some of the land where they cultivate is owned and some is under leasing.

Table 9-1 Descriptive statistics and profiles of the segments - Hyderabad

	Mean (St. Dev.)	Min.	Max.	Segment 1 (n = 47)	Segment 2 (n = 71)
Gender (% male) [a]	94.9			95.7	94.4
Age (years)	47.1 (14.3)	20	78	47 (13.7)	47 (14.7)
Household size (number)	4.4 (1.3)	1	9	4 (1.1)	5 (1.4)
Education (% literate) [a]	43.1			48.9	39.4
Occupation (% full time farmer)	89.8			87.2	91.6
Location * (%)					
Peri-urban	24.6			17.0	29.6
Peri-urban – Rural	41.5			40.4	42.3
Rural	33.9			42.6	28.2
Income (USD/month)					
Irrigated farming	77.9 (80.3)	0	637.6	76.1 (69.5)	79.0 (87.2)
Other farming activities	49.7 (86.2)	0	546.5	46.1 (73.5)	52.1 (94.1)
Other activities	14.7 (59.3)	0	546.5	16.2 (40.0)	13.75 (69.4)
Land ownership (%)					
Owned	38.1			42.6	35.2
Leased in	44.9			44.7	45.1
Owned and leased in	16.9			12.8	19.7
Sources of irrigation water (%)					
River	81.4			76.6	84.5
River and groundwater	11.9			12.8	11.3
Groundwater	6.8			10.6	4.2
Crops cultivated (%)					
Vegetables	5.9			2.1	8.5
Paddy	72.0			78.7	67.6
Para-grass	11.9			8.5	14.1
Vegetables and paddy	4.2			6.4	2.8
Paddy and para-grass	4.2			4.3	4.2
Vegetables and banana	0.8			0.0	1.4
Banana	0.8			0.0	1.4

T-tests, Pearson Chi-Square and Linear by Linear Association Tests show significant differences at 1% (***), 5% (**) and 10% (*) level.

(a) Segment 1, number of respondents is n = 45

The most important source of water for irrigation – for the respondents, is the Musi River. Some farmers also have access to groundwater for irrigation. It is important to highlight that the quality of the water in the river in the proximity to the city is comparable to raw sewage, whereas further downstream it improves (see Ensink et al., 2010). By far, paddy is the main crop cultivated in the area. This is in accordance with the findings of Reddy (2011). However, also para-grass fodder and vegetables are cultivated to a lesser degree.

9.3.2 Farmers' perceptions on wastewater

9.3.2.1 Water pollution: negative effects on health and crops

The questionnaire included questions related to health risks and effects of the water on crop growth. When asked directly[22] around 75% of the respondents claimed that they were aware of the health risks associated with the use of this water (Table 9-2). This might explain farmers' preference for the Wastewater Treatment option as it will be seen in the next section. Previous studies, e.g. McDonald (2009) or Keremane (2009) reported a much lower awareness, so there might be a bias created by the formulation of the question. On the other hand, the focus on the issue by the research community (e.g., by Ensink et al., 2008 or Amerasinghe et al., 2009a), the awareness campaigns by IWMI (see Buechler et al., 2006) and the projects by the local authorities such as the "Save the Musi" campaign might have increased concern about the issue in recent years.

Table 9-2 Farmers' general perceptions on wastewater - Hyderabad

	Mean (St. Dev.)	Segment 1 (n = 47)	Segment 2 (n = 71)
Taxes * (% don't pay) [a]	69.00	60.87	74.63
Claimed health risk awareness (% aware)	75.40	76.60	74.65
Claimed nutrient content awareness *** (% not aware)	53.40	34.04	66.20
Negative effects on health * (% didn't experience) [b]	33.90	24.44	40.00
Negative effects on crops (% didn't experience) [c]	23.90	23.40	24.29
Change of crops (if water is treated) (% won't change) [d]	22.10	25.00	20.29
Access to other water source (% no access)	82.20	76.60	85.92
Water scarcity (% didn't experience)	79.70	78.72	80.28

T-tests, Pearson Chi-Square and Linear by Linear Association Tests show significant differences at 1% (***), 5% (**) and 10% (*) level.

(a) Segment 1, number of respondents is n = 46; in segment 2 is n = 67

(b) Segment 1, number of respondents is n = 45; in segment 2 is n = 70

(c) Segment 2, number of respondents is n = 70

(d) Segment 1, number of respondents is n = 44; in segment 2 is n = 69

[22] Question: "Are you aware of the health risks related to irrigating with Musi water?"

Similarly, farmers were asked whether they knew about the nutrient content in the water[23]. Here 53.4% indicated that they are not aware of this. So this aspect seems to be less known. However, the nutrient content awareness differs significantly between both segments (34% and 66.2% for segment one and two, respectively) (Table 9-2). Possibly farmers closer to the city are unaware of this positive effect of wastewater due to the overall poor quality of the water.

Contaminants in the water can have negative effects on people's health and on crop growth. When respondents were asked whether they experienced negative health effects from the use of the water for irrigation[24], about 34% answered "no", and nearly two thirds of the sample answered "yes" (Table 9-2). In the open ended follow-up question respondents reported itchy skin, skin rashes, foot cracks, joint pain and fever as effects. Similar complaints by farmers were reported by Buechler et al. (2002) and by Srinivasan & Reddy (2009).

Likewise, when respondents were asked whether they experienced negative effects on crop growth[25], only 23.9% answered "no" (either because there was no effect or because they did not associate it to the water) whereas 75% indicated that they experienced negative effects on crops[26]. Note that more farmers reported negative effects on crop growth (about 10 percentage points more) than on health (Table 9-2).

When respondents were asked about shifting crops if the water would improve in quality, about three fourth indicates that they would grow other crops (e.g., vegetables for a higher income or for self-consumption). This suggests that water quality might be an aspect that farmers consider for crop selection. However, paddy may still remain an important crop in the area associated to food security (Cheralu, n/d).

9.3.2.2 Water scarcity and water taxes

About 82.2% of the respondents indicated that they do not have access to other sources of water besides the river. Farmers in this area largely depend on Musi River for irrigation (Table 9-2). Water scarcity does not seem to be an issue, 79.7% of the respondents indicated that they did not experience water scarcity in the past five years (Table 9-2). Those who mentioned some experiences mainly referred to temporal obstruction of the canals due to maintenance, but not real lack of water in the river.

---

[23] Question: "Are you aware of the nutrient content of the Musi water, which decreases the need for fertilizer use?"

[24] Question: "Did you experience any negative effect in your health when using Musi water? Please mention the effects".

[25] Question: "Did you experience any negative effect on the crops when using Musi water? Please mention the effects"

[26] Examples mentioned by the respondents: decrease in crop yield and decrease in grain-filling both for paddy. Abdullah et al. (2001) discuss the effects of salinity on floral characteristics, yield components, and biochemical and physiological attributes of rice. Their results showed decreases in filled seeds/panicle.

About 69% of the respondents indicated that they do not pay taxes for land or water (Table 9-2). Formally, farmers are expected to pay a fee for water based on crop type and land size. In practice, the collection rate accounts to only 40% (Tirupataiah, 2013). Events where farmers refused to pay for such quality of water were reported in areas nearby the city (see TOI, 2002).

9.3.3 Farmers' preferences for wastewater reuse scenarios

In this section, the results of the CL and the 2-segment LC model are discussed, this model outperformed the CL model (LRI = 0.26). Table 9-3 displays the coefficients in the upper part, and the segment membership in the second part.

To identify the membership coefficients for the first segment, the segment membership coefficients for the second segment are normalized to zero (Birol et al., 2006a). The coefficients are interpreted relative to the normalized segment (Speelman & Veettil, 2013). The segment membership coefficients indicate that 'awareness of the nutrient content' decreases the probability that a respondent belongs to the first segment. Other variables do not affect membership significantly. The probability for each respondent of belonging to one of the segments is calculated by eq. 8 (Chapter 8). In this case, 38.6% of the respondents belong to segment one, and 61.4% belong to segment two.

Results of the CL model indicate that the Water Treatment (WT) option is preferred by farmers compared to No Intervention (NI) and Restrictions (R) options. The NI option is least preferred. These results are significant; the implication of opting for water treatment is that farmers prefer 'reduced health risks' compared to 'high health risks', 'low water quantity' compared to 'high water quantity', and 'low nutrient content' compared to 'high nutrient content'. Furthermore, the attribute 'tolerable health risks' is less preferred by farmers compared to 'reduced health risks'. The strong preference for the WT option can be explained by the negative experiences reported by farmers in terms of health and crop growth as a consequence of the poor-quality water in the river. Moreover, although not significant, the sign of the price attribute is consistent with the theory. Other attribute levels are not statistically significant. Notice that the alternative specific constants (ASC) in the CL model are significant compared to the attribute coefficients. It is possible that farmers might have paid more attention to the alternative label than to the level of attributes.

Similarly, in the LC model, farmers of segment one preferred the WT option over the other two options. Here the R option is less preferred. In contrast, farmers in segment two preferred WT over the NI option, significant at 5%. The ASC of the R option is not significant, which means that farmers in segment two are indifferent between the R and WT option. Comparable to the results of the CL model, the coefficients of the attributes in segment one are not statistically significant. The explanation given previously is also applicable here: farmers might have paid attention to the alternative labels only in contrast to the levels of the attributes. In this case farmers of segment one could be considered as opponent to the R option.

Furthermore, striking is that the coefficient for price is positive and not significant. This means that price was not a determinant of choice for respondents in segment one. This estimate was not expected. It might be that farmers used strategic responses opting for WT option in the hope that water quality would be improved, despite that they were not willing to pay for that. This can also be linked to the fact that many respondents do not pay water taxes (only about 40% reported to pay water taxes in segment one). This is significantly different between the segments (at 10%). Another possibility is that farmers focused on the label, which suggested an improved quality compared to the status-quo, overlooking the price attribute. In informal talks, many farmers revealed their desire of improving the water quality in the river, and their lack of trust in the city managers concerning wastewater management, as over the years the wastewater discharged in the river only increased.

Another highlight is the negative effect of ‘medium water quantity’ relative to ‘low water quantity’. Though not significant, the negative sign suggests that water quantity is not a determinant of choice for segment one. One farmer expressed this as follows: “over the years, more water is available in the river, but also more pollution”.

In segment two, the coefficient for price is significant and negative. This is consistent with the assumption that price increase reduces preferences for alternatives. Next ‘moderate restrictions’ has a positive effect (significant at 10% level) relative to ‘no restrictions’. This implies that farmers prefer some restrictions for using water despite that this might limit their options on crop selection or irrigation methods. It can be interpreted by the fact that farmers seek for an improvement of water quality. This is also expressed in the ‘tolerable health risks’ coefficient, significant and negative. The effect means that farmers prefer ‘reduced health risks’. Taking into consideration that these farmers are predominantly peri-urban, such preferences might be explained by the fact that the water is more polluted in the proximities to the city. Some attribute coefficients are significant in segment two – which was not the case in segment one – it might be that in this case farmers paid less attention to the labels and more to attributes than in segment one.

The segments differ in terms of perceptions on negative health effects (Table 9-2). A larger percentage of farmers reported negative health experiences in segment one, compared to segment two. The interpretation is that farmers in segment one, who are predominantly rural, openly stated their experiences, whereas farmers in segment two, predominantly peri-urban, were hiding their negative experiences on health. Farmers closer to the city were more reluctant to answer the questions. Some mentioned that the media is often in the area reporting the Musi River pollution, and this has had an impact on crop marketing, mainly for leafy vegetables.

Table 9-3 Results of the CL and LC models and WTP - Hyderabad

Labels	CLM	LCM Segment 1	LCM Segment 2
No Intervention	-1.23*** (0.24)	-1.36**(0.67)	-0.81**(0.34)
Restrictions	-0.74*** (0.28)	-5.75**(2.82)	-0.30 (0.35)
Water Treatment			
Attributes			
Price	-0.000079 (0.0003)	0.011 (0.008)	-0.0008*(0.0004)
Strict crop restriction	-0.30 (0.31)	-19.88 (278500.1)	-0.05 (0.38)
Moderate crop restriction	0.28 (0.19)	1.28 (1.42)	0.48* (0.28)
Tolerable health risks	-0.47*** (0.15)	-1.52 (1.38)	-0.63***(0.20)
Medium water quantity	0.31 (0.22)	-0.81 (2.45)	0.21(0.28)
Models statistics			
Pseudo ρ^2	0.02	0.26	
Log likelihood	-433.8	-380.7	
Segment function LCM: respondents' awareness or experience on health issues, water scarcity and nutrient content			
Constant		0.29 (0.61)	
Claimed Nutrient content awareness [a]		-1.32*** (0.46)	
Claimed health risk awareness [b]		-0.08 (0.56)	
Experienced negative effects on crops [c]		0.06 (0.59)	
Experienced water scarcity [d]		-0.09 (0.61)	
WTP for changes in attribute levels and 95% confidence intervals			
No Intervention			-18.77** (-34.36 ; -3.18)
Restrictions			-6.97 (-20.62 ; 6.68)
Water Treatment			
Attributes			
Strict crop restriction			-1.19 (-18.83; 16.46)
Moderate crop restriction			11.21(-6.27; 28.69)
Tolerable health risks			-14.66* (-31.83; 2.51)
Medium water quantity			4.87 (-9.21; 18.94)

Significance level at 1% (***), 5% (**) and 10% (*)

(a) Dummy variable indicating whether respondents are aware of the nutrients contained in the river water.

(b) Dummy variable indicating whether respondents are aware of the risks for the health when irrigating with river water.

(c) Dummy variable indicating whether respondents have ever experienced negative effects on the crops due to irrigation with the river water.

(d) Dummy variable indicating whether respondents experience water scarcity.

Note: WTP estimates in USD/ha per year.

Finally, by opting for the WT option farmers in both segments implicitly prefer low water quantity compared to high water quantity, and low nutrient content compared to high nutrient content. Again, it might be that farmers overlooked the attributes and focused only on the alternative labels. However, farmers are significantly different in terms of the nutrient content attribute. More farmers in segment one claimed nutrient content awareness compared to farmers in segment two (Table 9-2). It is possible that farmers in segment two did not reveal this aspect because they were more concerned with the negative aspects of the water (in terms of health and crop growth), which is also expressed by their preferences for restrictions for the use of water and reduced health risks. Concerning water quantity, the fact that water scarcity is not an issue for most farmers was revealed by the fact that this attribute was not a determinant of choice for farmers.

No significant differences between segments were found in terms of household size, literacy rate or type of land ownership (Table 9-1). The average income from irrigated farming and other farming activities was estimated at USD 122.18 and USD 131.08 per month, for segment one and two, respectively. If this is divided by the household average size (4 and 5, respectively), it gives an average income per capita of USD 30.54 and USD 26.22 per month, respectively. Note that it is about 16% more in segment one. These estimates are above the per capita income for rural population (from agriculture/livestock) in Andhra Pradesh, which according to Reddy (2011) is USD 18.14 per month.

Regarding landownership, in segment one a slightly larger portion of farmers owns the land (7.3 percentage points more), a similar percentage (0.4 percentage points difference) lease in, and a slightly larger portion of farmers in segment two (6.95 percentage points more) owns/leases-in the land. Concerning the geographical location, farmers in segment one, are predominantly rural whereas farmers in segment two are predominantly peri-urban. This trend was tested and is significant at 10% level.

The main water source for irrigation for both segments is the Musi River. However, a slightly larger percentage of farmers in segment one use more groundwater. Paddy is by far the main crop for both segments. In segment two vegetables and para-grass are cultivated by a slightly larger proportion of farmers than in segment one. This is in line with the findings of previous studies indicating that vegetables and para-grass production is more important closer to the city (Buechler & Devi, 2003; Amerasinghe et al., 2009a).

Concerning the perceptions of negative effects on crops, in both segments about the same proportion reported experiences of negative effects on crop growth. When asked directly[27] around 75% of the respondents claimed that they were aware of the health risks associated with the use of this water. There is no large difference between segments, less than 2% (Table 9-2).

[27] Question: “Are you aware of the health risks related to irrigating with Musi water?”

9.3.4 WTP for changes

The second part of Table 9-3 presents the implicit prices for segment two only. Estimates for segment one are not reported because the coefficient for price was not significant. The implicit prices reflect the respondents' WTP for changes in attributes' levels. Two values are statistically significant. The mean WTP to go from NI option to WT option is USD 18.77 ha per year. This estimate is about the double of what farmers are expected to pay as water tax for wet crops (about USD 9.11 ha per cropping season). And the mean WTP to go from 'tolerable health risks' to 'reduced health risks' is USD 14.66 ha per year. Considering that in this segment 60% of the farmers reported experiences of negative effects on health due to the use of Musi water, this is not surprising.

Starkl et al. (2015) estimated farmers' WTP for using treated water for irrigation in a village about 15 km downstream Hyderabad. There 71% of the farmers were willing to pay between INR 100 and 400 per month (some USD 1.8 and 7.3 per month). However, they also estimated the 'genuine willingness to pay'; this was estimated at INR 200 per month (or USD 3.6 per month). They suggest that farmers' response to an implementation of water treatment is rather negative, with farmers actually be unwilling to pay for this. According to the "polluter pays principle" recognized in India, it is not a responsibility of the farmers to pay for the treatment. Our findings suggest that a part of the farmers are ready to contribute. In this light, it might also be interesting for authorities to consider incentives for low-cost on-farm treatment alternatives, in the pursuit of reducing adverse effects of wastewater on farmers.

Farmers' WTP for improvements in water service delivery or water quality is not unusual. Bakopoulou et al. (2010) studied farmers' WTP for using recycled water for irrigation purposes in Thessaly region, Greece. There, farmers are willing to pay for recycled water, especially during droughts. In that case drought may be a determinant factor, which was not revealed in our case. Ben Brahim-Neji et al. (2014) found that farmers in Tunisia, irrigating with treated wastewater, are willing to pay more for improving the quality of water. Their result suggests that farmers who do not irrigate with recycled water would not be willing to use it even when this option involves quality improvements, which indicates that some farmers are reluctant to use recycled water. In that study, farmers' fears of health risks due to using wastewater are expressed. Although wastewater as source for irrigation was not a choice for farmers in our study area, they certainly are concerned with health risks as it is reflected in their choice for water treatment option. Any improvement in the water quality can be regarded as beneficial for these farmers. Birol et al. (2008) investigated farmers' WTP for treated wastewater in rural Cyprus; they found that farmers are willing to adopt this option as they derive the highest economic values from treated wastewater use.

Ndunda & Mungatana (2013) found that urban and peri-urban farmers, using wastewater for irrigation in Nairobi, Kenya, are willing to pay significant monthly municipal taxes for treatment of wastewater. Water quality and quantity are in that case significant factors in farmers' preferences. However, Abu Madi et al. (2003) found that the price that farmers are willing to pay hardly covers the operation and maintenance cost for conveyance and distribution of reclaimed water in Jordan and Tunisia. In our case, given the household's total monthly income (which includes irrigated farming and other activities) estimated at 144.83 USD, these WTP estimates expressed per month (1.56 and 1.22 USD/ha, respectively) represent about 1% of the total household income. This could be seen as their potential contribution to water treatment.

9.4 Conclusions

Wastewater offers opportunities to deal with increasing pressure on water resources, mostly in water-scarce countries. However, in this case study wastewater is not an alternative source of water but the only source of water. Using wastewater, farmers are exposed to a number of health and environmental risks, which influence their livelihoods and consequently their behavior. This chapter is a contribution to the literature on the use of wastewater in agriculture. Furthermore, it contributes to the field of environmental valuation as it applies a CE to assess farmers' preferences for wastewater use scenarios and estimates their WTP. This is important because the literature on WTP for treated wastewater for irrigation applying a CE approach is rather limited. Moreover, this study goes beyond the mere characteristics of the water itself; it also assesses other aspects such as health risks and restrictions on the use of wastewater for irrigation.

The findings of the CE suggest that farmers prefer the Water Treatment option over the two other options (No Intervention and Restrictions). This might be a reflection of past negative experiences of being exposed to low-quality water. In this respect, important to keep in mind is that the Water Treatment option implied lower water quantity and lower nutrient content compared to the other options. This shows that farmers are keen to irrigate crops with improved-quality water. Note that in this case, as in many other cases worldwide, irrigation with low-quality water is not a choice for farmers, but a consequence of dysfunctional institutional and regulatory frameworks that fails to safely dispose sewage. Although there have been some governmental initiatives to address this issue, the common argument is the high costs associated with wastewater treatment.

This study also shows heterogeneity in preferences among farmers. One of the segments is opposed to water use restrictions and is not sensitive to price, whereas the second segment is not sensitive to water use restrictions but is sensitive to health risks. The farmers' WTP in segment two for a change from No Intervention to Water Treatment, and the WTP for 'reduced health risks' relative to 'tolerable health risks' suggest a possible link between the WTP and the negative experiences on health. These are farmers living closer to the city, they are more dependent on Musi water, and they grow more vegetables and para-grass than farmers in segment one. Compared to segment one, more respondents in segment two indicated that they are not aware of the nutrient content in the water, and that they did not experienced (or do not know of) negative effects on health when using Musi water. Nevertheless, health risks awareness is high for both segments. Notwithstanding farmers take little action on this respect. Solutions for reducing these problems are not easily accessible to poor farmers or they are not well known to them. One explanation is the limited in-depth risk awareness to actually trigger a behavior change. More research on risk perceptions is thus needed. Nevertheless, the willingness of farmers to contribute to the costs of wastewater treatment is important in the light of the cost recovery issues in many developing countries. It is a factor which can be taken into account by governments when developing plans. While the impact of this contribution on different treatment scenarios should be further investigated, it should be kept in mind that treatment should remain the responsibility of the government, and that the cost should in the first place be recovered from the polluters.

Finally, this study had limitations that may have influence the significance of the attributes, thus impeding the interpretation of segment preferences. In the future, this study could be improved in several ways, e.g. 1) by eliminating the labels to avoid farmers overlooking the attributes, and 2) by increasing the sample size. Nevertheless, this study provided a snapshot of the importance for the farmers of improving water quality in the river.

Chapter 10. Discussion of the results of the choice experiment in Cochabamba

Abstract

Agricultural use of wastewater in developing countries is mostly indirect and often unintentional, resulting from a lack of treatment capacity in cities. Accordingly, farmers divert water from rivers, carrying a mix of fresh and wastewater. There are trade-offs in using wastewater, but in water scarce regions it may be the only option. Bolivia has recognized the need to address water pollution, because of the negative impacts on public health, the environmental consequences, and the diminished water availability. Wastewater reuse is part of this initiative. The aim of this study is to identify elements for frameworks of wastewater reuse and to understand farmers' preferences for such frameworks. To this end a choice modelling approach was applied. The study was conducted in peri-urban and rural communities along the Rocha River in Cochabamba, Bolivia. The results suggest that farmers prefer 'treated wastewater'; and they are willing to contribute to irrigation systems conceived for treated wastewater. At the same time, the type of farmers' involvement is important for the sustainability of the irrigation systems.

Keywords: water reuse, irrigation, agriculture, choice experiment, Bolivia

10.1 Introduction

The use of wastewater is gaining momentum (Wichelns et al., 2015). The reasons for this include: water scarcity, resulting from economic and population growth increasing water demands; environmental concerns about some more traditional approaches of water supply, such as water transfers; governments' understanding of the 'double value proposition' in water reuse; and the importance of informal wastewater irrigation as engine of growth (GWI, 2010b; Jimenez et al., 2010). Unfortunately, there are risks in wastewater reuse, related to public health and the environment, e.g., soil degradation, groundwater pollution. To compensate for the potential adverse effects and to enhance the benefits from an additional water source, it is important to understand the ground rules whereby wastewater reuse is to be implemented. At the same time this is important in designing policies and planning interventions. A study of the perceptions and preferences of water users can facilitate this.

The objective of this study is to identify the key elements necessary to develop a framework for wastewater reuse for irrigation based on the preferences of the farmers, through a choice modelling (CM) approach. Mean willingness-to-pay (WTP) for changes within the framework is also estimated. The study focuses on peri-urban and rural communities located along the Rocha River in the hinterland of Cochabamba, Bolivia. These communities practice agriculture as main activity and traditionally diverted water from the Rocha River, which became heavily polluted with domestic and industrial effluents from the urbanized areas. This study provides empirical grounds for assessing the acceptability of wastewater reuse and offers lessons for policy formulation in a developing country context.

10.2 The study area

The study area consists of three communities located in the Rocha River Basin. The Rocha River originates in Sacaba municipality (Chapare Province). Downstream, it passes through Cochabamba municipality (Cercado Province), and Colcapirhua, Quillacollo, Vinto and Sipe Sipe municipalities (Quillacollo Province), these are located in the Department of Cochabamba (Figure 10-1). The Rocha River Basin is divided into three regions: Sacaba Valley, Central Valley and Lower Valley. This basin has an area of 1606 km^2; the altitudinal variation is between 4160 and 2550 m above sea level. The average annual rainfall is 480 mm (Saravia, 2013), which occurs during the summer period from December till March (with January and February as rainiest months). Over one million people live in this river basin, most of them located in the metropolitan area. This number is more than half of the total population of the Department of Cochabamba (SDC-DGIA, 2014).

Figure 10-1 Location of the study area - Cochabamba

The Rocha River Basin is a water scarce region, mainly due to an increase of the population concentrated in the metropolitan area. Basically, there are more people demanding more water for different uses. Furthermore, over the years the quality of the water in the river has deteriorated drastically. This factor affects the availability of safe water for human consumption. The main reason for the poor water quality in the river is the lack of sewerage networks, as well as the lack of plants to treat the wastewater generated in the urbanized area, but also a lack of institutional support to act on this issue. At present (2015), only one wastewater treatment plant (WWTP) exists in the metropolitan area of Cochabamba. This is the Alba Rancho WWTP, which serves part of the City of Cochabamba. The plant is 28 years old; the treatment process consists of stabilization ponds. It was designed to treat 380 l/s, but at present it receives an average rate of more than 500 l/s. This plant works mainly as a by-pass and proper treatment is not always possible. Moreover, industries also discharge their effluents directly into the river, and there is a lack of control over these activities. Ultimately, the Rocha River has *de facto* become a sewer.

Nonetheless, there are plans from the Departmental Government to update Alba Rancho WWTP and to construct eleven WWTPs in various municipalities along the river (e.g., one treatment plant is currently under construction in Sacaba municipality). The purpose of this is to improve the quality of the water in the Rocha River, and by doing so to restore the river and its functions (e.g., source of water for irrigation) (Salazar, 2014). In response to the increasing water scarcity and the effects of climate change, this plan fosters the possibility to integrate reuse of wastewater for agricultural irrigation (SDC-DGIA, 2014).

Traditionally, agriculture has been an important activity in the country. It contributed to 13.3% as share of the gross domestic product (GDP) in 2013 (www.quandl.com). In the past, Cochabamba was known as the "Bolivian breadbasket" due to the importance of the sector. However, the contribution of this sector to the economy in the Department has dropped from 18.4 to 8.7% between 1988 and 2012. In spite of this, the agricultural sector still remains a major employer (Encinas, 2013).

Three communities were selected for the study: Huerta Mayu (in Sacaba municipality), Maica Chica (in Cochabamba municipality) and Maica (in Sipe Sipe municipality). Farmers in Huerta Mayu and Maica grow mainly vegetables (e.g., lettuce, onion, carrot, beetroot, parsley and potato). These are cash crops and they are sold in local and regional markets mainly through intermediaries. Crops that can be preserved for longer periods (e.g., onions or carrots) are commercialized in main cities across the country. In contrast, in Maica Chica cattle feed is cultivated (e.g., alfalfa, maize and ryegrass). This area is a main milk producer, supplying milk to large industries in the region. The production systems are adapted to climatic and soil conditions, as well as to water availability. For instance, the soils in Maica Chica are more saline and therefore the crops found there are more salt tolerant (Román, 2009). The agricultural production is highly dependent on irrigation. The common irrigation methods applied are either furrow or flooding. These methods are neither efficient nor safe. They are not safe because water – in this case wastewater containing pathogens – is in direct contact with the crops, and if crops are eaten raw they can cause intestinal diseases. Although some farmers have access to other water sources, the Rocha River remains the main source of water for irrigation in these communities. As the Rocha River became polluted, irrigation in these communities is mainly with wastewater, which represents risks for both farmers and consumers.

10.3 Results and discussion

A conditional logit (CL) model was first applied to analyze the data. Then, a latent class (LC) model was applied in a second stage to reveal possible variations in preferences that may result from heterogeneity among respondents, which is of interest for the analysis. The socio-economic and farm characteristics, the farmers' perceptions regarding wastewater as well as the results of the two models are discussed in the following sections.

10.3.1 Socio-economic and farm characteristics

The socio-economic characteristics of the sample are summarized in Table 10-1. This table also reports the socio-economic characteristics of the segments of respondents, but they will be discussed in the last part of section: farmers' preferences for wastewater reuse scenarios.

Over half of the respondents were women, and the average age was 48 years old (this is significantly different between the segments). They were mainly fulltime farmers (about 63%). Their education level was rather basic: most respondents had either elementary or secondary schooling. The average monthly household income reported by the respondents was Bs. 3665 (approx. USD 527). Most farmers own the land (55%), but it was found that they also rent some land (30.6%), and a minor proportion rent land (14%). Farms were rather small with average land size of 0.50 ha. This size of land is not unusual. It is the result of a process of land fragmentation, which has been ongoing in the Bolivian highlands and valleys since the land Reform of 1953. The problem of smallholding is that such small land is often unable to ensure the basic livelihood for the household (Ferrás et al., 2004). Nevertheless, it is argued that even in such smallholdings (less than 1 ha) it is possible to find suitable crops and technologies to have profitable agriculture (Morales, 2011). In this case, farmers located upstream (44.9%) and downstream (14.3%) practiced intensive vegetable production. The main crops produced were: lettuce, beetroots, radish, onions, carrots, and parsley. Farmers located in the middle zone (40.8%) were mainly dairy farmers; therefore they grew fodder crops (e.g., alfalfa, maize and ryegrass).

More than half of the farmers (about 55%) depend directly on the Rocha River as main source of water for irrigation. The rest (42.8%) indirectly depends on the same river since their wells, which are used for irrigation, depend greatly on infiltration from the river. The use of water pumps is widespread, 83.7% used a pump to irrigate. Farmers either own or rent water pumps. A rental service of pumps also existed in the middle zone, charging between Bs. 20-25 per hour (about USD 2.9-3.6).

Table 10-1 Descriptive statistics and profiles of the segments - Cochabamba

	Mean (St. Dev.)	Min.	Max.	Segment 1 (n = 25)	Segment 2 (n = 24)
Age***	48 (14.6)	19	75	54 (12.8)	42 (14.4)
Gender (% male)	42.9			36	50
Household size (number)	5.0 (2.7)	1	13	5.2 (3.0)	4.8 (2.4)
Household income [(a)] (Bs/month)	3665 (5304)	400	26,000	4075 (7080)	3231(2476)
Household income from agriculture [(b)] (Bs/month)	3356 (6318)	0	30,000	2901 (6299)	3903 (6460)
Education** (%)					
Illiterate	4.1			4	4.2
Elementary	42.9			64	20.8
Secondary	46.9			28	66.7
Technical degree	2			0	4.2
University	4.1			4	4.2
Occupation* (% fulltime farmer)	63.3			76	50
Location *** (%)					
Upstream	44.9			76	12.5
Middle	40.8			20	62.5
Downstream	14.3			4	25
Land tenure** (%)					
Own	55.1			72	37.5
Own and rent	30.6			16	45.8
Rent	14.3			12	16.7
Crops cultivated *** (%)					
Vegetables	59.2			80	37.5
Fodder crops	40.8			20	62.5
Water sources*** (%)					
Groundwater	2			4	-
Groundwater and River	6.1			4	8.3
River	12.2			-	25
River and Reservoir	36.7			20	54.2
Well and groundwater	20.4			28	12.5
Well	22.4			44	-
Use of pump * (% does use)	83.7			96	70.8

T-tests and Pearson Chi-Square Tests show significant differences at (*) 10%; (**) 5% and (***) 1% level.
Note 1: For frequencies only valid percent is reported.
Note 2: USD 1 = Bs. 6.96
(a) For the sample n= 35. For segment 1, n= 18. For segment 2, n= 17.
(b) For the sample n= 44. For segment 1, n= 24. For segment 2, n= 20.

Given these demographics, it becomes evident that both land and water are scarce resources in these communities. Furthermore, the issue of water pollution in the river decreases the availability of water. Despite of this, agriculture is intensive in these communities. The dominance of vegetable production (upstream and downstream) and dairy farming (middle zone) is a reflection of a long agricultural tradition. The Central and Lower Valleys of Cochabamba have favorable climatic and soil conditions to grow vegetables and fodder crops (maize and alfalfa). Nevertheless, the market opportunities were also fundamental for the development of agriculture. Farmers, have easy access to markets in the City of Cochabamba, and other capitals of provinces. The produce is sold fresh to intermediaries, who act as retailers.

10.3.2 Farmers' perceptions on wastewater

Table 10-2 presents the farmers' perceptions of the sample, and for the segments generated by the LC model, on the use of wastewater for agricultural irrigation. Overall, respondents agreed that irrigation with wastewater is a threat to the health of farmers and workers, consumers or the environment. In the same line, farmers considered that there are risks when using wastewater (98% answered affirmative). They indicated that the risks are for both farmers and consumers. This overall negative perception in relation to (untreated) wastewater might be related to water pollution in the river. This issue has been followed closely by the media (e.g., Olmedo, 2013; Oblitas, 2014), which resulted in an environmental audit, in 2011, conducted by the Comptroller General of the State Office (Contraloría General del Estado) that classified the Rocha River as 'highly polluted'. Another study conducted on water quality in the Rocha River reveals a high content of organic matter from domestic and industrial sources (Toledo & Amurrio, 2006).

Furthermore, farmers agreed that irrigation with (untreated) wastewater can damage the soils (farmers of segment one tend to agree more, whereas farmers in segment two tend to be more indifferent). This is interesting considering that farmers located in the middle zone, which are predominant in segment two, have experienced soil degradation. This is particularly true for various communities around La Maica (Cercado municipality), where soil degradation has forced farmers to replace vegetable crops with more salt-tolerant crops, e.g., fodder crops (Huibers et al., 2004). Furthermore, the extended use of wastewater can have a negative impact on groundwater quality (Gallegos et al., 1999). Farmers seemed to be aware of this aspect. On average, they agreed that irrigation with wastewater could pollute groundwater (this result is significantly different between the segments).

Although, farmers seemed to be aware of the current state of pollution of the river and about the negative impacts on the health of the people and the environment, they continue using this water for irrigation. This can be explained by the lack of other water sources in the area. About 67.3% of the respondents reported that they have experienced water scarcity in the last five years and about 53.1% reported to have experienced water-related conflicts[28] in the same period (these results are significantly different

[28] The term 'conflict' is used in the surveys of this study to refer to any event where disputes over water may exist among users, between the irrigation sector and the water supply agencies/authorities or among sectors. It encompasses any event related to water disputes. Most common examples of water conflicts among farmers are: blocking of irrigation canals, stealing water, overtaking of water turns.
The UN recognizes that water disputes result from opposing interests of water users; public or private (see IWA Water Wiki, http://www.iwawaterwiki.org/xwiki/bin/view/Articles/WaterConflict).

between segments). At large, wastewater is considered as an alternative water source to fight water scarcity (this result is significantly different between the segments). On the other hand, not all farmers seemed to agree that irrigation with wastewater enhances agricultural production (this result is significantly different between the segments).

Furthermore, when farmers were asked if they would use ‘treated wastewater’ for irrigation in the future, 93.9% replied affirmative. Undoubtedly, this answer was expected, considering that securing water is one determinant in the success of agricultural production. On average, farmers agreed that authorities should promote irrigation with treated wastewater. Farmers (91.8%) were willing to contribute to an irrigation system for treated wastewater (this result is significantly different between segments). This contribution can be either in monetary or labor terms, with preference for labor contributions. This is an interesting finding, considering that funding is a main obstacle for the wider use of treated wastewater (Bixio et al., 2006) and reuse schemes remain largely subsidized (Hochstrat et al., 2007).

It is acknowledged that there are benefits in terms of nutrients contained in wastewater (Durán–Álvarez & Jiménez–Cisneros, 2014). However, farmers in this area did not seem to perceive this as entirely beneficial. When they were asked whether they agree or not that irrigation with wastewater reduces the quantity of fertilizers to be applied in the soil, on average respondents tended to neither agree nor disagree (this result is significantly different between segments). Furthermore, 44.9% of the farmers reported to have experienced negative effects on the soil as consequence of irrigation with wastewater, and about 42.9% reported to have experienced negative effects on crop growth (this result is significantly different between segments). As for the price they obtain when selling their crops, 61.2% of the respondents reported that the selling price of the products is the same than products irrigated with clean water (this result is significantly different between segments). This is interesting from the point of view that farmers usually deny using wastewater to irrigated crops (Huibers et al., 2004). Comparing this to the answer in relation to water scarcity, the main benefit from wastewater reuse perceived by farmers might be in terms of water availability.

In relation to the health of farmers, only 26.5% of the respondents stated that they have experienced negative effects on their health as a consequence of using wastewater (this result is significantly different between segments). The most common diseases mentioned were diarrhea and skin irritation. In contrast, 73.5% of the farmers stated that they take precautions to minimize possible health risks. The most common measures taken included: use of rubber boots and gloves when in contact with wastewater. Huibers et al. (2004) found that farmers stated that they are not confronted with specific health problems related to the use of polluted water, contradicting reports from local health workers.

Table 10-2 Respondents' perceptions on wastewater - Cochabamba

Perceptions on wastewater & irrigation (average score) [(a)]	Mean (St. Dev.)	Min.	Max.	Segment 1 (n=25)	Segment 2 (n=24)
a. Irrigation with wastewater is a threat to the health of farmers/workers	2.20(0.91)	1	4	2.24(0.66)	2.17(1.13)
b. Irrigation with wastewater is a threat to the health of the consumers of crops	2.14(0.61)	1	4	2.04(0.46)	2.25(0.74)
c. Irrigation with wastewater is a threat to the environment	2.18(0.86)	1	4	2.16(0.63)	2.21(1.06)
d. Irrigation with wastewater can damage the soil	2.43(0.94)	1	4	2.24(0.66)	2.63(1.14)
e. Irrigation with wastewater could pollute groundwater**	2.27(0.95)	1	4	2.60(0.82)	1.92(0.97)
f. Irrigation with wastewater enhances agricultural production*	2.78(0.92)	1	4	3.00(0.96)	2.54(0.83)
g. Wastewater is an alternative water source to fight water scarcity***	1.96(0.64)	1	4	2.20(0.65)	1.71(0.55)
h. Irrigation with wastewater reduces the quantity of fertilizers to be applied in the soil***	2.76(1.11)	1	4	3.44(0.87)	2.04(0.86)
i. Authorities should promote irrigation with treated wastewater	1.74(0.70)	1	4	1.76(0.60)	1.71(0.81)
Farmers experienced water scarcity (last 5 yr.)** (% yes)	67.3			80.0	54.2
Farmers experienced water-related conflicts (last 5 yr.)** (% yes)	53.1			36.0	70.8
Farmers are willing to use 'treated' wastewater for irrigation (% yes)	93.9			96.0	91.7
Farmers are willing to contribute to an irrigation system for treated wastewater** (% yes)	91.8			100	83.3
Farmers consider there are risks when using wastewater (% yes)	98.0			100.0	95.8
Farmers report selling price of products compared to clean-water-irrigated products* (% same price obtained)	61.2			69.6	58.3
Farmers experienced negative effects on their 'health' as consequence of irrigation with wastewater* [(b)] (% yes)	26.5			13.0	41.7
Farmers know of negative effects on the 'health' of the consumers as consequence of eating crops irrigated with wastewater [(b)] (% yes)	10.2			4.4	16.7
Farmers take precautions to minimize health risks [(b)] (% yes)	73.5			78.3	75.0
Farmers take precautions for the consumers' health** [(b)] (% yes)	57.1			73.9	45.8
Farmers experienced negative effects on their 'crops' as consequence of irrigation with wastewater* [(b)] (% yes)	42.9			52.2	37.5
Farmers experienced negative effects on the 'soil' as consequence of irrigation with wastewater [(b)] (% yes)	44.9			47.8	45.8

T-tests and Pearson Chi-Square Tests show significant differences at (*) 10%, (**) 5% and (***) 1% level.
(a)Treated as continuous variables with the following scale for reference: 1= strongly agree; 2= agree; 3= neither; 4= disagree; 5= strongly disagree.
(b) For segment 1, n = 23

Last but not least, only 10.2% of the farmers stated that they knew of negative effects on the health of the consumers as a result of eating crops irrigated with wastewater. In contrast, 57.1% of the respondents stated that they take precautions to protect consumers' health (this result is significantly different between segments). The measures taken include: waiting periods before harvesting and washing of crops with clean water, some also mentioned the use of chemicals as a measure to kill organisms found on the plants. Certainly these numbers show that farmers were aware of the possible risks for the health of the consumers of crops irrigated with wastewater. On the other hand, farmers do not take responsibility for that.

10.3.3 Farmers' preferences for wastewater reuse scenarios

A CL model was first applied to analyze the data. However, a LC model was applied in a second stage to reveal possible variations in preferences that may result from heterogeneity among respondents, which is of interest for the analysis. The results are reported in Table 10-3. The LC model proved to be superior to the CL (LRI = 0.54).

Results of the CL model indicate that farmers prefer treated wastewater over untreated wastewater (significant at 1%). This result is only logical considering that farmers have expressed their willingness to use treated wastewater for irrigation and that a large share of the respondents considers that there are risks implicit when using wastewater (see Table 10-2). On the other hand, farmers might have experienced negative effects on their health as a result of using wastewater; although only a small share of farmers (26.5%) has reported this aspect. In contrast, a larger share of respondents (57.1%) has reported to take precautions for the consumers' health. This suggests that farmers might be hiding the real effects on their health as a consequence of being in contact with wastewater.

Next, 'high use restrictions' has a negative effect (significant at 1%), which means that farmers do not favor strict restrictions on crops, strict control over irrigation methods and periodic controls over water use practices. It can be interpreted that farmers – in this area – would rather prefer less restriction in terms of water use practices. This aspect is important considering that some measures proposed to reduce health risks are related to the use of protective clothing, restrictions on irrigation methods, selection of crops, and appropriate handling of produce during and after harvesting, which in many cases might be difficult to implement.

The results also show that in terms of farmers' involvement in the irrigation system and the WWTP, the model 1 proposed is less preferred (the effect is negative and significant at 1% level) compared to model 2. This can be interpreted as follows: farmers might prefer a model where they can participate in decision-making, as proposed in model 2. This aspect is not rare for the Bolivian context; irrigation systems there are mainly community-managed where decisions are taken in consultation with all users of the system (farmers are responsible for all aspects related to water distribution, maintenance of infrastructure, and in kind contributions for operation and maintenance), and users are often active members within the system (often they take different roles in the operation of the system). Finally, the price attribute is consistent with the theory (negative sign and significant at 1% level), which suggests that an increase in price decreases the preference for alternatives.

The results of the 2-segment LC model are discussed in the next paragraphs. In section 8.5.2, it has been explained that due to the small sample size, it was appropriate to analyze the model for two segments only. These segments are balanced: segment one held 49.9%, whereas segment two held 50.1%. The perception on ‘irrigation with wastewater reduces the quantity of fertilizers to be applied in the soil’ is what determined segment membership. This difference between segments is significant at 5% level. Other variables tested in the segmentation were not statistically significant.

The results of the LC model indicate that in both segments farmers prefer the ‘treated wastewater’ option compared to the ‘untreated wastewater’ option. This result is significant at 1% level in both segments. The ‘treated wastewater’ option implies lower health risks for farmers in contact with the water. The nutrient content in the water is reduced, but also the content of pollutants or salts. The quantity of water available to farmers in this option is restricted to the capacity of the WWTP. It is important to emphasize that in planned and direct use of wastewater for irrigation, the wastewater needs to pass through a WWTP, which can be taken as the source of water for the irrigation system. In that case, the quantity of water available to farmers will be linked to the capacity of the WWTP. This aspect is familiar to farmers, as they can understand the difference between water sources in terms of water availability. In most developing countries, and certainly in the case of Bolivia, the capacity to treat wastewater cannot keep pace with the wastewater generated. Therefore, planned wastewater reuse systems would imply limited supply of water compared to open access water from polluted rivers.

Next, ‘restricted access to water’ is significant (at 5% level) and negative for segment two. This means that this option is less preferred compared to ‘non-restricted access to water’. In ‘restricted access to water’, only farmers from the irrigation system have access to water, whereas in the option ‘non-restricted access to water’, water is accessible to anybody. For segment one, the effect is positive but not significant. This result is interesting considering that in the Bolivian highland community membership plays a major role in access to water. It is possible that the proximity to the city has influenced this aspect.

Next, the ‘high use restrictions’ option is significant (at 1% level) and negative in segment one. This means that this option is less preferred compared to ‘low use restrictions’. The ‘high use restrictions’ option implies restrictions for the farmers on the crops to be cultivated, strict control over irrigation methods, and control on water use practices. In segment two, the coefficient for this option is not significant, but the effect is still negative as in segment one.

Next, the 'model 1' option for farmers' involvement in the irrigation system and the WWTP is significant (at 5% level) and negative for both segments. However, the coefficient in segment one is larger than in segment two (2.2 > 1.0). These coefficients indicate that in both segments the option 'model 1' is less preferred by the respondents, compared to 'model 2'. The 'model 1' option implies that the irrigation system works independently from the WWTP; farmers are not involved in tasks concerning the WWTP or in decision making processes. Whereas in 'model 2' option, when water is provided from a WWTP, farmers participate and are involved in some decisions concerning the WWTP. In both options the WWTP remains operated by the municipality (or EPSA), and farmers are still responsible for all aspects of the irrigation system. This result is interesting because it suggests that farmers are willing to take part in the decision-making of irrigation systems conceived for wastewater reuse. This aspect is consistent with the local practices of community-managed irrigation systems, where farmers are decision-makers.

Table 10-3 Results of the CL and LC models and WTP estimates

	CL model	LC model	
		Segment 1	Segment 2
Treated wastewater	3.19*** (0.40)	5.48***(1.64)	3.09***(0.85)
Restricted access to water	-0.42(0.28)	0.66(0.79)	-0.94**(0.46)
High use restrictions	-1.40***(0.26)	-3.97***(1.51)	-0.62(0.51)
Farmers' involvement – model 1	-1.03***(0.26)	-2.20**(0.86)	-1.00**(0.47)
Price of petrol	-4.30***(1.60)	2.50(4.50)	-7.98***(2.81)
Model statistics			
Pseudo ρ^2	0.49	0.49	0.54
Log likelihood	-86.25	-86.25	-77.76
Segment function LC model			
Constant		-4.59**(2.13)	
Irrigation with wastewater reduces the quantity of fertilizers to be applied in the soil [(a)]		1.34**(0.60)	
Selling price of products is the same (than products irrigated with clean water) [(b)]		-0.31(1.32)	
Experienced water scarcity (last 5 yr.)		0.65(1.25)	
Occupation		0.95(1.35)	
WTP for changes in attribute levels and 95% intervals			
Treated wastewater		-2.19(0.56; -9.63)	0.39**(0.02; 0.05)
Restricted access to water		-0.26(0.63; -1.32)	-0.12**(0.04; -0.23)
High use restrictions		1.59(0.55; -3.61)	-0.08(0.27; -0.22)
Farmers' involvement – model 1		0.88(0.57; -2.17)	-0.13*(0.08; -0.27)

Significance at (*) 10%; (**) 5% and (***) 1% level.
Note: WTP estimates are expressed in Bs/L; USD 1 = Bs. 6.96
(a) Dummy variable on 'opinions regarding wastewater & irrigation with wastewater'
(b) Dummy variable on 'perception of selling price of products'

Finally, the price attribute is significant (at 1% level) and negative for segment two. The negative sign was expected for this coefficient; it indicates a negative preference for an increase in the price attribute. This result is expected under the assumption that a price increase reduces preferences for alternatives. In segment one, however, the price attribute has a positive sign, but is not significant. A positive sign for the price attribute is usually not expected. It means that price was not a determinant of choice for respondents in segment one.

Respondents of the two segments have some differences in terms of their socio-economic characteristics (see Table 10-1). For instance, segment one has a larger share of women compared to segment two, where the share of men and women are about 50% each. The household monthly income in segment one was slightly higher than in segment two (about Bs. 844 or USD 121). Nevertheless, the household income generated from agriculture – as reported by the farmers – in segment two is higher than in segment one (about Bs. 1002 or USD 144). The education level was higher in segment two (about 45.9% more people reached secondary school). More than three quarters of the farmers in segment one practice agriculture as a fulltime activity, whereas in segment two only about half.

Regarding the location, most farmers from segment one, were located in the upstream community: 76% belonged to Huerta Mayu (upstream community), 20% belonged to Maica Chica (middle zone community) and only 4% belonged to Maica (downstream community). In contrast, most farmers from segment two were located in the middle zone community: 12.5% belonged to Huerta Mayu, 62.5% belonged to Maica Chica and 25% belonged to Maica. In congruence with this, vegetables were dominant in segment one, whereas fodder crops were dominant in segment two. As to land tenure, most farmers in segment one owned the land (72%), whereas in segment two, most farmers owned and rented the land (45.8%). Concerning the sources of water for irrigation, in segment one the main source of water were wells, for segment two the main source of water was the river and the Angostura reservoir. As for the use of water pumps, a higher percentage of farmers in segment one used them compared to segment two.

10.3.4 WTP for changes

The results for mean WTP are reported in the second part of Table 10-3. Mean WTP for a change from ‘untreated wastewater’ to ‘treated wastewater’ is estimated at Bs. 0.39 (or USD 0.06) per liter for segment two only (this estimate is not statistically significant for segment one). This value represents about 0.1% of the per capita average monthly income estimated at Bs. 673 or USD 97 (based on the average monthly household income and the average household size reported for segment two). This result is not completely unexpected, because treated wastewater implies less health risks for the farmers, which is beneficial for them. Furthermore, the WTP for ‘treated wastewater’ suggests that users are prepared to contribute to cost recovery. But more research is necessary on this aspect.

Next, the mean WTP for 'restricted access to water' relative to 'non-restricted access to water' is negative and significant in segment two. The negative sign indicates that respondents see a reduction in the utility when choosing this option. It can be interpreted as willingness-to-accept for a change from 'non-restricted access to water' to 'restricted access to water'.

Finally, mean WTP for 'model 1' relative to 'model 2' for farmers' involvement in the irrigation system and the WWTP is negative and significant for segment two only (this estimate is not statistically significant for segment one). The negative sign can be interpreted as a willingness-to-accept to opt for 'model 1'. In this case, 'model 1' is less valued by farmers of segment two. This result suggests that the level of farmers' involvement in the decision-making for irrigation systems seems to matter.

10.4 Conclusions

This study contributes to the literature in the sense that it reveals the preferences of farmers for frameworks that consider agricultural wastewater reuse by means of a quantitative approach, such as choice modelling. The information generated is important in designing policies and planning interventions.

Without doubt the agricultural use of wastewater in the peri-urban and rural hinterland of Cochabamba is unintentional. This means that farmers use poor-quality water because the river is polluted with domestic and industrial effluents, which ultimately is attributed to the cities' low capacity to treat wastewater (Huibers et al., 2004). Under these circumstances, the health of farmers and workers, as well as of the consumers of crops irrigated with such water is at risk. Farmers appear to be aware of such risks. However, they continue to use the river water in order to sustain their livelihoods.

Largely, farmers have a clear preference for 'treated wastewater' and they affirm to be willing to engage in irrigation systems that use treated wastewater as main water source, mainly because they are aware of water scarcity and probably because they perceive as beneficial any improvement in the quality of the water. Farmers of one segment are also willing to pay for this change. Moreover, farmers state their willingness to contribute to an irrigation system for treated wastewater, both in labor or monetary terms. These aspects are important. The use of treated effluent has implications for public health and this is a cause why people are discouraged to engage in this enterprise. Public perceptions and acceptance of water reuse are main components of success for any reuse project (Po et al., 2003).

Next, the willingness-to-accept a 'restricted access to water' is an interesting result from the point of view that this suggests that users favor non-restricted access (at least in one of the segments), which means that the water is accessible to any user. It suggests the possibility to reconfigure the concept of water access based on community membership. Huibers et al. (2004) pointed out strong traditional water rights as one of the constraints to the improvement of wastewater management in Cochabamba.

In terms of use restrictions, farmers tend to dislike strict procedures for agricultural practices, especially those growing vegetables. Although this is understandable, it is fundamental that agricultural wastewater use is guided and regulated, in order to protect public health. Certainly, such guides should take into account the local cultural and socio-economic conditions (Mizyed, 2013).

Finally, the type of involvement of farmers in wastewater reuse schemes seems to matter. Participation in processes of decision-making is an important aspect to take into consideration. Finding the optimal level of farmer participation in the management of irrigation systems is an essential part of achieving optimal performance (Groenfeldt, 1988). The World Bank (2003) identified that farmers' participation in the whole process of system design and management ensures sustainability of the system, reduces public expenditure, and improves efficiency, equity and service performance. This is certainly valid for the planning of irrigation systems for wastewater reuse.

Chapter 11. Discussion of the results of the choice experiment in Western Cape[29]

Abstract

Wastewater has emerged as an alternative source to meet water demand. Since the agricultural sector remains the largest water user world-wide, it is regarded as the main potential user of treated wastewater. Certainly there are trade-offs in using wastewater; however, in water scarce regions it might be the only option to meet demand. As part of the measures for water demand management, South Africa has included water reuse in its policy framework. The aim of this study is to understand farmers' preferences regarding water reuse frameworks for irrigation. A choice modelling approach was applied to identify the elements defining these frameworks and to quantify their relative importance. The analysis was conducted for the agricultural region surrounding Cape Town. The findings suggest that water reuse is well accepted amongst farmers in the area. Furthermore, farmers prefer options that guarantee good quality water and low levels of restrictions on use practices. Due to low trust in water service providers, farmers are willing to pay for a privately-managed scheme for water reuse, which suggests that the management model for implementing such schemes is important.

Keywords: water reuse, irrigation, agriculture, choice experiment, South Africa

11.1 Introduction

Wastewater has been recognized as an alternative source of water in water scarce countries, especially for agriculture, which is the largest user with differentiated water quality requirements. For many water scarce countries water reuse is the only affordable alternative (Lazarova et al., 2001). Unfortunately, there are trade-offs in using wastewater. Thus, to offset the potential adverse effects of wastewater on public health and the environment, and to maximize the benefits from access to additional water, it is important to understand the framework within which and ground rules whereby water reuse is to be implemented. This is possible from a study of the perceptions and preferences of water users. To this end, the purpose of this study was to identify the key elements required to develop a framework for water reuse based on the preferences of farmers, using a choice experiment (CE) approach, and to estimate their willingness-to-pay (WTP) for changes to this framework.

This analysis focused on the rural hinterland of Cape Town, South Africa, a water scarce area whose agricultural sector is highly dependent on rainfall for both dryland and irrigation farming. Overall, water availability is the most important limiting factor for agricultural production in the country (NPC, 2012), a situation that will worsen due

[29] This chapter is forthcoming as: Saldías, C., Speelman, S., Van Huylenbroeck, G. & Vink, N. Understanding farmers' preferences for wastewater reuse frameworks in agricultural irrigation: lessons from a choice experiment in the Western Cape, South Africa. *Water SA*, 42(1), 26-37.

to the increasing demand for water from other sectors (Goldblatt, 2012). In this context, it becomes vital to search for alternative sources of water. Farmers in the study area already have some experience with water reuse, as some are already using treated wastewater (or treated effluent) from a municipal treatment plant to irrigate crops. It is envisaged that this case study can provide empirical grounds for assessing the acceptability of water reuse and offer lessons for policy formulation in a developing country context.

11.2 The study area

The Western Cape Province (WC) has a Mediterranean climate characterized by cool and wet winters (May-September) and warm, dry summers (October-February). Although the average annual rainfall, which varies between 500 and 1500 mm across the area, is higher than the average for South Africa, it is a water scarce region because of the rapidly growing urban population, the large water demand for irrigation, and the short run-off distances of surface water from the mountains to the sea.

In order to address problems of water shortage and equitable distribution and access to water, the Department of Water Affairs has formulated the Western Cape Sustainable Water Management Plan. Under this plan, water resources are to be used efficiently across sectors, while provision is made to further explore and implement non-conventional sources of water, such as desalination, use of deep aquifers, and most importantly water reuse (DWA, 2012b) for, inter alia, crop irrigation, in order to decrease pressure on existing water sources (DWA, 2013a).

Farmers in the study area grow mainly wine grapes, deciduous fruit and vegetables under irrigation and also produce dryland grains (wheat, oats, and canola). Production systems are adapted to the climatic and soil conditions as well as to water availability. The irrigation technology preferred is drip irrigation. Some farmers already use treated effluent from municipal wastewater treatment plants (WWTP) (e.g., from Potsdam WWTP near Cape Town, and from Malmesbury WWTP north of Cape Town) (Figure 11-1). Overall, water use efficiency is high in this area (AGRIPROBE, 2007).

The agricultural sector is strategically important both nationally and for the region. The direct contribution of agriculture to the gross domestic product (GDP) is about 3%. If the entire value chain of agriculture is considered, its contribution to the GDP is below 8% (Greyling, 2012). WC contributes some 23% of the value added by the sector to GDP. Furthermore, agriculture in the region accounts for 60% of exports and is a major employer of mainly seasonal labor (Murray, 2010). Considering the importance of this sector in the economy, water demand is expected to remain high. Midgley et al. (2007) suggested that any agricultural production dependent on winter rainfall will face major threats in the near future. In this context, water reuse offers opportunities that need to be explored.

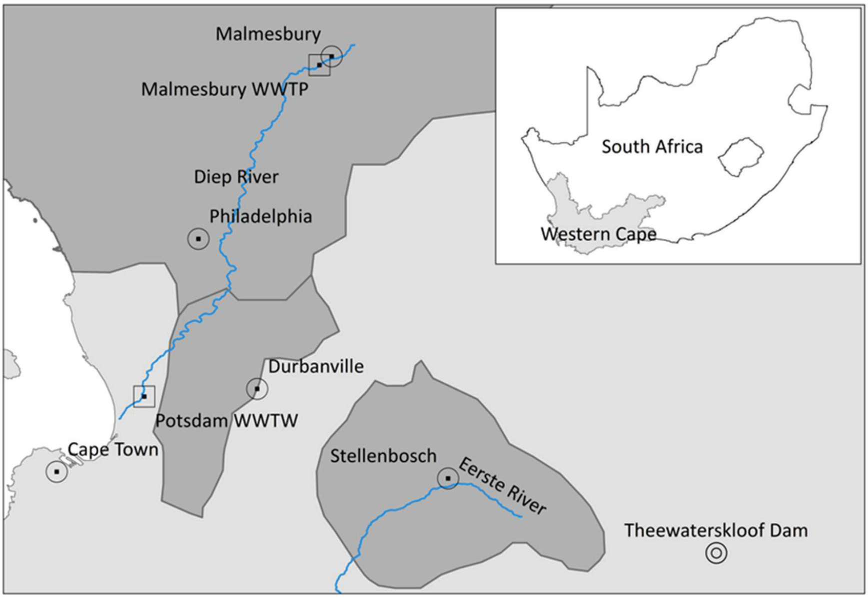


Figure 11-1 Location of the study area – Western Cape (schematic only)

11.3 Results and discussion

11.3.1 Socio-economic and farm characteristics

Table 11-1 shows the demographic characteristics of the farmers. The table also reports the socio-economic characteristics of the segments of respondents; these will be discussed in the last part of section: farmers' preferences for wastewater reuse scenarios.

Most farmers are white males with 79.5% being full time farmers. Their level of education is high: about 75% of the respondents have a tertiary degree (either university or post graduate), and their average monthly household income is estimated at about ZAR 38,397 (or USD 3792) (median = ZAR 30,000 or USD 2962). Farms are also relatively large in terms of cultivated area: for instance, the average size of land cultivated with (1) grapes is 78.1 ha (max. 500 ha; min. 10 ha); with (2) fruit trees is 15.7 ha (max. 30 ha; min. 4 ha); and with (3) grains is 330.9 ha (max. 1600 ha; min. 30 ha). Given the high level of education, it was expected that farmers are aware of the issues of water scarcity and water pollution, and how this can affect agricultural production.

About a third of the respondents in the sample grew only wine grapes at the time of the survey, while 46.7% grew wine grapes in combination with other crops, e.g., olive trees, fruit trees or grains. And some 20% grew a combination of other crops, which did not include grapes. The dominance of wine grapes in the area dates back to the 17th century (Ponte & Ewert, 2009), and since then it remained an important crop. In effect, when respondents were asked if they would shift to other crops if more water was available, only 32.6% answered 'yes'. The long history in wine grape production has allowed farmers to develop the expertise required. As many of them stated, they have all the infrastructure and know-how in place, and to change to something different would not seem right. However, some respondents expressed a willingness to explore other market opportunities.

Table 11-1 Descriptive statistics and profiles of the segments –Western Cape

	Mean (St. Dev.)	Min.	Max.	Seg.1 (n=26)	Seg.2 (n=20)
Gender (% male)	91.3			92.3	90.0
Household size (number) [(a)]	3.2 (1.4)	1	7	3.0 (1.2)	3.6 (1.5)
Dependent children (number) [(b)]	1.6 (1.1)	0	4	1.5 (1.0)	1.73 (1.2)
Household income (ZAR/month)	38,397 (22,375)	4500	100,000	41,381 (24,440)	33,577 (18,453)
Education (%) [(c)]					
Higher	75.6			73.1	79.0
Basic	24.4			26.9	21.1
Occupation (% full time farmer) [(d)]	79.5			80.8	77.8
Crops cultivated (%) [(e)]					
Grapes	33.3			40.0	25.0
Grapes & others	46.7			36.0	60.0
Other crops	20.0			24.0	15.0
Would shift to other crops if water is accessible (% yes)	32.6			23.1	45.0
Currently using treated effluent for irrigation *** (%)	37.0			3.9	80.0
Water scarcity in past 5 years (% did experience)	41.3			42.3	40.0
Water conflicts in past 5 years (% did experience)	10.9			11.5	10.0
Willing to exchange water entitlements for treated effluent (% yes) [(f)]	15.0			16.0	13.3
Would use treated effluent in the future (% yes)	69.0			-	-

T-tests and Pearson Chi-Square Tests show significant differences at (*) 10%; (**) 5% and (***) 1% level.
Note: For frequencies only valid percent is reported.

a) For segment 1 the n° of respondents, n=23; for segment 2, n=17
b) For segment 1 the n° of respondents, n=20; for segment 2, n=15
c) For segment 2 the n° of respondents, n=19
d) For segment 2 the n° of respondents, n=18
e) For segment 1 the n° of respondents, n=25
f) For segment 1 the n° of respondents, n=25; for segment 2, n=15.

In terms of irrigation water, most farmers stored rainfall runoff. A portion of the respondents in the sample (37%) currently use treated effluent as a source for irrigation, while others had access to water from the Theewaterskloof dam, and to a lesser extent to water from boreholes. When respondents were asked if they had experienced water scarcity in the past five years, 41.3% responded affirmatively, ostensibly because the cropping pattern is clearly adapted to the current availability of water. Similarly, the technology used for irrigation is efficient, which decreases the amount of water wasted.

Finally, the rainfall pattern varies across the peninsula, so there might be some areas which in effect do not experience severe water shortages, while others are naturally drier. Overall, those that access water from Theewaterskloof were satisfied. Water conflicts were not reported as a major issue in the area. Only 10.9% of the respondents indicated that they had experienced water-related conflicts in the past five years.

More than half of the respondents indicated that they would use treated effluent for irrigation in the future, but overall only 15% were willing to give up their entitlements to current water sources in exchange for access to treated effluent. Obviously, this answer was not unexpected, considering that securing water is one of the determinants of success in agricultural production.

11.3.2 Farmers' perceptions on the use of treated wastewater

In Table 11-2, the farmers' perceptions on the use of treated wastewater are presented for the whole sample and for the segments generated by the LC. The results indicate that respondents disagreed that irrigation with treated effluent is a threat to the health of farmers or workers; to the health of the consumers (this result is significantly different between the segments); or to the environment. Similar results were reported by Adewumi et al. (2010), who found that the perception of risks associated with water reuse was low among respondents in a survey conducted in the City of Cape Town. Jovanovic (2008) found that – despite some concerns about poor quality water and its effects on soils, crop yields, human health and the environment, farmers in the Bottelary catchment in WC were willing to use treated effluent for irrigation. This overall positive perception regarding treated wastewater is important considering that acceptance has been identified as the main obstacle to the implementation of water reuse projects (Po et al., 2003). In this case, it might be associated with high awareness of water scarcity. Adewumi et al. (2010) indicated that conserving drinking water and mitigating the effects of water shortages are the main drivers of water reuse in the City of Cape Town. Jovanovic (2008) suggested that compared to other water sources, treated effluent has a relative cost advantage.

On average, respondents were indifferent towards the statements that irrigation with treated effluent can damage the soils or can pollute groundwater. In relation to the statement about the soils, however, there is a significant difference between the segments. One reason why respondents in segment two tend to disagree might be linked to the fact that more farmers in this segment currently use treated effluent compared to segment one; therefore, they advocated for this practice and they did not want to reveal possible negative effects on the soil, or did not experience. However, it has been demonstrated that extended use of treated effluent can increase electrical conductivity and sodium content in soils (Castro et al., 2011). Additionally, it can have consequences for groundwater, resulting in potential contamination with fecal coliforms and parasite ova (El Lateef et al., 2006). More information on this aspect is required for the area.

A similar answer was obtained for reduction in quantities of nutrients to be applied in the soil. Although it is acknowledged that there are benefits in terms of nutrients contained in wastewater (Durán–Álvarez & Jiménez–Cisneros, 2014), respondents on average did not seem to perceive this as entirely beneficial. On the other hand, the average respondent agreed that irrigation with treated effluent should be encouraged by the authorities and that it is an alternative water source to fight water scarcity. In this case, the main benefit from wastewater might be in terms of water availability.

Table 11-2 Respondents' perceptions – Western Cape

Perceptions on the use of treated effluent (average score)[(a)]	Mean (St. Dev.)	Min.	Max.	Seg.1 (n=26)	Seg.2 (n=20)
Irrigation with treated effluent:					
is a threat to the health of farmers and workers	3.9 (0.90)	1	5	3.62 (0.98)	4.25 (0.64)
is a threat to the health of consumers of the produce**	3.8 (1.02)	1	5	3.46 (1.10)	4.30 (0.66)
is a threat to the environment	3.9 (0.89)	2	5	3.58 (0.86)	4.35 (0.75)
can damage the soils***	3.2 (1.04)	1	5	2.96 (0.82)	3.45 (1.23)
can pollute groundwater	3.3 (1.07)	1	5	2.92 (0.89)	3.75 (1.12)
enhances agricultural production	2.5 (1.03)	1	5	2.81 (0.80)	2.15 (1.18)
reduces the quantities of nutrients to be applied in the soil	2.9 (1.06)	1	5	2.62 (0.98)	3.25 (1.07)
should be encouraged by the authorities	1.7 (0.86)	1	4	1.69 (0.88)	1.80 (0.83)
Treated effluent is an alternative source to fight water scarcity	1.5 (0.62)	1	4	1.62 (0.70)	1.45 (0.51)
Regulations for reuse of treated effluent in agriculture are poor [(b)]	3.2 (1.01)	1	5	3.00 (0.96)	3.40 (1.05)
Regulations for reuse of treated effluent in agriculture are comprehensive and encourage reuse [(b)]	2.9 (1.00)	2	5	3.08 (0.91)	2.70 (1.08)
Water quality standards for agricultural use of treated effluent are poor and put public health and the environment at risk [(b)]	3.7 (0.97)	1	5	3.48 (1.01)	3.95 (0.89)
Water quality standards for agricultural use of treated effluent are too stringent to comply with [(b)]	3.6 (0.86)	1	5	3.64 (0.81)	3.60 (0.94)
Institutions responsible for implementing reuse of treated effluent are not supportive [(b)]	2.7 (0.94)	1	4	2.72 (0.94)	2.75 (0.97)
Infrastructure required to convey treated effluent to fields is too costly, which impedes the use of treated effluent for agricultural irrigation [(b)]	2.8 (1.00)	1	4	2.60 (1.00)	3.00 (0.97)
Process of registration of water use licenses, permits or authorizations for treated effluent, is too bureaucratic and discouraging [(b)]	2.6 (1.17)	1	4	2.68 (1.18)	2.55 (1.19)
Authorities don't support the use of treated effluent in agricultural irrigation; as a consequence there aren't enough incentives to take this option [(b)]	2.7 (0.97)	1	4	2.80 (0.91)	2.55 (1.05)

T-tests and Pearson Chi-Square Tests show significant differences at (*) 10%, (**) 5% and (***) 1% level.

(a) Treated as continuous variables with the following scale for reference: 1 = strongly agree; 2 = agree; 3 = neither; 4 = disagree; 5 = strongly disagree

(b) For segment 1, the n° of respondents is n = 25 (one respondent did not answer).

Furthermore, respondents did not seem to have a clear position on regulations for reuse of treated effluent in agriculture. However, they considered that water quality standards were sufficient to protect public health and the environment, and not too stringent to comply with, even though national guidelines do not really exist (these results might not be significant due to the small difference in answers between the segments and in some cases due to the sample size). The “South African guide for the permissible utilization and disposal of treated effluent” (DNHPD, 1978 cited in Adewumi et al., 2010) promotes the concept of ‘no potential risk’ to public health when using wastewater. Adewumi et al. (2010) argued that under this guideline, expensive technology and processes are required, rendering the water unaffordable for developing communities.

Respondents’ perception concerning the institutional support, for implementing reuse of treated effluent was again indistinct, probably because of a lack of communication between institutions and water users (UBC EnvCom, n/d). Furthermore, the costs of water conveyance were not seen as an impediment to the use of treated effluent in agricultural irrigation. This is contrary to what Adewumi et al. (2010) found for water reuse in Cape Town. They found that as distance from the treated wastewater source increased, fewer respondents were willing to use treated effluent because the capital costs of laying pipelines were considered to be significant. The opinion of farmers on this matter is important, given that funding remains an obstacle to wider use of treated wastewater (Bixio et al., 2006). In most countries, reuse schemes are still largely subsidized (Hochstrat et al., 2007) as distortions still exist in water supply markets (Bixio et al., 2006). Adewumi et al. (2010) did, however, find that if the tariff for treated effluent was lower than for drinking water, more respondents indicated willingness to reuse wastewater in Cape Town.

11.3.3 Farmers’ preferences for wastewater reuse scenarios

The data were first analyzed by means of a CL model. However, since possible variations in preferences that could result from heterogeneity amongst respondents were of interest, the data were also analyzed by means of a LC model. This model proved to be superior (LRI = 0.26). The results are presented in Table 11-3, more emphasis is put to the discussion of the results of the LC model.

In the CL model, only two attributes present significant results. The coefficient of the attribute ‘high practices restrictions’ is negative and significant at 1% level, which suggests that farmers do not prefer this option compared to ‘low practice restrictions’. This option implies strict restriction on crops and irrigation methods, and strict monitoring of water use practices. This is understandable considering that farmers would prefer more freedom to choose crops and select irrigation methods. The second coefficient with significant result is the price attribute (at 1% level); this result was expected and is consistent with the theory that increase in price would decrease preference for alternatives. Other attributes were not statistically significant; the explanation for this is that the small sample size might have had an effect on finding significant coefficients.

In the LC model, the segments were balanced. Segment one held 54.4% of the respondents, whereas segment two held 45.6%. The ‘current use of treated effluent’ was what differentiated the two segments most: 80% of respondents in segment two currently already use treated effluent versus 3.9% in segment one. This difference was significant at the 1% level (see Table 11-1), but as ‘segmenting variable’ in the LC model this variable was not statistically significant (see Table 11-3). Respondents that are currently using treated effluent were motivated mainly by water scarcity in the area and access to a municipal WWTP. Other variables, such as socio-economic variables (e.g., age, income, educational level) or perceptions variables (e.g., irrigation with treated effluent is a threat to the health of farmers and workers; or irrigation with treated effluent is a threat to the environment) were not statistically significant.

Table 11-3 Results of the CL and LC models, and WTP estimates

	CL	LC	
		Segment 1	Segment 2
A1	0.19(0.27)	1.10* (0.66)	-0.33(0.59)
A2	-0.44(0.28)	-0.14(0.56)	-0.68(0.43)
A3	0.21(0.29)	-1.08(0.88)	0.95(0.90)
High practice restrictions	-1.10*** (0.30)	-1.93** (0.85)	-1.16* (0.68)
Moderate practice restrictions	-0.21(0.26)	0.25(0.65)	-0.80(0.69)
Private scheme model	0.17(0.20)	-0.47(0.35)	1.00** (0.46)
Private-Public Partnership scheme model	0.04(0.22)	-0.41(0.38)	0.64(0.49)
Price	-0.42*** (0.08)	-0.63** (0.26)	-0.42*** (0.13)
Model statistics			
Pseudo ρ^2	0.15	0.26	
Log likelihood	-170.82	-149.91	
Segment function LC: respondents' perceptions on irrigation with treated effluent			
Constant		8.05(5.42)	
Irrigation with treated effluent is a threat to the health of farmers and workers [(a)]		-1.07(2.36)	
Irrigation with treated effluent is a threat to the environment [(b)]		-0.56(1.61)	
Use of treated effluent		-4.70(3.67)	
WTP for changes in attribute levels and 95% confidence intervals			
High practice restrictions		-3.07*** (-4.46; -1.69)	-2.76* (-5.92; 0.41)
Private scheme model		-0.75 (-1.95; 0.45)	2.37* (-0.38; 5.11)

Significance at (*) 10%; (**) 5% and (***) 1% level.
(a) Dummy variable on the perception of irrigation with treated effluent in relation to health of farmers/workers
(b) Dummy variable on the perception of irrigation with treated effluent in relation to the environment
Note: Only significant WTP estimates are reported, in ZAR/m^3 (USD 1 = ZAR 10.13).

Respondents in both segments presented similar socio-economic characteristics (see Table 11-1). However, more respondents in segment one grew only grapes (about 15 percentage points more) while more respondents grew a combination of grapes and other crops (about 24 percentage points more) in segment two. For other crops the difference between segments is about 9 percentage points. In segment two, respondents were more inclined to shift to other crops if water was accessible (about 22 percentage points more).

In terms of the 'water quantity-quality' attribute, respondents in segment one preferred the alternative with limited water quantity, strict quality standards and reduced nutrient content over the reference level: unlimited water quantity, quality standards less strict than the general standards and high nutrient content. The latter was selected as the reference level because it described a less stringent scenario in terms of water quantity and quality. In contrast, other levels became more stringent. This preference was not found in segment two. Familiarity with the practice of reuse of treated effluent suggests that farmers in segment two were less inclined to choose strict quality standards. 'High practice restrictions', which implies strict restriction on crops to be cultivated, strict control over irrigation methods and strict monitoring, was not favored by the respondents in either of the segments.

Then, respondents in segment two preferred a 'private scheme model' compared to a 'public scheme'; this result is significant. In contrast, for segment one this coefficient is not statistically significant. In this regard, while there is on-going debate about the public versus private management of water and sanitation provision (e.g., Budds & McGranahan, 2003; Smith, 2004), the public sector still seems to struggle to deliver optimal services in developing countries because of lack of accountability, corruption, poor financial capacity, and inability to expand and upgrade water services in a reliable and cost-effective way (McDonald & Ruiters, 2005). South Africa has not escaped these effects, as attested by widespread public protests against the quality of public service delivery (Mpehle, 2012). Furthermore, Mpehle (2012, p. 213) argued that service delivery in South Africa has been negatively affected by aspects such the "deployment of unskilled, unqualified and inexperienced cadres to municipal management positions, the accumulation of wealth by a few individuals through the abuse of the tendering system, inadequate revenue due to centralization of funding, and absence of proper systems of collecting revenue by municipalities".

Finally, both segments expressed a negative preference for an increase in the price attribute. These results are expected under the assumption that a price increase reduces preferences for alternatives. Notwithstanding, a higher price is less preferred in segment one, ostensibly because respondents in segment two currently use treated effluent for which they already pay.

11.3.4 WTP for changes

Mean WTP for a change from 'high-practice-restrictions' to 'low-practice-restrictions' is estimated at ZAR 3.07 (or USD 0.30) and ZAR 2.76 (or USD 0.27) per m^3 for segment one and segment two, respectively. Both values are statically significant. Furthermore, for segment two, the mean WTP for a 'private scheme model' is estimated at ZAR 2.37 (or USD 0.23) per m^3 (this estimate is not statistically significant for segment one). Only significant results are reported in Table 11-3.

Interestingly, farmers value fewer restrictions on the selection of crops, application of irrigation methods and monitoring of water use if they are to irrigate with treated effluent. This can be understood from two perspectives. First, it is assumed that wastewater has undergone treatment, which produces treated effluent of acceptable quality and therefore can be applied to crops. Under this assumption, farmers should be able to irrigate more varieties of crops. Similarly, for the type of irrigation method applied, there is no real problem as farmers in this area generally use drip irrigation. Second, since agriculture is export oriented, they are already subjected to various food quality and farm practice regulations, therefore adding extra restrictions might not be preferred.

Another significant finding is that the type of management model for service provision seems to matter. In this case, a private scheme is valued in segment two. This result is in line with the expectation, considering that some farmers expressed their mistrust in public institutions. Moreover, this finding is in line with the assumption that users may prefer a private scheme based on the reliability of the service. A previous study on WTP for multiple use water services suggested that in rural South Africa there is room for the adoption of cost-recovery mechanisms, provided that the water services proposed respond to the needs of users (Kanyoka et al., 2008). The WTP for a private scheme for water reuse suggests that users are prepared to contribute to cost recovery. Nevertheless, more research is needed on this aspect.

11.4 Conclusions

This chapter contributes to the literature in two respects. First, important elements that have to be considered in frameworks for water reuse in agriculture were identified. Second, farmers' preferences for these frameworks were explored through CM. To the best of our knowledge, this kind of study has not been done before; therefore this is a contribution to the literature on economic valuation of the use of wastewater for irrigation.

Generally, farmers in the rural hinterland of Cape Town have a positive perception of water reuse for irrigation, largely because they are aware of the problem of water scarcity. This aspect is important since public perceptions and acceptance of water reuse are recognized as the main components of success for any reuse project (Po et al., 2003). Furthermore, one of the segments showed that strict water quality standards are preferred despite the concomitant limitations on water quantity. It implies that farmers will irrigate crops with treated effluent if ‘good-quality water’ is guaranteed. This is in line with Po et al. (2003) who suggested that the perceived risk of using recycled water is another important factor that influences public acceptance. They argued that in the context of water reuse, the risk perception is commonly related to public health issues from using the water. Although, on average, the respondents disagreed that irrigation with treated effluent was a threat to the health of farmers and workers, or to the health of consumers, guaranteeing water quality was their main concern, apparently because agriculture in the area is export-oriented.

Another interesting finding was that farmers who already made use of treated wastewater preferred a privately-managed scheme over a public scheme. This preference is in line with the utilitarian standpoint, which suggests that water users are expected to value private services based on the reliability of the water service (see Vásquez, 2011). Trust in the authorities to provide safely treated effluent has already been identified as a fundamental issue in determining public acceptance of water reuse (Po et al., 2003). A study in Australia indicated that trust in the service provision agency to provide safe recycled water was the main reason why people were willing to use wastewater (Kaercher et al., 2003). In the WC, farmers are willing to pay for a privately-managed scheme, probably because of a lack of trust in the service provision agency. This is in line with the finding by Adewumi et al. (2010), who found that poor trust in the service provider for treated effluent was probably influenced by the poor quality of treated effluent supplied over time. This suggests that the type of scheme for reuse of water is important.

Finally, when using treated effluent, there are implications for public health, which is one reason why people were discouraged from choosing this option (Po et al., 2003). However, in this study, the WTP for a change from ‘high-practice-restrictions’ to ‘low-practice-restrictions’ may reflect farmers’ dislike of strict regulations for agricultural practices. This may negatively influence users’ willingness to opt for this option. Although regulations and guidelines should protect public health and allow for safe reuse of water, they should, at the same time, take into account the local cultural and socioeconomic conditions (Mizyed, 2013). We agree with Mizyed (2013) on the need for regular reviews of the implementation, applicability and acceptance of quality standards for water reuse, taking into consideration the dynamics of a changing society.

Chapter 12. Comparing farmers' preferences

Abstract

In this chapter, the desired characteristics for frameworks of wastewater reuse in Cochabamba, Western Cape and Hyderabad are compared. These characteristics were identified through a choice modeling approach. The results suggest that in the three case studies farmers prefer treated wastewater and they are willing to contribute to irrigation systems conceived for treated wastewater. Concurrently, farmers' participation in decision making is important for them and for the sustainability of irrigation systems.

Keywords: water reuse, irrigation, agriculture, choice experiment, Bolivia, India, South Africa

12.1 Introduction

Three case studies, namely Cochabamba in Bolivia, Western Cape in South Africa, and Hyderabad in India were selected to conduct choice experiments in order to reveal farmers' preferences for frameworks of wastewater reuse in agriculture, and to identify key elements for these frameworks. The mean willingness-to-pay (WTP) was also estimated for proposed changes within the frameworks. In addition, farmers' perceptions towards wastewater reuse were explored. These results are explained in detail in the corresponding chapters. However, the purpose of this chapter is to compare the main results of the choice experiments amongst the three case studies, and to discuss the main differences and similarities with respect to farmers' perceptions regarding wastewater reuse.

The chapter provides, in section two, a description of the context of the study areas, highlighting the main similarities. The socio-economic conditions of farmers are compared in section three; whereas farmers' perceptions on wastewater reuse are discussed in section four. In section five the preferences for frameworks of wastewater reuse are compared, and in section six the WTP for changes are discussed. Finally, the main conclusions are presented in the last section.

12.2 Context of the study areas

The study areas in Bolivia, India and South Africa are located in semi-arid regions with limited water resources. In Cochabamba, Bolivia, the study area is located within the Rocha River Basin, where the average annual rainfall is 480 mm (Saravia, 2013) and occurs during the summer period from December till March. In India, the Musi River Basin is located in Hyderabad, capital city of the State of Telangana (former State of Andhra Pradesh). The average annual rainfall is 700-800 mm, which occurs during the monsoon season from June to October (Buechler & Devi, 2003). In both cases, these river basins are densely populated. Over a million people live in the Rocha River Basin, which represents more than half of the total population of the Department of Cochabamba (SDC-DGIA, 2014). Meanwhile, Hyderabad, the capital city of Telangana (and Andhra), is the fourth largest city in India with about 6.8 million people (Census, 2011a). The Western Cape Province in South Africa has a Mediterranean climate characterized by cool and wet winters, and warm and dry summers. The average annual rainfall varies between 500 and 1500 mm across the area, however, it still is considered a water scarce region because of the rapidly growing urban population and the large water demand.

Limited water availability for the development of agriculture is a common factor in these regions. The Rocha River, in Cochabamba, is the main source of water for irrigation in the study area. However, the water quality in the river has heavily deteriorated over the years. Similarly, the Musi River, in Hyderabad, is the main source of water for irrigation in the study area. Yet, this river is heavily polluted. These rivers have become *de facto* sewers due to the lack of sewerage networks and plants to treat the wastewater generated by the growing cities, as well as a lack of institutional support to act on these issues. The consequence is that farmers in both cases use untreated (polluted) wastewater to irrigate crops, which represents health risks for them. Moreover, there are environmental risks such as soil degradation and groundwater pollution. High salinity soils are found in some parts of the study areas in Cochabamba as well as in Hyderabad. In contrast, in the case of Western Cape farmers use treated effluent from a municipal wastewater treatment plant (WWTP). Wastewater from the city of Cape Town is treated and reused in agriculture. Obviously, the water quality is better than the river water, since it has undergone treatment. The most common irrigation methods found in Cochabamba and Hyderabad are furrow and flooding, whereas in Western Cape, farmers mostly use drip irrigation. Certainly, water use efficiency in Western Cape is higher compared to the other two cases.

Agriculture in these areas is an important economic activity. The contribution of this sector to the economy in the Department of Cochabamba was some 8.7% in 2012, and it remains a major employer (Encinas, 2013). In the Western Cape economy, agriculture contributed some 4% to the regional GDP in 2009 (Bureau for Economic Research, 2011) and also is a major employer of mainly seasonal labor (Murray, 2010). In the State of Telangana, agriculture is critical for economic and social development, as a majority of the population still lives in rural areas and depends on agriculture for their livelihoods and food security (Government of Telangana, 2015).

The production systems found in these areas are adapted to the climatic and soil conditions, as well as to the water availability. In the case of Cochabamba, farmers mainly grow vegetables (e.g., lettuce, onion, carrot, beetroot, parsley and potato) and fodder crops (e.g., alfalfa, maize and ryegrass). Agriculture, in this case, is market oriented. Similarly, in the case of Western Cape agriculture is export oriented. Farmers grow wine grapes, deciduous fruit and vegetables under irrigation and also produce dryland grains (wheat, oats, and canola). In contrast, in the case of Hyderabad, farmers grow leafy vegetables, para-grass fodder and paddy. They are mainly subsistence farmers.

12.3 Similarities and differences in socio-economic and farm characteristics

In the samples of Hyderabad and Western Cape, farmers were predominately male, whereas in the case of Cochabamba over half of the respondents were females. In all cases, farmers were mainly fulltime farmers (about 90%, 80% and 63%, respectively). Their education level is one aspect that differentiates Cochabamba and Hyderabad the most from Western Cape. In Cochabamba and Hyderabad, the education level was rather basic, whereas in Western Cape most farmers had higher education. This factor is connected to another factor which is the monthly household income. In Western Cape, the average monthly income was reported at USD 3792, which is seven times more than the average monthly income in Cochabamba and about 27 times more than the one reported for Hyderabad.

Furthermore, land ownership also varies. In Hyderabad, most farmers rent the land, followed by ‘own’ the land. In contrast, in Cochabamba, most farmers own the land, followed by ‘own and rent’ the land. The average land size also differed among the cases. In Cochabamba, the average land size is 0.50 ha, which is not atypical for the Bolivian highlands and valleys. Similarly, in Hyderabad the average land size is about 1 ha, whereas in Western Cape the size of land cultivated can range from 10 to 500 ha.

In the cases of Cochabamba and Hyderabad, the river water constitutes the main water source for irrigation followed by groundwater. Since the water in the river – in both cases – is polluted, the use of wastewater is indirect and unplanned. In contrast, in Western Cape the use of wastewater is planned and direct, where treated effluent from Potsdam WWTP is supplied to farmers through a network of infrastructure built and run by the farmers themselves.

12.4 Farmers’ perceptions on wastewater use

In Cochabamba farmers agreed that irrigation with wastewater is a threat to the health of farmers and workers, consumers or the environment. Similarly, in Hyderabad, most farmers had claimed they were aware of the health risk of irrigation with wastewater. Meanwhile, in Western Cape, farmers disagreed that irrigation with treated wastewater is a threat to the health of farmers or workers; to the health of consumers or to the environment. Thus, there is common understanding that untreated wastewater represents health and environmental risks; and that risks can be offset when wastewater has undergone a treatment process. This overall negative perception in relation to untreated wastewater might be related to past negative experiences. In contrast, there is a general positive perception regarding treated wastewater. Farmers in Cochabamba and Western Cape agreed that treated wastewater is an alternative water source to fight water scarcity. Moreover, in Hyderabad, more than half of farmers would shift crops if wastewater is treated. In all cases, farmers are willing to use treated wastewater for irrigation. In Cochabamba and Western Cape, farmers consider that authorities should promote this. Certainly, this is in line with the assumption that securing water is one determinant in the success of agricultural production.

Next, although it is acknowledged that wastewater can contribute with nutrients, farmers are more skeptical and they do not seem to perceive these benefits. In both cases, Cochabamba and Western Cape, farmers were more indifferent with the statement that irrigation with wastewater/treated effluent reduces the quantity of fertilizers to be applied in the soil. In contrast, in Hyderabad about half of the farmers claimed they were aware of the nutrient content of wastewater. Furthermore, farmers in Cochabamba and Hyderabad reported to have experienced negative effects on the crops as consequence of irrigation with untreated wastewater (43% and 76%, respectively), while this was not the case for the treated wastewater in the Western Cape. Regarding the effects of wastewater on the soils, farmers in Cochabamba tend to agree that irrigation with untreated wastewater can damage the soil. In Western Cape, farmers tend to be indifferent towards the statement that irrigation with treated effluent can damage the soil. This question was not asked to farmers in Hyderabad; however, in many fields irrigated with wastewater from the Musi River it is possible to find salinity problems. McCartney et al. (2008) for example indicated – for fields irrigated with Musi water – that soil salinity levels are above the recommended salinity threshold for rice.

In general, farmers seemed to be aware of the risks associated to the use of untreated wastewater; however, in the case of Cochabamba and Hyderabad they continue using poor-quality water for irrigation. The explanation for this is the lack of other water sources available in the areas. In Cochabamba, a higher percentage of farmers (67.3%) reported having experienced water scarcity in the last five years compared to the Western Cape (41.3%) and Hyderabad (20.3%). In Hyderabad water scarcity is evaluated as less severe because the Musi River became a perennial river due to the discharges of wastewater. So in fact, farmers experience less pressure on water thanks to the wastewater flowing from the city into the Musi River. This should also be the case for farmers in Cochabamba; however, they do not seem to perceive this in the same way. Comparing these answers to the answer in relation to nutrient content, the main benefit from wastewater reuse perceived by farmers might be mainly in terms of water availability.

Moreover, in the Western Cape and Hyderabad surprisingly farmers reported low percentages for experiencing water-related conflicts in the last five years (10.9% and 2.5%, respectively); whereas in Cochabamba about 53.1% of the farmers reported to have experienced water-related conflicts. The explanation for this high percentage in Cochabamba is that water in this area is highly political issue and very often contested, which does not seem to be the case in Western Cape and Hyderabad. This aspect might be related to cultural characteristics, which are important to consider since they can become an obstacle when planning and developing interventions.

In relation to farmers' experience of negative effects on their health, as consequence of irrigation with wastewater, farmers in Hyderabad reported the largest percentage (66.1%) compared to farmers in Cochabamba (26.5%). The diseases commonly reported were: diarrhea and skin irritation. Huibers et al. (2004) found that farmers in Cochabamba stated that they are not confronted with health problems related to the use of polluted water, which contradicts reports from local health workers. In other words, it seems that farmers in Cochabamba were not willing to reveal health problems due to wastewater irrigation, maybe because by doing so they will not be able to sell their crops. On the field, farmers were in general reluctant to answer this question. Moreover, in Western Cape, farmers using treated wastewater did not report any negative health experience. Furthermore, both Western Cape and Cochabamba reported high percentages for farmers' precautions to minimize possible health risks (65% of farmers using treated wastewater, and 73.5%, respectively). In Cochabamba, the measures mentioned included: use of rubber boots and gloves when in contact with wastewater; whereas in Western Cape farmers pointed out the use of signaling for pipes, taps, and reservoirs, and educating workers as main measures. In Hyderabad, farmers indicated that the use of rubber boots is uncomfortable, most of them mentioned to bathe after being exposed to wastewater as protective measure.

As a last point, more farmers in Cochabamba (57.1%) stated that they take measures to protect consumers' health, such as waiting periods before harvesting and washing of crops with clean water, compared to farmers in Western Cape. In the latter, a smaller percentage of farmers currently using treated effluent (18%) stated that they take some precaution, mainly because they rely on the quality of the treated effluent. In general, these numbers indicate that farmers are aware of the risks of wastewater irrigation.

12.5 Preferences for characteristics of wastewater reuse frameworks

Farmers' preferences for characteristics of wastewater reuse frameworks were determined through a choice modelling approach and the results were estimated applying a conditional logit (CL) model and a latent class (LC) model for each case study, namely Cochabamba, Western Cape and Hyderabad. For the first two, a generic choice experiment was constructed, whereas for Hyderabad a labeled choice experiment was applied. Some attributes are common; however, other attributes are specific for each case study. This is because the design of the choice experiment was adjusted to the local characteristics of the study site. The selection of attributes and the design of the choice experiments for each case are described in detail in the corresponding chapters, as well as the results of the LC models are discussed. In this chapter, findings in farmers' preferences emphasizing the results of the CL model are compared. Table 12-1 contains the summary of the results for the CL and LC models, for all cases.

The results of the CL model for the cases of Cochabamba and Hyderabad indicate that 'treated wastewater' and 'water treatment' options are preferred by farmers, respectively. Note that in both cases, the water currently used for irrigation is untreated wastewater from the river. The 'treated wastewater' option implies lower health risks for farmers in contact with the water; lower nutrient content in the water, and lower content of pollutants or salts. The quantity of water available is restricted to the capacity of the WWTP. Meanwhile, the 'water treatment' option implies that water has undergone treatment. This preference was not captured in the case of Western Cape.

Table 12-1 Results of CL and LC models

	CL model	LC model	
		Segment 1	Segment 2
Cochabamba, Bolivia			
Treated wastewater	3.19*** (0.40)	5.48***(1.64)	3.09***(0.85)
Restricted access to water	-0.42(0.28)	0.66(0.79)	-0.94**(0.46)
High use restrictions	-1.40***(0.26)	-3.97***(1.51)	-0.62(0.51)
Model 1- Farmers' involvement	-1.03***(0.26)	-2.20**(0.86)	-1.00**(0.47)
Price of petrol	-4.30***(1.60)	2.50(4.50)	-7.98***(2.81)
Western Cape, South Africa			
A1: limited water quantity – up to 50 m^3/d, strict quality standards and reduced nutrient content	0.19(0.27)	1.10* (0.66)	-0.33(0.59)
A2: limited water quantity – up to 50 m^3/d, general quality standards and high nutrient content	-0.44(0.28)	-0.14(0.56)	-0.68(0.43)
A3: maximum water quantity – up to 2000 m^3/d, general quality standards and high nutrient content	0.21(0.29)	-1.08(0.88)	0.95(0.90)
High practice restrictions	-1.10*** (0.30)	-1.93** (0.85)	-1.16* (0.68)
Moderate practice restrictions	-0.21(0.258)	0.25(0.65)	-0.80(0.69)
Private scheme model	0.17(0.20)	-0.47(0.35)	1.00** (0.46)
Private-Public Partnership scheme model	0.04(0.22)	-0.41(0.38)	0.64(0.49)
Price	-0.42*** (0.08)	-0.63** (0.26)	-0.42*** (0.13)
Hyderabad, India			
Labels			
No Intervention	-1.23*** (0.24)	-1.36**(0.67)	-0.81**(0.34)
Restrictions	-0.74*** (0.28)	-5.75**(2.82)	-0.30 (0.35)
Water Treatment			
Attributes			
Medium water quantity	0.31 (0.22)	-0.81 (2.45)	0.21(0.28)
Strict crop restriction	-0.30 (0.31)	-19.88 (278500.1)	-0.05 (0.38)
Moderate crop restriction	0.28 (0.19)	1.28 (1.42)	0.48* (0.28)
Tolerable health risks	-0.47*** (0.15)	-1.52 (1.38)	-0.63***(0.20)
Price	-0.0000789 (0.0003)	0.0105 (0.0078)	-0.0008*(0.0004)

Significance at (*) 10%; (**) 5% and (***) 1% level.

Furthermore, in Cochabamba and Western Cape ‘high use restrictions’ or ‘high practice restrictions’ are less preferred. In both cases, this option implies strict restriction on crops for human consumption (e.g., vegetables eaten raw not allowed); strict control over irrigation methods (implies periodic inspections); and strict monitoring of water use (e.g., protective measures, including the use of protective clothes, waiting periods between irrigation and harvesting, avoiding direct contact between water and crops, drip irrigation is recommended). This was not captured in the case of Hyderabad. However, farmers in Hyderabad preferred the option ‘reduced health risks’ compared to ‘tolerable health risks’.

Next, the price attribute was significant and negative in both Cochabamba and Western Cape. The sign indicates a negative preference for an increase in the price attribute as expected, under the assumption that a price increase reduces preferences for alternatives. However, although not significant, the price attribute has a positive sign in the case of Hyderabad. The interpretation for this is that price was not a determinant of choice for respondents in Hyderabad.

12.6 Comparing WTP for changes

WTP for changes in attribute levels are discussed in detail in the corresponding chapters for each segment of the LC model, as well as the socio-economic characteristics of the segments are provided. Here, the fact that farmers are willing to pay for improvements in terms of water quality and health protection is highlighted. Table 12-2 summarizes mean WTP for changes in attribute levels, only significant results are reported.

For instance, farmers in Cochabamba (segment two only) are willing to pay for treated wastewater. Their contribution to an irrigation system for treated wastewater could be either in monetary or labor terms. Something similar is found in Hyderabad where farmers are willing to pay for a water treatment option (segment two only). These results are important from the point of view that, although farmers are not responsible for water treatment, they are prepared to contribute in order to improve water quality. This aspect is also important, considering that funding is critical to implement wastewater reuse (Bixio et al., 2006).

Furthermore, in Western Cape, farmers are willing to accept ‘high practice restrictions’. In other words, they are willing to pay for ‘lower practice restrictions’ as this option implies no restrictions on crops; no restriction of irrigation methods and regular monitoring of water use (significant in both segments). This aspect is interesting because it reveals that farmers do not want to take the burden of strict restrictions when using treated wastewater. In formalized structures of wastewater reuse, such as in Israel, unlimited use of wastewater is only possible when the water presents high quality standards. Therefore, low practices restrictions would necessary imply high water quality.

Table 12-2 WTP for changes in attribute levels and 95% confidence intervals

	LC model	
	Segment 1	Segment 2
Cochabamba, Bolivia		
Treated wastewater		0.39**(0.02; 0.05)
Restricted access		-0.12**(0.04; -0.23)
Farmers' involvement – model 1		-0.13*(0.08; -0.27)
Western Cape, South Africa		
High practice restrictions	-3.07*** (-4.46; -1.69)	-2.76* (-5.92; 0.41)
Private scheme model		2.37*(-0.38; 5.11)
Hyderabad, India		
Labels		
No Intervention		-18.77** (-34.36 ; -3.18)
Water Treatment		
Attributes		
Tolerable health risks		-14.66* (-31.83; 2.51)

Significance at (*) 10%; (**) 5% and (***) 1% level. Only significant WTP estimates are reported.
Note 1: WTP estimates for Cochabamba are expressed in Bs/L; USD 1 = Bs. 6.96
Note 2: WTP estimates for Western Cape are expressed in ZAR/m^3; USD 1 = ZAR 10.13
Note 3: WTP estimates for Hyderabad are expressed in USD/ha per year; USD 1 = INR 54.90

Furthermore, in Cochabamba, farmers are willing to accept 'model 1' (segment two only). This model implies less involvement in decision-making concerning the WWTP and the irrigation system compared to the other alternative, which suggests that the level of farmers' involvement in the decision-making for irrigation systems is important to them. In the same line, farmers in Western Cape (segment two only) are willing to pay for a private scheme model, which implies that they are prepared to finance, operate and manage a wastewater reuse scheme by themselves. This also puts forward that farmers are prepared to contribute to cost recovery. Certainly, these results are indicators that there is room to explore farmers' contribution in wastewater reuse systems. This may also indicate that as water becomes scarce, farmers' are more prepared to be involved in irrigation systems conceived for wastewater.

12.7 Conclusions

In this chapter, the main findings on farmers' perceptions on wastewater use and their preferences for characteristics of wastewater reuse frameworks are compared for the three case studies. The evidence suggests that farmers are in general aware of the risks of irrigating with untreated wastewater. These risks are mainly for the health of farmers and for crops and soils. Farmers do not seem to perceive the benefits of additional nutrient contained in the water or such benefits might be offset by the risks. Furthermore, it becomes evident that wastewater reuse is overall well perceived, but an improvement in water quality is fundamental for farmers. This aspect points out that farmers are willing to take the burden of formalization in order to receive higher quality water.

Finally, farmers' participation in the entire process of system design and management ensures sustainability of irrigation systems (World Bank 2003). The results indicate that participation in decision-making was an important aspect for farmers; therefore it needs to be taken into consideration for planning and implementation of wastewater reuse systems.

Chapter 13. General conclusions and recommendations

This study was inspired by the idea that wastewater reuse has great potential to reduce pressure on water resources and more specifically for the agricultural sector. At the same time, wastewater reuse needs to be addressed because of the risks it represents for public health and the environment. As water becomes scarce in many regions around the world, and the informal use of wastewater for irrigation propagates specially in developing countries, wastewater reuse needs to be reconsidered within the broader concept of water resources management. Nevertheless, water resources management in general, and wastewater management in particular are complex and difficult tasks because water problems are heterogeneous and variable over time and space. Therefore, solutions to water problems will depend not only on water availability, but on many other factors such as institutional capacity, legal and regulatory frameworks, socio-political conditions, environmental conditions, educational and development conditions, availability of financial resources and technology, attitudes and perceptions, and modes of governance including issues like political interference, transparency, and corruption (Biswas, 2008). Given this complexity, the need to unravel the institutional dimensions of wastewater reuse, in order to understand the challenges for its formalization becomes evident.

This study explored how four countries at different stages of formalization of reuse, manage wastewater reuse for irrigation (Part 1). The case of India (Chapter 3) presented a scenario where the use of wastewater is indirect, unplanned, unrecognized, and therefore mostly informal, where the lack of clear mandates of institutions involved inhibits the development of formalization of wastewater reuse. The case of Bolivia (Chapter 4) characterized a scenario where wastewater has been recognized as potential water source and a process of formalization has been initiated, which implies introduction of water reuse in the water policy framework, development of regulatory framework, development of infrastructure, etc. This case highlights that political will is determinant to promote changes in institutional arrangements in the process of formalization of wastewater reuse. Next, the case of South Africa (Chapter 5) explained the direct, planned and regulated use of wastewater for irrigation. In other words, formal wastewater reuse in a context of a developing country, where institutional arrangements were set in place for its realization, as well as the importance of farmers' initiative to be part of such ventures. However, this case also identified some elements that were missing to fully implement formal wastewater reuse throughout the country, such as capital-intensive water use linked to profitable markets. Meanwhile, the case of Israel (Chapter 6) showed a scenario situation where wastewater reuse is fully formalized. This case showed the importance of having clear objectives, regulatory frameworks, educational development supporting behavioral change, and accountability to the people. Throughout the chapters, the elements that constraint and facilitate formalization of wastewater reuse were identified, and the particular conditions where wastewater reuse takes place were featured, including the institutional environment (e.g., historical, socio-economic and physical conditions) and the institutional structure (e.g., policy and regulatory framework, and administrative structure). The cross-case comparison (Chapter 7) presented the main findings which included: the drivers behind the formalization of wastewater reuse, similarities and differences in institutional settings, the importance of risk awareness, the need for institutional changes and the role of guidelines.

As the focus of the study was the agricultural sector, it was vital to understand the farmers' perspective regarding wastewater reuse (Part 2). To this end, farmers' preferences for wastewater reuse frameworks were evaluated, and their willingness-to-pay (WTP) for changes in the frameworks proposed was estimated, by applying a choice modeling approach. This methodology (Chapter 8) was applied to three case studies, namely: Hyderabad in India (Chapter 9), Cochabamba in Bolivia (Chapter 10) and the Western Cape in South Africa (Chapter 11). The results of the findings of the individual case studies were then discussed and compared (Chapter 1), suggesting that farmers overall are prepared to take the burden of formalization in order to receive higher quality water, and they are willing to contribute to irrigation systems conceived for treated wastewater. Concurrently, farmers' participation in decision making is important for them and for the sustainability of irrigation systems. Finally, the general conclusions of the study and the recommendations are integrated in this last chapter (Chapter 13).

13.1 Conclusions

13.1.1 Towards formalization of wastewater reuse

Wastewater offers a window of opportunities for water resources management, mostly for the agricultural sector. Countries can benefit enormously from this alternative water source; however, formalization of wastewater reuse is essential to enjoy the benefits of an additional water source, while still protecting people from the risks associated to the reuse of wastewater. In order to formalize wastewater reuse, it is fundamental that countries first recognize the potential of this water source, as well as the risks associated to it, and then that countries are prepared to provide institutional arrangements for the practice. Political will is inherently part of this process. However, public awareness regarding water scarcity and water pollution is also necessary to initiate such institutional changes and to generate the behavioral change required to guarantee safety. Most developing countries fail at generating such changes mainly because there is an overall low level of education and a high level of tolerance towards unsafe use of wastewater. Furthermore, important institutional changes include clarity in the institutional arrangements, which imply specific mandates and well-defined responsibilities for wastewater management and reuse; and a regulatory framework in place to guide the practice, which includes water quality standards, treatment levels and processes, crop restrictions, categories of types of uses, etc.

Moreover, an important aspect to reflect on in the process of formalization is that formalization of wastewater might be linked to the creation of water rights. On the one hand, this can be regarded as positive because it provides security to access water in irrigation systems. However, in a market-oriented context, where water is regarded as an economic good, the creation of wastewater rights might turn into wastewater markets. This can represent a threat to poor farmers, who despite the health risks of wastewater in the informal context still benefit in terms of livelihood support and economic development opportunities. Water rights can be addressed, however, from different perspectives, e.g. state-defined and centralized water control, a market-focused neoliberal model, and in terms of decentralized platform structures for negotiating local water rights and mediating conflicts among multiple users (Boelens et al., 2005). It is likely that wastewater rights will resemble the configuration of existing water rights and will fit the local approaches for water resources management. So for instance, it will be more feasible to develop wastewater markets in contexts that foster water markets. In any case the discussion on wastewater rights can be included in the broader discussion on water rights. What remains central in the analysis of water rights is to consider water problems as inherently local and context-specific, and that water is not only a commodity to be redistributed and allocated according to market principles but also a crucial resource for rural livelihoods (Boelens et al., 2005).

13.1.2 Understanding farmers' preferences for wastewater reuse frameworks

Understanding farmers' preferences for wastewater reuse frameworks is crucial to design sound policies in water resources management that incorporates wastewater reuse as part of the strategies to deal with increasing water demand. The importance of understanding farmers' preferences is that it provides valuable information from the farmers' perspective – the final users – regarding perceived risks, preferred water use practices, and willingness-to-pay for changes. Especially the last aspect is important to address the costs of wastewater reuse. Furthermore, understanding farmers' preferences is strongly linked to participatory processes in water resources management, which are believed to be central for sustainable water governance structures.

The case studies analyzed showed that overall, farmers are aware of the risks that irrigating with untreated wastewater represents for their health, their produce and the soil. Farmers also know that irrigating crops with untreated wastewater can have negative consequences for the health of consumers. However, in informal settings of wastewater reuse, they are unaccountable for this. Furthermore, wastewater represents for the farmers security to sustain their livelihoods. This is important since water guarantees agricultural production. Moreover, the general perception regarding wastewater reuse is positive, but subject to an improvement in terms of water quality.

This aspect is fundamental for farmers, who are willing to support wastewater reuse if 'good' water quality is guaranteed. This aspect is central in the process of formalization. On the other hand, farmers apparently do not perceive the benefits of additional nutrient content in the water, mainly because such benefits might be offset by the risks. As a final point, an important element to ensure sustainability of irrigation systems conceived for wastewater reuse is farmers' participation in the entire process of system design and management. This aspect is vital during the planning and implementation of wastewater reuse systems.

13.1.3 Theoretical and methodological implications

The findings of this research add to the literature on the fact that addressing wastewater offers great opportunities to reduce pressure on water resources, but also to reduce environmental pollution and achieving sustainability in water resources management (Angelakis et al., 1999; Asano, 2001; Lazarova et al., 2001; Salgot et al., 2006; Qadir et al., 2007b). Therefore, wastewater reuse should be included in the planning of water resources management as central component for water conservation. Along this line, growing water scarcity is the main driver for the use of wastewater (Bixio et al., 2006; Raschid-Sally & Jayakody, 2008), but mostly for the formalization of wastewater reuse. Nonetheless, it has been shown that in developing countries the use of untreated wastewater is rather the result of a lack of adequate sanitation and wastewater management (Drechsel & Evans, 2010; Qadir et al., 2010a).

In line with Bixio et al. (2006) and Qadir et al. (2010a), it became evident from the study that clear institutional arrangements are needed, as they are central for the process of formalization. This should be accompanied by guidelines in order to protect public health, increase water availability, prevent water pollution and enhance water resources and nature conservation policies (Angelakis et al., 1999; Bixio et al., 2006).

The methodological contribution of this study is that it applies a choice experiment (CE) that in addition to pure characteristics of the water also incorporates institutional aspects concerning the use of the water, such as management issues and rules, to reveal farmers' preferences for wastewater reuse frameworks. This is perhaps the most innovative part of the application of CE in this study, because it helps to understand farmers' preferences from a multidimensional perspective. It also shows that not only the characteristics of the water are important in the choice of farmers, but also the institutional aspects. Strong emphasis was put in understanding the local context in terms of water management, particularly on wastewater management, and agricultural practices in order to provide comprehensive attributes.

The CE approach has gained recognition in the field of environmental valuation (Hanley et al., 2001) and it has increasingly been applied to value water resources such as wetlands (e.g., Carlsson et al., 2003; Birol et al., 2006a; Milon & Scrogin, 2006) or water services (e.g., Snowball et al., 2008; Kanyoka et al., 2008). In relation to wastewater, limited studies that apply CE exist. Birol & Das (2010) applied CE to estimate WTP for improvements in the capacity and technology of a sewage treatment plant in Chandernagore municipality, India. Genius et al. (2012) applied CE to elicit the value of the attributes of a wastewater treatment plant in a rural area in Greece. Ndunda & Mungatana (2013) applied CE to estimate the benefits of improved wastewater treatment programs to mitigate the impacts of water pollution in Nairobi, Kenya.

The main advantage of CE is that it has the potential to generate rich information for policy-makers, in this particular case on the preferences for wastewater reuse. In this regard, this study also contributes to the literature by assessing farmers' preferences for frameworks of water reuse for irrigation, by applying a CE in contrast to other methods such as contingent valuation (CV). The application of a CE with farmers on water management issues in developing countries is limited, most studies applying CE on water issues focus on developed countries. From that perspective, this study also offers important lessons. Compared to CV, CE can estimate economic values for any environmental resource, including non-use and use values, and the implicit value of the attributes; their implied ranking and the value of changing more than one attribute at once (Bennett & Blamey, 2001). In this respect, CE is a convenient approach for the analysis of changes and tradeoffs between attributes (Snowball et al., 2008); and by including price as one the attributes, this survey-based methodology for modelling preferences for goods enables the estimation of WTP (Hanley et al., 2006).

13.1.4 Limitations of the study

This study focused on developing countries where data availability with respect to wastewater reuse is limited. The data collected on the institutional part was mainly from policy documents, official reports, peer-reviewed journal articles and available grey literature. This was complemented with semi-structured interviews with public servants from key institutions. Most difficulties were encountered with the latter. The main barrier was that informal wastewater reuse is a sensitive issue in most developing countries because, at large, it is the result of malfunctioning of institutions responsible for wastewater collection and treatment. Therefore, in some cases public servants were reluctant to openly discuss these issues; in other cases they did not answer the requests for the interviews, which indicate their lack of interest in sharing information. Thus, sharing of information was a barrier often encountered.

Next, the choice experiment was characterized by small samples, this because the target populations were rather small. Wastewater reuse is a phenomenon that is not common at the same scale in every location. Therefore, there are enormous differences in terms of target populations. In the case of South Africa (formal setting) the scheme of farmers using treated effluent comprised only 43 farmers. In the case of Bolivia, also the target communities using wastewater were rather small (accounting to some 230 famers). In this case, as well as in the Indian case, farmers were reluctant to take part of the questionnaire, as they feared to reveal information on the use of untreated wastewater. It is important to remember that in these cases wastewater reuse takes place in informal settings, hence it can be a sensitive issue. Farmers' reluctance to openly discuss the issue also affected the possibility of having focus groups. In the case of Bolivia, the engagement with the community leaders was crucial in order to access the field. Without their consent it would have been almost impossible to have access to the farmers. Even so, some farmers were apprehensive when sharing information. Further engagement with farmers could improve the process of data collection.

A potential consequence of the small samples is that many coefficients of the conditional logit and latent class models were not significant. However, this can also happen with large samples. Despite of this main limitation, this study still provides interesting and significant results. Moreover, due to recent advances in experimental design theory choice modelling can be done with smaller sample sizes (see Rose & Bliemer, 2013; de Bekker-Grob et al., 2015). Overall, the choice experiment was a learning experience where many aspects were improved throughout the case studies. For instance, a first approach in Hyderabad was to develop an efficient design in the software package SAS. For this case study a labeled choice experiment was designed. It was observed that this type of design might have had an effect in obtaining significant coefficients for the attributes, mainly because farmers might have focused too much on the labels. This lesson was incorporated in the second and third case study, where generic choice experiments were then developed. Moreover, in order to account for the small target populations, the choice experiment – for Western Cape and Cochabamba– was developed in the software package JMP targeting a certain sample size, guaranteeing in this way that an efficient design was achieved. In addition, the designs were generally simple without too many attributes or levels. In this way, many of the lessons from the previous case study were included in the next case in order to improve the design and development of the choice experiments.

Furthermore, to limit the dimension of the design sometimes different aspects were combined in one attribute. By doing so, it is no longer possible to reveal preference structure for these aspects. However, in describing the attributes in bundles also reflects reality, for instance, the management models for the cases of Western Cape and Cochabamba, which included aspects such as funding, operation and maintenance, and decision-making.

Finally, the literature on institutional analysis for water institutions has a range of methodological approaches. There is no standardized way to conduct institutional analysis. This required that, based on the data available, two different methodologies were adopted for the analysis. Nonetheless, an important contribution of this study is the compilation of data from various sources regarding institutional settings for wastewater reuse in countries located in different regions around the world.

13.2 Recommendations

The following are general recommendations, targeted to policy-makers, for stepwise changes in wastewater governance structures for countries moving along the trajectory from informal to formal. Some recommendations require profound interventions in the water governance structure of a country, while others can be implemented in the short term.

- Recognize the potential of wastewater for reducing pressure on water resources, as well as the environmental and health risks associated to informal reuse.
- Couple sanitation strategies with wastewater reuse strategies, in order to promote an integrated approach for water resources management, with the purpose of reducing environmental pollution and achieving sustainability in water resources management.
- Design clear mandates for institutions, where responsibilities and benefits are stipulated; and create an agency to deal with wastewater reuse issues and to coordinate actions among agencies.
- Adopt guidelines, so that they provide the reference framework for safe use of wastewater in irrigation. Guidelines shall be adapted to local realities in terms of technology and infrastructure available, budget, and personnel skills and competences, so agencies can provide the minimum water quality standards. The adoption of the WHO Guidelines for irrigation with wastewater can work as substitute; however, countries shall target to develop their own guidelines taking into account the local realities.
- Increase awareness of the general public on the risks of water pollution and the need for water conservation measures through long-lasting educational campaigns.
- Involve farmers and facilitate extension services on the safe use of wastewater. This should include educational campaigns for farmers and workers on in-situ safety measures.
- Promote small-scale approaches for wastewater treatment on-farm level, in order to improve water quality, while cities solve the water and sanitation problems.
- Finally, provide incentives to farmers for the use of treated wastewater, including promotion of their production as ‘sustainable products’, subsidized water tariffs, etc.

ANNEXES

Annex 1 – Ranking of countries according to indicators

LEVEL OF ECONOMIC DEVELOPMENT	SITUATION OF WATER SCARCITY/STRESS				HEALTH PERFORMANCE ASSOCIATED WITH DEFICIENT HYGIENE, SANITATION AND WATER SUPPLY			HOW CLOSE TO REACH MDG TARGETS ON WATER & SANITATION: SOCIAL PERFORMANCE				EFFORTS TO REDUCE POLLUTION LOADS FROM CITIES: ENVIRONMENTAL SUSTAINABILITY		QUALITY OF PUBLIC SERVICES, CIVIL SERVICE AND POLICY: GOVERNANCE			POSITION IN THE RANK
GROUP	1. Water Stress Index (%)		2. Water Availability Index (m3/cap.yr)		3. Mortality rate, under-5 (per 1,000 live births)		Death due to Diarrhoea, under-5 (%)	4. Population using Improved Drinking Water Sources (%)		5. Population using Improved Sanitation Facilities (%)		6. Population connected to wastewater treatment (%)		7. Government effectiveness (percentile)			
	from high to low stress	year 2010	from low to high availability	year 2009	from low to high mortality rate	year 2010	year 2010	from high to low coverage	year 2010	from high to low coverage	year 2010	from high to low coverage	last year available	from high to low effectiveness	estimate, year 2010	percentile	
high income countries: GNI> 11,906 USD/cap (2008)	Kuwait	90.6	Andorra	0.0	San Marino	1.9		Monaco	100.0	Monaco	100.0	Monaco	100.0	Finland	2.240	100	1
	Israel	75.3	Kuwait	8.0	Liechtenstein	2.1		Norway	100.0	Norway	100.0	Singapore	100.0	Singapore	2.240	100	2
	Saudi Arabia	51.6	United Arab Emirates	22.0	Iceland	2.6	0	Luxembourg	100.0	Luxembourg	100.0	Netherlands	99.0	Denmark	2.160	99	3
	Belgium	49.8	Qatar	36.0	Singapore	2.6	1	Qatar	100.0	Qatar	100.0	Andorra	98.0	Sweden	2.000	99	4
	Australia	45.7	Bahamas	59.0	Sweden	2.9	0	Denmark	100.0	Denmark	100.0	United Kingdom	97.5	Switzerland	1.910	98	5
	United Arab Emirates	41.6	Saudi Arabia	90.0	Finland	3.0	0	Switzerland	100.0	Switzerland	100.0	Switzerland	97.0	Austria	1.880	98	6
	Oman	37.5	Libyan Arab Jamahiriya	96.0	Slovenia	3.0	3	Sweden	100.0	Kuwait	100.0	Kuwait	95.6	Canada	1.860	97	7
	Spain	37.1	Bahrain	99.0	Norway	3.2	0	Ireland	100.0	Sweden	100.0	Luxembourg	95.0	New Zealand	1.870	97	8
	Libyan Arab Jamahiriya	24.7	Singapore	121.0	Japan	3.2	2	Netherlands	100.0	Netherlands	100.0	Germany	95.0	Norway	1.790	96	9
	Hungary	24.5	Malta	122.0	Luxembourg	3.3	0	Finland	100.0	Finland	100.0	China, Hong Kong SAR	93.2	Australia	1.810	96	10
	Netherlands	24.1	Israel	245.0	Cyprus	3.4	0	Iceland	100.0	United States of America	100.0	Austria	93.0	Liechtenstein	1.760	95	11
	United States of America	21.3	Saint Kitts and Nevis	462.0	Andorra	3.5	0	Austria	100.0	Iceland	100.0	Spain	92.0	China, Hong Kong SAR	1.730	95	12
	Qatar	19.3	Oman	516.0	Portugal	3.6	0	United Arab Emirates	100.0	Austria	100.0	Israel	91.0	Luxembourg	1.710	94	13
	Italy	17.7	Antigua and Barbuda	591.0	Denmark	3.9	0	United Kingdom	100.0	United Kingdom	100.0	United States of America	90.0	Netherlands	1.730	94	14
	Germany	15.9	Cyprus	716.0	Italy	3.9	0	Belgium	100.0	Belgium	100.0	Australia	90.0	Iceland	1.580	93	15
	Portugal	10.0	Denmark	1,086.0	Monaco	4.0	0	Canada	100.0	Canada	100.0	Greenland	90.0	Belgium	1.590	93	16
	Republic of Korea	9.7	Czech Republic	1,260.0	Ireland	4.1	0	Germany	100.0	Germany	100.0	Bahrain	88.0	United Kingdom	1.560	92	17
	United Kingdom	8.4	Republic of Korea	1,453.0	Germany	4.1	0	Australia	100.0	Australia	100.0	Denmark	87.9	Germany	1.550	92	18
	France	8.4	Belgium	1,717.0	Czech Republic	4.1	1	France	100.0	France	100.0	Greece	87.0	Andorra	1.520	91	19
	Japan	5.6	Germany	1,869.0	Estonia	4.1	0	Andorra	100.0	Andorra	100.0	Sweden	86.0	United States of America	1.440	90	20
	Lithuania	5.4	Puerto Rico	1,891.0	Netherlands	4.2	0	Japan	100.0	Japan	100.0	Ireland	84.0	Cyprus	1.500	90	21
	Greece	4.5	United Kingdom	2,375.0	France	4.2	1	Italy	100.0	Singapore	100.0	Finland	81.0	France	1.440	89	22
	Czech Republic	2.6	Spain	2,443.0	Austria	4.3	0	Singapore	100.0	Spain	100.0	France	80.0	Japan	1.400	89	23
	Estonia	2.5	Trinidad and Tobago	2,874.0	Belgium	4.4	1	Spain	100.0	Greenland	100.0	New Zealand	80.0	Ireland	1.310	88	24
	Denmark	2.3	Italy	3,175.0	Switzerland	4.5	0	Greenland	100.0	Cyprus	100.0	Bahamas	80.0	China, Macao SAR	1.320	88	25
	Canada	1.7	France	3,379.0	Spain	4.5	1	New Zealand	100.0	Bahamas	100.0	Estonia	80.0	Israel	1.240	87	26
	New Zealand	1.2	Japan	3,398.0	Israel	4.5	0	Cyprus	100.0	Israel	100.0	Norway	79.0	Estonia	1.220	85	27
	Iceland	0.9	Netherlands	5,496.0	Greece	4.6	0	Greece	100.0	Slovenia	100.0	Republic of Korea	78.8	Republic of Korea	1.190	84	28
	Finland	0.4	Luxembourg	6,225.0	Australia	4.7	0	Israel	100.0	Portugal	100.0	United Arab Emirates	78.3	Malta	1.150	83	29
	Sweden	0.4	Portugal	6,446.0	Republic of Korea	4.9	0	Malta	100.0	Republic of Korea	100.0	Czech Republic	76.0	Bahamas	1.070	82	30
	Norway	0.0	Greece	6,555.0	United Kingdom	5.3	0	Czech Republic	100.0	Malta	100.0	Canada	71.7	Slovenia	1.030	81	31
	Luxembourg	0.0	Switzerland	7,020.0	Croatia	5.3	0	Slovakia	100.0	Slovakia	100.0	Lithuania	71.0	Portugal	1.040	81	32
	Switzerland	0.0	Lithuania	7,453.0	Canada	5.6	0	Hungary	100.0	Hungary	100.0	Portugal	70.0	Czech Republic	1.000	80	33
	Ireland	0.0	Slovakia	9,189.0	New Zealand	6.0	0	Kuwait	99.0	Ireland	99.0	Belgium	69.0	Spain	0.980	79	34
	Austria	0.0	Austria	9,283.0	Malta	6.1	0	United States of America	99.0	Oman	99.0	Italy	69.0	Qatar	0.940	78	35
	Greenland	0.0	Estonia	9,545.0	Lithuania	6.2	1	Slovenia	99.0	Croatia	99.0	Japan	67.0	Brunei Darussalam	0.880	78	36
	Cyprus	0.0	United States of America	9,974.0	Hungary	6.6	0	Portugal	99.0	United Arab Emirates	98.0	Latvia	65.0	Greenland	0.980	78	37
	Bahamas	0.0	Hungary	10,398.0	United Arab Emirates	7.0	0	Croatia	99.0	Greece	98.0	Iceland	57.0	Slovakia	0.860	77	38
	Slovenia	0.0	Ireland	11,786.0	Brunei Darussalam	7.4	0	Saint Kitts and Nevis	99.0	Czech Republic	98.0	Slovakia	57.0	United Arab Emirates	0.780	76	39
	Malta	0.0	Latvia	15,679.0	United States of America	7.5	0	Latvia	99.0	Libyan Arab Jamahiriya	97.0	Hungary	57.0	Saint Kitts and Nevis	0.720	74	40
	Trinidad and Tobago	0.0	Slovenia	15,746.0	Slovakia	8.0	1	Republic of Korea	98.0	Saint Kitts and Nevis	96.0	Slovenia	52.0	Latvia	0.700	73	41
	Puerto Rico	0.0	Sweden	18,688.0	Qatar	8.1	0	Estonia	98.0	Estonia	95.0	Malta	48.0	Lithuania	0.720	73	42
	Slovakia	0.0	Finland	20,592.0	Antigua and Barbuda	8.1	0	Trinidad and Tobago	94.0	Trinidad and Tobago	92.0	Oman	37.4	Hungary	0.700	72	43
	Equatorial Guinea	0.0	Brunei Darussalam	21,684.0	Saint Kitts and Nevis	8.1	0	Lithuania	92.0	Equatorial Guinea	89.0	Cyprus	30.0	Bahrain	0.590	70	44
	Croatia	0.0	Australia	22,464.0	Latvia	8.9	0	Saudi Arabia	90.0	Lithuania	86.0	Croatia	27.3	Croatia	0.620	70	45
	Latvia	0.0	Croatia	23,917.0	Oman	9.4	1	Oman	89.0	Latvia	78.0	Trinidad and Tobago	25.2	Oman	0.590	69	46
	Monaco		Equatorial Guinea	38,179.0	Saudi Arabia	9.9	2	Equatorial Guinea	51.0	Liechtenstein		Qatar	14.9	Greece	0.520	68	47
	Liechtenstein		New Zealand	75,642.0	Bahrain	10.2	0	Liechtenstein		San Marino		Saint Kitts and Nevis	13.4	Italy	0.510	67	48
	San Marino		Norway	79,024.0	Kuwait	11.0	1	San Marino		Italy		Libyan Arab Jamahiriya	7.1	Antigua and Barbuda	0.490	67	49
	Andorra		Canada	86,177.0	Bahamas	16.2	0	Brunei Darussalam		Brunei Darussalam		Equatorial Guinea	0.0	Puerto Rico	0.340	65	50
	Singapore		Iceland	537,975.0	Libyan Arab Jamahiriya	17.0	1	China, Macao SAR		China, Macao SAR		Liechtenstein		Trinidad and Tobago	0.250	64	51
	Brunei Darussalam		Greenland	10,578,947.0	Trinidad and Tobago	28.0	0	China, Hong Kong SAR		China, Hong Kong SAR		San Marino		Kuwait	0.100	59	52
	China, Macao SAR		Monaco		Equatorial Guinea	122.0	7	Bahamas		New Zealand		Brunei Darussalam		Saudi Arabia	-0.080	53	53
	China, Hong Kong SAR		Liechtenstein		China, Macao SAR			Bahrain		Bahrain		China, Macao SAR		Libyan Arab Jamahiriya	-1.200	10	54
	Bahrain		San Marino		China, Hong Kong SAR			Puerto Rico		Saudi Arabia		Saudi Arabia		Equatorial Guinea	-1.680	2	55
	Antigua and Barbuda		China, Macao SAR		Greenland			Antigua and Barbuda		Puerto Rico		Puerto Rico		Monaco			56
	Saint Kitts and Nevis		China, Hong Kong SAR		Puerto Rico			Libyan Arab Jamahiriya		Antigua and Barbuda		Antigua and Barbuda		San Marino			57

LEVEL OF ECONOMIC DEVELOPMENT	SITUATION OF WATER SCARCITY/STRESS				HEALTH PERFORMANCE ASSOCIATED WITH DEFICIENT HYGIENE, SANITATION AND WATER SUPPLY			HOW CLOSE TO REACH MDG TARGETS ON WATER & SANITATION: SOCIAL PERFORMANCE				EFFORTS TO REDUCE POLLUTION LOADS FROM CITIES: ENVIRONMENTAL SUSTAINABILITY		QUALITY OF PUBLIC SERVICES, CIVIL SERVICE AND POLICY: GOVERNANCE			POSITION IN THE RANK
GROUP	1. Water Stress Index (%)		2. Water Availability Index (m3/cap.yr)		3. Mortality rate, under-5 (per 1,000 live births)		Death due to Diarrhoea, under-5 (%)	4. Population using Improved Drinking Water Sources (%)		5. Population using Improved Sanitation Facilities (%)		6. Population connected to wastewater treatment (%)		7. Government effectiveness (percentile)			
	from high to low stress	year 2010	from low to high availability	year 2009	from low to high mortality rate	year 2010	year 2010	from high to low coverage	year 2010	from high to low coverage	year 2010	from high to low coverage	last year available	from high to low effectiveness	estimate, year 2010	percentile	
upper-middle income countries: 3,856 < GNI < 11,905 USD/cap (2008)	South Africa	54.8	Maldives	96.0	Cuba	5.9	2	Barbados	100.0	Barbados	100.0	Barbados	100.0	Barbados	1.410	89	1
	Namibia	52.0	Barbados	293.0	Poland	6.1	0	Turkey	100.0	Uruguay	100.0	Belarus	94.9	Chile	1.180	84	2
	Tunisia	51.9	Algeria	334.0	Belarus	6.1	1	Uruguay	100.0	Palau	100.0	Chile	83.3	Malaysia	1.100	82	3
	Bulgaria	36.5	Tunisia	443.0	Malaysia	6.8	2	Malaysia	100.0	Bulgaria	100.0	Uruguay	77.0	Saint Lucia	0.810	77	4
	Mexico	31.5	South Africa	1,005.0	Serbia	7.4	0	Lebanon	100.0	Iran	100.0	Poland	64.0	Mauritius	0.760	76	5
	Azerbaijan	31.4	Lebanon	1,073.0	Montenegro	7.6	0	Bulgaria	100.0	Lebanon	98.0	Bosnia and Herzegovina	62.7	Saint Vincent and the Grenadines	0.720	74	6
	Botswana	30.6	Poland	1,610.0	Bosnia and Herzegovina	7.9	1	Belarus	100.0	Grenada	97.0	Montenegro	59.4	Poland	0.700	72	7
	Cuba	28.7	Iran	1,880.0	Chile	8.8	1	TFYR Macedonia	100.0	Kazakhstan	97.0	South Africa	57.0	Uruguay	0.650	71	8
	Iran	25.3	Mauritius	2,129.0	Lebanon	9.9	4	Mauritius	99.0	Maldives	97.0	Panama	55.0	Dominica	0.660	71	9
	Algeria	24.5	Dominican Republic	2,144.0	Costa Rica	10.1	1	Serbia	99.0	Chile	96.0	Algeria	53.0	Botswana	0.520	68	10
	Argentina	24.1	Bulgaria	2,824.0	TFYR Macedonia	10.2	3	Bosnia and Herzegovina	99.0	Malaysia	96.0	Tunisia	52.5	Turkey	0.350	66	11
	Dominican Republic	20.4	Turkey	2,973.0	Uruguay	10.8	2	Brazil	98.0	Costa Rica	95.0	Russian Federation	46.2	South Africa	0.380	66	12
	Kazakhstan	20.1	TFYR Macedonia	3,111.0	Dominica	12.1	0	Montenegro	98.0	Bosnia and Herzegovina	95.0	Turkey	46.0	Costa Rica	0.320	65	13
	Romania	17.2	Cuba	3,385.0	Maldives	12.4	3	Maldives	98.0	Algeria	95.0	Bulgaria	45.0	Jamaica	0.180	63	14
	Peru	16.7	Jamaica	3,443.0	Russian Federation	12.5	1	Tuvalu	98.0	Belarus	93.0	Argentina	42.5	Tunisia	0.190	63	15
	Chile	16.5	Azerbaijan	3,825.0	Bulgaria	12.7	1	Fiji	98.0	Serbia	92.0	Iran	40.0	Seychelles	0.170	62	16
	Turkey	13.9	Mexico	4,081.0	Grenada	13.1	0	Russian Federation	97.0	Venezuela	91.0	Mexico	35.0	Grenada	0.170	62	17
	Lebanon	10.0	Belarus	6,019.0	Romania	13.6	0	Costa Rica	97.0	Cuba	91.0	Kazakhstan	34.0	Mexico	0.170	61	18
	Venezuela	9.7	Botswana	6,176.0	Seychelles	13.9	1	Chile	96.0	Poland	90.0	Maldives	34.0	Colombia	0.140	61	19
	Poland	5.6	Kazakhstan	6,919.0	Argentina	14.5	2	Mexico	96.0	Turkey	90.0	Malaysia	33.6	Panama	0.140	60	20
	Colombia	2.8	Namibia	7,904.0	Mauritius	15.2	0	Argentina	96.0	Argentina	90.0	Azerbaijan	31.4	Namibia	0.090	59	21
	Panama	2.6	Romania	9,839.0	Venezuela	15.6	7	Botswana	96.0	Montenegro	90.0	Saint Lucia	29.9	Montenegro	0.080	58	22
	Brazil	2.3	Bosnia and Herzegovina	9,952.0	Saint Lucia	15.8	3	Saint Lucia	96.0	Mauritius	89.0	Romania	29.0	Brazil	0.070	57	23
	Russian Federation	2.1	Serbia	19,863.0	Turkey	16.3	1	Iran	96.0	TFYR Macedonia	88.0	Brazil	26.0	Bulgaria	0.010	56	24
	Belarus	1.8	Argentina	20,319.0	Mexico	16.6	4	Dominica	95.0	Mexico	85.0	Mauritius	25.0	Suriname	-0.090	52	25
	Serbia	1.6	Malaysia	20,752.0	Brazil	16.8	3	Kazakhstan	95.0	Tuvalu	85.0	Cuba	24.0	Serbia	-0.100	52	26
	Malaysia	0.7	Costa Rica	24,483.0	Fiji	17.1	4	Cuba	94.0	Tunisia	85.0	Venezuela	23.8	Romania	-0.150	50	27
	Uruguay	0.0	Russian Federation	31,510.0	Tunisia	17.2	3	Tunisia	94.0	Suriname	83.0	Serbia	19.0	TFYR Macedonia	-0.160	49	28
	Gabon	0.0	Fiji	33,509.0	Colombia	18.3	4	Panama	93.0	Dominican Republic	83.0	Peru	15.6	Argentina	-0.210	47	29
	Mauritius	0.0	Uruguay	41,406.0	Jamaica	19.0	4	Jamaica	93.0	Fiji	83.0	Dominica	13.0	Peru	-0.210	47	30
	Suriname	0.0	Brazil	42,604.0	Palau	19.1	2	Namibia	93.0	Azerbaijan	82.0	Dominican Republic	12.0	Maldives	-0.220	46	31
	Costa Rica	0.0	Panama	42,750.0	Barbados	19.3	0	Suriname	92.0	Dominica	81.0	Jamaica	11.2	Cuba	-0.240	46	32
	Jamaica	0.0	Venezuela	43,233.0	Peru	19.4	4	Colombia	92.0	Jamaica	80.0	Colombia	8.5	Kazakhstan	-0.280	44	33
	Bosnia and Herzegovina	0.0	Colombia	46,699.0	Panama	20.0	11	South Africa	91.0	Brazil	79.0	TFYR Macedonia	7.0	Lebanon	-0.350	43	34
	TFYR Macedonia	0.0	Chile	54,376.0	Saint Vincent and the Grenadines	21.2	0	Romania	89.0	South Africa	79.0	Costa Rica	2.4	Russian Federation	-0.400	42	35
	Fiji	0.0	Peru	66,504.0	Dominican Republic	25.7	4	Gabon	87.0	Colombia	77.0	Lebanon	1.3	Tuvalu	-0.490	38	36
	Barbados		Gabon	110,961.0	Iran	26.2	4	Dominican Republic	86.0	Romania	73.0	Suriname	0.8	Iran	-0.500	38	37
	Seychelles		Suriname	234,615.0	Botswana	27.5	6	Palau	85.0	Peru	71.0	Gabon	0.0	Algeria	-0.560	33	38
	Grenada		Seychelles		Kazakhstan	29.2	6	Peru	85.0	Russian Federation	70.0	Grenada	0.0	Dominican Republic	-0.630	32	39
	Palau		Grenada		Suriname	29.8	3	Algeria	83.0	Saint Lucia	65.0	Botswana	0.0	Bosnia and Herzegovina	-0.730	28	40
	Dominica		Palau		Tuvalu	31.1	1	Azerbaijan	80.0	Botswana	62.0	Namibia	0.0	Fiji	-0.730	27	41
	Montenegro		Dominica		Algeria	31.3	5	Poland		Gabon	33.0	Seychelles		Azerbaijan	-0.830	22	42
	Saint Lucia		Montenegro		Namibia	45.9	5	Seychelles		Namibia	32.0	Palau		Gabon	-0.850	21	43
	Saint Vincent and the Grenadines		Saint Lucia		Azerbaijan	46.4	8	Venezuela		Seychelles		Saint Vincent and the Grenadines		Palau	-0.870	20	44
	Maldives		Saint Vincent and the Grenadines		South Africa	52.6	5	Grenada		Panama		Tuvalu		Venezuela	-1.020	15	45
	Tuvalu		Tuvalu		Gabon	67.4	7	Saint Vincent and the Grenadines		Saint Vincent and the Grenadines		Fiji		Belarus	-1.130	12	46

LEVEL OF ECONOMIC DEVELOPMENT	SITUATION OF WATER SCARCITY/STRESS				HEALTH PERFORMANCE ASSOCIATED WITH DEFICIENT HYGIENE, SANITATION AND WATER SUPPLY			HOW CLOSE TO REACH MDG TARGETS ON WATER & SANITATION: SOCIAL PERFORMANCE				EFFORTS TO REDUCE POLLUTION LOADS FROM CITIES: ENVIRONMENTAL SUSTAINABILITY		QUALITY OF PUBLIC SERVICES, CIVIL SERVICE AND POLICY: GOVERNANCE			POSITION IN THE RANK
GROUP	1. Water Stress Index (%)		2. Water Availability Index (m3/cap.yr)		3. Mortality rate, under-5 (per 1,000 live births)		Death due to Diarrhoea, under-5 (%)	4. Population using Improved Drinking Water Sources (%)		5. Population using Improved Sanitation Facilities (%)		6. Population connected to wastewater treatment (%)		7. Government effectiveness (percentile)			
	from high to low stress	year 2010	from low to high availability	year 2009	from low to high mortality rate	year 2010	year 2010	from high to low coverage	year 2010	from high to low coverage	year 2010	from high to low coverage	last year available	from high to low effectiveness	estimate, year 2010	percentile	
lower-middle income countries: 3,855 < GNI < 976 USD/cap (2008)	Jordan	75.0	Timor-Leste	0.0	Ukraine	10.7	2	Tonga	100.0	Jordan	98.0	Morocco	80.0	Bhutan	0.570	69	1
	Armenia	68.6	Yemen	90.0	Sri Lanka	12.6	3	Egypt	99.0	Turkmenistan	98.0	Georgia	62.7	Georgia	0.290	64	2
	Yemen	55.9	Jordan	155.0	Thailand	12.8	3	Belize	98.0	Samoa	98.0	Ukraine	62.0	China	0.120	60	3
	Syrian Arab Republic	55.6	Djibouti	344.0	Vanuatu	13.7	3	Armenia	98.0	Thailand	96.0	Jordan	61.0	Thailand	0.080	58	4
	Republic of Moldova	54.7	Cape Verde	610.0	Albania	15.0	1	Ukraine	98.0	Tonga	96.0	Republic of Moldova	60.0	Jordan	0.080	57	5
	Morocco	47.6	Egypt	719.0	Tonga	15.7	3	Georgia	98.0	Georgia	95.0	Egypt	55.0	El Salvador	0.010	56	6
	India	33.5	Syrian Arab Republic	838.0	China	15.9	3	Jordan	97.0	Syrian Arab Republic	95.0	Syrian Arab Republic	38.1	India	-0.010	56	7
	Turkmenistan	27.9	Morocco	917.0	Syrian Arab Republic	15.9	7	Thailand	96.0	Egypt	95.0	Turkmenistan	34.3	Cape Verde	-0.020	55	8
	Iraq	26.0	Lesotho	1,406.0	El Salvador	16.3	5	Samoa	96.0	Albania	94.0	Armenia	34.3	Ghana	-0.040	54	9
	Egypt	25.5	Sudan	1,518.0	Republic of Moldova	16.6	0	Bhutan	96.0	Ukraine	94.0	Thailand	33.6	Samoa	-0.050	53	10
	Ukraine	24.2	India	1,582.0	Belize	17.6	10	Republic of Moldova	96.0	Ecuador	92.0	China	32.5	Guyana	-0.140	51	11
	Djibouti	23.6	Nigeria	1,853.0	Armenia	18.3	1	Albania	95.0	Sri Lanka	92.0	Sri Lanka	32.2	Philippines	-0.100	51	12
	Paraguay	23.5	China	2,080.0	Samoa	18.9	3	Marshall Islands	94.0	Belize	90.0	Philippines	25.9	Armenia	-0.150	50	13
	China	19.6	Ghana	2,233.0	Jordan	21.1	4	Ecuador	94.0	Armenia	90.0	Iraq	25.7	Sri Lanka	-0.170	49	14
	Ecuador	19.2	Iraq	2,461.0	Georgia	21.5	1	Micronesia (Fed. States of)	94.0	El Salvador	87.0	Indonesia	18.9	Morocco	-0.170	48	15
	Sri Lanka	16.5	Armenia	2,518.0	Honduras	22.2	5	Guyana	94.0	Republic of Moldova	85.0	Mongolia	17.9	Indonesia	-0.190	48	16
	Mauritania	15.8	Sri Lanka	2,555.0	Solomon Islands	22.2	5	Guatemala	92.0	Guyana	84.0	Nicaragua	17.7	Albania	-0.270	45	17
	Senegal	13.4	Ukraine	3,054.0	Cape Verde	22.5	8	Philippines	92.0	Guatemala	78.0	Timor-Leste	16.5	Vanuatu	-0.270	45	18
	Mongolia	11.3	Senegal	3,205.0	Egypt	22.5	7	India	92.0	Honduras	77.0	Bhutan	15.4	Lesotho	-0.320	44	19
	Sudan	10.7	Republic of Moldova	3,233.0	Paraguay	23.4	5	China	91.0	Marshall Islands	75.0	Belize	15.1	Tonga	-0.330	43	20
	Thailand	8.8	Mauritania	3,375.0	Ecuador	23.6	4	Sri Lanka	91.0	Philippines	74.0	India	11.9	Egypt	-0.430	41	21
	Georgia	7.0	Swaziland	3,861.0	Philippines	26.4	6	Vanuatu	90.0	Iraq	73.0	Bolivia	8.1	Belize	-0.440	40	22
	Angola	5.5	El Salvador	4,096.0	Nicaragua	27.0	9	Syrian Arab Republic	90.0	Paraguay	71.0	Albania	7.3	Bolivia	-0.450	39	23
	Nigeria	4.7	Côte d'Ivoire	4,193.0	Marshall Islands	27.7	6	Sao Tome and Principe	89.0	Morocco	70.0	Paraguay	5.7	Senegal	-0.490	39	24
	Swaziland	4.0	Turkmenistan	4,964.0	Guatemala	31.6	7	El Salvador	88.0	China	64.0	Ecuador	4.6	Swaziland	-0.520	36	25
	Philippines	3.0	Philippines	5,223.0	Mongolia	33.0	7	Cape Verde	88.0	Cape Verde	61.0	Yemen	3.3	Syrian Arab Republic	-0.550	34	26
	Honduras	2.3	Thailand	6,384.0	Indonesia	33.3	5	Bolivia	88.0	Angola	58.0	Honduras	2.3	Mongolia	-0.610	32	27
	Bolivia	2.1	Guatemala	7,931.0	Morocco	34.3	6	Djibouti	88.0	Swaziland	57.0	El Salvador	1.7	Republic of Moldova	-0.630	31	28
	Côte d'Ivoire	1.8	Angola	7,976.0	Guyana	37.0	3	Honduras	87.0	Vanuatu	57.0	Ghana	1.1	Honduras	-0.670	30	29
	Papua New Guinea	1.8	Indonesia	8,504.0	Iraq	38.6	6	Paraguay	86.0	Indonesia	54.0	Guatemala	0.8	Ecuador	-0.670	29	30
	Indonesia	0.2	Mongolia	12,832.0	Micronesia (Fed. States of)	42.0	6	Ghana	86.0	Yemen	53.0	Marshall Islands	0.0	Guatemala	-0.700	29	31
	Albania	0.0	Honduras	12,877.0	Kiribati	48.7	9	Nicaragua	85.0	Nicaragua	52.0	Angola	0.0	Papua New Guinea	-0.750	27	32
	Belize	0.0	Albania	13,060.0	Bolivia	52.9	9	Turkmenistan	84.0	Senegal	52.0	Swaziland	0.0	Ukraine	-0.780	25	33
	El Salvador	0.0	Sao Tome and Principe	13,374.0	Turkmenistan	54.0	8	Morocco	83.0	Mongolia	51.0	Cape Verde	0.0	Micronesia (Fed. States of)	-0.790	25	34
	Timor-Leste	0.0	Georgia	14,479.0	Bhutan	55.9	7	Indonesia	82.0	Djibouti	50.0	Guyana	0.0	Sao Tome and Principe	-0.810	23	35
	Guatemala	0.0	Cameroon	14,889.0	Timor-Leste	57.6	8	Mongolia	82.0	Cameroon	49.0	Congo, Rep	0.0	Kiribati	-0.850	21	36
	Guyana	0.0	Ecuador	29,757.0	Papua New Guinea	59.5	8	Côte d'Ivoire	80.0	Timor-Leste	47.0	Djibouti	0.0	Cameroon	-0.880	19	37
	Congo, Rep	0.0	Nicaragua	34,431.0	India	63.4	13	Iraq	79.0	Papua New Guinea	45.0	Nigeria	0.0	Paraguay	-0.920	18	38
	Bhutan	0.0	Paraguay	52,980.0	Senegal	69.1	9	Lesotho	78.0	Bhutan	44.0	Cameroon	0.0	Mauritania	-0.930	18	39
	Cameroon	0.0	Belize	60,820.0	Yemen	78.5	11	Cameroon	77.0	Kiribati	34.0	Mauritania	0.0	Solomon Islands	-0.940	17	40
	Nicaragua	0.0	Bolivia	63,696.0	Ghana	79.6	7	Senegal	72.0	India	34.0	Côte d'Ivoire	0.0	Djibouti	-0.990	16	41
	Lesotho	0.0	Solomon Islands	85,305.0	Sudan	87.7	12	Swaziland	71.0	Nigeria	31.0	Lesotho	0.0	Nicaragua	-0.960	16	42
	Solomon Islands	0.0	Bhutan	109,244.0	Sao Tome and Principe	89.1	11	Congo, Rep	71.0	Bolivia	27.0	Sao Tome and Principe	0.0	Yemen	-1.030	14	43
	Ghana	0.0	Papua New Guinea	119,499.0	Djibouti	91.2	11	Solomon Islands	70.0	Sudan	26.0	Senegal	0.0	Angola	-1.120	12	44
	Marshall Islands		Congo, Rep	211,114.0	Lesotho	93.0	7	Timor-Leste	69.0	Mauritania	26.0	Tonga		Nigeria	-1.180	11	45
	Tonga		Guyana	320,053.0	Congo, Rep	99.6	7	Kiribati	63.0	Lesotho	26.0	Samoa		Timor-Leste	-1.210	10	46
	Cape Verde		Marshall Islands		Swaziland	109.2	7	Nigeria	58.0	Sao Tome and Principe	26.0	Micronesia (Fed. States of)		Iraq	-1.220	9	47
	Samoa		Tonga		Mauritania	112.9	11	Sudan	58.0	Côte d'Ivoire	24.0	Vanuatu		Congo, Rep	-1.230	9	48
	Micronesia (Fed. States of)		Samoa		Côte d'Ivoire	116.7	9	Yemen	55.0	Congo, Rep	18.0	Kiribati		Marshall Islands	-1.270	8	49
	Vanuatu		Micronesia (Fed. States of)		Cameroon	128.9	13	Angola	51.0	Ghana	14.0	Sudan		Sudan	-1.370	7	50
	Kiribati		Vanuatu		Nigeria	129.2	11	Mauritania	50.0	Micronesia (Fed. States of)		Papua New Guinea		Côte d'Ivoire	-1.330	7	51
	Sao Tome and Principe		Kiribati		Angola	161.0	15	Papua New Guinea	40.0	Solomon Islands		Solomon Islands		Turkmenistan	-1.580	3	52

LEVEL OF ECONOMIC DEVELOPMENT	SITUATION OF WATER SCARCITY/STRESS				HEALTH PERFORMANCE ASSOCIATED WITH DEFICIENT HYGIENE, SANITATION AND WATER SUPPLY			HOW CLOSE TO REACH MDG TARGETS ON WATER & SANITATION: SOCIAL PERFORMANCE				EFFORTS TO REDUCE POLLUTION LOADS FROM CITIES: ENVIRONMENTAL SUSTAINABILITY		QUALITY OF PUBLIC SERVICES, CIVIL SERVICE AND POLICY: GOVERNANCE			POSITION IN THE RANK
GROUP	1. Water Stress Index (%)		2. Water Availability Index (m3/cap.yr)		3. Mortality rate, under-5 (per 1,000 live births)		Death due to Diarrhoea, under-5 (%)	4. Population using Improved Drinking Water Sources (%)		5. Population using Improved Sanitation Facilities (%)		6. Population connected to wastewater treatment (%)		7. Government effectiveness (percentile)			
	from high to low stress	year 2010	from low to high availability	year 2009	from low to high mortality rate	year 2010	year 2010	from high to low coverage	year 2010	from high to low coverage	year 2010	from high to low coverage	last year available	from high to low effectiveness	estimate, year 2010	percentile	
low income countries: GNI < 975 USD/cap (2008)	Uzbekistan	42.1	Kenya	778.0	Vietnam	22.6	10	Vietnam	95.0	Uzbekistan	100.0	Uzbekistan	35.0	Rwanda	-0.050	54	1
	Pakistan	33.4	Burkina Faso	782.0	Kyrgyzstan	31.7	6	Comoros	95.0	Tajikistan	94.0	Tajikistan	32.9	Vietnam	-0.310	44	2
	Niger	28.7	Rwanda	921.0	Lao, PDR	43.9	10	Pakistan	92.0	Kyrgyzstan	93.0	Kyrgyzstan	32.6	Ethiopia	-0.350	42	3
	Kyrgyzstan	20.5	Malawi	1,197.0	Cambodia	46.0	8	Kyrgyzstan	90.0	Vietnam	76.0	Vietnam	26.6	Malawi	-0.430	40	4
	Zimbabwe	20.4	Eritrea	1,236.0	Bangladesh	48.7	6	Gambia	89.0	Gambia	68.0	Lao, PDR	22.1	Benin	-0.500	37	5
	Ethiopia	18.2	Pakistan	1,354.0	Uzbekistan	49.6	7	Nepal	89.0	Lao, PDR	63.0	Comoros	19.8	United Republic of Tanzania	-0.500	37	6
	Chad	16.4	Haiti	1,422.0	Nepal	50.3	6	Uzbekistan	87.0	Bangladesh	56.0	Zimbabwe	19.7	Uganda	-0.520	36	7
	Tajikistan	14.0	Ethiopia	1,503.0	Rwanda	60.4	12	Malawi	83.0	Rwanda	55.0	Bangladesh	19.6	Kenya	-0.530	35	8
	Malawi	13.9	Burundi	1,535.0	Madagascar	64.3	10	Bangladesh	81.0	Malawi	51.0	Pakistan	16.8	Mozambique	-0.520	35	9
	Kenya	13.9	Zimbabwe	1,603.0	Tajikistan	66.1	9	Zimbabwe	80.0	Zambia	48.0	Afghanistan	13.0	Burkina Faso	-0.540	34	10
	Mali	13.5	Comoros	1,676.0	Eritrea	69.8	11	Burkina Faso	79.0	Pakistan	48.0	Guinea	11.0	Kyrgyzstan	-0.630	31	11
	Mozambique	13.4	Uzbekistan	1,858.0	Zimbabwe	72.4	8	Benin	75.0	Burundi	46.0	Cambodia	10.9	Gambia	-0.670	30	12
	Burkina Faso	12.2	Uganda	2,039.0	United Republic of Tanzania	72.5	9	Guinea	74.0	Zimbabwe	40.0	Nepal	10.9	Niger	-0.710	28	13
	Madagascar	11.9	Afghanistan	2,126.0	Pakistan	73.7	11	Liberia	73.0	Afghanistan	37.0	Kenya	4.9	Pakistan	-0.770	26	14
	Afghanistan	11.3	United Republic of Tanzania	2,212.0	Kenya	76.1	9	Uganda	72.0	Comoros	36.0	Zambia	0.0	Nepal	-0.770	26	15
	United Republic of Tanzania	10.8	Niger	2,248.0	Comoros	81.3	9	Burundi	72.0	Central African Republic	34.0	Benin	0.0	Zambia	-0.800	24	16
	Bangladesh	8.8	Tajikistan	2,356.0	Ethiopia	81.5	14	Haiti	69.0	Uganda	34.0	Haiti	0.0	Uzbekistan	-0.800	24	17
	Vietnam	3.0	Togo	2,491.0	Liberia	83.1	9	Lao, PDR	67.0	Kenya	32.0	Chad	0.0	Cambodia	-0.820	23	18
	Haiti	1.6	Benin	3,068.0	Malawi	89.0	7	Central African Republic	67.0	Cambodia	31.0	Gambia	0.0	Bangladesh	-0.840	22	19
	Uganda	1.4	Chad	3,932.0	Zambia	90.4	9	Rwanda	65.0	Nepal	31.0	Mali	0.0	Madagascar	-0.840	22	20
	Nepal	0.9	Kyrgyzstan	4,379.0	Uganda	94.2	10	Tajikistan	64.0	Democratic Republic of the Congo	24.0	Guinea-Bissau	0.0	Mali	-0.870	20	21
	Central African Republic	0.5	Gambia	4,756.0	Gambia	102.6	9	Cambodia	64.0	Mali	22.0	Burkina Faso	0.0	Tajikistan	-0.900	19	22
	Zambia	0.1	Mali	6,707.0	Afghanistan	103.9	16	Mali	64.0	Ethiopia	21.0	Togo	0.0	Lao, PDR	-0.940	17	23
	Lao, PDR	0.0	Nepal	7,142.0	Mozambique	108.4	9	Guinea-Bissau	64.0	Guinea-Bissau	20.0	United Republic of Tanzania	0.0	Guinea-Bissau	-1.040	13	24
	Benin	0.0	Zambia	8,268.0	Benin	108.8	10	Zambia	61.0	Mozambique	18.0	Rwanda	0.0	Burundi	-1.090	13	25
	Cambodia	0.0	Bangladesh	8,345.0	Togo	111.7	10	Togo	61.0	Guinea	18.0	Central African Republic	0.0	Guinea	-1.150	11	26
	Gambia	0.0	Mozambique	9,497.0	Guinea	129.8	10	Eritrea	60.0	Liberia	18.0	Uganda	0.0	Sierra Leone	-1.190	11	27
	Guinea-Bissau	0.0	Vietnam	10,174.0	Niger	130.9	14	Kenya	59.0	Haiti	17.0	Madagascar	0.0	Liberia	-1.250	8	28
	Togo	0.0	Madagascar	16,746.0	Burundi	141.7	15	Sierra Leone	55.0	Burkina Faso	17.0	Mozambique	0.0	Togo	-1.380	6	29
	Rwanda	0.0	Democratic Republic of the Congo	19,983.0	Burkina Faso	148.8	12	United Republic of Tanzania	53.0	Madagascar	15.0	Niger	0.0	Eritrea	-1.370	6	30
	Guinea	0.0	Guinea-Bissau	20,889.0	Haiti	160.7	7	Chad	51.0	Benin	13.0	Sierra Leone	0.0	Central African Republic	-1.460	5	31
	Sierra Leone	0.0	Guinea	23,153.0	Guinea-Bissau	161.7	12	Afghanistan	50.0	Chad	13.0	Ethiopia	0.0	Afghanistan	-1.470	5	32
	Eritrea	0.0	Sierra Leone	27,879.0	Central African Republic	164.6	11	Niger	49.0	Togo	13.0	Malawi	0.0	Chad	-1.500	4	33
	Burundi	0.0	Central African Republic	33,441.0	Democratic Republic of the Congo	169.9	13	Mozambique	47.0	Sierra Leone	13.0	Eritrea	0.0	Zimbabwe	-1.540	4	34
	Liberia	0.0	Cambodia	34,061.0	Chad	171.3	14	Madagascar	46.0	Eritrea	13.0	Burundi	0.0	Haiti	-1.610	3	35
	Democratic Republic of the Congo	0.0	Lao, PDR	54,565.0	Mali	178.9	14	Democratic Republic of the Congo	45.0	United Republic of Tanzania	10.0	Liberia	0.0	Comoros	-1.730	1	36
	Comoros		Liberia	60,480.0	Sierra Leone	188.8	12	Ethiopia	44.0	Niger	9.0	Democratic Republic of the Congo	0.0	Democratic Republic of the Congo	-1.720	1	37

Annex 2 – Countries ranked according to thresholds set up for each indicator

COUNTRY	Water Stress Index		Water Availability Index		Mortality rate, under 5		Improved Water		Improved Sanitation		Connexion to WWTP		Government Effectiveness		The country faces water stress at territory level	The country faces water scarcity at per capita level	The country reduced the mortality rate - MDG4	The country increased the proportion of people with access to safe drinking water - MDG7c	The country increased the proportion of people with access to basic sanitation - MDG7c	The country addresses water pollution by treating wastewater in treatment plants	The country has strong government effectiveness
	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	(> 40 %)	(<1,000 m3/cap.yr)	(< 29 per 1,000 live births)	(>88%)	(>75%)	(>50%)	(> 0.6 ~ 70 percentile)
Andorra	no data	no data	0	100	3.5	95	100.0	90	100.0	90	98.0	99	1.5	19	no data	yes	yes	yes	yes	yes	yes
Antigua and Barbuda	no data	no data	591	94	8.1	72	no data	no data	no data	no data	no data	no data	0.5	49	no data	yes	yes	no data	no data	no data	no
Australia	45.7	98	22464	70	4.7	83	100.0	92	100.0	92	90.0	93	1.8	10	yes	no	yes	yes	yes	yes	yes
Austria	0.0	78	9283	78	4.3	89	100.0	95	100.0	94	93.0	95	1.9	6	no	no	yes	yes	yes	yes	yes
Bahamas	0.0	77	59	98	16.2	65	no data	no data	100.0	87	80.0	88	1.1	30	no	yes	yes	no data	yes	yes	yes
Bahrain	no data	no data	99	97	10.2	67	no data	no data	no data	no data	88.0	92	0.6	44	no data	yes	yes	no data	no data	yes	no
Belgium	49.8	99	1717	91	4.4	88	100.0	93	100.0	93	69.0	79	1.6	16	yes	no	yes	yes	yes	yes	yes
Brunei Darussalam	no data	no data	21684	70	7.4	76	no data	no data	no data	no data	no data	no data	0.9	36	no data	no	yes	no data	no data	no data	yes
Canada	1.7	87	86177	65	5.6	80	100.0	93	100.0	93	71.7	81	1.9	7	no	no	yes	yes	yes	yes	yes
China, Hong Kong SAR	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	93.2	96	1.7	12	no data	no data	no data	no data	no data	yes	yes
China, Macao SAR	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	1.3	25	no data	no data	no data	no data	no data	no data	yes
Croatia	0.0	70	23917	69	5.3	81	99.0	77	99.0	78	27.3	70	0.6	45	no	no	yes	yes	yes	no	yes
Cyprus	0.0	78	716	93	3.4	95	100.0	85	100.0	88	30.0	70	1.5	21	no	yes	yes	yes	yes	no	yes
Czech Republic	2.6	89	1260	92	4.1	91	100.0	81	98.0	76	76.0	82	1.0	33	no	no	yes	yes	yes	yes	yes
Denmark	2.3	88	1086	93	3.9	94	100.0	98	100.0	98	87.9	92	2.2	3	no	no	yes	yes	yes	yes	yes
Equatorial Guinea	0.0	70	38179	68	122.0	53	51.0	68	89.0	70	0.0	65	-1.7	55	no	no	no	no	yes	no	no
Estonia	2.5	88	9545	78	4.1	90	98.0	73	95.0	73	80.0	87	1.2	27	no	no	yes	yes	yes	yes	yes
Finland	0.4	83	20592	72	3.0	98	100.0	96	100.0	96	81.0	89	2.2	1	no	no	yes	yes	yes	yes	yes
France	8.4	91	3379	87	4.2	89	100.0	91	100.0	91	80.0	89	1.4	22	no	no	yes	yes	yes	yes	yes
Germany	15.9	93	1869	90	4.1	92	100.0	92	100.0	92	95.0	96	1.6	18	no	no	yes	yes	yes	yes	yes
Greece	4.5	89	6555	81	4.6	84	100.0	84	98.0	77	87.0	91	0.5	47	no	no	yes	yes	yes	yes	no
Greenland	0.0	78	10578947	59	no data	no data	100.0	88	100.0	88	90.0	93	1.0	37	no	no	no data	yes	yes	yes	yes
Hungary	24.5	96	10398	77	6.6	78	100.0	80	100.0	80	57.0	74	0.7	43	no	no	yes	yes	yes	yes	yes
Iceland	0.9	84	537975	64	2.6	99	100.0	95	100.0	95	57.0	77	1.6	15	no	no	yes	yes	yes	yes	yes
Ireland	0.0	79	11786	76	4.1	92	100.0	97	99.0	79	84.0	90	1.3	24	no	no	yes	yes	yes	yes	yes
Israel	75.3	100	245	95	4.5	85	100.0	83	100.0	85	91.0	94	1.2	26	yes	yes	yes	yes	yes	yes	yes
Italy	17.7	94	3175	88	3.9	93	100.0	89	no data	no data	69.0	78	0.5	48	no	no	yes	yes	no data	yes	no
Japan	5.6	90	3398	85	3.2	96	100.0	90	100.0	90	67.0	78	1.4	23	no	no	yes	yes	yes	yes	yes
Kuwait	90.6	100	8	100	11.0	67	99.0	79	100.0	97	95.6	97	0.1	52	yes	yes	yes	yes	yes	yes	no
Latvia	0.0	69	15679	74	8.9	70	99.0	74	78.0	69	65.0	78	0.7	41	no	no	yes	yes	yes	yes	yes
Libyan Arab Jamahiriya	24.7	96	96	97	17.0	64	no data	no data	97.0	74	7.1	67	-1.2	54	no	yes	yes	no data	yes	no	no
Liechtenstein	no data	no data	no data	no data	2.1	100	no data	no data	no data	no data	no data	no data	1.8	11	no data	no data	yes	no data	no data	no data	yes
Lithuania	5.4	90	7453	80	6.2	78	92.0	70	86.0	70	71.0	81	0.7	42	no	no	yes	yes	yes	yes	yes
Luxembourg	0.0	81	6225	83	3.3	96	100.0	99	100.0	99	95.0	97	1.7	13	no	no	yes	yes	yes	yes	yes
Malta	0.0	74	122	96	6.1	78	100.0	82	100.0	81	48.0	73	1.2	29	no	yes	yes	yes	yes	no	yes
Monaco	no data	no data	no data	no data	4.0	93	100.0	100	100.0	100	100.0	100	no data	no data	no data	no data	yes	yes	yes	yes	no data
Netherlands	24.1	95	5496	84	4.2	90	100.0	96	100.0	96	99.0	99	1.7	14	no	no	yes	yes	yes	yes	yes
New Zealand	1.2	85	75642	67	6.0	79	100.0	87	no data	no data	80.0	88	1.9	8	no	no	yes	yes	no data	yes	yes
Norway	0.0	81	79024	67	3.2	97	100.0	100	100.0	100	79.0	85	1.8	9	no	no	yes	yes	yes	yes	yes
Oman	37.5	97	516	94	9.4	69	89.0	69	99.0	78	37.4	72	0.6	46	no	yes	yes	yes	yes	no	no
Portugal	10.0	93	6446	82	3.6	94	99.0	78	100.0	83	70.0	80	1.0	32	no	no	yes	yes	yes	yes	yes
Puerto Rico	0.0	73	1891	90	no data	no data	no data	no data	no data	no data	no data	no data	0.3	50	no	no	no data	no data	no data	no data	no
Qatar	19.3	94	36	99	8.1	73	100.0	99	100.0	99	14.9	68	0.9	35	no	yes	yes	yes	yes	no	yes
Republic of Korea	9.7	92	1453	92	4.9	82	98.0	73	100.0	82	78.8	84	1.2	28	no	no	yes	yes	yes	yes	yes
Saint Kitts and Nevis	no data	no data	462	95	8.1	70	99.0	76	96.0	73	13.4	67	0.7	40	no data	yes	yes	yes	yes	no	yes
San Marino	no data	no data	no data	no data	1.9	100	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	yes	no data	no data	no data	no data
Saudi Arabia	51.6	99	90	98	9.9	68	90.0	70	no data	no data	no data	no data	-0.1	53	yes	yes	yes	yes	no data	no data	no
Singapore	no data	no data	121	96	2.6	99	100.0	89	100.0	89	100.0	100	2.2	2	no data	yes	yes	yes	yes	yes	yes
Slovakia	0.0	72	9189	79	8.0	73	100.0	81	100.0	81	57.0	76	0.9	38	no	no	yes	yes	yes	yes	yes
Slovenia	0.0	76	15746	73	3.0	97	99.0	78	100.0	84	52.0	73	1.0	31	no	no	yes	yes	yes	yes	yes
Spain	37.1	97	2443	89	4.5	87	100.0	88	100.0	89	92.0	95	1.0	34	no	no	yes	yes	yes	yes	yes
Sweden	0.4	82	18688	73	2.9	98	100.0	97	100.0	97	86.0	90	2.0	4	no	no	yes	yes	yes	yes	yes
Switzerland	0.0	80	7020	81	4.5	88	100.0	98	100.0	98	97.0	98	1.9	5	no	no	yes	yes	yes	yes	yes
Trinidad and Tobago	0.0	73	2874	88	28.0	59	94.0	72	92.0	72	25.2	69	0.3	51	no	no	yes	yes	yes	no	no
United Arab Emirates	41.6	98	22	99	7.0	77	100.0	94	98.0	78	78.3	83	0.8	39	yes	yes	yes	yes	yes	yes	yes
United Kingdom	8.4	92	2375	89	5.3	81	100.0	94	100.0	94	97.5	98	1.6	17	no	no	yes	yes	yes	yes	yes
United States of America	21.3	95	9974	78	7.5	74	99.0	78	100.0	95	90.0	94	1.4	20	no	no	yes	yes	yes	yes	yes

COUNTRY	Water Stress Index		Water Availability Index		Mortality rate, under 5		Improved Water		Improved Sanitation		Connexion to WWTP		Government Effectiveness		The country faces water stress at territory level	The country faces water scarcity at per capita level	The country reduced the mortality rate - MDG4	The country increased the proportion of people with access to safe drinking water - MDG7c	The country increased the proportion of people with access to basic sanitation - MDG7c	The country addresses water pollution by treating wastewater in treatment plants	The country has strong government effectiveness
	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	(> 40 %)	(<1,000 m3/cap.yr)	(< 29 per 1,000 live births)	(>88%)	(>75%)	(>50%)	(> 0.6 ~ 70 percentile)
Algeria	24.5	68	334	82	31.3	22	83.0	28	95.0	63	53.0	68	-0.6	38	no	yes	no	no	yes	yes	no
Argentina	24.1	66	20319	52	14.5	60	96.0	59	90.0	59	42.5	63	-0.2	29	no	no	yes	yes	yes	no	no
Azerbaijan	31.4	74	3825	62	46.4	20	80.0	27	82.0	46	31.4	59	-0.8	42	no	no	no	no	yes	no	no
Barbados	no data	no data	293	84	19.3	46	100.0	89	100.0	89	100.0	89	1.4	1	no data	yes	yes	yes	yes	yes	yes
Belarus	1.8	52	6019	61	6.1	82	100.0	72	93.0	63	94.9	84	-1.1	46	no	no	yes	yes	yes	yes	no
Bosnia and Herzegovina	0.0	43	9952	57	7.9	72	99.0	66	95.0	65	62.7	74	-0.7	40	no	no	yes	yes	yes	yes	no
Botswana	30.6	72	6176	61	27.5	33	96.0	58	62.0	27	0.0	28	0.5	10	no	no	yes	yes	no	no	no
Brazil	2.3	57	42604	46	16.8	52	98.0	66	79.0	43	26.0	56	0.1	23	no	no	yes	yes	yes	no	no
Bulgaria	36.5	77	2824	66	12.7	62	100.0	74	100.0	77	45.0	63	0.0	24	no	no	yes	yes	yes	no	no
Chile	16.5	62	54376	42	8.8	71	96.0	61	96.0	68	83.3	82	1.2	2	no	no	yes	yes	yes	yes	yes
Colombia	2.8	59	46699	43	18.3	47	92.0	44	77.0	38	8.5	44	0.1	19	no	no	yes	yes	yes	no	no
Costa Rica	0.0	46	24483	50	10.1	68	97.0	61	95.0	66	2.4	42	0.3	13	no	no	yes	yes	yes	no	no
Cuba	28.7	71	3385	63	5.9	89	94.0	50	91.0	61	24.0	52	-0.2	32	no	no	yes	yes	yes	no	no
Dominica	no data	no data	no data	no data	12.1	65	95.0	52	81.0	46	13.0	47	0.7	9	no data	no data	yes	yes	yes	no	yes
Dominican Republic	20.4	66	2144	68	25.7	38	86.0	38	83.0	47	12.0	46	-0.6	39	no	no	yes	no	yes	no	no
Fiji	0.0	38	33509	47	17.1	50	98.0	62	83.0	47	no data	no data	-0.7	41	no	no	yes	yes	yes	no data	no
Gabon	0.0	47	110961	38	67.4	12	87.0	38	33.0	22	0.0	33	-0.9	43	no	no	no	no	no	no	no
Grenada	no data	no data	no data	no data	13.1	62	no data	no data	97.0	72	0.0	32	0.2	17	no data	no data	yes	no data	yes	no	no
Iran	25.3	71	1880	71	26.2	38	96.0	56	100.0	76	40.0	62	-0.5	37	no	no	yes	yes	yes	no	no
Jamaica	0.0	44	3443	63	19.0	47	93.0	47	80.0	44	11.2	46	0.2	14	no	no	yes	yes	yes	no	no
Kazakhstan	20.1	65	6919	60	29.2	32	95.0	52	97.0	71	34.0	61	-0.3	33	no	no	no	yes	yes	no	no
Lebanon	10.0	61	1073	74	9.9	71	100.0	76	98.0	74	1.3	38	-0.4	34	no	no	yes	yes	yes	no	no
Malaysia	0.7	50	20752	52	6.8	77	100.0	77	96.0	66	33.6	60	1.1	3	no	no	yes	yes	yes	no	yes
Maldives	no data	no data	96	89	12.4	63	98.0	63	97.0	71	34.0	61	-0.2	31	no data	yes	yes	yes	yes	no	no
Mauritius	0.0	47	2129	71	15.2	59	99.0	71	89.0	57	25.0	52	0.8	5	no	no	yes	yes	yes	no	yes
Mexico	31.5	76	4081	62	16.6	52	96.0	60	85.0	52	35.0	62	0.2	18	no	no	yes	yes	yes	no	no
Montenegro	no data	no data	no data	no data	7.6	74	98.0	65	90.0	58	59.4	72	0.1	22	no data	no data	yes	yes	yes	yes	no
Namibia	52.0	84	7904	59	45.9	21	93.0	46	32.0	21	0.0	27	0.1	21	yes	no	no	yes	no	no	no
Palau	no data	no data	no data	no data	19.1	46	85.0	33	100.0	82	no data	no data	-0.9	44	no data	no data	yes	no	yes	no data	no
Panama	2.6	58	42750	46	20.0	43	93.0	47	no data	no data	55.0	71	0.1	20	no	no	yes	yes	no data	yes	no
Peru	16.7	63	66504	38	19.4	44	85.0	32	71.0	33	15.6	47	-0.2	30	no	no	yes	no	no	no	no
Poland	5.6	60	1610	72	6.1	84	no data	no data	90.0	61	64.0	76	0.7	7	no	no	yes	no data	yes	yes	yes
Romania	17.2	63	9839	58	13.6	61	89.0	42	73.0	38	29.0	57	-0.2	27	no	no	yes	yes	no	no	no
Russian Federation	2.1	56	31510	49	12.5	63	97.0	62	70.0	32	46.2	66	-0.4	35	no	no	yes	yes	no	no	no
Saint Lucia	no data	no data	no data	no data	15.8	57	96.0	57	65.0	28	29.9	58	0.8	4	no data	no data	yes	yes	no	no	yes
Saint Vincent and the Grenadines	no data	no data	no data	no data	21.2	42	no data	no data	no data	no data	no data	no data	0.7	6	no data	no data	yes	no data	no data	no data	yes
Serbia	1.6	52	19863	56	7.4	76	99.0	68	92.0	62	19.0	49	-0.1	26	no	no	yes	yes	yes	no	no
Seychelles	no data	no data	no data	no data	13.9	61	no data	no data	no data	no data	no data	no data	0.2	16	no data	no data	yes	no data	no data	no data	no
South Africa	54.8	89	1005	76	52.6	15	91.0	43	79.0	42	57.0	71	0.4	12	yes	no	no	yes	yes	yes	no
Suriname	0.0	46	234615	33	29.8	28	92.0	46	83.0	49	0.8	38	-0.1	25	no	no	no	yes	yes	no	no
TFYR Macedonia	0.0	42	3111	65	10.2	66	100.0	71	88.0	56	7.0	43	-0.2	28	no	no	yes	yes	yes	no	no
Tunisia	51.9	82	443	77	17.2	49	94.0	49	85.0	50	52.5	66	0.2	15	yes	yes	yes	yes	yes	yes	no
Turkey	13.9	62	2973	66	16.3	56	100.0	84	90.0	60	46.0	65	0.4	11	no	no	yes	yes	yes	no	no
Tuvalu	no data	no data	no data	no data	31.1	27	98.0	63	85.0	52	no data	no data	-0.5	36	no data	no data	no	yes	yes	no data	no
Uruguay	0.0	49	41406	47	10.8	66	100.0	82	100.0	84	77.0	77	0.7	8	no	no	yes	yes	yes	yes	yes
Venezuela	9.7	61	43233	44	15.6	58	no data	no data	91.0	62	23.8	50	-1.0	45	no	no	yes	no data	yes	no	no

COUNTRY	Water Stress Index		Water Availability Index		Mortality rate, under 5		Improved Water		Improved Sanitation		Connexion to WWTP		Government Effectiveness		The country faces water stress at territory level	The country faces water scarcity at per capita level	The country reduced the mortality rate - MDG4	The country increased the proportion of people with access to safe drinking water - MDG7c	The country increased the proportion of people with access to basic sanitation - MDG7c	The country addresses water pollution by treating wastewater in treatment plants	The country has strong government effectiveness
	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	(> 40 %)	(<1,000 m3/cap.yr)	(< 29 per 1,000 live births)	(>88%)	(>75%)	(>50%)	(> 0.6 ~ 70 percentile)
Albania	0.0	27	13060	25	15.0	57	95.0	51	94.0	54	7.3	39	-0.3	17	no	no	yes	yes	yes	no	no
Angola	5.5	39	7976	30	161.0	3	51.0	7	58.0	32	0.0	27	-1.1	44	no	no	no	no	no	no	no
Armenia	68.6	64	2518	48	18.3	51	98.0	58	90.0	49	34.3	54	-0.2	13	yes	no	yes	yes	yes	no	no
Belize	0.0	25	60820	17	17.6	51	98.0	60	90.0	50	15.1	43	-0.4	22	no	no	yes	yes	yes	no	no
Bhutan	0.0	18	109244	14	55.9	23	96.0	53	44.0	18	15.4	44	0.6	1	no	no	no	yes	no	no	no
Bolivia	2.1	31	63696	16	52.9	25	88.0	32	27.0	14	8.1	40	-0.5	23	no	no	no	no	no	no	no
Cameroon	0.0	17	14889	21	128.9	7	77.0	17	49.0	21	0.0	18	-0.9	37	no	no	no	no	no	no	no
Cape Verde	no data	no data	610	57	22.5	45	88.0	34	61.0	34	0.0	25	0.0	8	no data	yes	yes	no	no	no	no
China	19.6	49	2080	50	15.9	56	91.0	43	64.0	36	32.5	51	0.1	3	no	no	yes	yes	no	no	no
Congo, Rep	0.0	18	211114	11	99.6	10	71.0	14	18.0	8	0.0	21	-1.2	48	no	no	no	no	no	no	no
Côte d'Ivoire	1.8	30	4193	39	116.7	8	80.0	19	24.0	9	0.0	16	-1.3	51	no	no	no	no	no	no	no
Djibouti	23.6	51	344	58	91.2	12	88.0	31	50.0	23	0.0	19	-1.0	41	no	yes	no	no	no	no	no
Ecuador	19.2	48	29757	19	23.6	41	94.0	49	92.0	51	4.6	36	-0.7	30	no	no	yes	yes	yes	no	no
Egypt	25.5	53	719	56	22.5	44	99.0	64	95.0	55	55.0	56	-0.4	21	no	yes	yes	yes	yes	yes	no
El Salvador	0.0	25	4096	39	16.3	54	88.0	36	87.0	48	1.7	31	0.0	6	no	no	yes	no	yes	no	no
Georgia	7.0	40	14479	23	21.5	48	98.0	56	95.0	56	62.7	64	0.3	2	no	no	yes	yes	yes	yes	no
Ghana	0.0	12	2233	49	79.6	16	86.0	29	14.0	7	1.1	30	0.0	9	no	no	no	no	no	no	no
Guatemala	0.0	21	7931	31	31.6	36	92.0	45	78.0	45	0.8	29	-0.7	31	no	no	no	yes	yes	no	no
Guyana	0.0	19	320053	10	37.0	30	94.0	48	84.0	45	0.0	23	-0.1	11	no	no	no	yes	yes	no	no
Honduras	2.3	32	12877	27	22.2	48	87.0	30	77.0	44	2.3	32	-0.7	29	no	no	yes	no	yes	no	no
India	33.5	56	1582	51	63.4	18	92.0	44	34.0	16	11.9	41	0.0	7	no	no	no	yes	no	no	no
Indonesia	0.2	29	8504	29	33.3	32	82.0	23	54.0	29	18.9	48	-0.2	16	no	no	no	no	no	no	no
Iraq	26.0	54	2461	48	38.6	29	79.0	18	73.0	40	25.7	49	-1.2	47	no	no	no	no	no	no	no
Jordan	75.0	69	155	60	21.1	49	97.0	56	98.0	69	61.0	58	0.1	5	yes	yes	yes	yes	yes	yes	no
Kiribati	no data	no data	no data	no data	48.7	27	63.0	10	34.0	17	no data	no data	-0.9	36	no data	no data	no	no	no	no data	no
Lesotho	0.0	16	1406	54	93.0	11	78.0	18	26.0	10	0.0	16	-0.3	19	no	no	no	no	no	no	no
Marshall Islands	no data	no data	no data	no data	27.7	39	94.0	50	75.0	43	0.0	29	-1.3	49	no data	no data	yes	yes	no	no	no
Mauritania	15.8	45	3375	41	112.9	9	50.0	7	26.0	11	0.0	17	-0.9	39	no	no	no	no	no	no	no
Micronesia (Fed. States of)	no data	no data	no data	no data	42.0	29	94.0	48	no data	no data	no data	no data	-0.8	34	no data	no data	no	yes	no data	no data	no
Mongolia	11.3	44	12832	29	33.0	34	82.0	21	51.0	25	17.9	48	-0.6	27	no	no	no	no	no	no	no
Morocco	47.6	56	917	55	34.3	31	83.0	25	70.0	39	80.0	69	-0.2	15	yes	yes	no	no	no	yes	no
Nicaragua	0.0	16	34431	18	27.0	39	85.0	27	52.0	27	17.7	45	-1.0	42	no	no	yes	no	no	no	no
Nigeria	4.7	39	1853	51	129.2	7	58.0	9	31.0	16	0.0	18	-1.2	45	no	no	no	no	no	no	no
Papua New Guinea	1.8	29	119499	12	59.5	19	40.0	3	45.0	18	no data	no data	-0.8	32	no	no	no	no	no	no data	no
Paraguay	23.5	50	52980	18	23.4	43	86.0	29	71.0	39	5.7	39	-0.9	38	no	no	yes	no	no	no	no
Philippines	3.0	34	5223	34	26.4	40	92.0	45	74.0	41	25.9	50	-0.1	12	no	no	yes	yes	no	no	no
Republic of Moldova	54.7	57	3233	43	16.6	53	96.0	51	85.0	48	60.0	57	-0.6	28	yes	no	yes	yes	yes	yes	no
Samoa	no data	no data	no data	no data	18.9	50	96.0	54	98.0	60	no data	no data	-0.1	10	no data	no data	yes	yes	yes	no data	no
Sao Tome and Principe	no data	no data	13374	25	89.1	14	89.0	39	26.0	9	0.0	14	-0.8	35	no data	no	no	yes	no	no	no
Senegal	13.4	45	3205	44	69.1	18	72.0	16	52.0	25	0.0	12	-0.5	24	no	no	no	no	no	no	no
Solomon Islands	0.0	14	85305	16	22.2	45	70.0	12	no data	no data	no data	no data	-0.9	40	no	no	yes	no	no data	no data	no
Sri Lanka	16.5	48	2555	45	12.6	64	91.0	41	92.0	51	32.2	51	-0.2	14	no	no	yes	yes	yes	no	no
Sudan	10.7	43	1518	53	87.7	16	58.0	9	26.0	12	no data	no data	-1.4	50	no	no	no	no	no	no data	no
Swaziland	4.0	36	3861	40	109.2	9	71.0	16	57.0	31	0.0	25	-0.5	25	no	no	no	no	no	no	no
Syrian Arab Republic	55.6	58	838	56	15.9	55	90.0	39	95.0	56	38.1	56	-0.6	26	yes	yes	yes	yes	yes	no	no
Thailand	8.8	41	6384	32	12.8	60	96.0	55	96.0	58	33.6	53	0.1	4	no	no	yes	yes	yes	no	no
Timor-Leste	0.0	23	0	69	57.6	21	69.0	11	47.0	19	16.5	45	-1.2	46	no	yes	no	no	no	no	no
Tonga	no data	no data	no data	no data	15.7	56	100.0	69	96.0	57	no data	no data	-0.3	20	no data	no data	yes	yes	yes	no data	no
Turkmenistan	27.9	55	4964	36	54.0	25	84.0	25	98.0	64	34.3	55	-1.6	52	no	no	no	no	yes	no	no
Ukraine	24.2	51	3054	45	10.7	69	98.0	57	94.0	53	62.0	60	-0.8	33	no	no	yes	yes	yes	yes	no
Vanuatu	no data	no data	no data	no data	13.7	58	90.0	40	57.0	30	no data	no data	-0.3	18	no data	no data	yes	yes	no	no data	no
Yemen	55.9	60	90	64	78.5	17	55.0	8	53.0	29	3.3	34	-1.0	43	yes	yes	no	no	no	no	no

COUNTRY	Water Stress Index		Water Availability Index		Mortality rate, under 5		Improved Water		Improved Sanitation		Connexion to WWTP		Government Effectiveness		The country faces water stress at territory level	The country faces water scarcity at per capita level	The country reduced the mortality rate - MDG4	The country increased the proportion of people with access to safe drinking water - MDG7c	The country increased the proportion of people with access to basic sanitation - MDG7c	The country addresses water pollution by treating wastewater in treatment plants	The country has strong government effectiveness
	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	value	rank	(> 40 %)	(<1,000 m3/cap.yr)	(< 29 per 1,000 live births)	(>88%)	(>75%)	(>50%)	(>0.6 ~ 70 percentile)
Afghanistan	11.3	26	2126	26	103.9	17	50.0	5	37.0	26	13.0	34	-1.5	32	no	no	no	no	no	no	no
Bangladesh	8.8	24	8345	11	48.7	37	81.0	35	56.0	36	19.6	35	-0.8	19	no	no	no	no	no	no	no
Benin	0.0	13	3068	22	108.8	13	75.0	30	13.0	5	0.0	24	-0.5	5	no	no	no	no	no	no	no
Burkina Faso	12.2	28	782	44	148.8	6	79.0	31	17.0	6	0.0	19	-0.5	10	no	yes	no	no	no	no	no
Burundi	0.0	4	1535	35	141.7	6	72.0	24	46.0	30	0.0	3	-1.1	25	no	no	no	no	no	no	no
Cambodia	0.0	11	34061	3	46.0	40	64.0	19	31.0	22	10.9	30	-0.8	18	no	no	no	no	no	no	no
Central African Republic	0.5	19	33441	4	164.6	4	67.0	22	34.0	24	0.0	11	-1.5	31	no	no	no	no	no	no	no
Chad	16.4	36	3932	22	171.3	3	51.0	5	13.0	5	0.0	23	-1.5	33	no	no	no	no	no	no	no
Comoros	no data	no data	1676	31	81.3	24	95.0	44	36.0	26	19.8	37	-1.7	36	no data	no	no	yes	no	no	no
Democratic Republic of the Congo	0.0	1	19983	6	169.9	4	45.0	1	24.0	20	0.0	1	-1.7	37	no	no	no	no	no	no	no
Eritrea	0.0	4	1236	37	69.8	31	60.0	11	13.0	3	0.0	4	-1.4	30	no	no	no	no	no	no	no
Ethiopia	18.2	37	1503	35	81.5	24	44.0	1	21.0	17	0.0	5	-0.4	3	no	no	no	no	no	no	no
Gambia	0.0	11	4756	19	102.6	19	89.0	37	68.0	37	0.0	22	-0.7	12	no	no	no	yes	no	no	no
Guinea	0.0	5	23153	5	129.8	11	74.0	28	18.0	11	11.0	31	-1.2	26	no	no	no	no	no	no	no
Guinea-Bissau	0.0	8	20889	5	161.7	5	64.0	13	20.0	13	0.0	20	-1.0	24	no	no	no	no	no	no	no
Haiti	1.6	22	1422	36	160.7	5	69.0	24	17.0	8	0.0	24	-1.6	35	no	no	no	no	no	no	no
Kenya	13.9	34	778	54	76.1	26	59.0	8	32.0	23	4.9	26	-0.5	8	no	yes	no	no	no	no	no
Kyrgyzstan	20.5	40	4379	20	31.7	44	90.0	40	93.0	42	32.6	42	-0.6	11	no	no	no	yes	yes	no	no
Lao, PDR	0.0	13	54565	1	43.9	42	67.0	23	63.0	37	22.1	37	-0.9	23	no	no	no	no	no	no	no
Liberia	0.0	3	60480	1	83.1	23	73.0	26	18.0	11	0.0	1	-1.3	28	no	no	no	no	no	no	no
Madagascar	11.9	26	16746	6	64.3	35	46.0	3	15.0	6	0.0	8	-0.8	20	no	no	no	no	no	no	no
Malawi	13.9	35	1197	40	89.0	22	83.0	35	51.0	35	0.0	4	-0.4	4	no	no	no	no	no	no	no
Mali	13.5	31	6707	17	178.9	1	64.0	17	22.0	19	0.0	22	-0.9	21	no	no	no	no	no	no	no
Mozambique	13.4	30	9497	11	108.4	13	47.0	4	18.0	13	0.0	6	-0.5	9	no	no	no	no	no	no	no
Nepal	0.9	20	7142	13	50.3	36	89.0	37	31.0	22	10.9	28	-0.8	15	no	no	no	yes	no	no	no
Niger	28.7	42	2248	24	130.9	8	49.0	4	9.0	1	0.0	6	-0.7	13	no	no	no	no	no	no	no
Pakistan	33.4	44	1354	37	73.7	26	92.0	42	48.0	31	16.8	35	-0.8	14	no	no	no	yes	no	no	no
Rwanda	0.0	6	921	42	60.4	35	65.0	22	55.0	35	0.0	13	-0.1	1	no	yes	no	no	no	no	no
Sierra Leone	0.0	5	27879	4	188.8	1	55.0	6	13.0	4	0.0	5	-1.2	27	no	no	no	no	no	no	no
Tajikistan	14.0	35	2356	24	66.1	34	64.0	20	94.0	44	32.9	44	-0.9	22	no	no	no	no	yes	no	no
Togo	0.0	6	2491	23	111.7	11	61.0	11	13.0	4	0.0	17	-1.4	29	no	no	no	no	no	no	no
Uganda	1.4	22	2039	28	94.2	20	72.0	26	34.0	24	0.0	11	-0.5	7	no	no	no	no	no	no	no
United Republic of Tanzania	10.8	24	2212	26	72.5	28	53.0	6	10.0	1	0.0	13	-0.5	6	no	no	no	no	no	no	no
Uzbekistan	42.1	54	1858	30	49.6	37	87.0	36	100.0	54	35.0	54	-0.8	17	yes	no	no	no	yes	no	no
Vietnam	3.0	23	10174	8	22.6	54	95.0	54	76.0	40	26.6	40	-0.3	2	no	no	yes	yes	yes	no	no
Zambia	0.1	17	8268	13	90.4	22	61.0	13	48.0	34	0.0	26	-0.8	16	no	no	no	no	no	no	no
Zimbabwe	20.4	37	1603	34	72.4	30	80.0	34	40.0	28	19.7	36	-1.5	34	no	no	no	no	no	no	no
192	162		173		188		177		176		172		190		16	30	115	111	105	58	53

Annex 3 – Countries shortlisted based on the use of wastewater & practical criteria

COUNTRY	Countries reporting the use of WW for various purposes (treated or untreated/planned or unplanned)	Countries reporting the use of WW for agriculture (treated or untreated/ planned or unplanned)	How is the use of WW for agriculture: direct or indirect / formal or informal? Future plans?			Practical criteria				
	Is WW used in the country?	Is WW used for agriculture?	Dir_InD	F_InF	Future plans	access to official documents (language barrier)	IWMI offices or local contacts	availability of secondary data	access to the country (including fieldwork)	safe for fieldwork
Andorra	-									
Antigua and Barbuda	-									
Australia	yes	yes	Direct	Formal	yes	yes	yes	yes	yes	yes
Austria	yes	no								
Bahamas	-									
Bahrain	yes	yes	Direct		yes	no	no	-	no	
Belgium	yes	no								
Brunei Darussalam	-									
Canada	yes	yes	NA	NA		yes	no	yes	no	
China, Hong Kong SAR	yes	no								
China, Macao SAR	-									
Croatia	-									
Cyprus	yes	yes	Direct	Formal	yes	no	no	-	no	
Czech Republic	-									
Denmark	-									
Equatorial Guinea	-									
Estonia	-									
Finland	-									
France	yes	yes	Direct	Formal	yes	yes	no	-	-	
Germany	yes	ambiguous								
Greece	yes	yes	Direct	Formal	yes	no	no	-	-	
Greenland	-									
Hungary	-									
Iceland	-									
Ireland	-									
Israel	yes	yes	Both	Both	yes	yes	yes	yes	yes	yes
Italy	yes	yes	Both	Formal	yes	no	no	-	-	
Japan	yes	yes	Direct	Formal	yes	no	no	-	-	
Kuwait	yes	yes	Direct	Formal	yes	no	no	-	-	
Latvia	-									
Libyan Arab Jamahiriya	yes	yes			yes	no	no	-	-	
Liechtenstein	-									
Lithuania	-									
Luxembourg	-									
Malta	yes	yes				yes	no	-	-	
Monaco	-									
Netherlands	yes	no								
New Zealand	yes	no								
Norway	-									
Oman	yes	yes		Formal	yes	no	no	-	-	
Portugal	yes	yes	Both		yes	no	no	-	-	
Puerto Rico	-									
Qatar	yes	yes				no	no	-	-	
Republic of Korea	yes	no								
Saint Kitts and Nevis	-									
San Marino	-									
Saudi Arabia	yes	yes	Direct	Formal	yes	no	no	-	-	
Singapore	yes	yes	Direct	Formal	yes	yes	no	-	-	
Slovakia	-									
Slovenia	-									
Spain	yes	yes	Both	Formal	yes	yes	no	yes	-	
Sweden	yes	yes				no	no	-	-	
Switzerland	-									
Trinidad and Tobago	-									
United Arab Emirates	yes	yes	Direct	Formal	yes	no	no	-	-	
United Kingdom	yes	no								
United States of America	yes	yes	Direct	Formal	yes	yes	yes	yes	-	

COUNTRY	Countries reporting the use of WW for various purposes (treated or untreated/planned or unplanned)	Countries reporting the use of WW for agriculture (treated or untreated/ planned or unplanned)	How is the use of WW for agriculture: direct or indirect / formal or informal? Future plans?			Practical criteria				
	Is WW used in the country?	Is WW used for agriculture?	Dir_InD	F_InF	Future plans	access to official documents (language barrier)	IWMI offices or local contacts	availability of secondary data	access to the country (including fieldwork)	safe for fieldwork
Algeria	-									
Argentina	yes	yes	Both		yes	yes	no	-	-	
Azerbaijan	-									
Barbados	-									
Belarus	-									
Bosnia and Herzegovina	-									
Botswana	yes	yes			yes	yes	no	yes	-	
Brazil	yes	yes	Indirect	Informal	yes	no	no	yes	-	
Bulgaria	-									
Chile	yes	yes	Both		yes	yes	yes	yes	yes	yes
Colombia	yes	yes	Indirect		yes	yes	no	-	-	
Costa Rica	yes	yes			yes	yes	no	-	-	
Cuba	-									
Dominica	-									
Dominican Republic	yes	yes				yes	no	-	-	
Fiji	-									
Gabon	-									
Grenada	-									
Iran	yes	yes			yes	no	no	-	-	
Jamaica	-									
Kazakhstan	-									
Lebanon	yes	yes	Both	Informal	not clear from country's report	no	no	-	-	
Malaysia	-									
Maldives	-									
Mauritius	yes	yes				yes	no	-	-	
Mexico	yes	yes	Both	Both	yes	yes	yes	yes	yes	yes
Montenegro	-									
Namibia	yes	no								
Palau	-									
Panama	-									
Peru	yes	yes	Both	Informal	yes	yes	yes	yes	yes	yes
Poland	yes	scarce info								
Romania	-									
Russian Federation	-									
Saint Lucia	-									
Saint Vincent and the Grenadines	-									
Serbia	-									
Seychelles	scarce info									
South Africa	yes	yes	Direct		yes	yes	yes	yes	yes	yes
Suriname	-									
TFYR Macedonia	-									
Tunisia	yes	yes	Direct	Formal		yes	yes	yes	yes	yes
Turkey	yes	yes	Indirect			no	no	-	-	
Tuvalu	-									
Uruguay	-									
Venezuela	no									

COUNTRY	Countries reporting the use of WW for various purposes (treated or untreated/planned or unplanned)	Countries reporting the use of WW for agriculture (treated or untreated/ planned or unplanned)	How is the use of WW for agriculture: direct or indirect / formal or informal? Future plans?			Practical criteria				
	Is WW used in the country?	Is WW used for agriculture?	Dir_InD	F_InF	Future plans	access to official documents (language barrier)	IWMI offices or local contacts	availability of secondary data	access to the country (including fieldwork)	safe for fieldwork
Albania	-									
Angola	-									
Armenia	-									
Belize	-									
Bhutan	-									
Bolivia	yes	yes	Both	Both	yes	yes	yes	yes	yes	yes
Cameroon	yes	yes				yes	no	-	-	
Cape Verde	-									
China	yes	yes	Both	Both	yes	no	no	-	-	
Congo, Rep										
Côte d'Ivoire	-									
Djibouti	-									
Ecuador	yes	yes			?	yes	no	-	-	
Egypt	yes	yes	Both	Both	yes	yes	yes	yes	yes	yes
El Salvador	-									
Georgia	-									
Ghana	yes	yes	Indirect	Informal	yes	yes	yes	yes	yes	yes
Guatemala	yes	yes	Indirect		yes	yes	no	-	-	
Guyana	-									
Honduras	-									
India	yes	yes	Both	Both	yes	yes	yes	yes	yes	yes
Indonesia	-									
Iraq	yes	no								
Jordan	yes	yes	Both	Both	yes	no	no	yes	-	
Kiribati	-									
Lesotho	negligible									
Marshall Islands	-									
Mauritania	-									
Micronesia (Fed. States of)	-									
Mongolia	-									
Morocco	yes	yes	Direct		yes	no	no	-	-	
Nicaragua	yes	yes				yes	no	-	-	
Nigeria	-									
Papua New Guinea										
Paraguay	practise reported/scarce info									
Philippines	-									
Republic of Moldova	-									
Samoa	-									
Sao Tome and Principe	-									
Senegal	yes	yes				yes	no	-	-	
Solomon Islands	-									
Sri Lanka	yes	yes	Indirect	Informal	not encouraged	no	yes	-	-	
Sudan	yes	yes	Indirect	Informal		no	no	-	-	
Swaziland	yes	yes				yes	no	-	-	
Syrian Arab Republic	yes	yes	Both	Formal	yes	no	no	-	-	
Thailand	yes	yes			yes	no	no	-	-	
Timor-Leste	-									
Tonga	-									
Turkmenistan	-									
Ukraine	-									
Vanuatu	-									
Yemen	yes	yes	Both	Both	yes	no	no	-	-	

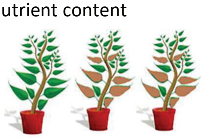
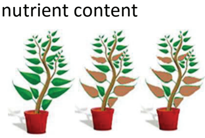
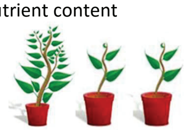
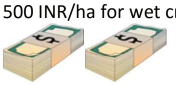
COUNTRY	Countries reporting the use of WW for various purposes (treated or untreated/planned or unplanned)	Countries reporting the use of WW for agriculture (treated or untreated/ planned or unplanned)	How is the use of WW for agriculture: direct or indirect / formal or informal? Future plans?			Practical criteria				
	Is WW used in the country?	Is WW used for agriculture?	Dir_InD	F_InF	Future plans	access to official documents (language barrier)	IWMI offices or local contacts	availability of secondary data	access to the country (including fieldwork)	safe for fieldwork
Afghanistan	yes	scarce info								
Bangladesh	yes	yes		Informal	not clear from country's report	no	no	-	-	
Benin	-									
Burkina Faso	-									
Burundi	scarce info									
Cambodia	-									
Central African Republic	-									
Chad	-									
Comoros	-									
Democratic Republic of the Congo	-									
Eritrea	-									
Ethiopia	yes	yes	Both	Informal		yes	yes	-	yes	yes
Gambia	-									
Guinea	-									
Guinea-Bissau	-									
Haiti	-									
Kenya	yes	yes	Both	Informal	yes	yes	no	-	-	
Kyrgyzstan	yes	yes	NA	NA		no	no	-	-	
Lao, PDR	-									
Liberia	-									
Madagascar	-									
Malawi	yes	yes				yes	no	-	-	
Mali	-									
Mozambique	no	negligible								
Nepal	yes	yes				no	yes	-	yes	yes
Niger	-									
Pakistan	yes	yes	Both	Both		yes	yes	yes	yes	?
Rwanda	-									
Sierra Leone	-									
Tajikistan	-									
Togo	-									
Uganda	scare info									
United Republic of Tanzania	yes	yes				yes	no	-	-	
Uzbekistan	-									
Vietnam	yes	yes	Direct	Formal		yes	yes	-	yes	yes
Zambia	-									
Zimbabwe	yes	yes	Direct	Formal	yes	yes	yes	yes	yes	no
192	76	64			40	36	18	19	16	14

Annex 4 – Example of choice set and pictograms, Hyderabad case study

Example of a choice set:

B1-a		
No intervention	**Restrictions**	**Wastewater Treatment**
High quantity	High quantity	Low quantity
No restrictions	Strict restriction	No restriction
High health risks	Tolerable health risks	Reduced health risks
High nutrient content	High nutrient content	Low nutrient content
Price 2	Price 1	Price 2
I choose:		
I choose none:		

Example of a choice set in pictograms:

B1-a		
No intervention	**Restrictions**	**Wastewater Treatment**
High quantity 	High quantity 	Low quantity 
No restrictions 	Strict restriction 	No restrictions 
High health risks 	Tolerable health risks 	Reduced health risks 
High nutrient content 	High nutrient content 	Low nutrient content 
Price 2: (Water tax only) 250 INR/ha for dry crop 500 INR/ha for wet crop 	Price 1: < 250 INR/ha for dry crops < 500 INR/ha for wet crops 	Price 2: (Water tax only) 250 INR/ha for dry crop 500 INR/ha for wet crop 

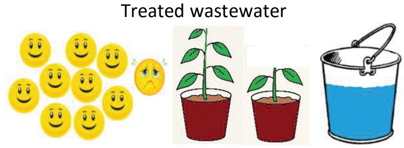
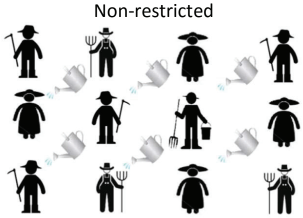
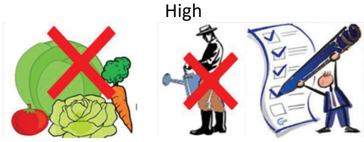
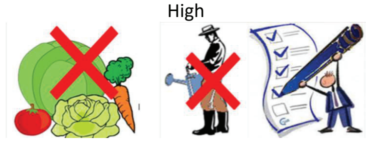
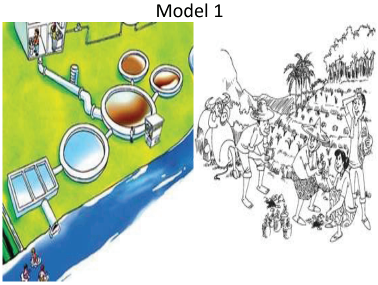
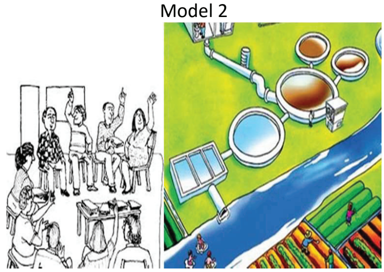
Annex 5 – Example of choice set and pictograms, Cochabamba case study

Example of a choice set:

B1-5	**Alternative 1**	**Alternative 2**
Water quality & quantity	Untreated wastewater	Treated wastewater
Access to water	Restricted	Non-restricted
Use restrictions	High	High
Farmers' involvement / participation	Model 1	Model 2
Price of petrol (Bs/L)	3.74	3.74

What alternative do you prefer?
None

Example of a choice set in pictograms:

B1-5	**Alternative 1**	**Alternative 2**
Water quality & quantity	Untreated wastewater 	Treated wastewater 
Access to water	Restricted 	Non-restricted 
Use restrictions	High 	High 
Farmers' involvement / participation	Model 1 	Model 2 
Price of petrol	3.74 Bs/L 	3.74 Bs/L 

Annex 6 – Example of choice set and pictograms, Western Cape case study

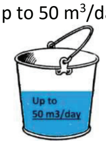
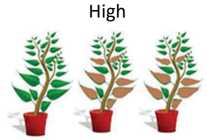
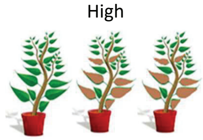
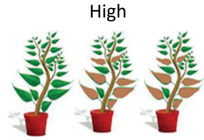
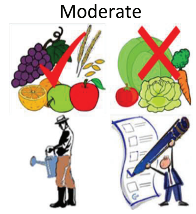
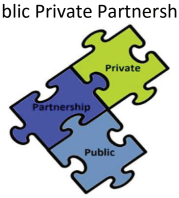
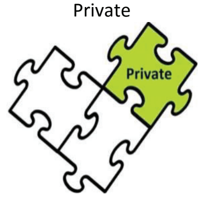
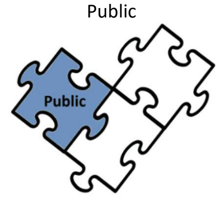
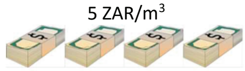
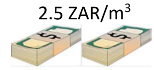
Example of a choice set:

B1-3	**Alternative 1**	**Alternative 2**	**Alternative 3**
Water quantity	Up to 50 m^3/day	Unlimited quantity	Up to 2000 m^3/day
Water quality	General quality standards	Less than General Standards	General quality standards
Nutrient content	High	High	High
Practice restrictions	Low	High	Moderate
Scheme model	Public Private Partnership	Private	Public
Price	5 ZAR/m^3	2.5 ZAR/m^3	2.5 ZAR/m^3

Which alternative do you prefer?

None of these alternatives:

Example of a choice set in pictograms:

B1-3	**Alternative 1**	**Alternative 2**	**Alternative 3**
Water quantity	Up to 50 m^3/day  	Unlimited quantity 	Up to 2000 m^3/day 
Water quality	General quality standards  	Less than General Standards  	General quality standards 
Nutrient content	High 	High 	High 
Practice restrictions	Low 	High 	Moderate 
Scheme model	Public Private Partnership  	Private  	Public 
Price	5 ZAR/m^3 	2.5 ZAR/m^3 	2.5 ZAR/m^3 

Summary

This study is inspired by the idea that wastewater reuse has a great potential to reduce pressure on water resources, specifically for the agricultural sector. At the same time, the issue of wastewater reuse needs to be addressed because of the risks it represents for public health and for the environment. As water becomes scarce in many regions around the world, and the informal use of wastewater for irrigation propagates particularly in developing countries, wastewater reuse needs to be reconsidered within the broader concept of water resources management. Nevertheless, water resources management in general, and wastewater management in particular are complex and difficult tasks because water problems are heterogeneous and variable over time and space. Solutions to water problems will depend not only on water availability, but on a range of other factors that influence the water sector such as institutional capacity, legal and regulatory frameworks, sociopolitical and environmental conditions, educational and development conditions, financial resources, technology, attitudes and perceptions, and modes of governance including issues like political interference, transparency and corruption. Given this complexity, the need to unravel the institutional dimensions of wastewater reuse, in order to understand the challenges for its formalization becomes evident. In the light of this challenge, the objective of this research is to provide understanding on the incentives and drivers for a (step-wise) change of the institutional settings, moving wastewater reuse in agriculture from its informal status towards a formal, safe and productive use. This is done by comparing countries with different governance structures along the trajectory towards formalization.

This study is structured using a conceptual framework identifying the key components of water governance: water policy, water law, water organization/ administration, and how they relate to wastewater reuse, with a focus on the agricultural sector. Before the analysis of the institutional challenges, along the trajectory from informal to formal reuse of wastewater, a set of countries were selected as case studies for comparison. This process of selection consisted of raking countries according to a set of selected indicators. The final choice of countries was determined based on practical issues to conduct research such as local contacts, access to the field, language barriers, and safety. Each country represents one step in the process towards formalization of wastewater reuse.

The analysis has been divided in two parts. Part 1 looks at the institutional analysis of the four countries along the trajectory. The countries include India, Bolivia, South Africa, and Israel. The case of India presents a scenario where the use of wastewater is indirect, unplanned, unrecognized, and therefore mostly informal, where the lack of clear mandates of institutions involved inhibits the development of formalization of wastewater reuse. The case of Bolivia characterizes a scenario where wastewater has been recognized as a potential water source, and a process of formalization has been initiated, which implies introduction of water reuse in the water policy framework,

development of a regulatory framework, development of infrastructure, etc. This case highlights that political will is crucial to promote changes in institutional arrangements in the process of formalization of wastewater reuse. Next, the case of South Africa explains the direct, planned and regulated use of wastewater for irrigation. In other words, formal wastewater reuse in a context of a developing country, where institutional arrangements are set in place for its realization, as well as the importance of farmers' initiative for take up. However, this case also identifies some elements that are missing to fully implement formal wastewater reuse throughout the country, such as capital-intensive water use linked to profitable markets. Meanwhile, the case of Israel shows a situation where wastewater reuse is fully formalized. This case shows the importance of having clear objectives, regulatory frameworks, educational development supporting behavioral change, and accountability to the people. Throughout the analysis, the elements that constrain and facilitate formalization of wastewater reuse are identified, and the particular conditions where wastewater reuse takes place are featured, including the institutional environment (e.g., historical, socioeconomic and physical conditions) and the institutional structure (e.g., policy and regulatory framework, and administrative structure). By using two different approaches, based on the characteristics of the case study and the type of data gathered, the institutional analysis is conducted. These approaches are: the Institutional Analysis and Development (IAD) framework proposed by Ostrom (2005), and the Institutional Decomposition Analysis (IDA) framework proposed by Saleth (2004). The cross-case comparison discusses the drivers behind formalization of wastewater reuse, similarities and differences in institutional settings, the importance of risk awareness, the need for institutional changes and the role of the guidelines. The institutional analysis for each case study is based on data collected through literature review; the sources of data include policy documents, reports, official websites, peer-reviewed journal articles and grey literature; complemented with information collected through semi-structured interviews conducted on the field with key informants.

Part 2 analyses the preferences of farmers for frameworks of wastewater reuse, as well as their willingness-to-pay (WTP) for changes in the frameworks proposed. Choice modelling was the methodological approach for the analysis in all cases. Three case studies were considered: Hyderabad in India, Cochabamba in Bolivia, and Western Cape in South Africa. The analysis is based on primary data collected during fieldwork in the countries mentioned. The results of each case study are presented and discussed separately. Then, the findings of the farmers' preferences and perceptions for wastewater reuse in different geographies and contexts in terms of agricultural production are compared. The results of the comparison indicate that farmers overall are prepared to take the burden of formalization in order to receive higher quality water, and they are willing to contribute to irrigation systems conceived for treated wastewater. Concurrently, farmers' participation in decision making is important for them and for the sustainability of irrigation systems.

The general conclusions of the study suggest that wastewater offers a window of opportunities for water resources management, mostly for the agricultural sector. Countries can benefit enormously from this alternative water source; however, formalization of wastewater reuse is essential to enjoy the benefits of an additional water source, while still protecting people from the risks associated to the reuse of wastewater. In order to formalize wastewater reuse, it is fundamental that countries first recognize the potential of this water source, as well as the risks associated to it, and then that countries are prepared to provide institutional arrangements for the practice. Political will is inherently part of this process. However, public awareness regarding water scarcity and water pollution is also necessary to initiate such institutional changes and to generate the behavioral change required to guarantee safety. Most developing countries fail at generating such changes mainly because there is an overall low level of education and a high level of tolerance towards unsafe use of wastewater. Important institutional changes include clarity in the institutional arrangements, which imply specific mandates and well-defined responsibilities for wastewater management and reuse; and a regulatory framework in place to guide the practice, which includes water quality standards, treatment levels and processes, crop restrictions, categories of types of uses, etc.

Overall, farmers are aware of the risks that irrigating with untreated wastewater represents for their health, their produce and the soil. Farmers also know that irrigating crops with untreated wastewater can have negative consequences for the health of consumers. However, in informal settings of wastewater reuse, they are unaccountable for this. Furthermore, wastewater represents for the farmers security to sustain their livelihoods. This is important since water guarantees agricultural production. Moreover, the general perception regarding wastewater reuse is positive, but the up-take of wastewater reuse is subject to an improvement in terms of water quality. This aspect is fundamental for farmers, who are willing to support wastewater reuse if ‘good’ water quality is guaranteed. This aspect is central in the process of formalization. On the other hand, farmers apparently do not perceive the benefits of additional nutrient contents in the water, mainly because such benefits might be offset by the risks. As a final point, an important element to ensure sustainability of irrigation systems conceived for wastewater reuse is farmers’ participation in the entire process of system design and management. This aspect is vital during the planning and implementation of wastewater reuse systems.

Finally, the findings of this research add to the literature on the fact that addressing wastewater offers great opportunities to reduce pressure on water resources, but also to reduce environmental pollution and achieving sustainability in water resources management. Therefore, wastewater reuse should be included in the planning of water resources management as a central component for water conservation. Along this line, growing water scarcity is the main driver for the use of wastewater, but mostly for the formalization of wastewater reuse. Nonetheless, it has been shown that in developing countries the use of untreated wastewater is rather the result of a lack of adequate sanitation and wastewater management. It became evident from the study that clear institutional arrangements are needed, as they are central for the process of formalization. This should be accompanied by guidelines in order to protect public health, increase water availability, prevent water pollution and enhance water resources and nature conservation policies. This study finally also contributes to the literature in relation to farmers' preferences concerning frameworks of water reuse for irrigation. This is crucial because farmers are the end users of water, and therefore their perspective on the institutional structure is central.

Samenvatting

Deze studie is geïnspireerd door het idee dat het hergebruik van afvalwater een groot potentieel heeft om de druk op de watervoorraden te verminderen, vooral in de agrarische sector. Tegelijkertijd dient het hergebruik van afvalwater ook kritisch bekeken te worden in verband met de risico's voor volksgezondheid en milieu. Omdat water schaarser wordt op vele plaatsen ter wereld, en het informele gebruik van afvalwater voor irrigatie steeds vaker voorkomt, vooral in ontwikkelingslanden, dient het hergebruik van afvalwater bestudeerd te worden binnen het bredere kader van het beheer van watervoorraden. Waterbeheer, en vooral het beheer van afvalwater, is echter een zeer moeilijke en complexe taak omdat waterproblemen vaak heterogeen zijn en variabel in tijd en ruimte. Oplossingen voor waterproblemen zullen niet enkel afhangen van de beschikbaarheid van water, maar ook van een hele reeks andere factoren zoals institutionele capaciteit, wet- en regelgeving, sociaalpolitieke en ecologische omstandigheden, onderwijs en ontwikkeling, financiële middelen, technologie, attitudes en percepties en vormen van bestuur, waaronder zaken vallen als politieke inmenging, transparantie en corruptie. Gelet op deze complexiteit is er een grote nood aan het ontrafelen van de institutionele dimensie van avalwaterhergebruik, omdat de uitdagingen voor formalisering ervan op deze manier duidelijk worden. In het licht van deze uitdaging is de doelstelling van dit onderzoek om meer inzicht te creëren in de motieven en drijfveren voor een (stapsgewijze) verandering in het institutionele kader, om het informele gebruik van afvalwater te hervormen tot formeel, veilig en productief gebruik. Dit wordt gedaan door landen te vergelijken met verschillende bestuurs- of governance structuren langsheen het traject naar formalisering.

Deze studie is gestructureerd volgens een conceptueel kader dat de sleutelcomponenten van water governance identificeert: waterbeleid, wetgeving rond water, organisatie/administratie van waterbeheer, en hoe ze verbonden zijn met het hergebruik van afvalwater, met een focus op de landbouwsector. Voor de analyse van de institutionele uitdagingen, langsheen het traject van informeel naar formeel hergebruik van afvalwater, werd een reeks van landen geselecteerd als case studies voor deze vergelijking. Het selectieproces bestond uit het ranken van landen volgens een set van zorgvuldig gekozen indicatoren. De finale keuze voor bepaalde landen werd bepaald door praktische overwegingen zoals de aanwezigheid van lokale contacten, toegang tot het terrein, taalbarrières en veiligheid. Elk land vertegenwoordigt een specifieke stap in het proces naar formalisering van het hergebruik van afvalwater.

De analyse werd opgedeeld in twee delen. Deel 1 is een institutionele analyse van de vier landen langsheen het traject van formalisering. Deze landen zijn Indië, Bolivia, Zuid-Afrika en Israël. De case van Indië vertegenwoordigt een scenario waarin het gebruik van afvalwater indirect gebeurt, niet georganiseerd, niet erkend en vandaar meestal informeel. Het gebrek aan een duidelijk mandaat voor betrokken (overheids-)instellingen remt de ontwikkeling naar formalisering van hergebruik van afvalwater.

De case van Bolivia stelt een scenario voor waarin afvalwater erkend is als potentiële bron van water, en het proces van formalisering werd er geïnitieerd via het introduceren van afvalwaterhergebruik in het kader van het waterbeleid, de ontwikkeling van een specifiek wetgevend kader, infrastructuurontwikkeling, enz. Deze case benadrukt dat politieke wil cruciaal is om institutionele veranderingen door te voeren in het proces van formalisering van afvalwaterhergebruik. Vervolgens is er de case van Zuid-Afrika waarin afvalwater op een directe, georganiseerde en gereguleerde manier gebruikt wordt voor irrigatiedoeleinden. Zuid-Afrika vertegenwoordigt met andere woorden een voorbeeld van afvalwaterhergebruik in de context van een ontwikkelingsland, waar institutionele arrangementen werden opgezet om dit te realiseren, en waar het initiatief voor hergebruik in belangrijke mate van de landbouwers kwam. Deze case identificeert echter ook een aantal belangrijke struikelblokken om formeel afvalwaterhergebruik succesvol te implementeren over het gehele land, zoals kapitaalsintensief watergebruik verbonden aan winstgevende markten. De case van Israël toont een situatie waarin afvalwaterhergebruik volledig geformaliseerd is, en geeft het belang weer van duidelijke doelstellingen, wetgevende kaders, onderwijsontwikkelingen die gedragsveranderingen ondersteunen en verantwoording naar de mensen toe. Doorheen de analyse worden verschillende elementen geïdentificeerd die de formalisering van afvalwaterhergebruik bemoeilijken en faciliteren, en worden aanbevelingen gedestilleerd over de specifieke voorwaarden voor afvalwaterhergebruik, met inbegrip van de institutionele omgeving (bv. historische, socio-economische en fysieke omstandigheden) en de institutionele structuur (vb. beleids- en wetgevend kader en de administratieve structuur). De institutionele analyse is uitgevoerd aan de hand van twee verschillende benaderingen, gebaseerd op de karakteristieken van de case studie en het type data dat verzameld werd. Deze benaderingen zijn: het Institutionele Analyse en Ontwikkelingskader (IAD) van Ostrom (2005), en het Institutionele Decompositie Analysekader (IDA) van Saleth (2004). De vergelijking over de cases heen analyseert de drijfveren voor formalisering van afvalwaterhergebruik, gelijkenissen en verschillen tussen institutionele contexten, het belang van risicobewustzijn, de nood aan institutionele veranderingen en de rol van richtlijnen. De institutionele analyse voor elke case is gebaseerd op data die verzameld zijn via literatuuronderzoek, waarbij de bronnen beleidsdocumenten zijn, rapporten, officiële websites, peer-reviewed artikels uit tijdschriften en grijze literatuur. Deze worden aangevuld met informatie verzameld via semigestructureerde interviews op het terrein met sleutelinformanten.

Deel 2 analyseert de voorkeuren van landbouwers voor kaders voor afvalwaterhergebruik, en hun betalingsbereidheid (willingness-to-pay) voor veranderingen in de voorgestelde kaders. Keuzemodellering is de methodologische aanpak die gevolgd wordt in alle cases. Drie case studies zijn opgenomen: Hyderabad in Indië, Cochabamba in Bolivia en Western Cape in Zuid-Afrika. De analyse is gebaseerd op primaire data die verzameld werd bij veldwerk in de genoemde landen. De resultaten van elke case studie worden apart gepresenteerd en bediscussieerd. Daarna worden de bevindingen m.b.t. de voorkeuren van landbouwers en percepties van afvalwaterhergebruik vergeleken tussen de verschillende contexten m.b.t. geografie en landbouwproductie. De resultaten van deze vergelijking geven aan dat landbouwers over het algemeen bereid zijn om de lasten op te nemen van formalisering om een hogere waterkwaliteit te bekomen, en dat ze bereid zijn bij te dragen voor irrigatiesystemen die bedacht zijn voor behandeld afvalwater. Tegelijkertijd hechten landbouwers belang aan participatie in beslissingsprocessen en de duurzaamheid van irrigatiesystemen.

De algemene conclusies van de studie suggereren dat afvalwater een waaier van mogelijkheden biedt voor het beheer van watervoorraden, vooral binnen de landbouwsector. Landen kunnen grote voordelen halen uit deze alternatieve waterbron, en tegelijkertijd nog altijd de risico's beperken die gepaard gaan met het hergebruik van afvalwater. Om afvalwaterhergebruik te formaliseren is het fundamenteel dat landen eerst het potentieel van deze waterbron erkennen, zowel als de risico's die gepaard gaan met het gebruik ervan, en dat landen bereid zijn om institutionele arrangementen te ontwikkelen voor deze praktijk. Politieke wil is een inherent deel van dit proces. Publiek bewustzijn m.b.t. waterschaarste en watervervuiling zijn echter ook noodzakelijk om dergelijke institutionele veranderingen te initiëren en om de gedragsveranderingen te genereren die noodzakelijk zijn om de veiligheid te garanderen. De meeste ontwikkelingslanden falen erin dergelijke veranderingen te genereren, hoofdzakelijk omwille van een algemeen laag onderwijsniveau en een hoge tolerantie t.o.v. onveilig gebruik van afvalwater. Belangrijke institutionele veranderingen zijn transparantie in institutionele arrangementen, wat specifieke mandaten impliceert en goed gedefinieerde verantwoordelijkheden voor afvalwaterbeheer en –hergebruik; alsook een wetgevend kader om de praktijk te sturen, inclusief waterkwaliteitsnormen, behandelingsniveaus en –processen, beperkingen m.b.t. het geteelde gewas, categorieën van gebruik, enz.

Over het algemeen zijn landbouwers zich bewust van de risico's die irrigatie met onbehandeld afvalwater meebrengt voor hun gezondheid, hun producten en de bodem. Landbouwers weten ook dat gewassen irrigeren met onbehandeld afvalwater negatieve gevolgen kan hebben voor de gezondheid van consumenten. Echter, zolang afvalwater gebruikt wordt in een informele context kunnen ze hiervoor niet verantwoordelijk gesteld worden. Bovendien draagt het gebruik van afvalwater bij tot het verzekeren van hun levensonderhoud. Dit is belangrijk omdat water een garantie is voor landbouwproductie. De algemene perceptie van landbouwers m.b.t. het hergebruik van afvalwater is positief, maar het toepassen van afvalwaterhergebruik is afhankelijk van een verbetering van de waterkwaliteit. Dit aspect is fundamenteel voor landbouwers, die bereid zijn afvalwater te gebruiken op voorwaarde dat een goede waterkwaliteit kan gegarandeerd worden. Dit aspect staat centraal in het formaliseringsproces. Het verhoogde nutriëntengehalte in afvalwater zien landbouwers niet meteen als een voordeel, vooral omdat dit het verhoogde risico niet zou compenseren. Tenslotte is een belangrijk element om de duurzaamheid te garanderen van irrigatiesystemen bedacht voor afvalwaterhergebruik de participatie van landbouwers in het gehele proces van systeemontwerp en –beheer. Dit aspect is vitaal tijdens de planning en uitvoering van systemen voor afvalwaterhergebruik.

De belangrijkste bijdrage van dit onderzoek aan de literatuur is dat afvalwater goede mogelijkheden biedt om de druk op watervoorraden te verkleinen, maar ook om milieuvervuiling te reduceren en duurzaamheid te creëren in het beheer van watervoorraden. Daarom is het belangrijk om afvalwaterhergebruik op te nemen in de planning van het beheer van watervoorraden en als centrale component bij strategieën voor waterbehoud. Toenemende waterschaarste is de voornaamste drijfveer voor het hergebruik van afvalwater, maar vooral voor de formalisering ervan. In ontwikkelingslanden is het gebruik van onbehandeld afvalwater vaak het gevolg van een gebrek aan adequate sanering en afvalwaterbeheer. De studie toonde aan dat duidelijke institutionele arrangementen nodig zijn, omdat ze centraal staan in het formaliseringsproces. Dit moet vergezeld gaan van richtlijnen ter bescherming van de volksgezondheid, vergroten van de watervoorraden, het vermijden van watervervuiling en een verbeterd beleid m.b.t. natuur en watervoorraden. Tenslotte draagt de studie bij aan de literatuur rond de voorkeuren van landbouwers voor bepaalde kaders voor afvalwatergebruik bij irrigatie. Dit is cruciaal, omdat landbouwers de eindgebruikers zijn van water en hun perceptie van de institutionele structuur moet daarom centraal staan.

References

Abaidoo, R. C., Keraita, B., Drechsel, P., Dissanayake, P. and Maxwell, A. X. (2009). Soil and crop contamination through wastewater irrigation and options for risk reduction in developing countries. In: P. Dion (ed.), Soil Biology and Agriculture in the Tropics, Heidelberg: Springer Verlag.

Abu Madi, M., Braadbaart, O., Al-Sa'ed, R., & Alaerts, G. (2003). Willingness of farmers to pay for reclaimed wastewater in Jordan and Tunisia. *Water Science and Technology: Water Supply*, 3 (4), 115-122.

ArunaJyothi, IWMI (2013). Map of Hyderabad and area of influence of wastewater-irrigated agriculture. International Water Management Institute (IWMI), Hyderabad Office, Patancheru, Hyderabad, India.

Abdullah, Z., Khan, M. A., & Flowers, T. J. (2001). Causes of Sterility in Seed Set of Rice under Salinity Stress. *Journal of Agronomy and Crop Science*, 187 (1), 25–32.

Adamowicz, W.L. (2004). What's it worth? An examination of historical trends and future directions in environmental valuation. *The Australian Journal of Agricultural and Resource Economics* 48 (3), 419–443.

Adamowicz, W., Louviere, J., & Swait, J. (1998). Introduction to Attribute-Based Stated Choice Methods. Edmonton Alberta: ADVANIS.

Adewumi, J. R., Ilemobade, A. A., & Van Zyl, J. E. (2010). Treated wastewater reuse in South Africa: Overview, potential and challenges. *Resources, Conservation and Recycling*, 55 (2), 221-231.

Agreda, E. (2000). The problematics of the use of polluted water in agriculture under irrigation: case study Rocha River – La Mayca and Caramarca areas. MSc thesis, Wageningen University, the Netherlands.

AGRIPROBE (2007). Satellite images show water use efficiency. http://www.waterwatch.nl/fileadmin/bestanden/Project/Africa/grapes/AgriProbe_2007_4_3.pdf (accessed 15 October 2014).

Ahmad, M. (2000). Water pricing and markets in the Near East: policy issues and options. *Water Policy*, 2 (3), 229 – 242.

Alcon, F., Pedrero, F., Martin-Ortega, J., Arcas, N., Alarcon, J. J., & De Miguel, M. D. (2010). The non-market value of reclaimed wastewater for use in agriculture: a contingent valuation approach. *Spanish Journal of Agricultural Research*, 8(S2), 187-196.

Amerasinghe, P. (2015). Personal communication (not published).

Amerasinghe, P., Weckenbrock, P., Simmons, R., Acharya, S., Drescher, A. W., & Blummel, M. (2009a). An atlas of water quality, health and agronomic risks and benefits associated with 'wastewater' irrigated agriculture: A study from the banks of the Musi River, India. Report, Colombo, Sri Lanka: IWMI.

Amerasinghe, P., Simmons, R., Evans, A., Blummel, M., & Drescher, A. (2009b). Ensuring Health and Food Safety from Rapidly Expanding Wastewater Irrigation in South Asia. BMZ Final Report 2005–2008, Colombo, Sri Lanka: IWMI.

Amerasinghe, P., Bhardwaj, R. M., Scott, C., Jella, K. & Marshall, F. (2013). Urban wastewater and agricultural reuse challenges in India. Research Report 147, Colombo, Sri Lanka: IWMI.

Ampuero, R. G. (2009). Re-use of wastewater in agriculture: A reality in the margins of the Rocha River in the Valley of Cochabamba, Bolivia (in Spanish). In: CGIAB (ed.), Environmental Justice and Water Sustainability (in Spanish), Cochabamba: CGIAB.

Ampuero, R. G. (2010) From an environmental perspective: The problem of pollution in the Rocha River in the metropolitan section of Cochabamba (in Spanish). http://www.bivica.org/upload/boletin-agua_rio_rocha.pdf (accessed 5 June 2015).

Anderson, B. A., Romani, J. H., Phillips, H., Wentzel, M., & Tlabela, K. (2007). Exploring environmental perceptions, behaviors and awareness: water and water pollution in South Africa. *Population and Environment*, 28 (3), 133-161.

Angelakis, A. N., Do Monte, M. M., Bontoux, L., & Asano, T. (1999). The status of wastewater reuse practice in the Mediterranean basin: need for guidelines. *Water Research*, 33 (10), 2201-2217.

Anon (2006). Hyderabad City Development Plan. Jawaharlal Nehru National Urban Renewal Mission, Hyderabad, India.

Ansink, E., & Weikard, H.P. (2009) Contested water rights. *European Journal of Political Economy*, 25 (2), 247 – 260.

AP Department of Agriculture (2014). http://agri.ap.nic.in/origin.htm (accessed 2 June 2014).

AP Gov. (1989). Hyderabad Metropolitan Water Supply and Sewerage Act. http://www.lawsofindia.org/pdf/andhra_pradesh/1989/1989AP15.pdf (accessed 15 April 2015).

AP Gov. (1997). AP Farmers' Management of Irrigation System Act. http://www.lawsofindia.org/pdf/andhra_pradesh/1997/1997AP11.pdf (accessed 15 April 2015).

AP Gov. (2002). Andhra Pradesh Water, Land and Trees Act. http://ielrc.org/content/e0202.pdf (accessed 27 May 2015).

AP Gov. (2008). Andhra Pradesh State Water Policy. http://www.cseindia.org/userfiles/AndhraPradeshStateWaterPolicy.pdf (accessed 15 April 2015).

APPCB (2009). http://www.appcb.ap.nic.in/aboutus/about_us.htm (accessed 2 May 2014).

AQUASTAT (2002). Water availability per person per year. http://www.unesco.org/bpi/wwdr/WWDR_chart1_eng.pdf (accessed 19 May 2015).

AQUASTAT (2011). Water resource information by country/territory and MDG Water Indicator. http://www.fao.org/nr/water/aquastat/maps/AQUASTAT_water_resources_and_MDG_water_indicator_November_2011.pdf (accessed September 2012).

Asano, T. (1998). Wastewater reuse. In: A. K. Biswas (ed.), Water Resources: Environmental Planning, Management, and Development, pp. 381–438. New Delhi: Tata McGraw-Hill Publishing Company Limited.

Asano, T. (2001). Water from (waste) water: The dependable water resource. Paper presented at the Eleventh Stockholm Water Symposium, Stockholm, Sweden, 12 – 18 August 2001.

Bahri, A. (1999). Agricultural reuse of wastewater and global water management. *Water Science & Technology*, 40 (4-5), 339–346.

Bakopoulou, S., Polyzos, S., & Kungolos, A. (2010). Investigation of farmers' willingness to pay for using recycled water for irrigation in Thessaly region, Greece. *Desalination*, 250 (1), 329-334.

Banzhaf, M. R., Johnson, F. R., & Mathews, K. E. (2001). Opt-out alternatives and anglers' stated preferences. In: J. Bennett & R. Blamey (eds.), The choice modelling approach to environmental valuation, pp. 157–177, London: Edward Elgar.

Barde, J. P. (1994). Economic instruments in environmental policy: lessons from the OECD experience and their relevance to developing economies. OECD Working Paper N°92, Paris: Development Centre of the Organization for Economic Co-operation and Development.

Bardhan, P., & Mookherjee, D. (2005). Decentralization, corruption and government accountability: An overview. http://sws.bu.edu/dilipm/publications/decorr.pdf (accessed 1 July 2015).

Barzel, Y. (2000). The state and the diversity of third-party enforcers. In: C. Menard (ed.), Institutions, contracts and organizations: Perspectives from New Institutional Economics. Cheltenham, UK: Edward Elgar.

Bazza, M. (2003). Wastewater recycling and reuse in the Near East Region: experience and issues. *Water Supply*, 3 (4), 33–50.

Bazzani, G. M (2005). A decision support for an integrated multi-scale analysis of irrigation: DSIRR. *Journal of Environmental Management*, 77 (4), 301–314.

Bdour, A.N., Hamdi, M.R., & Tarawneh, Z. (2009). Perspectives on sustainable wastewater treatment technologies and reuse options in the urban areas of the Mediterranean region. *Desalination*, 237 (1 – 3), 162 – 174.

Beccar, L., Boelens, R., & Hoogendam, P. (2002). Water rights and collective action in community irrigation. In: R. Boelens & P. Hoogendam (eds.), Water Rights and Empowerment. The Netherlands: Koninklijke van Gorcum.

Becker, N., & Ward, F. A. (2014). Adaptive water management in Israel: structure and policy options. *International Journal of Water Resources Development*, (ahead-of-print), 1-18.

Ben Brahim-Neji, H., Ruiz-Villaverde, A., & González-Gómez, F. (2014). Decision aid supports for evaluating agricultural water reuse practices in Tunisia: The Cebala perimeter. *Agricultural Water Management*, 143, 113-121.

Ben-Gal, A. (2010). Sustainable water supply for agriculture in Israel. In: A. Tal & A. A. Rabbo (eds.), Water Wisdom: Preparing the groundwork for cooperative and sustainable water management in the Middle East. New Brunswick, New Jersey, and London: Rutgers University Press.

Bennett, J., & Blamey, R. (2001). The strengths and weaknesses of environmental choice modelling. In: J. Bennett & R. Blamey (eds.), The choice modelling approach to environmental valuation. UK: Edward Elgar Publishing Limited.

Berck, P., & Lipow, J. (1994). Real and ideal water rights: the prospects for water-rights reform in Israel, Gaza, and the West Bank. *Resource and energy economics*, 16 (4), 287-301.

Birol, E., & Das, S. (2010). Estimating the value of improved wastewater treatment: The case of River Ganga, India. *Journal of Environmental Management*, 91 (11), 2163–2171.

Birol, E., Karousakis, K., & Koundouri, P. (2006a). Using a choice experiment to account for preference heterogeneity in wetland attributes: the case of Cheimaditida wetland in Greece. *Ecological economics*, 60 (1), 145-156.

Birol, E., Karousakis, K., & Koundouri, P. (2006b). Using economic valuation techniques to inform water resources management: A survey and critical appraisal of available techniques and an application. *Science of the total environment*, 365 (1), 105-122.

Birol, E., Koundouri, P., & Kountouris, Y. (2008). Evaluating farmers' preferences for wastewater: quantity and quality aspects. *International Journal of Water*, 4 (1-2), 69-86.

Biswas, A. K. (2001). Water policies in the developing world. *Water Resources Development*, 17 (4), 489–499.

Biswas, A. K. (2004). Integrated water resources management: a reassessment: a water forum contribution. *Water International*, 29 (2), 248–256.

Biswas, A. K. (2008). Integrated water resources management: is it working?. *Water Resources Development*, 24 (1), 5–22.

Bixio, D., Thoeye, C., De Koning, J., Joksimovic, D., Savic, D., Wintgens, T., & Melin, T. (2006). Wastewater reuse in Europe. *Desalination*, 187 (1), 89–101.

Blamey, R. K., Bennett, J. W., Louviere, J. J., et al. (2000). A test of policy labels in environmental choice modelling studies. *Ecological Economics*, 32 (2), 269–286.

Boelens, R. (2007). Aguas locales, políticas culturales y leyes universales: la gestión hídrica indígena frente a la legislación nacional y las “políticas de participación”. In: R. Boelens, M. Chiba, D. Nakashima & V. Renata (eds.), El agua y los pueblos indígenas. Paris: UNESCO.

Boelens, R. (2008). Water rights arenas in the Andes: Upscaling the defense networks to localize water control. *Water Alternatives*, 1 (1), 48–65.

Boelens, R. (2014). Cultural politics and the hydrosocial cycle: Water, power and identity in the Andean highlands. *Geoforum*, 57, 234–247.

Boelens, R., & Doornbos, B. (2001). The battlefield of water rights: rule making amidst conflicting normative frameworks in the Ecuadorian highlands. *Human Organization*, 60 (4), 343–355.

Boelens, R., & Doornbos, B. (2002). The battlefield of water rights: Rulemaking and empowerment in the arena of conflicting normative frameworks – irrigation development in Ceceles, Ecuador. In: R. Boelens & P. Hoogendam (eds.), Water rights and empowerment. The Netherlands: Koninklijke van Gorcum.

Boelens, R., Zwarteveen, M., & Roth, D. (2005). Legal complexity in the analysis of water rights and water resources management. In: D. Roth, R. Boelens & M.

Zwarteveen (eds.), Liquid relations: Contested water rights and legal complexity, pp. 1-20. New Brunswick, New Jersey, London: Rutgers University Press.

Bos, R., Carr, R., & Keraita, B. (2010). Assessing and mitigating wastewater-related health risks in low-income countries: An introduction. In: P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (eds.), Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-Income Countries, pp. 29-47. London, Sterling, VA: Earthscan, IDRC, IWMI.

Bouwer, H. (2000). Integrated water management: emerging issues and challenges. *Agricultural water management*, 45 (3), 217–228.

Boxall, P. C., & Adamowicz, W. L. (2002). Understanding heterogeneous preferences in random utility models: a latent class approach. *Environmental and resource economics*, 23 (4), 421–446.

Briscoe, J. (1996). Water as an economic good: the idea and what it means in practice. Proceedings of the World Congress of the International Commission on Irrigation and Drainage (ICID), Cairo, September 1996.

Briscoe, J. (1997). Managing water as an economic good: rules for reformers. Keynote paper presented at the International Committee on Irrigation and Drainage (ICID) Conference on Water as an Economic Good, Oxford, September 1997.

Bruns, B.R., Ringler, C., & Meinzen-Dick, R. (2005). Water Rights Reform: Lessons for institutional design. International Food Policy Research Institute, Washington, D.C.

Budds, J., & McGranahan, G. (2003). Are the debates on water privatization missing the point? Experiences from Africa, Asia and Latin America. *Environment and Urbanization*, 15 (2), 87–114.

Buechler, S., & Devi, G. (2003). Household food security and wastewater-dependent livelihood activities along the Musi River in Andhra Pradesh, India. Report submitted to the World Health Organization (WHO), Geneva, Switzerland.

Buechler, S., Devi, G., & Rashid, L. (2002). Livelihoods and wastewater irrigated agriculture along the Musi River in Hyderabad City, Andhra Pradesh, India. *Urban Agriculture Magazine*, 8, 14–17.

Buechler, S., Devi, G., & Keraita, B. (2006). Wastewater use for urban and peri-urban agriculture. http://www.ruaf.org/sites/default/files/Chapter%209.pdf (accessed 27 January 2014).

Bureau for Economic Research (2011). The current state and short term (2011/12) prospects for the South African & Western Cape economies.

https://www.westerncape.gov.za/other/2011/7/2011_q2_wcer.pdf (accessed 5 August 2015).

Cape Wine Academy (2002). Introduction to South African Wine. Stellenbosch: Cape Wine Academy.

Carlsson, F., Frykblom, P., & Liljenstolpe, C. (2003). Valuing wetland attributes: an application of choice experiments. *Ecological Economics*, 47 (1), 95–103.

Castro, E., Mañas, M. P., & De las Heras, J. (2011). Effects of wastewater irrigation on soil properties and turfgrass growth. *Water Science & Technology*, 63 (8), 1678–1688.

Caves, K., Plummer, R., Loë, R. (2013). Exploring water governance and management in Oneida Nation of the Thames (Ontario, Canada): An application of the Institutional Analysis Development framework. *Indigenous Policy Journal*, 23 (4), 1–27.

CDI – IMG Consulting (2006). Diagnosis: Local development strategy for Cercado Municipality, Cochabamba (in Spanish). http://www.bibliotecadigital.fam.bo/files/biblioteca/370/b74cba733d9530584bb05ac8017c5dc0.pdf (accessed 28 November 2014).

Census (2011a) Hyderabad (Greater Hyderabad) City Census 2011 data. http://www.census2011.co.in/census/city/392- hyderabad.html (accessed 22 October 2013).

Census (2011b). Census in brief. http://www.statssa.gov.za/Census2011/Products/Census_2011_Census_in_brief.pdf (accessed 17 August 2015).

Challen, R. (2000). Institutions, Transaction Costs, and Environmental Policy: Institutional Reform for Water Resources. Cheltenham, UK: Edward Elgar.

Chary, N. S., Kamala, C. T. & Raj, D. S. S. (2008). Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. *Ecotoxicology and Environmental Safety*, 69 (3), 513–524.

Cheepi, P. (2012). Musi River pollution its impact on health and economic conditions of downstream villages – a study. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 1 (4), 40–51.

Cheralu, C. (n/d). Status Paper on rice in Andhra Pradesh. http://www.rkmp.co.in/sites/default/files/ris/rice-state-wise/Rice%20State%20Wise%20Andhra%20Pradesh_0.pdf (accessed 30 October 2013).

Chigurupati, R., & Manikonda, V. (2007). Hyderabad's water issues and the Musi River, need for integrated solutions. Draft Paper presented at the International Water Conference, Berlin, 12–14 September 2007.

Choukr-Allah, R. (2010). Wastewater treatment and reuse. In Arab environment: water: sustainable management of a scarce resource. Report of the Arab Forum for Environment and Development (AFED), pp. 107–124, Beirut, Lebanon. http://www.afedonline.org/Report2010/pdf/En/Chapter7.pdf (accessed January 2013).

Ciriacy-Wantrup, S. V. (1967). Water policy and economic optimizing: Some conceptual problems in water research. *The American Economic Review*, 57 (2), 179-189.

City of Cape Town (2010). City of Cape Town: Treated effluent By-law. Promulgated 30 July 2010, PG 6772, LA 22158. https://www.capetown.gov.za/en/ByLaws/Promulgated%20bylaws/Treated%20Effluent%20By-law.pdf (accessed May 2014).

Coase, R. H. (1960). The problem of social cost. *Journal of Law and Economics*, 3, 1–44.

Colombo, S., Hanley, N., & Louviere, J. (2009). Modeling preference heterogeneity in stated choice data: an analysis for public goods generated by agriculture. *Agricultural Economics*, 40 (3), 307–322.

Commons, J. R. (1931). Institutional economics. *The American Economic Review*, 21 (4), 648–657.

Crase, L., & Gandhi, V. P. (2009). The effectiveness of water institutions. In: L. Crase & V. P. Gandhi (eds.), Reforming Institutions in Water Resource Management: Policy and Performance for Sustainable Development, pp. 3–19. London, UK: Earthscan.

Creswell, J. W. (2007). Qualitative inquiry and research design: Choosing among five approaches. Thousand, CA: Sage Publications Inc.

Curtis, A., Shindler, B., & Wright, A. (2002). Sustaining local watershed initiatives: lessons from landcare and watershed councils. *Journal of the American Water Resources Association*, 38 (5), 1207–1216.

De Bekker-Grob, E. W., Donkers, B., Jonker, M. F., & Stolk, E. A. (2015). Sample Size Requirements for Discrete-Choice Experiments in Healthcare: a Practical Guide. Patient, 8, 373–384. DOI 10.1007/s40271-015-0118-z.

De Wit, M., & Stankiewicz, J. (2006). Changes in surface water supply across Africa with predicted climate change. *Science*, 311, 1917–1921, doi: 10.1126/science.1119929

DEC: Department of Environment and Conservation (NSW) (2004). Environmental guidelines: Use of effluent by irrigation. http://www.environment.nsw.gov.au/resources/water/effguide.pdf (accessed 25 June 2015).

Devi, M. G. (2006). Wastewater, a valuable resource for urban, peri-urban agriculture – A case study of Hyderabad, India. Paper presented at Cultivating Sustainable Cities Multi-Stakeholder Policy-Making and Action Planning, Third World Urban Forum, Vancouver, 19–23 June 2006.

Devi, M. G., & Samad, M. (2008). Wastewater treatment and reuse: an institutional analysis for Hyderabad, India. In International Water Management Institute Conference Papers (No. h041888).

Dinar, A., Rosegrant, M. W., & Meinzen-Dick, R. S. (1997). Water allocation mechanisms: principles and examples. World Bank Policy Research Working Paper N°1779, Agriculture and Natural Resources Department.

Dovers S. (2001). Institutions for sustainability. Working/Technical Paper, Centre for Resource and Environmental Studies, Australian National University, Tela, Australia.

Drechsel, P., & Evans, A. E. V. (2010). Wastewater use in irrigated agriculture. *Irrigation and Drainage Systems*, 24 (1–2), 1–3.

Drechsel, P., Scott, C.A., Raschid-Sally, L., Redwood, M., & Bahri, B. (2010). Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-income Countries. London, Sterling, VA: Earthscan, IWMI, IDRC.

Drechsel, P., & Seidu, R. (2011). Cost-effectiveness of options for reducing health risks in areas where food crops are irrigated with treated or untreated wastewater. *Water International*, 36(4), 535–548.

Drechsel, P., Graefe, S., Sonou, M., & Cofie, O. O. (2006). Informal irrigation in urban West Africa: an overview. Research Report 102, Colombo, Sri Lanka: IWMI.

Dublin Principles (1992). The Dublin Statement on water and sustainable development. http://www.wmo.int/pages/prog/hwrp/documents/english/icwedece.html (accessed 16 April 2012).

Dunlap, R. E., Gallup, G. H. Jr., & Gallup, A. (1993). Of global concern: Results of the Health of the Planet Survey. *Environment*, 35(6–15), 33–39.

Durán–Álvarez, J. C., & Jiménez–Cisneros, B. (2014). Beneficial and negative impacts on soil by the reuse of treated/untreated municipal wastewater for agricultural irrigation: A review of the current knowledge and future perspectives. In: M. C. Hernandez Soriano (ed.), Environmental Risk Assessment of Soil Contamination. InTech, Open Science.

DWA: Department of Water Affairs (2009). Executive Summary, Municipal Wastewater Treatment: Base Information for Targeted Risk-based Regulation. Western Cape Province. Status at June 2009.

DWA: Department of Water Affairs (2012a). Managing our water wisely into the future: Water Affairs refines National Water Resource Strategy. https://www.dwa.gov.za/nwrs/ (accessed 23 July 2015).

DWA: Department of Water Affairs (2012b). Western Cape Sustainable Water Management Plan 2012 – Part 1, The Water Plan. http://eadp.westerncape.gov.za/sites/default/files/news/files/2012-12-05/sustainable-water-management-plan-approved-by-MEC-Bredell-13-06-2012.pdf (accessed 20 October 2014).

DWA: Department of Water Affairs (2013a). National water resource strategy 2: Water for an equitable and sustainable future, Second edition, June 2013. http://www.dwaf.gov.za/nwrs/LinkClick.aspx?fileticket=u_qFQycClbI%3d&tabid=91&mid=496 (accessed 21 October 2014).

DWA: Department of Water Affairs (2013b). Revision of general authorizations in terms of Section 39 of the National Water Act (Act 36 of 1998). Government Notice 665, Government Gazette 6 September 2013.

DWAF: Department of Water Affairs and Forestry (2004a). Strategies for water resources management, Chapter 3, National Water Resource Strategy. http://www.dwaf.gov.za/Documents/Policies/NWRS/Default.htm (accessed 7 May 2012).

DWAF: Department of Water Affairs and Forestry (2004b). National water resources strategy, First edition. http://www.dwaf.gov.za/Documents/Policies/NWRS/Default.htm (accessed May 2014).

DWAF: Department of Water Affairs and Forestry (2004c). Berg Water Management Area: Internal – Strategic Perspective. Prepared by Ninham Shand (Pty) Ltd in association with Jakoet & Associates, Umvoto Africa & Tlou, and Matji on behalf of the Directorate: National Water Resource Planning. Report PWMA19/000/00/0304.

DWAF: Department of Water Affairs and Forestry (2007). Western Cape water supply system: Reconciliation strategy study, overview of water re-use potential from wastewater treatment plants. https://www.dwa.gov.za/Projects/RS_WC_WSS/Docs/Overview-Water%20Re-use%20Potential.pdf (accessed May 2014).

DWS: Department of Water and Sanitation (2011). Green drop report – 2011. https://www.dwa.gov.za/Documents/GD/GDWC.pdf (accessed May 2014).

DWS: Department of Water and Sanitation (2015). WARMS. https://www.dwa.gov.za/Projects/WARMS/ (access July 2015).

EBTC (2011). Water and wastewater in India – Snapshot. http://www.ebtc.eu/pdf/111031_SNA_Snapshot_Water-and-wastewater-in-India.pdf (accessed 22 April 2013).

EC: European Commission (2012). The EU Water Framework Directive, integrated river basin management for Europe. http://ec.europa.eu/environment/water/water-framework/index_en.html (accessed 7 May 2012).

El Lateef, E. M. A., Hall, J. E., Lawrence, P. C., & Negm, M. S. (2006). Cairo-East Bank effluent re-use study 3 – Effect of field crop irrigation with secondary treated wastewater on biological and chemical properties of soil and groundwater. *Biologia*, 61 (19), S240-S245.

Elsenburg (2014). Agricultural statistics in brief. http://www.elsenburg.com/economics/statistics/start.htm (accessed May 2014).

Emongor, V. E., & Ramolemana, G. M. (2004). Treated sewage effluent (water) potential to be used for horticultural production in Botswana. *Physics and Chemistry of the Earth*, 29(15-18), 1101–1108.

Encinas, G. (2013). Cochabamba in numbers and alternative resources for the Department (in Spanish). http://www.economiabolivia.net/2013/10/02/cochabamba-en-cifras-recursos-alternativos-para-el-departamento/ (accessed 8 May 2015).

Ensink, J. H. (2006). Wastewater quality and the risk of hookworm infection in Pakistani and Indian sewage farmers. PhD thesis, University of London, UK.

Ensink, J. H., & van der Hoek, W. (2007). Editorial: New international guidelines for wastewater use in agriculture. *Tropical Medicine & International Health*, 12 (5), 575–577.

Ensink, J. H. J., Blumenthal, U. J., & Brooker, S. (2008). Wastewater quality and the risk of intestinal nematode infection in sewage farming families in Hyderabad, India. *American Journal of Tropical Medicine and Hygiene*, 79 (4), 561–567.

Ensink, J. H. J., Scott, C. A., Brooker, S., & Cairncross, S. (2010). Sewage disposal in the Musi-River, India: water quality remediation through irrigation infrastructure. *Irrigation and Drainage Systems*, 24 (1–2), 65–77.

EPI (2010a). Environmental Performance Indicator 2010. http://www.epi2010.yale.edu/file_columns/0000/0157/epi2010_report.pdf (accessed January 2013).

EPI (2010b). Water Stress Index. http://www.epi2010.yale.edu/Metrics/WaterStressIndex (accessed January 2013).

Evans, A. E. V., Rashid-Sally, L., & Cofie, O. O. (2010). Multi-Stakeholder Processes for Managing Wastewater Use in Agriculture. In: P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (eds.), Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-Income Countries, pp. 355-377. London, Sterling, VA: Earthscan, IDRC, IWMI.

Fairbanks, D. H. K., Hughes, C. J., & Turpie, J. K. (2004). Potential impact of viticulture expansion on habitat types in the Cape Floristic Region, South Africa. *Biodiversity and Conservation*, 13, 1075–1100.

Falkenmark, M., & Widstrand, C. (1992). Population and water resources: a delicate balance. *Population bulletin*, 47 (3), 1–36.

FAO (2012a). Hot issues: water scarcity. http://www.fao.org/nr/water/issues/scarcity.html (accessed 26 September 2012).

FAO (2012b). Wastewater Database. http://www.fao.org/nr/water/topics_qual_reuse.html (accessed 27 September 2012).

Farolfi, S., & Perret, S. (2002). Inter-sectoral competition for water allocation in rural South Africa: Analysing a case study through a standard environmental economics approach. Department of Agricultural Economics Working Paper 23, Pretoria: University of Pretoria.

Fatta, D., & Kythreotou, N. (2005). Wastewater as valuable water resource – concerns, constraints and requirements related to reclamation, recycling and reuse. Paper presented at the IWA International Conference on Water Economics, Statistics and Finance, Rethymno, Greece, 8–10 July 2005.

Feitelson, E. (2013). The four eras of Israeli water policies. In: N. Becker (ed.), Water Policy in Israel: context, issues and options. Dordrecht, Heidelberg, New York, and London: Springer.

Ferrás, C., Macía, X. C., García, M. Y., & Armas, F. X. (2004). Sustainable smallholding as a new scenario for the Galician economy (in Spanish). *Revista Galega de Economía*, 13(1–2), 1–25.

Fine, P., Halperin, R., & Hadas, E. (2006). Economic considerations for wastewater upgrading alternatives: An Israeli test case. *Journal of Environmental Management*, 78 (2), 163–169.

Fraiture, C., Molden, D., & Wichelns, D. (2010). Investing in water for food, ecosystems, and livelihoods: an overview of the comprehensive assessment of water management in agriculture. *Agricultural Water Management*, 97 (4), 495–501.

Friends of Rietvlei (2015). http://friendsofrietvlei.co.za/friends.html (accessed 18 February 2015).

FSD: Foundation for Sustainable Development (n/d). http://www.fsdinternational.org/country/bolivia/envissues (accessed 20 May 2015).

Funamizu, N., Huang, X., Chen, G-H., Jiangyong, H., & Visvanathan, C. (2008). Water reuse in Asia. In: B. Jiménez & T. Asano (eds.), Water Reuse: An international survey of current practice, issues and needs. London: IWA Publishing.

Gallegos, E., Warren, A., Robles, E., Campoy, E., Calderón, A., Sainz, M. G., Bonilla, P., & Escolero, O. (1999). The effects of wastewater irrigation on groundwater quality in Mexico. *Water Science & Technology*, 40 (2), 45–52.

Genius, M., Menegaki, A. N., & Tsagarakis, K. P. (2012). Assessing preferences for wastewater treatment in a rural area using choice experiments. *Water Resources Research*, 48 (4), doi:10.1029/2011WR010727.

Ghneim, A. (2010). Wastewater reuse and management in the Middle East and North Africa: A case study of Jordan. PhD thesis, Technical University Berlin, Germany.

Goldblatt, A. (2012). Agriculture: Facts & Trends, South Africa. http://awsassets.wwf.org.za/downloads/facts_brochure_mockup_04_b.pdf (accessed 13 July 2015).

Government Gazette (2013). Government Notice N°665. Department of Water Affairs, Revision of General Authorizations in terms of Section 39 of the National Water Act, 1998. http://faolex.fao.org/docs/pdf/saf126916.pdf (accessed 30 April 2014).

Government of Telangana (2015). Reinventing Telangana, the first steps: Socio-economic outlook. http://www.telangana.gov.in/PDFDocuments/Socio%20economic%20outlook%202015.pdf (accessed 5 August 2015).

Grafton, R. Q., Adamowicz, W., Dupont, D., Nelson, H., Hill, R. J., & Renzetti, S. (2004). The Economics of the Environment and Natural Resources. First Edition, USA, UK, and Australia: Blackwell Publishing.

Greene, W., & Hensher, D. (2003). A latent class model for discrete choice analysis: contrasts with mixed logit. *Transportation Research Part B: Methodological*, 37(8), 681–698.

Greyling, J. C. (2012). The role of the agricultural sector in the South African economy. MSc thesis (unpublished), Stellenbosch University, South Africa.

Grigg, N. S. (2008). Integrated water resources management: balancing views and improving practice. *Water International*, 33 (3), 279–292.

Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, 319 (5864), 756-760.

Groenfeldt, D. (1988). The potential for farmer participation in irrigation system management. *Irrigation and Drainage Systems*, 2 (3), 241–257.

Groenfeldt, D. (2000). Introduction: A Global Consensus on Participatory Irrigation Management. In: D. Groenfeldt & M. Svendsen (eds.), Case Studies in Participatory Irrigation Management, pp. 1-2. Washington, D.C: WBI learning resources series.

GWI: Global Water Intelligence (2010a). Peru promotes treated wastewater reuse. http://www.globalwaterintel.com/archive/11/11/general/peru-promotes-treated-wastewater-reuse.html (accessed 28 September 2012).

GWI: Global Water Intelligence (2010b). Municipal water reuse markets 2010. Oxford: Media Analytics Ltd.

GWP: Global Water Partnership (2000). Integrated Water Resources Management. TAC Background Papers N°4. Stockholm: GWP Secretariat.

GWP: Global Water Partnership (2002). Introducing Effective Water Governance. Mimeo.

Hamilton, A. J., Stagnitti, F., Xiong, X., Kreidl, S. L., Benke, K. K., & Maher, P. (2007). Wastewater irrigation: The state of play. *Vadose Zone Journal*, 6 (4), 823-840.

Hanley, N., Wright, R. E., & Adamowicz, V. (1998). Using choice experiments to value the environment. *Environmental and resource economics*, 11(3-4), 413-428.

Hanley, N., Mourato, S., & Wright, R. E. (2001). Choice modelling approaches: a superior alternative for environmental valuation?. *Journal of economic surveys*, 15 (3), 435-462.

Hanley, N., Wright, R. E., & Alvarez-Farizo, B. (2006). Estimating the economic value of improvements in river ecology using choice experiments: an application to the Water Framework Directive. *Journal of Environmental Management*, 78(2), 183-193.

Haruvy, N. (1997). Agricultural reuse of wastewater: Nation-wide cost benefit analysis. *Agriculture, Ecosystems and Environment*, 66 (2), 113 – 119.

Hebinck, P. (2001). Maize and socio-technical regimes. In: P. Hebinck & G. Verschoor (eds.), Resonances and dissonances in development: actors, networks and cultural repertoires. Assen, The Netherlands: Van Gorcum.

Hellegers, P. J. G. J., & Perry, C. J. (2004). Water as an economic good in irrigated agriculture. Agricultural Economics Research Institute (LEI), Report 3.4.12. The Hague.

Hensher, D.A., Rose, J.M., Greene, W.H. (2005). Applied Choice Analysis: A Primer. Cambridge: Cambridge University Press.

Herrera, P. A. (2004). Institutional economic assessment of the governance of irrigated agriculture: The case of the Peninsula of Santa Elena, Ecuador. Ghent University, Agricultural Economics, Faculty of Bioscience Engineering.

HMDA (2013). STPs taken up under HMDA. http://www.hmda.gov.in/Tenders/Statement__STPs.pdf (accessed 31 January 2014).

Hochstrat, R., Joksimovic, D., Wintgens, T., Melin, T., & Savic, D. (2007). Economic considerations and decision support tool for wastewater reuse scheme planning. *Water Science & Technology*, 56 (5), 175–182.

Hodgson, G. M. (1998). The approach of Institutional Economics. *Journal of Economic Literature*, 36 (1), 166–192.

Hodgson, S. (2006). Modern water rights: theory and practice. FAO Legislative Study 92, Rome.

Hoekstra, A. Y. (2011). The global dimension of water governance: why the river basin approach is no longer sufficient and why cooperative action at global level is needed. *Water*, 3 (1), 21–46.

Hoffman, S. D., & Duncan, G. J. (1988). Multinomial and conditional logit discrete-choice models in demography. *Demography*, 25 (3), 415–427.

Holling, C. S. (1995). What barriers? What bridges? In: L. H. Gunderson, C. S. Holling & S. S. Light (eds.), Barriers and Bridges to the Renewal of Regional Ecosystems. New York, USA: Columbia University Press.

Hoyos, D. (2010). The state of the art of environmental valuation with discrete choice experiments. *Ecological Economics*, 69 (8), 1595–1603.

Huibers F.P., Moscoso O., Duran A., & van Lier J. B. (2004). The use of wastewater in Cochabamba, Bolivia: A degrading environment. In: C. Scott, N. I. Faruqui, & L. Raschid-Sally (eds.), Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities, pp. 135–144. Wallingford, UK: CABI Publishing.

Huibers, F. P., & van Lier, J. B. (2005). Use of wastewater in agriculture: The water chain approach. *Irrigation and Drainage*, 54 (1), S3–S9.

Hunt, R. C. (1989). Appropriate social organization? Water users associations in bureaucratic canal irrigation systems. *Human Organization*, 48 (1), 79–90.

Hynes, S., Hanley, N., & Scarpa, R. (2008). Effects on welfare measures of alternative means of accounting for preference heterogeneity in recreational demand models. *American Journal of Agricultural Economics*, 90 (4), 1011-1027.

Inbar, Y. (2007). New standards for treated wastewater reuse in Israel. In: M. K. Zaidi (ed.), Wastewater Reuse–Risk Assessment, Decision-Making and Environmental Security, pp. 291–296. NATO Science for Peace and Security Series 2007.

Inbar, Y. (2010). Wastewater treatment and reuse in Israel. In: A. Tal & A. A Rabbo (eds.), Water Wisdom: Preparing the Groundwork for Cooperative and Sustainable Water Management in the Middle East. New Brunswick, New Jersey, and London: Rutgers University Press.

INE (2012). Bolivia: Characteristics of population and housing. National Census of Population and Housing, Bolivia 2012 (in Spanish). http://www.ine.gob.bo:8081/censo2012/PDF/resultadosCPV2012.pdf (accessed 22 May 2015).

INE (2014). Urban population of the city of Cochabamba and surrounding municipalities grew 96.9% (in Spanish) Press note. http://www.ine.gob.bo/pdf/boletin/NP_2014_14.pdf (accessed 27 November 2014).

Inglehart, R. (1995). Public support for environmental protection: Objective problems and subjective values in 43 societies. *PS: Political Science and Politics*, 28 (1), 57–72.

Ingram, H. M., Mann, D. E., Weatherford, G. D., & Cortner, H. J. (1984). Guidelines for Improved Institutional Analysis in Water Resources Planning. *Water Resources Research*, 20(3), 323–334.

IWMI: International Water Management Institute (2006). Recycling realities: managing health risks to make wastewater an asset. Water Policy Briefing 17. Colombo: IWMI.

IWMI: International Water Management Institute (2007). Comprehensive assessment of water management in agriculture. Water for food, water for life: a comprehensive assessment of water management in agriculture. London: Earthscan, Colombo: IWMI.

Jackson, V. A., Paulse, A. N., Odendaal, J. P., & Khan, W. (2009). Investigation into the metal contamination of the Plankenburg and Diep Rivers, Western Cape, South Africa. *Water SA*, 35, 289–299.

Jairath, J. (2001). Water Users Associations in Andhra Pradesh – initial feedback. Centre for Economic and Social Studies Hyderabad, New Delhi, India.

Jayakody, P., Gunawardana, I., Guneratne, S., Clemett, A., & Dissanayake, P. (2007). Wastewater agriculture in Kurunegala city, Sri Lanka. Research Report 8. Colombo, Sri Lanka: IWMI.

Jiménez, B. (2005). Treatment technology and standards for agricultural wastewater reuse: A case study in Mexico. *Irrigation and Drainage*, 54 (1), S23–S33.

Jiménez, B. (2006). Irrigation in developing countries using wastewater. *International Review for Environmental Strategies*, 6 (2), 229–250.

Jiménez, B. (2008). Water reuse in Latin America and the Caribbean. In: B. Jiménez & T. Asano (eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. London: IWA Publishing.

Jiménez, B., & Asano, T. (2008). Water reclamation and reuse around the world. In: B. Jiménez & T. Asano (eds.), Water Reuse: An International Survey of Current Practice, Issues and Needs. London: IWA Publishing.

Jiménez, B., Drechsel, P., Koné, D., Bahri, A., Raschid-Sally, L., Qadir, M. (2010). Wastewater, sludge and excreta use in developing countries: an overview. In: P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (eds.), Wastewater irrigation and health: assessing and mitigating risk in low-income countries, pp. 3–27. London, Sterling, VA: Earthscan.

JMP: Joint Monitoring Program (2012). Progress on drinking water and sanitation, 2012 update. http://www.wssinfo.org/fileadmin/user_upload/resources/JMP-report-2012-en.pdf (accessed 12 November 2012).

JMP (11.2.0) [computer software] http://www.jmp.com/software/jmp/.

Jouravlev, A. (2004). Potable water and sanitation in the twenty-first century (in Spanish). CEPAL. http://www.eclac.org/publicaciones/xml/9/19539/lcl2169e.pdf (accessed January 2013).

Jovanovic, N. Z. (2008). The use of treated effluent for agricultural irrigation: current status in the Bottelary catchment (South Africa). In: Villacampa Esteve, Y., Brebbia, C. A. & Prats Rico, D. (eds.), Proceedings of the Second International Conference on Sustainable Irrigation Management, Technologies and Policies, Alicante, Spain, 11–13 June 2008.

Kaercher, J. D., Po, M., & Nancarrow, B. E. (2003). Water recycling community discussion meeting I (unpublished manuscript). Australian Research Centre for Water in Society (ARCWIS).

Kamyotra, J. S., & Bhardwaj, R. M. (2011). Municipal wastewater management in India. In: Infrastructure Development Finance Company Limited (eds.), India Infrastructure Report 2011: Water: Policy and Performance for Sustainable Development. New Delhi: Oxford University Press.

Kantor, S. (n/d). The National Water Carrier. http://research.haifa.ac.il/~eshkol/kantorb.html (accessed 15 July 2015).

Kanyoka, P., Farolfi, S., & Morardet, S. (2008). Households' preferences and willingness to pay for multiple use water services in rural areas of South Africa: an analysis based on choice modelling. *Water SA*, 34(6), 715–723.

Kaufmann, D., Kraay, A., & Mastruzzi, M. (2010). The worldwide governance indicators: A summary of methodology, data and analytical issues. World Bank Policy Research Working Paper N°5430. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1682130 (accessed November 2012).

Kaur, R., Wani, S., Singh, A. & Lal, K. (2012). Wastewater production, treatment and use in India. Country Report. http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/111/CountryReport_India.pdf (accessed 15 April 2015).

Kenny, J. F., Barber, N. L., Hutson, S. S., Linsey, K. S., Lovelace, J. K., & Maupin, M. A. (2009). Estimated use of water in the United States in 2005. United States Geological Survey (USGS). http://pubs.usgs.gov/circ/1344/pdf/c1344.pdf (accessed 1 July 2015).

Keremane, G. B. (2009). Urban wastewater use for irrigation: A case study of farmers along Musi River in Hyderabad. *Karnataka Journal of Agricultural Sciences*, 22(1), 235–237.

Kislev, Y. (2011). The water economy of Israel. Policy Paper N° 2011.15, TAUB Center for Social Policy Studies in Israel. http://taubcenter.org.il/wp-content/files_mf/thewatereconomyofisrael.pdf (accessed 15 June 2015).

Kivaisi, A. K. (2001). The potential for constructed wetlands for wastewater treatment and reuse in developing countries: a review. *Ecological Engineering*, 16 (4), 545–560.

Klohn, W., & Wolter, H. W. (1998). Perspectives on food and water. International Conference Water and Sustainable Development, Paris.

Kolstad, C.D (2011). Environmental Economics. Second Edition. New York, Oxford: Oxford University Press.

Kuhfeld, F. (2000). Multinomial logit, discrete choice modelling – An introduction to designing choice experiments, and collecting, processing, and analyzing choice data with the SAS System. Technical Support Document, SAS Institute Inc. http://www.stat.auckland.ac.nz/~balemi/Choice.pdf (accessed 24 October 2014).

La Patria (2012). Polluted water causes 80% of diseases in Bolivia (in Spanish). http://lapatriaenlinea.com/?nota=113557 (accessed 20 May 2015).

Lancaster, K. (1966). A new approach to consumer theory. *Journal of Political Economy*, 74 (2), 132–157.

Laster, R., & Livney, D. (2009). Israel: the evolution of water law and policy. In: J.W. Dellapenna & J. Gupta (eds.), The evolution of the law and politics of water, pp. 121–137. The Netherlands: Springer.

Lavee, D., & Ash, T. (2013). Wastewater supply and management. In: N. Becker (ed.), Water Policy in Israel: Context, Issues and Options, pp. 83–100. Dordrecht, Heidelberg, New York, and London: Springer.

Lazarova, V., Levine, B., Sack, J., Cirelli, G., Jeffrey, P., Muntau, H., Salgot, M. & Brissaud, F. (2001). Role of water reuse for enhancing integrated water management in Europe and Mediterranean countries. *Water Science & Technology*, 43(10), 25–33.

Leas, E. C., Dare, A., & Al-Delaimy, W. K. (2014). Is gray water the key to unlocking water for resource-poor areas of the Middle East, North Africa, and other arid regions of the world?. *Ambio*, 43, 707–717, doi: 10.1007/s13280-013-0462-y.

Libralato, G., Volpi Ghirardini, A., & Avezzù, F. (2012). To centralize or to decentralize: An overview of the most recent trends in wastewater treatment management. *Journal of Environmental Management*, 94 (1), 61–68.

Lizarazu, A. (2014). Personal communication (not published).

Louviere, J. J., Hensher, D. A., & Swait, J. D. (2000). Stated choice methods: analysis and applications. Cambridge, New York and Melbourne: Cambridge University Press.

Louviere, J. J., Islam, T., Wasi, N., Street, D., & Burgess, L. (2008). Designing Discrete Choice Experiments: Do Optimal Designs Come at a Price?. *Journal of Consumer Research*, 35 (2), 360–375.

Louw, E. (2007). Climate change in the Western Cape – A disaster risk assessment of the impact on human health. PhD thesis (unpublished), University of Stellenbosch, South Africa.

Mara, D. (2004). Domestic wastewater treatment in developing countries. London, UK, Sterling, VA, USA: Earthscan.

Marka, L. (n/d). Capacity building project for the safe use of wastewater in agriculture. Production of wastewater, treatment and use in Bolivia (in Spanish). http://www.ais.unwater.org/ais/pluginfile.php/378/mod_page/content/148/BOLIVIA.pdf (accessed 3 June 2015).

Marka, L. (2011). Development of individual capacities for the safe use of wastewater in agriculture in Bolivia (in Spanish). http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/124/Bolivia_Reuso%20%2802.11.2011%29.pdf (accessed 21 November 2014).

Martijn, E. J., & Redwood, M. (2005). Wastewater irrigation in developing countries - limitations for farmers to adopt appropriate practices. *Irrigation and Drainage*, 54 (S1), S63–S70.

Maslow, A. H. (1954). Motivation and personality. New York: Harper.

Massoud, M. A., Tarhini, A., & Nasr, J. A. (2009). Decentralized approaches to wastewater treatment and management: Applicability in developing countries. *Journal of Environmental Management*, 90 (1), 652–659.

Mateo-Sagasta, J., Raschid-Sally, L., & Thebo, A. (2015). Global wastewater and sludge production, treatment and use. In: P. Drechsel, M. Qadir, & D. Wichelns (eds.), Wastewater: Economic Asset in an Urbanizing World, pp. 15-38. Dordrecht, Heidelberg, New York, London: Springer.

Maurer, M., Rothenberger, D., & Larsen, T. A. (2005). Decentralized wastewater treatment technologies from a national perspective: at what cost are they competitive?. *Water Science & Technology*: *Water Supply*, 5(6), 145–154.

McCartney, M., Scott, C., Ensink, J., Jiang, B., & Biggs, T. W. (2008). Salinity implications of wastewater irrigation in the Musi river catchment in India. *Ceylon Journal of Science*, 37 (1), 49–59.

McCutcheon, A. L. (1987). Latent Class Analysis. Sage University Papers Series: Quantitative Applications in the Social Sciences, N°07-064. Newbury Park, CA: Sage Publications.

McDonald, L. (2009). Development of a protocol for measuring wastewater exposure for farmers engaging in wastewater irrigated agriculture in Hyderabad, India. MSc thesis (unpublished), London School of Hygiene and Tropical Medicine, UK.

McDonald, D. A., & Ruiters, G. (2005). Theorizing water privatization in Southern Africa. In: D. A. McDonald & G. Ruiters (eds.), The age of commodity: Water privatization in Southern Africa, pp. 13–42. UK, USA: Earthscan.

McDonald, S., Punt, C., & Bhanisi, S. (2006). The impact of an increase in wine industry exports on the South African economy, focusing on the Western Cape. Elsenburg, PROVIDE Project Working Paper 3. http://www.elsenburg.com/provide/documents/WP2006_3%20Wine%20exports.pdf

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In: P. Zarembka (ed.), Frontiers in econometrics. New York: Academic Press.

McFadden, D. (1986). The choice theory approach to market research. *Marketing Science*, 5, 275–297.

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework. *Policy Studies Journal*, 39 (1), 169–183.

Megdal, S. B. (2012). Israel Water Management Program Provides Rich Learning Experience. https://wrrc.arizona.edu/isreal-learning-experience (accessed 30 June 2015).

Meinzen-Dick, R., & Mendoza, M. (1996). Alternative water allocation mechanisms: Indian and international experiences. *Economic and Political Weekly*, 31 (13), A25–A30.

Meinzen-Dick, R., & Zwarteveen, M. (1998). Gendered participation in water management: Issues and illustrations from water users' associations in South Asia. *Agriculture and Human Values*, 15 (4), 337–345.

Mekorot website (n/d). General information. http://www.mekorot.co.il/Eng/newsite/AboutUs/Pages/GeneralInformation.aspx (accessed 1 July 2015).

Merriam, S. B. (2009). Qualitative research: A guide to design and implementation. San Francisco, CA: Jossey-Bass.

Midgley, G. F., Chapman, R. A., Hewitson, B., Johnston, P., de Wit, M., Ziervogel, G., & Forsyth, G. G. (2005). A status quo, vulnerability and adaptation assessment of the physical and socioeconomic effects of climate change in the Western Cape. Report to the Western Cape Government, Cape Town, South Africa. CSIR Report ENV-S-C 2005-073, Stellenbosch.

Midgley, G., Chapman, R., Mukheibir, P., Tadross, M., Hewitson, B., Wand, S., Schulze, R., Lumsden, T., Horan, M., Warburton, M. et al. (2007). Impacts, Vulnerability and Adaptation in Key South African Sectors: An Input into the Long Term Mitigation Scenarios Process. Energy Research Centre, Cape Town, LTMS Input Report 5. http://www.erc.uct.ac.za/Research/publications/07Midgley-etal-LTMS_Impacts_Vulnerability_Adaptation.pdf (accessed 20 October 2014).

Miglio, R., & Spittler, H. (n/d). Ecological Sanitation (ECOSAN) as a tool to save water in the transport of excreta (in Spanish). http://www.rotaria.net/peru3/rotaria/files/ponencias/SANEAMIENTO%20ECOL%C3%93GICO%20%28ECOSAN%29%20COMO%20INSTRUMENTO%20PARA%20AHORRAR%20AGUA.pdf (accessed January 2013).

Milon, J. W., & Scrogin, D. (2006). Latent preferences and valuation of wetland ecosystem restoration. *Ecological Economics*, 56 (2), 162-175.

Ministry of Development Planning, Plurinational State of Bolivia (2006). National Development Plan 2006 (in Spanish). http://www.planificacion.gob.bo/sites/folders/documentos/plan.pdf (accessed 11 June 2015).

Ministry of Economy, State of Israel (2012). Israel's agricultural water efficiency continues to improve. OECD, FAO Report. http://itrade.gov.il/canada/israels-agricultural-water-efficicency-continues-to-improve-oecd-fao-report/ (accessed 30 June 2015).

Ministry of Environmental Protection, State of Israel (2012). Water and wastewater. http://www.sviva.gov.il/English/Legislation/Pages/WaterAndWastewater.aspx (accessed 29 June 2015).

Ministry of Environment and Water, Plurinational State of Bolivia (2009). Basic Sanitation National Plan 2008 – 2015 (in Spanish).

http://www.washinschoolsmapping.com/projects/pdf/Bolivia%20PlandeSaneamiento BasicoSENASBA.pdf (accessed 24 November 2014).

Ministry of Environment and Water, Plurinational State of Bolivia (2011). Sectorial Development Plan of Basic Sanitation 2011-2015 (in Spanish). http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37001128 (accessed 3 June 2015).

Ministry of Environment and Water, Plurinational State of Bolivia (2013). Systematization of treatment and reuse of wastewater (in Spanish). ISBN: 978 - 99974-807-2–9. La Paz, Bolivia.

Ministry of Environment and Water, Plurinational State of Bolivia (n/d). Technical Regulations for Treated Wastewater Use and Sludge of Domestic Origin (in Spanish). Draft version (Unpublished).

Ministry of National Infrastructures, Energy and Water Resources, State of Israel (2015). Israel's water economy. http://energy.gov.il/English/Subjects/water/Pages/AboutWater.aspx (accessed 29 June 2015).

Ministry of Water Resources, Republic of India (2002). National water policy. http://www.dowrorissa.gov.in/ActsnPolicies/NWP2002/NationalWaterPolicy2002.pdf (accessed 15 April 2015).

Ministry of Water Resources, Republic of India (2012). National water policy. Section 6: Demand management and water use efficiency. http://www.prsindia.org/parliamenttrack/report-summaries/summaryon-draft-national-water-policy-2012–2431/(accessed 15 April 2015).

Mizyed, N. R. (2013). Challenges to treated wastewater reuse in arid and semi-arid areas. *Environmental Science and Policy*, 25, 186-195, doi: 10.1016/j.envsci.2012.10.016.

Moilanen, P., & Ulla-Maija Mroueh, U. M (2010). Mobilizing funding in the water sector: the potential for private sector participation and desalination in the Levant region. FIIA Report 25/2010. http://www.isn.ethz.ch/Digital-Library/Publications/Detail/?lang=en&id=124605 (accessed 1 July 2015).

Molle, F., & Berkoff, J. (2006). Cities versus agriculture: revisiting intersectoral water transfers, potential gains and conflicts. Comprehensive Assessment Secretariat, Colombo, Sri Lanka.

Molle, F., Mollinga, P. P., & Wester, P. (2009). Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. *Water Alternatives*, 2 (3), 328–349.

Morales, M. (2011). Size does matter (in Spanish). In: M. Morales, V. Gianotten, M. Devisscher & D. Pacheco (eds.), Let's talk about land: Smallholdings, land management, forests and agricultural tax in Bolivia (in Spanish), pp. 67–74. Sucre, Bolivia, The Netherlands: Plural Editors.

Morrison, M. & Bennett, J. (2000). Choice modelling, non-use values and benefit transfer. *Economic Analysis and Policy*, 30 (1), 13-32.

Moseley, W. G. (2007). Neoliberal agricultural policy versus agrarian justice: Farm workers and land redistribution in South African's Western Cape Province. *South African Geographical Journal*, 89, 4–13.

Mpehle, Z. (2012). Are service delivery protests justifiable in the democratic South Africa?. *Journal of Public Administration*, 4 (1.1), 213-227.

Muga, H. E., & Mihelcic, J. R. (2008). Sustainability of wastewater treatment technologies. *Journal of Environmental Management*, 88 (3), 437–447.

Murray, M. (2010). Key trends in the agricultural economy of the Cape Winelands District Municipality: Implications for farm workers and dwellers. http://www.phuhlisani.com/oid%5Cdownloads%5C20100619CWDMAgricTrendsV04f%20edited.pdf (accessed 6 July 2015).

Myburgh, P. A. (2011). Response of Vitis vinifera L. cv. Merlot to low frequency irrigation and partial root zone drying in the Western Cape Coastal Region – Part II. Vegetative growth, yield and quality. *South African Journal of Enology and Viticulture*, 32, 104–116.

Nabli, M. K., & Nugent, J. B. (1989). The New Institutional Economics and its applicability to development. *World Development*, 17 (9), 1333–1347.

Naidoo, D., & Constantinides, G. (2000). Integrated approaches to efficient water use in South Africa. *International Journal of Water Resources Development*, 16 (1), 155–164.

Ndunda, E. N., & Mungatana, E. D. (2013). Evaluating the welfare effects of improved wastewater treatment using a discrete choice experiment. *Journal of Environmental Management* 123, 49-57.

Newson, M. (1997). Land, Water and Development: Sustainable Management of River Basin Systems. London, New York: Routledge.

NLOGIT (5.0) [computer software]. https://www.limdep.com/products/nlogit/.

North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge, UK: Cambridge University Press.

North, D. C. (2000). Understanding institutions. In: C. Menard (ed.), Institutions, Contracts and Organizations: Perspectives from New Institutional Economics. Cheltenham, UK: Edward Elgar.

NPC: National Planning Commission (2012). Our future: Make it work. National Development Plan 2030. National Planning Commission, Pretoria.

Oblitas, M. (2014). Rocha River, report of an agony (in Spanish). http://www.lostiempos.com/oh/actualidad/actualidad/20140216/rio-rocha-informe-de-una-agonia_245228_534533.html (accessed 12 May 2015).

OECD (2008). Brief note on environmental policy and institutional framework of Israel. Paper for the OECD Environment Policy Committee, Paris, France. http://www.sviva.gov.il/subjectsEnv/InternationalRelations/OECD/Documents/background_notes_to_the_environment_policy_committee.pdf (accessed 29 June 2015).

OECD (2010). OECD Review of agricultural policies: Israel. http://browse.oecdbookshop.org/oecd/pdfs/product/5110011e.pdf (accessed 15 June 2015).

OECD (2011). Benefits of investing in water and sanitation: An OECD perspective (OECD studies on water). Paris: OECD Publishing.

OECD (2015). Israel: country profile. In: Water Resources Allocation: Sharing Risks and Opportunities. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/11-Water-Resources-Allocation-Israel-OECD-Report-March-2015.pdf (accessed 12 June 2015).

Olmedo, R. (2013). The Rocha River, a real problem (in Spanish). http://www.lostiempos.com/diario/opiniones/columnistas/20130720/el-rio-rocha-un-verdadero-problema_221312_477172.html (accessed 12 May 2015).

Opinion (2011). Projects are delayed for lack of agreements (in Spanish). http://www.opinion.com.bo/opinion/articulos/2011/0731/noticias.php?id=19719 (accessed 9 June 2015).

Ostrom, E. (1986). An agenda for the study of institutions. *Public Choice*, 48 (1), 3–25.

Ostrom, E. (1990). Governing the Commons: The evolution of institutions for collective action. Cambridge: Cambridge University Press.

Ostrom, E. (1993). Design principles in long-enduring irrigation institutions. *Water Resources Research*, 29 (7), 1907–1912.

Ostrom, E. (2005). Understanding Institutional Diversity. Princeton, New Jersey: Princeton University Press.

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework. *Policy Studies Journal*, 39 (1), 7–27.

Oxford Dictionary, Oxford University Press. http://oxforddictionaries.com/definition/policy?q=policy (accessed 27 April 2012).

Pagan, P. (2009). Laws, customs and rules: identifying the characteristics of successful water institutions. In: L. Crase & V. P. Gandhi. (eds.), Reforming Institutions in Water Resource Management: Policy and Performance for Sustainable Development, pp. 20–44. London, UK: Earthscan.

Palanisami, K. (2013). Personal communication (not published).

Paraskevas, P. A., Giokas, D. L., & Lekkas, T. D. (2002). Wastewater management in coastal urban areas: the case of Greece. *Water Science & Technology*, 46 (8), 177–186.

Perreault, T. (2005). State restructuring and the scale politics of rural water governance in Bolivia. *Environment and Planning A*, 37 (2), 263–284.

Perreault, T. (2008). Custom and contradiction: rural water governance and the politics of usos y costumbres in Bolivia's irrigator movement. *Annals of the Association of American Geographers*, 98 (4), 834–854.

Perry, C. (2007). Efficient irrigation; inefficient communication; flawed recommendations. *Irrigation and Drainage*, 56 (4), 367-378.

Pescod, M. B. (1992). Wastewater treatment and use in agriculture. Irrigation and Drainage Paper 47. Rome: FAO.

Peter, J. R. (2004). Participatory irrigation management. http://166.119.78.61/e/nousin/kaigai/inwepf/i_document/pdf/sympo_inpim.pdf (accessed 17 November 2015).

Pfaffenberger, B. (1988). Fetishized objects and humanized nature: Towards an anthropology of technology. *Man, New Series*, 23 (2), 236–252.

Plurinational State of Bolivia (2009). Constitution of the Plurinational State of Bolivia. http://www.harmonywithnatureun.org/content/documents/159Bolivia%20Consitucion.pdf (accessed 3 June 2015).

Plurinational State of Bolivia (2011). Audit Report concerning the environmental performance of negative impacts on the Rocha River, Environmental Audit K2/AP06/M11, Office of the Comptroller General of the State (in Spanish).

Plurinational State of Bolivia (2012). Mother Earth and Integral Development to Live Well Act N° 300 (in Spanish). http://www.ine.gob.bo/indicadoresddhh/archivos/alimentacion/nal/Ley%20N%C2%B0%20300.pdf (accessed 11 June 2015).

Po, M., Kaercher, J. D., & Nancarrow, B. E. (2003). Literature review of factors influencing public perceptions of water reuse. Report to Australian Urban Water Conservation and Reuse Research Program. http://www.clw.csiro.au/publications/technical2003/tr54-03.pdf (accessed 23 October 2014).

Polski, M. M., & Ostrom, E. (1999). An institutional framework for policy analysis and change. https://mason.gmu.edu/,mpolski/documents/PolskiOstromIAD.pdf (accessed 14 July 2015).

Ponte, S., & Ewert, J. (2009). Which way is ‘‘up” in upgrading? Trajectories of change in the value chain for South African wine. *World Development*, 37 (10), 1637–1650.

PRI: Policy Research Initiative (2005). Economic instruments for water demand management in an Integrated Water Resources Management Framework. Synthesis Report. http://www.horizons.gc.ca/doclib/WaterSymposium_e.pdf (accessed 26 September 2012).

Provencher, B., & Bishop, R. C. (2004). Does accounting for preference heterogeneity improve the forecasting of a random utility model? A case study. *Journal of Environmental Economics and Management*, 48 (1), 793–810.

Provencher, B., & Moore, R. (2006). A discussion of using angler characteristics and attitudinal data to identify environmental preference classes: a latent-class model. *Environmental & Resource Economics*, 34 (1), 117–124.

Provencher, B., Baerenklau, K. A., & Bishop, R. C. (2002). A finite mixture logit model of recreational angling with serially correlated random utility. *American Journal of Agricultural Economics*, 84 (4),1066–1075.

Przeworski, A. (2004). Institutions matter?. *Government and Opposition*, 39, 527–540.

Qadir, M., & Scott, C.A. (2010). Non-pathogenic trade-offs of wastewater irrigation. In: P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (eds.), Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-Income Countries, pp. 101-126. London, Sterling, VA: Earthscan, IDRC, IWMI.

Qadir, M., Sharma, B. R., Bruggeman, A., Choukr-Allah, R., & Karajeh, F. (2007a). Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. *Agricultural Water Management*, 87 (1), 2-22.

Qadir, M., Wichelns, D., Raschid-Sally, L., Minhas, P. S., Drechsel, P., Bahri, A., & McCornick, P. G. et al. (2007b). Agricultural use of marginal-quality water: opportunities and challenges. In: D. Molden (ed.), Water for food, water for life: a Comprehensive Assessment of Water Management in Agriculture, pp.425-457. London, UK: Earthscan; Colombo, Sri Lanka: IWMI.

Qadir, M., Wichelns, D., Raschid-Sally, L., McCornick, P. G., Drechsel, P., Bahri, A., & Minhas, P. S. (2010a). The challenges of wastewater irrigation in developing countries. *Agricultural Water Management*, 97 (4), 561–568.

Qadir, M., Bahri, A., Sato, T., & Al-Karadsheh, E. (2010b). Wastewater production, treatment, and irrigation in Middle East and North Africa. *Irrigation and Drainage Systems*, 24 (1–2), 37–51.

Quiroz, F., Bustamante, R., & Heredia, G. (2007). Institutional analysis: drinking water and irrigation in Bolivia (in Spanish). Working Paper, Project MUS, Multiple Use Services. Challenge Program on Water and Food (CGIAR), International Water and Sanitation Centre (IRC) and Program "Agua Tuya".

Raschid-Sally, L., & Jayakody, P. (2008). Drivers and characteristics of wastewater agriculture in developing countries: Results from a global assessment. Research Report 127, Colombo, Sri Lanka: IWMI.

Rijsberman, F. R. (2006).Water scarcity: Fact or fiction?. *Agricultural Water Management*, 80 (1–3), 5–22.

Reddy, A. A. (2011). Regional disparities in employment and income in rural Andhra Pradesh, India. *Bangladesh Development Studies*, 34 (3), 1–19.

Reddy, R. V., & Reddy, P. P. (2006). How participatory is participatory irrigation management? Water users 'associations in Andhra Pradesh. *Economic and Political Weekly*, 40 (53), 5587–5595.

Republic of Bolivia (1992). Environment Act N°1333 (in Spanish). http://www.aaps.gob.bo/?p=334&aid=335&pid=334&sa=1 (accessed 2 June 2015).

Republic of Bolivia (2000). Supply and Use of Water and Sanitation Services Act N° 2066 (in Spanish). http://www.aaps.gob.bo/?p=323&aid=324&pid=323&sa=1 (accessed 1 June 2015).

Republic of Bolivia (2001). Act N° 2256. http://www.lexivox.org/norms/BO-L-2256.pdf (accessed 5 June 2015).

Republic of Bolivia (2004a). Promotion and Support to the Irrigation Sector Act N° 2878 (in Spanish).

http://www.senari.gob.bo/archivos/Ley%20de%20Riego%20Bueno.pdf (accessed 1 June 2015).

Republic of Bolivia (2004b). Act N° 2866. http://www.lexivox.org/norms/BO-L-2866.xhtml (accessed 5 June 2015).

Republic of Bolivia (2005). Act N° 3175. http://www.gacetaoficialdebolivia.gob.bo/normas/descargar/9780 (accessed 5 June 2015).

Republic of South Africa (1997). Water Services Act (Act 108 of 1997). Government Gazette No.18522 Cape Town: Office of the President. http://portal.unesco.org/en/files/47386/12670896091Water_Services_Act_1997.pdf/Water%2BServices%2BAct%2B1997.pdf

Republic of South Africa (1998). National Water Act (Act 36 of 1998). Government Gazette Vol. 398. Cape Town: Office of the President. http://www.dwaf.gov.za/Documents/Legislature/nw_act/NWA.pdf

Richards, A. & Singh, N. (2002). Inter-state water disputes in India: institutions and policies. *International Journal of Water Resources Development*, 18 (4), 611–625.

River Health Program (2003). State-of-Rivers Report: Diep, Hout Bay, Lourens and Palmiet River Systems. DWAF Pretoria, ISBN No: 0-620-30757-9.

Rogers, P., & Hall, A. W. (2003). Effective Water Governance. TEC Background Papers 7. Stockholm: Global Water Partnership.

Rogers, P., de Silva, R., & Bhatia, B. (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability. *Water Policy*, 4 (1), 1–17.

Román, C. E. (2009). Use of wastewater for irrigation and its relationship with local environmental changes in Cochabamba, Bolivia. MSc thesis, International Institute for Geo-information Science and Earth Observation, the Netherlands.

Rose, J. M., & Bliemer, M. C. (2013). Sample size requirements for stated choice experiments. *Transportation*, 40 (5), 1021-1041.

Rosegrant, M. W, & Binswanger, H. P. (1994). Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation. *World Development*, 22 (11), 1613–1625.

Rousseau, D., & Hooijmans, T. (2010). WHO reuse guidelines 2006. SWITCH Training Course, San Jose, Costa Rica, 24 November 2010. http://www.switchtraining.eu/fileadmin/template/projects/switch_training/db/event_upload_folder/97/Day_3_-_2.WHO_Guidelines.pdf (accessed 25 June 2015).

Rutkowski, T., Raschid-Sally, L., & Buechler, S. (2007). Wastewater irrigation in the developing world – Two case studies from Katmandu Valley in Nepal. *Agricultural Water Management*, 88, 83–91.

Ruto, E., Garrod, G., & Scarpa, R. (2008). Valuing animal genetic resources: a choice modeling application to indigenous cattle in Kenya. *Agricultural Economics*, 38 (1), 89–98.

Ruys P., van den Brink R., & Semenov, R. (2000). Values and governance systems. In: C. Menard (ed.), Institutions, Contracts and Organizations: Perspectives from New Institutional Economics. Cheltenham, UK: Edward Elgar.

Sagebiel, J. (2011). Comparing the latent class model with the random parameters logit: a choice experiment analysis of highly heterogeneous electricity consumers in Hyderabad, India. Department for Agricultural Economics, Humboldt-Universitat zu Berlin.

Salazar, L. (2014). Personal communication (not published).

Saldías, C., Boelens, R., Wegerich, K., & Speelman, S. (2012). Losing the watershed focus: a look at complex community-managed irrigation systems in Bolivia. *Water International*, 37 (7), 744–759.

Saleth, R. M. (2004). Strategic analysis of water institutions in India application of a new research paradigm. Research Report 79. Colombo, Sri Lanka: IWMI.

Saleth, R. M. (2005). Water institutions in India: structure, performance, and change. In: P. C. Gopalakrishnan, A. K. Biswas & D. C. Tortajada (eds.), Water Institutions: Policies, Performance and Prospects, Water Resources Development and Management, pp. 47–80. Berlin: Springer.

Saleth, R. M., & Dinar, A. (1999). Evaluating Water Institutions and Water Sector Performance. World Bank Technical Paper 447. Washington D.C.: World Bank.

Saleth, R. M., & Dinar, A. (2000). Institutional changes in global water sector: trends, patterns, and implications. *Water Policy*, 2 (3), 175–199.

Saleth, R.M., & Dinar, A. (2005). Water institutional reforms: theory and practice. *Water Policy*, 7 (1), 1–19.

Salgot, M., Huertas, E., Weber, S., Dott, W., & Hollender, J. (2006). Wastewater reuse and risk: definition of key objectives. *Desalination*, 187 (1), 29–40.

Saravia R. (2013). Inventory of irrigation systems using the Rocha River water (in Spanish). Research report (Unpublished).

SAS [computer software] http://www.sas.com/en_us/software/analytics/stat.html.

Sato, T., Qadir, M., Yamamoto, S., Endo, T., & Zahoor, A. (2013). Global, regional, and country level need for data on wastewater generation, treatment, and use. *Agricultural Water Management*, 130, 1-13.

Savenije, H. H. G. (2002). Why water is not an ordinary economic good, or why the girl is special. *Physics and Chemistry of the Earth*, 27 (11), 741–744.

Scheierling, S. M., Bartone, C., Mara, D. D., & Drechsel, P. (2010). Improving wastewater use in agriculture: An emerging priority. World Bank Policy Research Working Paper Series.

Scheierling, S. M., Bartone, C. R., Mara, D. D., & Drechsel, P. (2011). Towards an agenda for improving wastewater use in agriculture. *Water International*, 36 (4), 420-440.

Schlager, E., & Ostrom, E. (1992). Property-Rights Regimes and Natural Resources: A Conceptual Analysis. *Land Economics*, 68 (3), 249–262.

Schoeman, C. (2012). Grape and wine quality of V. vinifera L. cv. Cabernet Sauvignon/99R in response to irrigation using winery wastewater. MSc thesis (unpublished), University of Stellenbosch, South Africa.

Schotter, A. (1981). The Economic Theory of Social Institutions. Cambridge: Cambridge University Press.

Scott, C. A., Faruqui, N. I., & Raschid-Sally, L. (2004a). Wastewater use in irrigated agriculture: Management challenges in developing countries. In: C. Scott, N. I. Faruqui, & L. Raschid-Sally (eds.), Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities, pp. 1–10. Wallingford, UK: CABI Publishing.

Scott, C. A., Faruqui, N. I., & Raschid-Sally, L. (2004b). Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities. Wallingford, UK: CABI Publishing.

Scott, C.A., & Raschid-Sally, L. (2012). The global commodification of wastewater. *Water International*, 37 (2), 147–155.

SDC: Departmental River Basin Service and DGIA: Planning and Integrated Water Management Directorate (2014). Director Plan for the Rocha River Basin: Current status and proposed strategic guidelines (in Spanish). Draft version.

SENARI: National Irrigation Service. http://www.senari.gob.bo/quienes.asp (accessed 1 June 2015).

Seth, B. L. (2012). National Water Policy 2012: Silent on Priorities. http://www.downtoearth.org.in/content/national-waterpolicy-2012-silent-priorities (accessed 2 April 2014).

Shevah, Y. (n/d). Israel. ICID, Irrigation & Drainage in the World, A Global Review. http://www.icid.org/i_d_israel.pdf (accessed 26 June 2015).

Shiklomanov, I. A. (1999). World water resources and their use a joint SHI/UNESCO product. International Hydrological Program, UNESCO's intergovernmental scientific program in water resources. http://webworld.unesco.org/water/ihp/db/shiklomanov/index.shtml (accessed 18 April 2012).

Shuping, L. S. (2008). Biomonitoring of metal contamination in the lower Diep River, Milnerton, Western Cape. MTech thesis (unpublished), Cape Peninsula University of Technology, South Africa.

Siebe, C., & Cifuentes, E. (1995). Environmental impact of wastewater irrigation in central Mexico: an overview. *International Journal of Environmental Health Research*, 5, 161-173.

Smajgl, A., Leitch, A., & Lynam, T. (2009). Outback Institutions: An application of the Institutional Analysis and Development (IAD) framework to four case studies in Australia's outback. DKCRC Report 31. Alice Springs, Australia: Desert Knowledge Cooperative Research Centre.

Smet, J. (2003). Management models study, water user associations. IRC International Water and Sanitation Centre.

Smith, L. (2004). The murky waters of the second wave of neoliberalism: Corporatization as a service delivery model in Cape Town. *Geoforum*, 35 (3), 375–393.

Snowball, J. D., Willis, K. G., & Jeurissen, C. (2008). Willingness to pay for water service improvements in middle-income urban households in South Africa: A stated choice analysis. *South African Journal of Economics*, 76 (4), 705–720.

Speelman, S., & Veettil, C. P. (2013). Heterogeneous preferences for water rights reforms among smallholder irrigators in South Africa. *Bio-based and Applied Economics*, 2 (2), 131–149.

Speelman, S., Farolfi, S., Frija, A., D'haese, M., & D'haese, L. (2010). The impact of the water rights system on smallholder irrigators' willingness to pay for water in Limpopo province, South Africa. *Environment and Development Economics*, 15 (4), 465–483.

Srinivasan, J. T., & Reddy, V. R. (2009). Impact of irrigation water quality on human health: A case study in India. *Ecological Economics*, 68 (11), 2800–2807.

Starkl, M., Brunner, N., Amerasinghe, P., et al. (2015). Stakeholder Views, Financing and Policy Implications for Reuse of Wastewater for Irrigation: A Case from Hyderabad, India. *Water*, 7 (1), 300-328.

State of Israel (1955a). Water Measurement Law. http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=020485&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL (accessed 26 June 2015).

State of Israel (1955b). Water Drilling Control Law 5715. http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=001272&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL (accessed 26 June 2015).

State of Israel (1957). Drainage and Flood Control Law. http://faolex.fao.org/cgi-bin/faolex.exe?rec_id=002675&database=faolex&search_type=link&table=result&lang=eng&format_name=@ERALL (accessed 26 June 2015).

State of Israel (1959). Water Law 5719 (unofficial translation). http://www.sviva.gov.il/English/Legislation/Documents/Water%20Laws%20and%20Regulations/WaterLaw1959-Excerpts.pdf (accessed 16 June 2015).

Statistics South Africa (2006). Census of Agriculture Provincial Statistics 2002-Western Cape: Financial and Production Statistics. Report N°11-02-02.

Steenkamp, W. (2006). Cocktail of pollutants poisoned vlei – South Africa. http://www.iol.co.za/news/south-africa/cocktail-of-pollutants-poisoned-vlei-1.309257#.VOPTrC6-OQc (accessed 18 February 2015).

STP Amberpet (2013). Personal communication (not published).

Tajrishy, M. (2011). Wastewater treatment and reuse in Iran: situation analysis. Presented at the Kick-off Workshop on Safe Use of Wastewater in Agriculture, Bonn, Germany, November 2011. http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/111/Iran_Paper%20Bonn%20%20version%202.1.pdf (accessed January 2013).

Tal, S. (2006). Sustainability in water sector management in Israel. Presentation by the Israeli Water Commissioner to the World Bank, March 2006.

Tal, A. (2010). Water resources: The Israeli perspective. In: A. Tal & A. A. Rabbo (eds.), Water Wisdom: Preparing the Groundwork for Cooperative and Sustainable Water Management in the Middle East, pp. 26–36. New Brunswick, New Jersey, and London: Rutgers University Press.

Tal, A., & Rabbo, A. A. (2010). Water Wisdom: Preparing the Groundwork for Cooperative and Sustainable Water Management in the Middle East. New Brunswick, New Jersey, and London: Rutgers University Press.

Thebe, T. A., & Mangore, E. N. (2012). Wastewater production, treatment, and use in Zimbabwe. Presented at the 3rd Regional Workshop on Safe Use of Wastewater in Agriculture for Anglophone Africa, Johannesburg, South Africa, 26-28 September 2012. http://www.ais.unwater.org/ais/pluginfile.php/231/mod_page/content/157/zimbabwe_country_repor_%20for_capacity_development_project_on_was_2.pdf (accessed December 2012).

Thurstone, L. (1927). A Law of Comparative Judgement. *Psychological Review*, 4, 273–286.

Tidåker, P., Kärrman, E., Baky, A., & Jönsson, H. (2006). Wastewater management integrated with farming – an environmental systems analysis of a Swedish country town. *Resources, Conservation and Recycling*, 47 (4), 295–315.

Tiongco, M. M., Narrod, C. A., & Bidwell, K. (2010). Risk Analysis Integrating Livelihood and Economic Impacts of Wastewater Irrigation on Health. In: P. Drechsel, C. A. Scott, L. Raschid-Sally, M. Redwood & A. Bahri (eds.), Wastewater Irrigation and Health Assessing and Mitigating Risk in Low-Income Countries, pp.127-145. London, Sterling, VA: Earthscan, IDRC, IWMI.

Tirupataiah, K. (2013). Personal communication (not published).

TOI: Times of India (2002). Ghatkesar ryots pay cess for polluted water. http://articles.timesofindia.indiatimes.com/2002-02-18/hyderabad/27111813_1_water-tax-polluted-water-musi (accessed 30 October 2013).

Toledo, R., & Amurrio, D. (2006). Evaluation of the water quality of the Rocha River in the jurisdiction of SEMAPA, Cercado Province, Cochabamba, Bolivia (in Spanish). *Acta Nova*, 3 (3), 521–542.

Toze, S. (2006). Reuse of effluent water - benefits and risks. *Agricultural Water Management*, 80 (1–3), 147–159.

Trang, D. T., Hien, B. T. T., Mølbak, K., Cam, P. D., & Dalsgaard, A. (2007a). Epidemiology and aetiology of diarrhoeal diseases in adults engaged in wastewater-fed agriculture and aquaculture in Hanoi, Vietnam. *Tropical Medicine and International Health*, 12 (2), 23–33.

Trang, D. T., Mølbak, K., Cam, P. D., & Dalsgaard, A. (2007b). Helminth infections among people using wastewater and human excreta in peri-urban agriculture and aquaculture in Hanoi, Vietnam. *Tropical Medicine and International Health*, 12 (2), 82–90.

UBC EnvCom (n/y). Involvement and Communication. http://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=CHAMP_guide_7.pdf (accessed 23 October 2014).

UN: United Nations (2010). Millennium Development Goals. http://www.un.org/millenniumgoals/ (accessed 19 April 2012).

UN: United Nations (2012). UN-Water activities: Set of key indicators for the water sector. http://www.unwater.org/indicators.html (accessed October 2012).

UNEP: United Nations Environmental Program (2007). Global Environment Outlook Report GEO-4. http://www.unep.org/geo/geo4/report/GEO-4_Report_Full_en.pdf (accessed 26 September 2012).

UNEP-FI: United Nations Environmental Program Finance Initiative (2009). Water Sustainability of Agribusiness Activities in South Africa. http://www.unepfi.org/fileadmin/documents/chief_liquidity1_01.pdf

UNICEF (2012). Levels and trends in child mortality: Report 2012. http://apromiserenewed.org/files/UNICEF_2012_child_mortality_for_web_0904.pdf (accessed January 2013).

UNPD (2008). An overview of urbanization, internal migration, Population distribution and development in the world. http://www.un.org/esa/population/meetings/EGM_PopDist/P01_UNPopDiv.pdf (accessed 26 September 2012).

UNstats (2011). Environmental Indicators: Inland Water Resources. Wastewater. http://unstats.un.org/unsd/ENVIRONMENT/wastewater.htm (accessed December 2012).

UNW-AIS: United Nations Water Activity Information System (2012a). Regional Workshops on Safe Use of Wastewater in Agriculture. Link to individual Workshops: http://www.ais.unwater.org/ais/course/view.php?id=6 (accessed October 2012).

UNW-AIS: United Nations Water Activity Information System (2012b). Presented at the 3rd Regional Workshop on Safe Use of Wastewater in Agriculture for Anglophone Africa, Johannesburg, South Africa, 26-28 September 2012. Country Report: Ghana. http://www.ais.unwater.org/ais/pluginfile.php/356/mod_page/content/110/New_FinalDraftReport_Ghana.pdf (accessed December 2012).

USEPA: United States Environmental Protection Agency (2012). Guidelines for Water Reuse 2012. EPA/600/R-12/618, September 2012.

Uyttendaele, M., Jaykus, L., Amoah, P., Chiodini, A., Cunliffe, D., et al. (2015). Microbial Hazards in Irrigation Water: Standards, Norms, and Testing to Manage Use of Water in Fresh Produce Primary Production. *Comprehensive Reviews in Food Science and Food Safety,* 4, 1-21. doi: 10.1111/1541-4337.12133.

Van der Hoek, W. (2004). A framework for a global assessment of the extent of wastewater irrigation: the need for a common wastewater typology. In: C. Scott, N. I. Faruqui, & L. Raschid-Sally (eds.), Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities, pp. 10–24. Wallingford, UK: CABI Publishing.

Van der Hoek, W., Ul Hassan, M., Ensink, J. H. J., Feenstra, S., Raschid-Sally, L., Munir, S., Aslam, R., Ali, N., Hussain, R., & Matsuno, Y. (2002). Urban wastewater: a valuable resource for agriculture. A case study from Haroonabad, Pakistan. Research Report 63. Colombo, Sri Lanka: IWMI.

Van Koppen, B., & Schreiner, B. (2014). Moving beyond integrated water resource management: Developmental water management in South Africa. *International Journal of Water Resources Development*, 30, 543–558, doi: 10.1080/07900627.2014.912111.

Van Lier, J., Seeman, P., & Lettinga, G. (1998). Decentralized urban sanitation concepts: Perspectives for reduced water consumption and wastewater reclamation for reuse. EP&RC Foundation, Sub-Department of Environmental Technology, Wageningen University.

Van Rooijen, D. J., Turral, H., & Biggs, T. W. (2005). Sponge city: water balance of mega-city water use and wastewater use in Hyderabad, India. *Irrigation and Drainage*, 54 (1), S81–S91.

Van Rooijen, D. J., Biggs, T. W., Smout, I., & Drechsel, P. (2010). Urban growth, wastewater production and use in irrigated agriculture: a comparative study of Accra, Addis Ababa and Hyderabad. *Irrigation and Drainage Systems*, 24 (1–2), 53–64.

Vásquez, W. F. (2011). Household preferences and governance of water services: A hedonic analysis from rural Guatemala. Discussion Paper 01152. Development Strategy and Governance Division, IFPRI.

Veettil, P. C. (2011) Irrigation water management and pricing institutions in Krishna River Basin, India. PhD thesis, Ghent University, Belgium.

Vermillion, D., & Sagardoy, J.A. (1999). Transfer of irrigation management services. Guidelines. FAO Irrigation and Drainage Paper 58. Rome: FAO.

Von Sperling, M., & de Lemos Chernicharo, C. A. (2002). Urban wastewater treatment technologies and the implementation of discharge standards in developing countries. *Urban Water*, 4 (1), 105–114.

VRHR: Vice-Ministry of Water Resources and Irrigation, Plurinational State of Bolivia (2013). Irrigation Agenda 2025: Contribution to the Patriotic Agenda of the Bicentenary (in Spanish). http://www.bivica.org/upload/agenda-riego.pdf (accessed 2 June 2015).

Waldoks, E. Z. (2008). Inside the National Water Carrier. http://www.jpost.com/Israel/Inside-the-National-Water-Carrier (accessed 15 July 2015).

Ward, F.A., & Michelsen, A. (2002). The economic value of water in agriculture: concepts and policy applications. *Water Policy*, 4 (5), 423–446.

Water Authority (2011). The State of Israel: National Water Efficiency Report. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/24-The-State-of-Israel-National-Water-Efficiency-Report.pdf (accessed 26 June 2015).

Water Authority (2012). Long-Term Master Plan for the National Water Sector, Part A - Policy Document, Version 4. http://www.water.gov.il/Hebrew/Planning-and-Development/Planning/MasterPlan/DocLib4/MasterPlan-en-v.4.pdf (accessed 26 June 2015).

Water Authority (2015a). Water sector in Israel: IWRM model. Presentation at the 7th World Water Forum, 2015. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/02-Israel%20Water%20Sector%20-%20IWRM%20Model.pdf (accessed 12 June 2015).

Water Authority (2015b). The wastewater and treated effluents infrastructure development in Israel. Presentation at the 7th World Water Forum, 2015. http://www.water.gov.il/Hebrew/ProfessionalInfoAndData/2012/03-The%20Wastewater%20and%20Treated%20Effluents%20Infrastructure%20Development%20in%20Israel.pdf (accessed 29 June 2015).

WaterWatch (n/d). Water use efficiency of grapes in the Winelands of South Africa: A remote sensing study in the Winelands region, Western Cape. http://www.waterwatch.nl/fileadmin/bestanden/Publications/0147_ZA_grapes.pdf

WB-AWC: World Bank – Arab Water Council (2011). Water reuse in the Arab world: from principle to practice, voices from the field. Proceedings: Expert Consultation Wastewater Management in the Arab World, Dubai, UAE, 22-24 May 2011. http://water.worldbank.org/sites/water.worldbank.org/files/publication/Water-Reuse-Arab-World-From-Principle%20-Practice.pdf (accessed January 2013).

Wegerich, K. (2008). Blueprints for water user associations' accountability versus local reality: evidence from South Kazakhstan. *Water International*, 33 (1), 43–54.

Weldesilassie, A. B., Amerasinghe, P., & Danso, G. (2011). Assessing the empirical challenges of evaluating the benefits and risks of irrigating with wastewater. *Water International*, 36 (4), 441–454.

Wester, P. (2009). Capturing the waters: the hydraulic mission in the Lerma–Chapala Basin, Mexico (1876–1976). *Water History*, 1 (1), 9–29.

Wester, P., Merrey, D. J., & De Lange, M. (2003). Boundaries of Consent: Stakeholder Representation in River Basin Management in Mexico and South Africa. *World Development*, 31 (5), 797–812.

Wester, P., Rap, E., & Vargas-Velázquez, S. (2009). The hydraulic mission and the Mexican hydrocracy: Regulating and reforming the flows of water and power. *Water Alternatives*, 2 (3), 395–415.

WGI: Worldwide Governance Indicator (2012). The Worldwide Governance Indicators (WGI) project. http://info.worldbank.org/governance/wgi/index.asp (accessed October 2012).

WHO (1989). Guidelines for the safe use of wastewater and excreta in agriculture and aquaculture: Measures for public health protection. http://apps.who.int/iris/bitstream/10665/41681/1/9241542489.pdf (accessed 25 June 2015).

WHO (2006). Guidelines for the Safe Use of Wastewater, Excreta and Grey Water. Volume 2. Wastewater Use in Agriculture. Geneva, Switzerland: WHO.

WHO (2009). Diarrheal disease: fact sheet 330. http://www.who.int/mediacentre/factsheets/fs330/en/index.html (accessed 19 November 2012).

WHO (2012a). Costs and benefits of water and sanitation improvements at the global level (Evaluation of the). http://www.who.int/water_sanitation_health/wsh0404summary/en/ (accessed 19 April 2012).

WHO (2012b). Children: reducing mortality. http://www.who.int/mediacentre/factsheets/fs178/en/index.html (accessed 19 November 2012).

WHO (2012c). World Health Statistics 2012. http://www.who.int/gho/publications/world_health_statistics/2012/en/index.html (accessed November 2012).

WHO (2015). Water-related diseases: Diarrhea. http://www.who.int/water_sanitation_health/diseases/diarrhoea/en/ (accessed 23 July 2015).

Wichelns, D. (2004). New policies are needed to encourage improvements in irrigation management. *Journal of Irrigation and Drainage Engineering*, 130 (5), 366–372.

Wichelns, D., Drechsel, P., & Qadir, M. (2015). Wastewater: economic asset in an urbanizing world. In: P. Drechsel, M. Qadir & D. Wichelns (eds.), Wastewater: economic asset in an urbanizing world, pp.3–14. Dordrecht, Heidelberg, New York, and London: Springer.

Windrock-Int (2006). Urban Wastewater: Livelihoods, Health and Environmental Impacts in India. Research Report, Comprehensive Assessment of Water Management in Agriculture. Colombo, Sri Lanka: IWMI.

Wines of South Africa (2009). http://www.wosa.co.za/sa/origin_label.php (accessed January 2015).

Winner, L. (1986) Technology as forms of life. In: The whale and the reactor: a search for limits in an age of high technology. Chicago: University Press.

Winpenny, J. T., Heinz, I., & Koo-Oshima, S. (2010). The wealth of waste: the economics of wastewater use in agriculture. FAO Water Report 35. Rome, Italy: FAO.

WLP: Water Land People (2007). Capitalization of experiences: Water, Land and People. The water context in Bolivia. http://www.waterlandpeople.net/pdf/en/Bolivia_Country_context.pdf (accessed 1 June 2015).

World Bank (2003). The World Bank Participation Sourcebook. Appendix II: Working Paper Summaries. http://www.worldbank.org/wbi/sourcebook/sba2.htm (accessed 7 August 2015).

World Bank (2007). Making the most of scarcity: accountability for better water management results in the Middle East and North Africa. MENA Development Report. Washington, D.C.

World Bank (n/d A). GNI per Capita, Atlas Method (current US$), Data. http://data.worldbank.org/indicator/NY.GNP.PCAP.CD?display=default (accessed November 2014).

World Bank (n/d B). Mortality rate, under-5 (per 1000 live births), Data. http://data.worldbank.org/indicator/SH.DYN.MORT (accessed November 2014).

World Water Council (2010). Water Crisis. http://www.worldwatercouncil.org/index.php?id=25 (accessed 18 April 2012)

WSFF: World Sanitation Financing Facility (2013). The sanitation gap. http://www.sanitationfinance.org/purpose/sanitationgap (accessed 13 February 2014).

WWAP: World Water Assessment Program (2012). The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk. Paris: UNESCO.

www.quandl.com. Agriculture share of GDP by country. https://www.quandl.com/collections/economics/agriculture-share-of-gdp-by-country (accessed 8 May 2015).

Yang, H., Reichert, P., Abbaspour, K. C., & Zehnder, A. J. B. (2003). A water resources threshold and its implications for food security. *Environmental Science & Technology*, 37 (14), 3048–3054.

Yercan, M. (2003). Management turning-over and participatory management of irrigation schemes: a case study of the Gediz River Basin in Turkey. *Agricultural Water Management*, 62 (3), 205–214.

Zabalaga, J., Amy, G., & von Münch, E. (2007). Evaluation of agricultural reuse practices and relevant guidelines for the Alba Rancho WWTP (primary and secondary facultative ponds) in Cochabamba, Bolivia. *Water Science & Technology*, 55(1–2), 469–475.

Zwarteveen, M., Roth, D., & Boelens, R. (2005). Water Rights and Legal Pluralism. Beyond Analysis and Recognition. In: D. Roth, R. Boelens & M. Zwarteveen (eds.), Liquid Relations: contested water rights and legal complexity. New Brunswick, New Jersey and London: Rutgers University Press.

Curriculum Vitae

Cecilia Saldías Zambrana was born in Oruro, Bolivia on 14 June 1979. She completed secondary education at 'Federico Froebel' German School in Cochabamba, Bolivia in 1997. In 2006, she obtained the degree of Civil Engineer, with specialization in sanitary engineering, at Universidad Mayor de San Simon, Cochabamba, Bolivia. Then, she started as intern at the Multipurpose Misicuni Project and later she joined the same project as junior engineer until August 2007.

In September 2009, she graduated as MSc. in International Land and Water Management, with specialization in irrigation and water management, from Wageningen University, the Netherlands. During that period she did an internship at the Institute of Landscape Hydrology of the Leibniz-Centre of Agricultural Landscape Research (ZALF), in Müncheberg, Germany; and she worked as student assistant at Wageningen University for the course Irrigation and Development. After graduation, she returned to her home country, where she worked as civil engineer.

In January 2012, she joined the Department of Agricultural Economics at Ghent University as PhD student, funded by BOF (Special Research Fund) and the International Water Management Institute (IWMI). In the framework of her PhD, she conducted research, as intern, at different offices of the IWMI: in Colombo, Sri Lanka; in Hyderabad, India; and in Pretoria, South Africa. Furthermore, she also conducted research in Cochabamba, Bolivia.

In 2015, she completed the Doctoral Training Program at the Faculty of Bioscience Engineering, Ghent University.

She also participated in national and international scientific conferences with oral contributions; and she is author and co-author of international peer-reviewed publications.

Articles in peer-reviewed international journals (A1)

Saldías, C., Speelman, S., van Koppen, B. & Van Huylenbroeck, G. (2015). Institutional arrangements for the use of treated effluent in irrigation, Western Cape, South Africa. *International Journal of Water Resources Development*, in press.

Saldías, C., Speelman, S., Amerasinghe, P. & Van Huylenbroeck, G. (2015). Institutional and policy analysis of wastewater (re)use for agriculture: case study Hyderabad, India. *Water Science & Technology*, 72(2), 322-331.

Saldías, C., Speelman, S. & Van Huylenbroeck, G. (2013). Access to Irrigation Water and Distribution of Water Rights in the Abanico Punata, Bolivia. *Society & Natural Resources*, 26(9), 1008-1021.

Saldías, C., Boelens, R., Wegerich, K. & Speelman, S. (2012). Losing the watershed focus: a look at complex community-managed irrigation systems in Bolivia. *Water International*, 37(7), 744-759.

Book chapter

Speelman, S. & Saldías, C. (2014). Institutional settings for wastewater use in agriculture. In: M. Falque & H. Lamotte (eds.), Agriculture and Forestry: Property rights, economics and environment. Brussels: Bruylant.

International conferences and proceedings

Saldías, C., Speelman, S. & Van Huylenbroeck, G. (2015). Revealing the preferences of farmers for a framework to use treated effluent in irrigation: case study Western Cape, South Africa. Presented at the IWRA World Water Congress XV, Edinburgh, Scotland, May 25-29, 2015.

Saldías, C., Speelman, S. & Van Huylenbroeck, G. (2015). "If opportunity doesn't knock, build a door" The trajectory of a successful story of formal use of treated effluent in Western Cape Province, South Africa. Presented at the Dresden Nexus Conference (DNC) 2015, Dresden, Germany, March 25-27, 2015.

Saldías, C., Speelman, S., Amerasinghe, P. & Van Huylenbroeck, G. (2014). Institutional and policy analysis of wastewater (re)use for agriculture: case study Hyderabad, India. Paper presented at the IWA World Water Congress & Exhibition, Lisbon, Portugal, September 21-26, 2014.

Saldías, C., Speelman, S. & Van Huylenbroeck, G. (2013). "A sewer is a cynic. It tells all": Preferences for agricultural wastewater (re)use among farmers in Hyderabad, India. Paper presented at the 7th Belgian Environmental Economics Day (BEED), Hasselt, Belgium, December 13, 2013.

Saldías, C., Speelman, S. & Van Huylenbroeck, G. (2011). A source of conflict? Distribution of water rights in Abanico Punata, Bolivia. Paper presented at the Water Resources Management VI, Riverside California, May 23-25, 2011. WIT Transactions on Ecology and the Environment, vol. 145, WIT Press.