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REPORT

A livelihood in a risky environment: Farmers' preferences for irrigation with wastewater in Hyderabad, India

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Abstract Most cities in developing countries fail to treat their wastewater comprehensively. Consequently, farmers downstream use poor-quality water for irrigation. This practice implies risks for farmers, consumers and the environment. Conversely, this water supply supports the livelihood of these farmers and other stakeholders along the value chains. Linking safer options for wastewater management with irrigation could therefore be a win–win solution: removing the risks for society and maintaining the benefits for farmers. However, in developing countries, the high investment costs for the required treatment are problematic and the willingness of farmers to pay for the water (cost recovery) is often questionable. Using a choice experiment, this paper gives insight into farmers' preferences for wastewater use scenarios, quantifying their willingness to pay. The case study is Hyderabad, India. Farmers there prefer water treatment and are prepared to pay a surplus for this. Considering the cost-recovery challenge, this information could be valuable for planning small on site wastewater treatment systems.

Keywords Agriculture · Choice experiment · India · Wastewater

INTRODUCTION

In many regions, water scarcity, resulting from population growth, economic development and climate change, is regarded as a major threat to food security. Competition for water exists between different sectors, mainly challenging the agricultural sector, which accounts for up to 70 % of the world's freshwater withdrawals (OECD 2010). Conversely, cities return water to the hydrological system in the form of 'wastewater'. While wastewater has the potential to reduce pressure on water resources (Toze 2006), in most developing countries it undergoes 'little' or no treatment. Consequently, farmers end up using poor-quality water for irrigation, primarily because of the lack of alternative water sources (Qadir et al. 2010). While the agricultural sector can benefit enormously from wastewater, especially in arid regions, the use of untreated wastewater carries risks for farmers, consumers and the environment. Health risks for farmers include helminth infections; the environmental risks are degradation of aquatic ecosystems and pollution of soils and groundwater (Raschid-Sally et al. 2005). To offset these risks, a shift from informal to formal (planned and regulated) use of wastewater is essential.

Unfortunately, many developing countries struggle to implement comprehensive wastewater treatment programs (Qadir et al. 2010). The high costs required for wastewater collection and treatment are a major challenge (Leas et al. 2014), and the willingness of farmers to contribute to cost recovery for the provision of safe wastewater is questioned where water is traditionally a free good, or the expectation is that the authorities or polluters have to pay for the treatment. However, there are regional differences, and more studies about farmers' perceptions and their willingness-to-pay (WTP) are necessary to better understand the potential for cost sharing (Drechsel et al. 2015) between stakeholders such as the government and the farmers.

The purpose of the study is to identify farmers' preferences for wastewater reuse, including the factors influencing these preferences, and to quantify their WTP for different reuse scenarios. The case study is Hyderabad, India. This case study is exemplary for many similar situations around large cities in developing countries, where urban growth has outpaced the capacity of the city to manage wastewater, and irrigation with untreated wastewater is practiced (see Saldías 2016).

To this end, a choice experiment (CE) was undertaken assessing farmers' preferences for hypothetical scenarios for wastewater irrigation. The collected data were analysed using a conditional logit (CL) and a latent class (LC) model, the latter to capture the potential heterogeneity in preferences among respondents. Finally, the WTP for changes in the water reuse scenarios were determined. This paper adds to the literature on valuation by farmers of wastewater for irrigation in several ways. First, compared to studies such as those of Abu Madi et al. (2003), Birol et al. (2008), Bakopoulou et al. (2010) and Weldesilassie et al. (2009), that apply contingent valuation, the use of a CE allows more detailed insight into the preference structure of farmers with respect to specific attributes of the reuse scenarios. Furthermore, compared to the few studies that apply CE (e.g. Birol et al. 2010; Genius et al. 2012; Ndunda and Mungatana 2013), in this study, nutrient content is identified as a separate water quality attribute. Finally, an institutional aspect of the reuse scenarios is also included, namely the level of restrictions on use. This is because, in developing countries, imposing restrictions can be a cheaper way (compared to treatment) to counter the risks associated with reuse.

THE CASE STUDY

Despite the provisions in the National Water Policy (Ministry of Water Resources, Republic of India 2012) to improve water quality, pollution of water sources across India is alarming. It has been estimated that 70 % of India's surface and groundwater resources have been polluted by biological, organic and inorganic pollutants (Rao and Mamatha 2004).

As cities grew, so did domestic water demand. The domestic sector is responsible for the highest proportion of wastewater generated in India. Most recent data indicate that the wastewater generated in Class-I cities and Class-II towns is above 38 000 million litres per day (MLD), of which only 35 % is treated (CPCB 2009). This suggests that an important volume of wastewater is disposed of with minimal treatment, which has implications for public health and the environmental status of water resources. Discharging untreated wastewater is forbidden in India; in practice, however, this is not enforced. The implication is that farmers have no choice but to irrigate with the poor-quality water flowing into the rivers.

While pollution with industrial and domestic effluents is linked to the lack of infrastructure to collect, treat and dispose of wastewater appropriately (see Rao and Mamatha 2004), the poor enforcement of the regulatory framework and dysfunctional institutions also play a role. In fact, the legal framework to manage environmental regulation in India is inadequate to respond to the increasingly complex set of environmental challenges (Quitzow et al. 2013).

The case study is the Musi River in Hyderabad, the Capital City of Telangana (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 rainfall is about 700–800 mm, occurring during the monsoon season (June–October) (Buechler and Devi 2003). The Musi River has a catchment area of about 11 300 km^2, representing 4 % of the Krishna River basin. In the past, this river was seasonal, only providing farmers with irrigation water during the rainy season (Ensink et al. 2010). Nowadays, downstream of Hyderabad it is perennial due to the poor-quality effluents from the city (Keremane 2009).

Hyderabad has experienced rapid growth and now has a population of 6.8 million people (Census 2011). It was estimated, in 2009, that Hyderabad generates about 1000 MLD of wastewater (Amerasinghe et al. 2009), whereas the current combined treatment capacity is around 602 MLD (official at Sewage Treatment Plant Amberpet, pers. comm.). The wastewater generated contains effluents from various industries, such as electroplating, lead extraction/battery units, pharmaceutical industry and production of leather, textile, paper, soap, cooking oil and jewellery (Buechler and Devi 2003). Recent sources estimate that the city has the capacity to treat about half of its sewage (Starkl et al. 2015). This is a noteworthy progress, but the other half continues to cause significant water pollution problems.

This was confirmed in studies on the quality of the water in the river and its effects on soils, farmers, public health and economic development (e.g. Amerasinghe et al. 2009; Ensink et al. 2010; Cheepi 2012). Ensink et al. (2010) for example, found that hookworm prevalence was high in farmers using untreated wastewater. The quality of the water, however, improved significantly downstream as a result of, e.g. sedimentation, dilution, aeration, and natural die-off (Ensink et al. 2010).

McCartney et al. (2008) assessed the impact of wastewater irrigation on the salinity of the river water and the soil in irrigated fields and evaluated whether declines in rice yield, reported by farmers, are attributable to salinization. Their results indicate that discharges from the city increase the total dissolved solids (TDSs)[1] in the river water and can therefore contribute to salinization. They also observed that fields closer to the city, irrigated with

[1] TDS represents the total quantity of dissolved minerals in the water; since the major part of the material dissolved is ionic, electrical conductivity (EC) is conventionally used as a measure of TDS (McCartney et al. 2008).

wastewater for longer periods, have higher soil salinity (McCartney et al. 2008). Finally, it was reported that the level of cadmium in the soil exceeded the EU maximum permissible level in 47 % of the samples. However, the overall risks of wastewater irrigation along the Musi River were considered negligible to the human food chain (Amerasinghe et al. 2009).

Besides the negative effects described above, wastewater irrigation downstream from Hyderabad contributes to livelihoods and food security for the urban and peri-urban poor (Buechler and Devi 2003). About 90 % of the wastewater generated in Hyderabad is used for irrigation (Van Rooijen et al. 2010), especially in the dry season. The area irrigated is some 12 000 ha. The main crops grown include para-grass[2] fodder and paddy (Buechler and Devi 2003) and, on smaller plots, also vegetables. Due to the water supply from the Musi River, farmers can grow para-grass throughout the year and harvest paddy twice per year (Van Rooijen et al. 2010).

The area sampled comprises peri-urban and rural fringes, in a stretch of about 25 km downstream from Hyderabad, between the first weir and the eighth weir located along the Musi River (Fig. 1). The area belongs to Ghatkesar Mandal, Rangareddi District. The total population in Ghatkesar Mandal is 88 935 (National Panchayat Portal 2013). There is no official information about the number of farmers irrigating with the Musi River (Amerasinghe pers. comm.), but Buechler and Devi (2003) estimated that some 12 000 ha are irrigated, with landholdings of around 1 ha/household. Considering these figures, the number of farm-households would be in the region of 12 000. The area sampled is estimated at approximately 4000 ha.

MATERIALS AND METHODS

A CE was used to reveal farmers' preferences regarding the use of wastewater in agriculture. CEs have become a popular method for environmental valuation (Hoyos 2010) and they have proved helpful in generating information for policy analysis (Sur et al. 2007). It is a survey-based technique that allows preferences for goods to be modelled. Goods are described based on their 'attributes' and these take different levels. Respondents are asked to choose between different alternative specifications of the goods (Louviere et al. 2000). By focusing on the attributes, CEs have the potential to generate multiple value estimates from a single application (Hanley et al. 2001). Another advantage is that, in CEs, the experimental stimuli are under the control of the researcher (Bennett and Blamey 2001). For a state of the art on CE, see Hoyos (2010).

[2] Para-grass is a type of grass, cultivated as fodder for buffalo feed.

Choice experiment design and implementation

Identification of attributes and their levels

The design of the CE followed the steps proposed by Hanley et al. (2001, p. 437). In the first step, the relevant attributes for the good to be valued were identified. In this case, the good is the use of water delivered by the Musi River for irrigation. To identify attributes, literature regarding the reuse practices around Hyderabad (see description of the study site) and consultation with experts were used. The experts included researchers from the local IWMI Office in Hyderabad undertaking research on reuse, economists from the triple-R unit at IWMI Headquarters in Sri Lanka and officers from different government institutions. Focus groups were not organized because wastewater irrigation is a sensitive issue, and bringing farmers together for this was considered quite difficult. However, special attention was paid during the first interviews to identify whether the attributes and their levels were considered relevant by the interviewees. The second step of the CE involved assigning levels to the different attributes. Levels should be "feasible, realistic, non-linearly spaced, and span the range of the respondents' preference maps" (Hanley et al. 2001, p. 437). Again, expert knowledge and literature were used in this step.

Five attributes were identified to describe important aspects of wastewater reuse in agriculture within the study area: water quantity, water use restrictions, health risks, nutrient content and price (Table 1). The 'water quantity' attribute referred to the amount of river water available for farmers. Three levels were proposed: high, medium and low. As there was no information on the exact quantity of water used by farmers, this attribute was described in qualitative terms. 'Medium quantity' was defined as the amount of water a farmer was (at the time of the survey) using to irrigate his/her entire farm. The other two levels described situations where more or less water was available.

The attribute 'water use restrictions' referred to the measures which should be taken while applying the water. Again, three levels were identified: high (with strict restrictions on crops, e.g. vegetables-eaten-raw are not allowed; strict control over irrigation methods; strict monitoring), moderate (some restriction with respect to crops, but more variation is allowed; control over irrigation methods with options for crop-method mix; sporadic monitoring) and low (crops or irrigation methods are unrestricted; farmer is responsible for cleaning of crops).

The attribute 'health risks' referred to the occurrence of negative health effects as a consequence of being in contact with water from the Musi River. Three levels were proposed: very high (where a large number of farmers suffer

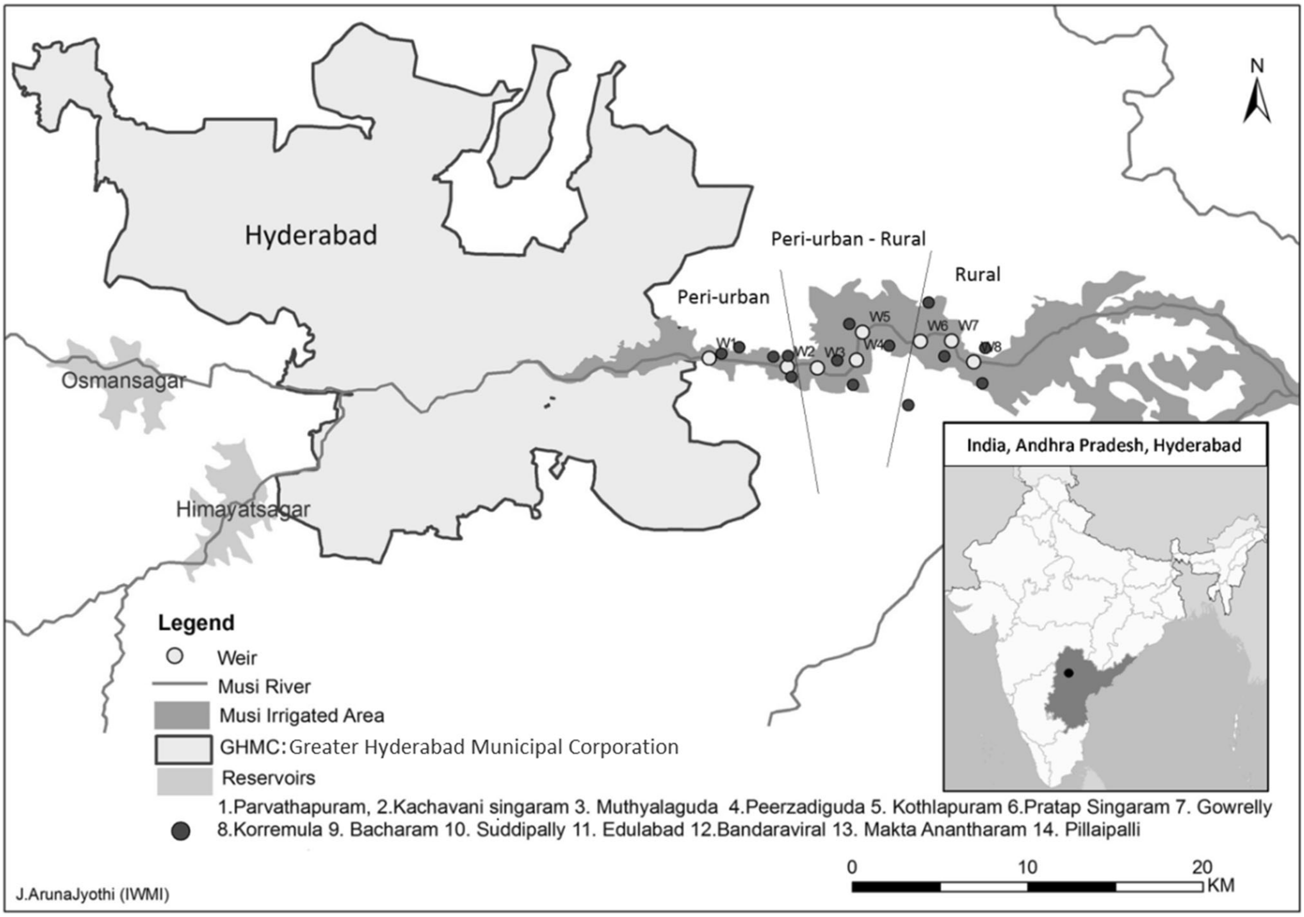

Fig. 1 The study site

Table 1 Attributes and their levels for the choice experiment

Attributes	Levels	Alternative "No intervention"	Alternative "Restrictions"	Alternative "Wastewater treatment"
Water quantity	High, medium, low	High	High	All
Water use restrictions	Strict, moderate, no restrictions	No restrictions	Strict, moderate	Moderate, no restrictions
Health risks	High, tolerable, reduced	High	Tolerable, reduced	Tolerable, reduced
Nutrient content	High, low	High	High	Low
Price[a] in INR/ha	<250, 250, 250+ between 250 and 500 and 250+ more than 750[b]	All	All	All
	<500, 500, 500+ between 250 and 500 and 500+ more than 750[c]			

[a] USD 1 = INR 54.90

[b] Dry crops

[c] Wet crops

from skin irritation and other problems), tolerable (where fewer farmers get sick, but still a significant number can get sick) and reduced (where the frequency of sickness is diminished because of an improvement in the water quality in the river).

The 'nutrient content' attribute referred to nutrients present in the water which are beneficial for crop development, also considering the pollutants and salts which can harm the plants or reduce yields. Two levels were proposed: high (water is high in nutrients, but also high in pollutants or salts that can reduce yields) and low (water is treated; the nutrient content is reduced, but so are the pollutant content and the salinity).

Finally, a price attribute was included to enable estimation of the respondent's WTP for changes in other attributes' levels. Four levels were proposed. First the actual water tax for one season of 250 INR/ha for dry crops and 500 INR/ha for wet crops[3] was used. Other levels constitute decreases and increases in the actual price level. An IWMI researcher working on the same area suggested that farmers were willing to pay between 250 and 500 INR/ha to treat the wastewater so that they can improve the water quality and go back to growing paddy.

Experimental design

The next step comprised the experimental design of the CE. This involves the selection of a set of choices from the universal set of all possible choice sets, which fulfil specific statistical properties, such as identification and precision, in combination with non-statistical properties such as realism and complexity (Louviere et al. 2000). A labelled CE was used, due to the interest in evaluating specific scenarios or alternatives, a focus which would have been lost in a generic design. However, labelled CEs have some disadvantages: (1) larger sample sizes are required, (2) the 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. See Hensher et al. (2005) for more details. In this study, an alternative specific design was constructed using the SAS software. Three alternatives were presented to the respondents, labelled as no intervention, restrictions and water treatment. In the design process, the different levels of the attributes were restricted by the alternatives. A fractional design maximizing *D*-efficiency with the following characteristics was obtained: *D*-efficiency 96.53 %, *A*-efficiency 93.02 % and *G*-efficiency 93.25 %. This design involved 12 choice sets.

Finally, to reduce response fatigue, the design was divided into three blocks (Adamowicz et al. 1998). Thus, each respondent had to consider four choice sets in this experiment. Considering that CE is a demanding exercise and respondents can be illiterate, pictograms were used to represent the various attribute levels (see Fig. 2).

[3] Water intensive crops (e.g. sugar cane and rice) are referred to as 'wet crops'; less water intensive crops (e.g. cotton and maize) are referred to as 'dry crops' (Tirupataiah, pers. comm.).

Data collection

The CE was included in a survey conducted between May and June 2013. Considering the findings from Ensink et al. (2010) concerning the improvement in water quality in the river downstream, the first-weir located near Peerzadiguda Village was the starting point for the survey gradually covering the areas downstream to the eighth-weir located in the proximity of Pillaipalli Village. The areas covered five villages in the peri-urban area, four villages in the peri-urban–rural fringe, and five villages in the rural area. Respondents were randomly selected within the villages. Farmers cultivating their fields were asked whether they were aged over 18. If so, they were asked to participate in the survey. The survey included additional questions on socio-economic and farming characteristics. Surveys were conducted face-to-face in the local language with support from assistants who were fluent in both Telugu and English. These assistants were trained before going into the field.

A total of 118 respondents were interviewed, generating 472 choice observations. Compared to many CEs in literature, this sample size is rather limited. However, because of the improvements in design theory (no longer using simple orthogonal designs, but efficient and optimal designs), it is no longer unusual to find studies with smaller sample sizes. De Bekker-Grob et al. (2015), for example, perform a meta-analysis of 69 CEs and report that 32 % have sample sizes smaller than 100 respondents. In addition, Rose and Bliemer (2013) show that, for efficient designs, having around 50 respondents is acceptable.

Econometric model

Farmers are heterogeneous in various aspects, which can influence their preference regarding irrigation water. In the standard multinomial regression model, preferences are assumed to be invariant between respondents (Boxall and Adamowicz 2002). This means that respondents' characteristics do not affect their preferences. To account for heterogeneity and allow preferences for different attributes to vary between individuals, a LC model can be applied (Birol et al. 2006). The advantage of this approach is that hidden structures or groupings of segments are revealed, allowing an objective understanding of preference heterogeneity across the sample population (Hope 2006). Compared to a CL or random parameter logit model, an LC provides policy makers with very useful information upon which they can tailor policies to specific population subgroups (Birol et al. 2006).

The underlying theory of the LC suggests that individual behaviour depends on 'observable attributes' and 'latent heterogeneity' that varies with factors unobservable by the

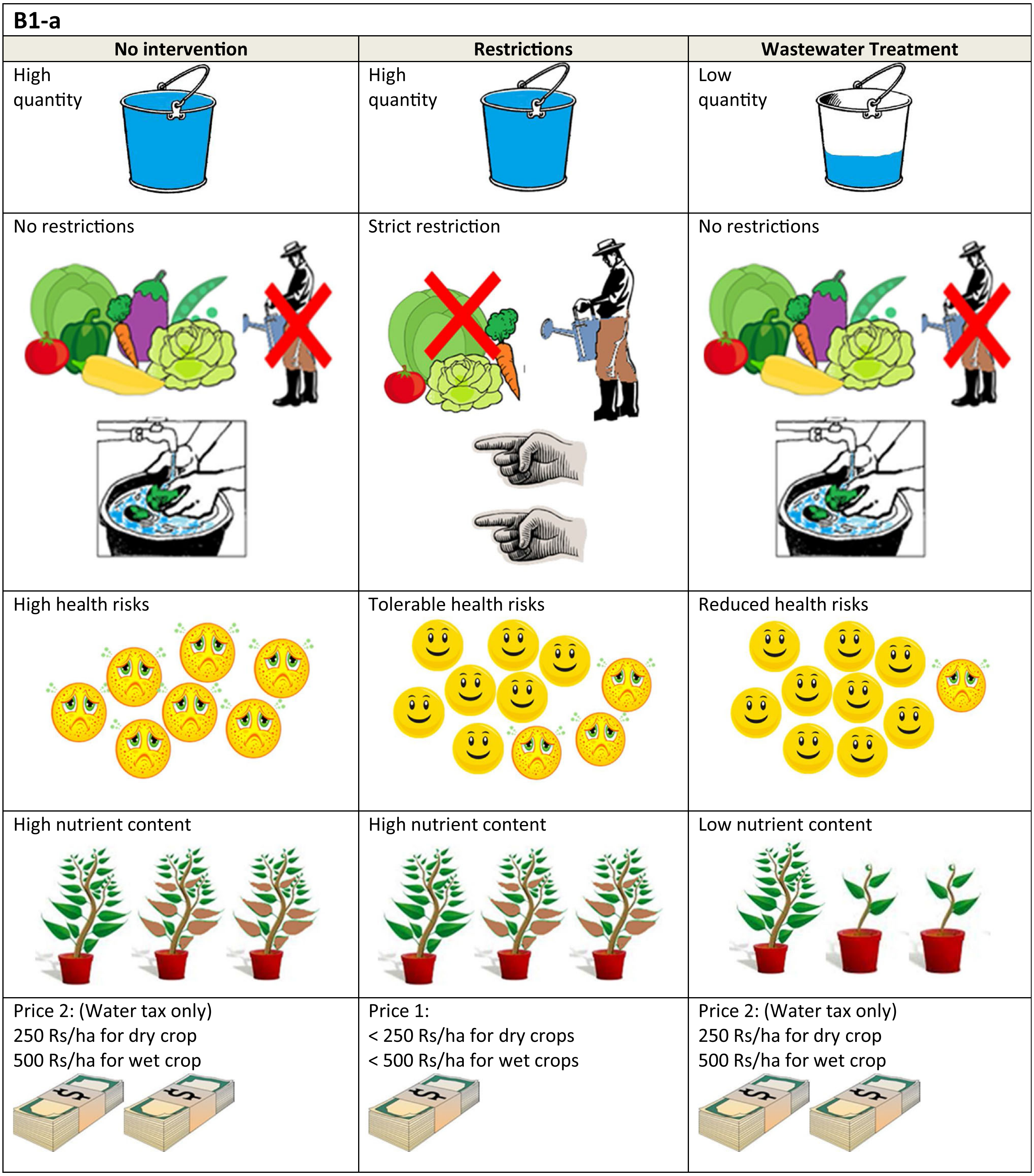

Fig. 2 Example of choice set

analyst (Greene and Hensher 2003). The population in an LC consists of a finite and identifiable number of segments (groups of individuals), who have relatively homogenous preferences. Segments, however, differ from each other in preference structure.

The specification of the model follows Greene and Hensher (2003). It has two components, an observable component ($\beta_s X_{nit}$) and an unobservable or random component ($\varepsilon_{nit|s}$). The utility of an individual n obtains from selecting alternative i in the tth choice set is given by

$$U_{nit|s} = \beta_s X_{nit} + \varepsilon_{nit|s}, \quad (1)$$

where U is the utility obtained by the individual, β is a vector of parameters of segment membership, X is the vector of attributes and ε is a random component following an extreme value Type I distribution. The observable component ($\beta_s X_{nit}$) can be decomposed into one component relating to the specific attributes of the choice made, and a second that captures individual-specific characteristics, e.g. socio-economic and attitudinal characteristics.

The probability of choice for an individual n, considering that the individual belongs to segment s, of selecting an alternative i from j alternatives, for a particular choice activity is

$$P_{nit|s} = \left(\frac{e^{\beta_s' X_{nit}}}{\sum_{i=1}^{I} e^{\beta_s' X_{njt}}} \right). \quad (2)$$

The probability that an individual belongs to a particular segment is expressed by

$$P_{ns} = \left(\frac{e^{a_s' Z_n}}{\sum_{s=1}^{S} e^{a_s' Z_n}} \right), \quad (3)$$

where Z_n is a vector of individual-specific variables and a_s is a vector of segment-specific parameters to be estimated; following this, the probability that a respondent chooses an alternative is obtained by combining the conditional probability (Eq. 2) with the segment membership probability (Eq. 3) as follows:

$$P_{ni} = \sum_{s=1}^{S} \left(\frac{e^{a_s' Z_n}}{\sum_{s=1}^{S} e^{a_s' Z_n}} \right) \prod_{t=1}^{T} \left(\frac{e^{\beta_s' X_{nit}}}{\sum_{j=1}^{J} e^{\beta_s' X_{njt}}} \right). \quad (4)$$

The parameters from Eq. 4 were estimated using NLOGIT 5.0. The model was run for one, two, three and four segments. To determine the 'optimal' number of segments, the following criteria were used: the log likelihood (ρ^2), Akaike information criterion (AIC) and the Bayesian information criterion (BIC; Louviere et al. 2000). In this case, the two-segment model seems optimal because the BIC is at its minimum, while improvements in AIC are minimal when further increasing the number of classes.

The goodness-of-fit for the model is measured using the likelihood ratio index (LRI) or pseudo-ρ^2. For well-fitted models, LRI take values larger than 0.2, and it is rare to find LRI larger than 0.4 (Hoyos 2010). In this case, the LRI is 0.258 (Table 2).

For the segment membership function, different variables were tested. The exercise was a trial-and-error procedure, in order to find a robust model. The set of explanatory variables tested was selected based on the assumption that they could have an effect on farmers' choices. The following variables were maintained: 'nutrient content awareness', 'health risk awareness', 'experiences of negative effects on crops' and 'water scarcity'. Other variables such as age, gender, location, education, household size, crop type, income and tax payment were also tested. In a second stage, T-tests and Pearson Chi-Square tests were used to reveal differences between the segments (Table 3).

Table 2 Criteria to determine optimal number of segments in the model Source own data, criteria from Boxall and Adamowicz (2002)

No. of segments	Log likelihood	ρ^2	AIC	BIC
1[a]	−433.8	0.021	1.888	1.950
2	−380.7	0.258	1.712	1.880
3	−358.6	0.301	1.668	1.944
4	−344.3	0.329	1.659	2.041

[a] These values also apply to the conditional logit model

Willingness-to-pay

By including price as an attribute in CEs, WTP estimates for changes in attribute levels can be made and, by combining different attribute changes, welfare measures can be obtained for various scenario changes (Hoyos 2010). This is done by taking the ratio between the coefficients of individual attributes and the price attribute:

$$\mathrm{WTP} = \frac{-\beta_k}{\beta_m}, \quad (5)$$

where β_k is the coefficient of the kth attribute of wastewater (re)use and β_m is the coefficient of the price attribute. These ratios are called marginal implicit prices. The WTP for attribute changes and the confidence intervals at the 95 % level were estimated applying the Wald procedure (delta method) in NLOGIT 5.0.

RESULTS AND DISCUSSION

Socio-economic and farm characteristics

The two-segment LC model was shown to perform best. Both segments consist predominantly of full-time farmers. No significant differences between segments were found in terms of age, household size, literacy rate, average land size or type of land ownership (Table 3). The average income from irrigated farming and other farming activities was 122.2[4] and 131.1 USD/month for segments one and two, respectively. If this is divided by the average household size from the sample (four and five, respectively), it

[4] USD 1 = INR 54.90 as of May 2013.

Table 3 Descriptive statistics and profiles of the segments, for the Latent Class model

	Mean (st. dev.)	Max.	Min.	Segment-one ($n = 47$)	Segment-two ($n = 71$)
Gender (% male)	94.9			95.7 ($n = 45$)	94.4
Age (years)	47.1 (14.3)	78	20	47 (13.7) ($n = 45$)	47 (14.7)
Household size (number)	4.4 (1.3)	9	1	4 (1.1)	5 (1.4)
Education (% literate)	43.1			48.9 ($n = 45$)	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)	637.6	0	76.1 (69.5)	79.0 (87.2)
Other farming activities	49.7 (86.2)	546.5	0	46.1 (73.5)	52.1 (94.1)
Other activities	14.7 (59.3)	546.5	0	16.2 (40.0)	13.8 (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
Land size (ha)	1.1 (1.4)	12.1	0.1	1.2 (1.1)	1.1 (1.6) ($n = 69$)
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
Taxes* (% of respondent that pay)	31.0			39.1 ($n = 46$)	25.4 ($n = 67$)
Negative effects on health* (% of respondent that experienced)	66.1			75.6 ($n = 45$)	60.0 ($n = 70$)
Claimed health risk awareness (% of respondent aware)	75.4			76.6	74.7
Negative effects on crops (% of respondent that experienced)	76.1			76.6	75.7 ($n = 70$)
Claimed nutrient content awareness*** (% of respondent aware)	46.6			66.0	33.8
Change of crops, if water is treated (% of respondent that would change)	77.9			75.0 ($n = 44$)	79.7 ($n = 69$)
Access to other water sources (% of respondent with access)	17.8			23.4	14.1
Water scarcity (% of respondent that experienced)	20.3			21.3	19.7

T-tests, Pearson χ^2 and linear by linear association tests show significant differences at 1 % (***), 5 % (**) and 10 % (*) level

gives an average income/capita of 30.5 and 26.2 USD/-month, respectively.

Concerning landownership, segment-one has a slightly higher proportion of farmers owning the land (7.3 % more) and a similar percentage (0.4 % difference) leasing. A slightly higher proportion of farmers in segment-two (7 % more) own/lease the land.

The segments are significantly different (at the 10 % level) in terms of location. Farmers in segment-one were predominantly rural, whereas farmers in segment-two were predominantly peri-urban. Paddy is by far the main crop for both segments (78.7 and 67.6 %, respectively), followed by para-grass (8.5 and 14.1 %, respectively) and a small proportion of vegetables (2.1 and 8.5 %, respectively). This suggests that a slightly larger proportion of para-grass and vegetables are cultivated by farmers from segment-two. This is in line with the findings of previous studies indicating that vegetables and para-grass production is only important closer to the city (Buechler and Devi 2003; Amerasinghe et al. 2009).

In both segments, the river is the main source of water for irrigation. Only a minority, which is greater in segment-one, also use groundwater (our figures for groundwater use are comparable with the findings of Amerasinghe et al. 2009). Only some 18 % of the respondents indicated that they have access to other sources of water besides the river. Water scarcity does not seem to be an issue; only 20 % of the respondents reported having experienced water scarcity in the past 5 years, which was linked to temporal obstruction of canals due to maintenance, but not to a real lack of water in the river.

Formally, farmers are expected to pay a fee for surface water (water tax) based on crop type and land size. According to a representative of the Water and Land Management Training and Research Institute, in practice, the collection rate accounts for 40 % (Tirupataiah, pers. comm.). In this survey, only about 31 % of the respondents reported the payment of water taxes. Segments differ significantly in this aspect. More farmers in segment-one report payment of water fees compared to segment-two. The poor water quality might be one of the reasons why farmers refuse to pay for water (see Times of India 2002).

Water pollution: Experiences and awareness

The survey included questions relating to the health risks and effects of the water on crop growth (see Table 3). When asked directly,[5] about 75 % of the respondents claimed that they were aware of the health risks associated with the use of this water. There is no significant difference between segments. Older studies, e.g. McDonald (2009) or Keremane (2009), reported lower awareness, so there might be a bias created by the question formulation. However, the focus on the issue by the research community (e.g. Amerasinghe et al. 2009; Ensink et al. 2010), the awareness campaigns by IWMI (see Buechler et al. 2006) and the projects by the local authorities, e.g. "Save the Musi" campaign, might have increased concern about the issue in recent years.

When respondents were asked whether they experienced negative health effects from the use of the water for irrigation,[6] about 66 % answered affirmatively. In the open-ended follow-up question, respondents reported itchy skin, skin rashes, foot cracks, joint pain and fever. Similar complaints by farmers were reported by Srinivasan and Reddy (2009). The segments differ significantly in this aspect. Surprisingly, more farmers in segment-one stated that they experienced negative health effects. A possible explanation is that farmers in segment-one, who are predominantly rural, openly shared their experiences, whereas farmers in segment-two, predominantly peri-urban, appeared to underrate their negative experiences. Generally, farmers closer to the city were more reluctant to answer the questions. Some mentioned that the media is often in the area reporting on the Musi River pollution, and this has had an impact on their crop marketing, mainly for leafy vegetables.

Farmers were also asked whether they were aware of the nutrient content of the water.[7] Here, 46.6 % answered affirmatively. This aspect differs significantly between segments. Farmers closer to the city seemed less aware of the nutrient content. Likewise, farmers were asked whether they experienced negative effects on crop growth.[8] About 76 % replied affirmatively.[9] Here, there is no significant difference between segments. Note that more respondents report negative effects on crops than on health. About 78 % indicated that they would grow other crops if the water quality were better (e.g. vegetables for a higher income or for self-consumption).

Farmers' preferences

First, a CL model was run, followed by an LC model with up to four segments. Except for price, all attributes were treated qualitatively, introducing dummies for each level. The reference levels were as follows: water treatment, no restrictions, reduced health risks, low water quantity and low nutrient content.

Furthermore, given that it consisted of a labelled CE, a separate utility function was written for two alternatives (no intervention and restrictions) each including one alternative specific constant (ASC), keeping the third alternative as a reference (see the utility functions in the footnote).[10]

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

[6] "Did you experience any negative effect on your health when using Musi water? Please mention the effects".

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

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

[9] Examples mentioned by the respondents: decrease in crop yield and in grain-filling both for paddy.

[10] The utility functions were specified as follows: $U(\mathrm{NI}) = \mathrm{ASC}_1 + A_1 * \mathrm{Price}/U(R) = \mathrm{ASC}_2 + A_2 * S_{\mathrm{crop}} + A_3 * M_{\mathrm{crop}} + A_4 * T_{\mathrm{hlth}} + A_1 * \mathrm{Price}/U(\mathrm{WT}) = A_5 * M_{\mathrm{wat}} + A_3 * M_{\mathrm{crop}} + A_4 * T_{\mathrm{hlth}} + A_1 * \mathrm{Price}$, where A_1–A_5 are the coefficients and ASC no intervention (ASC_1), ASC restrictions (ASC_2), strict crop restriction (S_{crop}), moderate crop restriction (M_{crop}), tolerable health risks (T_{hlth}) and medium water quantity (M_{wat}).

Table 4 Results of the Latent Class model and estimation of WTP

Labels	LC	
	Segment-one	Segment-two
No intervention	−1.363** (0.670)	−0.805** (0.342)
Restrictions	−5.748** (2.824)	−0.299 (0.354)
Water treatment		
Attributes		
Price	0.0105 (0.0078)	−0.0008* (0.0004)
Strict restrictions	−19.884 (278 500.1)	−0.051 (0.384)
Moderate restriction	1.275 (1.419)	0.480* (0.280)
Tolerable health risks	−1.517 (1.379)	−0.628*** (0.195)
Medium water quantity	−0.808 (2.446)	0.209 (0.284)
Models statistics		
Pseudo ρ^2	0.258	
Log likelihood	−380.7	
Segment function LCM: respondents' awareness or experience on health issues, water scarcity and nutrient content		
Constant	0.294 (0.612)	
Claimed nutrient content awareness[a]	−1.323*** (0.464)	
Claimed health risk awareness[b]	−0.078 (0.558)	
Experienced negative effects on crops[c]	0.055 (0.592)	
Experienced water scarcity[d]	−0.085 (0.608)	
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 restrictions		−1.19 (−18.83; 16.46)
Moderate restrictions		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 % (*). Reference levels: water treatment; no restrictions; reduced health risks; low water quantity, and low nutrient content. WTP estimates in USD/ha/year

[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

Based on the criteria presented in Table 2, the LC model with two segments was considered superior to the CL model and the three- and four-segment LC models. The latter is based on the value of BIC, which increases when adding more than two segments. Therefore, only the results of the two-segment LC model are reported and discussed (Table 4).

The probability of each respondent belonging to one of the segments is calculated by Eq. 3. Based on this, 38.6 and 61.4 % of the respondents belonged to segments one and two, respectively.

The ASCs in the LC model indicate that farmers in segment-one preferred the water treatment option over the other two options. The restrictions option is least preferred. Farmers in segment-two preferred water treatment over the no-intervention option, but the ASC for the restrictions option is not significant. This means that farmers are indifferent between restrictions and water treatment. By choosing water treatment, farmers implicitly also choose 'reduced health risks', 'low water quantity' and 'low nutrient content'. The clear preference for the water treatment option can be explained by the negative experiences with poor-quality water.

For the first segment, the coefficients of the attribute levels are not statistically significant. Given that the ASCs are highly significant, it might be that farmers have focused on the alternative labels rather than on the attribute levels.

For the second segment, three coefficients are statistically significant. First, the coefficient for the price attribute is significant and negative; this suggests that, as expected, price increases reduce preference for alternatives. For segment-one, the coefficient for price was not significant, meaning that price was not a determinant of choice. As the proportion of farmers who do not pay the water tax is significantly higher in this segment; this raises the possibility of strategic answers by the farmers opting for the water treatment option in the hope that water quality would be improved. In informal talks, farmers revealed their desire for 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 into the river has only increased. It might also be linked to the fact that most respondents currently do not pay water taxes.

Second, the coefficient for the attribute 'moderate restrictions' has a positive effect (significant at the 10 % level) relative to 'no restrictions'. This implies that farmers in segment-two prefer some restrictions on using water despite this potentially limiting their freedom in crop selection or irrigation methods. Third, compared to the reference level of 'reduced health risks', 'tolerable health risks' decreases the preference of farmers in segment-two. Taking into consideration that farmers in this segment are predominantly peri-urban, such preference might be explained by the fact that the water is more polluted closer to the city.

The water quantity attribute was not a determinant of choice; this might indicate that water scarcity is not an issue for farmers. One farmer expressed this as follows: "over the years, more water is available in the river, but also more pollution".

The segment membership coefficients for the second segment are normalized to zero (Birol et al. 2006). The coefficients for the first segment need to be interpreted relative to the normalized segment. Only the segment membership coefficient for 'awareness of the nutrient content' is found significant. Respondents in the first segment are shown to be less aware of the nutrient content.

Willingness-to-pay

Table 4 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 attribute levels. Two values are statistically significant. The mean WTP to go from no intervention to water treatment option is 18.8 USD/ha/year. This estimate is approximately double what farmers are expected to pay as water tax for wet crops (about 9.1 USD/ha/cropping season[11]). Furthermore, the mean WTP to go from 'tolerable health risks' to 'reduced health risks' is 14.7 USD/ha/year. In this segment, 60 % of the farmers reported negative health effects due to the use of Musi water, which is not surprising.

Starkl et al. (2015) estimated farmers' WTP for using treated water for irrigation in a village about 15 km downstream of Hyderabad. There, 71 % of the farmers were initially willing to pay 100–400 INR/month (this would represent between 12.6 and 51.1 USD/year for a 7-month irrigation period). Nevertheless, they tested the genuine-WTP and found that farmers' response to the implementation of water treatment is rather negative, with farmers actually unwilling to pay for this. According to the "polluter pays principle", which is recognized in India, it is also not the responsibility of the farmers to pay for the treatment. In contrast to Starkl et al. (2015), our findings suggest, however, that a proportion of the farmers are ready to contribute. In this light, it might be interesting for authorities to consider incentives for occupational health protection or low-cost on-farm treatment alternatives (e.g. constructed wetlands), in the pursuit of reducing adverse effects of wastewater on farmers.

It is not unusual for farmers to be willing to pay for improvements in water service delivery or water quality. Bakopoulou et al. (2010) studied farmers' WTP for using recycled water for irrigation purposes in the Thessaly region, Greece. Particularly during droughts, farmers were willing to pay for recycled water. Ben Brahim-Neji et al. (2014) found that farmers in Tunisia, irrigating with treated wastewater, are willing to pay extra for improving water quality. However, farmers who do not irrigate with recycled water were not willing to use it, even when quality improved. This indicates that some farmers are reluctant to use recycled water. This reluctance seems to be mostly related to health risks. While in our study area farmers had no choice but to use wastewater as a source for irrigation, results show that they are certainly concerned with health risks.

Also Ndunda and 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 the wastewater. In that study, water quality and quantity are significant factors in farmers' preferences. However, Abu Madi et al. (2003) describe, for Jordan and Tunisia, that the price farmers are willing to pay barely covers the operational and maintenance cost for the conveyance and distribution of reclaimed water. In our case, given the household's total monthly income (including irrigated farming and other activities)

[11] State government fixed water fees based on crop type and land size per season: wet crops approximately 500 INR/ha; dry crops approximately 250 INR/ha (Tirupataiah, pers. comm.).

estimated at 144.8 USD (Table 3), these WTP estimates expressed per month (1.6 and 1.2 USD/ha, respectively) represent about 1 % of the total household income.

CONCLUSIONS

Wastewater is seen as an opportunity to deal with increasing pressure on water resources, mostly in water-scarce countries. However, wastewater is often not simply an alternative source of water but the only source. Using this water encompasses health and environmental risks, influencing people's livelihoods. This paper contributes to the literature on wastewater reuse by looking at farmers' preferences around Hyderabad, India.

The findings of the CE suggest that farmers prefer a water treatment option over the two other options (no intervention and restrictions). This might be a reflection of past negative experiences with poor-quality water. In this respect, it is important to bear in mind that the water treatment option implied higher water prices, lower water quantity and lower nutrient content compared to the other options. So the results show that farmers are keen to irrigate crops with improved water quality.

This study also shows the heterogeneity in farmer preferences. 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 very sensitive to health risks. Farmers from the second segment live closer to the city, they are more dependent on Musi water, and they grow relatively more vegetables and para-grass. Compared to segment-one, less respondents in segment-two are aware of the nutrient content in the water, and experience (or know about) negative health effects. While health risk awareness is high for both segments, farmers take little action in this respect. Solutions for reducing health risks are not easily accessible to poor farmers or they are not well known to them. Another explanation is the limited in-depth risk awareness to actually trigger a behavioural change. More research on risk perceptions is therefore needed. Nevertheless, the observed 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. Depending on the number of farmers and size of treatment plant, farmers' contributions can fund some of the operational costs. While the impact of this contribution on different treatment scenarios should be further investigated, it should be borne in mind that treatment should remain the responsibility of the government, and that the cost should, in the first place, be borne by the polluters, as also expressed in the study area. Furthermore, follow-up research could investigate whether or not the positive WTP we found arises from strategic answering.

Finally, while the rather small sample size and the labelled design may have influenced the significance of the attributes, this study provided an interesting snapshot of how farmers perceive and value water quality.

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