Evaluating farmers' preferences for wastewater: quantity and quality aspects

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Abstract: This paper employs the Contingent Valuation (CV) method to investigate farmers' willingness to adopt a new water resource, namely treated wastewater, and to estimate their Willingness To Pay (WTP) for varying quantities and qualities of treated wastewater for irrigation. A pilot CV study is undertaken with 97 farmers located around Cyprus' Akrotiri aquifer, a common-pool water resource with rapidly deteriorating water quantity and quality. The results reveal that farmers are willing to adopt this new water resource, and they derive the highest economic values from a treated wastewater use programme, which provides high quality treated wastewater, and high water quantity in the aquifer.

Keywords: contingent valuation; CV; willingness to pay; WTP; water quantity; water quality; treated wastewater; aquifer recharge.

1 Introduction

The Millennium Development Goals of the United Nations list access to water supply among the most important global challenges (UN, 2005). A third of the world's population lives in water-stressed countries, and by 2025 this figure is expected to rise to two-thirds (UNEP, 2004). Lack of access to and scarcity of water resources are a result of reduced water availability emerging from increased demand and/or of reduced water quality arising from increased pollution. It has been argued that both in developed and developing countries, the main cause of water quality and quantity deterioration is the increasing volume and intensity of the agricultural sector (Young, 2005), which currently accounts for 70% of the water used worldwide (FAO Aquastat, 2004). Agricultural production, in return, is likely to become unsustainable in the long run due to reduced water quality and quantity, thereby resulting in food safety and security problems at the face of ever increasing global population.

The main economic reasons behind the inefficient management of water quality and quantity include market and government failures. Market failure arises as a result of the public good nature of many water resources, which implies that water resources are not traded in the markets as other goods are, and hence they do not have readily available market prices, to enable their efficient and sustainable management. Even though several of the water resources used for irrigation, such as groundwater, are not pure public goods, they are common-pool resources, which face problems including overexploitation and pollution, resulting in significant costs to the local economy in the long run, as well as in the short run (Cornes and Sandler, 1996). Government failure arises as several agricultural policies/programs of the governments distort the values of inputs (e.g., subsidies to water, fertilisers, etc.) and outputs (price subsidies and fixed prices for final agricultural produce), such that they do not reflect the economic scarcity of water resources.

The magnitude and gravity of the water scarcity problem, coupled with the imminent food security and safety issues, highlight the urgent need for development and implementation of economic instruments and adoption of new technologies and resources for efficient and sustainable management of the world's scarce water resources. Among economic instruments, efficient pricing of the water resources, which takes scarcity value of these resources into account, is the foremost measure to ensure appropriate economic incentives for efficient and sustainable management of water resources. A detailed account of the economic methods that can be employed to estimate the efficient prices for water to inform sustainable water resources policy making is given in Birol et al. (2006). Among the recent water scarcity alleviation technologies, treatment of wastewater to be used in agricultural irrigation is a promising supply side solution, especially following the recent positive experiences of several countries, including Israel, Jordan, Tunisia (see case studies in Scott et al. (2004)), which have employed this technology.

This paper investigates farmers' stance to use of treated wastewater for irrigation to tackle water resources scarcity in Cyprus, and evaluates the efficient price to charge for this new water resource. In order to examine farmers' willingness to adopt treated wastewater and to establish its efficient price, a non-market valuation method, namely a CV study was undertaken with 97 randomly selected farmers in the Akrotiri aquifer area. The results of this study reveal that on average farmers are willing to adopt this new technology, and that they also derive significant economic values from higher levels of water quantity in the aquifer, and replenishment of the aquifer with higher quality treated wastewater, expressed in terms of WTP. These results have important implications for adoption of this new source of water in Cyprus; the level of treated wastewater quality and quantity preferred by the farmers, as well as for determining the efficient price to charge for the water in the aquifer, once it is replenished with treated wastewater.

The rest of the paper unfolds as follows. The next section presents the current situation of quality and quantity of water resources in Cyprus and the possible impacts of water scarcity on Cyprus' economic growth and food production. Section 3 describes the Akrotiri aquifer case study; the theoretical framework and the data collection methodology employed. Section 4 reports the results of this valuation exercise, and the final section concludes the paper and draws some policy implications.

2 Background

Efficient and equitable management and allocation of scarce water resources have historically been one of the most important resource management challenges in Cyprus. Despite the dam building campaign of the past two decades, which aimed to provide water security for domestic, agricultural and industrial purposes, management of water resources in Cyprus is far from efficient and sustainable. Water quantity and quality in Cyprus are still at serious risk due to climatic, geographical, social, economic and policy related causes (Koundouri, forthcoming).

Water resources scarcity in Cyprus is primarily caused by climatic conditions. Precipitation rates are low and not sufficient to maintain the hydrological balance. This is further exacerbated by the timing of precipitation, since rain falls during the winter, while water demand for irrigation and domestic use peaks during the summer. In addition, geographical location of Cyprus, as an isolated island in the eastern Mediterranean, complicates the water scarcity problem further by preventing drawing of water from other countries. These issues most of which lie beyond the control of policy makers have led successive Cypriot governments to focus their attention on the efficient management of available water resources, in order to maintain high levels of water quality and quantity, although water scarcity still persists and is likely to persist in the mid to long run (Koundouri, forthcoming).

Agriculture is the foremost consumer of groundwater, using around 60% of pumped groundwater for irrigation purposes. Lack of defined property rights, easy access to groundwater and its low (or no) cost have led to over-pumping, resulting in coastal aquifers with negative hydrological balance, exhibiting a heavily depleting trend. It is estimated that most coastal aquifers have been mined down to 15% of their capacity (Iacovides, forthcoming). This has led to further degradation of groundwater resources through seawater intrusion. Furthermore, there is large discrepancy between the water consumed and the contribution to national income: 70% of all water in Cyprus is used by agriculture, a sector accounting for 2.7% of national income (Iacovides, forthcoming; Cyprus National Statistics, 2007). Despite the government's promotion of water saving irrigation schemes, inefficient use of water resources by agriculture persists mainly as a result of the high number of small-scale farmers, who constitute a large proportion of those employed in agriculture.

Water quality problems for water resources are also emerging. In general, water quality is considered to be satisfactory for irrigation purposes. Pollution due to pesticide, nitrate and fertiliser run off, however, has been detected both in ground and surface water, especially in areas with intensive agricultural activity. This has led to the planning of gradual phasing out of groundwater from domestic water supply. In addition, if current climatic conditions and water demand patterns persist, combined with decreased precipitation rates, it is expected that salinity levels will increase, rendering groundwater from major aquifers unusable (Koundouri, forthcoming).

Sustainable management of water resources is extremely important for Cyprus to maintain its current rates of economic growth and development. The well-established and expanding tourism industry strains water resources, especially during Summer months. Water demand from tourism sector is expected to increase further following the controversial legislation which allows for the construction of golf courts. Episodes of prolonged drought may affect households, agriculture and industry alike, as experienced in the previous droughts. During the drought of 1990's, for example, water supply was limited to a few hours per day in major cities.

A complex legal framework for managing water resources is in place in Cyprus, with various different government agencies being responsible for their application, leading to sluggish management of water resources. As a result of its recent accession to the European Union (EU), Cyprus is currently in the process of implementing the EU Water Framework Directive (WFD, 2000/60/EC), which calls for integrated water resources management in order to achieve 'good water status' for European water resources by 2015.

A well-documented target for Cypriot water management bodies is to achieve water security by the use of alternative water resources that were unexploited in the past, such as desalinated water and treated wastewater. In the 1990's the need to utilise these resources to respond to the problems arising from climate change and decreasing precipitation rates became pressing. Failure to exploit alternative water resources could lead to permanent desertification, causing irreparable environmental and economic damage. During the past decade, two desalination plants have been built and were successful in addressing demand for domestic water use in Nicosia, Larnaca and their surrounding areas, by producing a total of 91,000 m^3 per day at a cost of CYP 0.54/m^3 and CYP 0.41/m^3, respectively.

The use of treated wastewater has mostly focused on irrigation, to contest the overdependence of agriculture on groundwater (Socratous, forthcoming). Using treated wastewater for agricultural, domestic and industrial applications has also attracted support from the water authorities during the 1990's. At that time it was realised that wastewater use could be seen as a lower cost alternative to desalination. Furthermore, environmental benefits could be attained by using wastewater to recharge depleted aquifers to reduce seawater intrusion while avoiding the ecological costs of discarding wastewater in the sea. Finally large savings in freshwater quantities could be achieved as a result of the use of treated wastewater for irrigation (Papaiacovou, 2001).

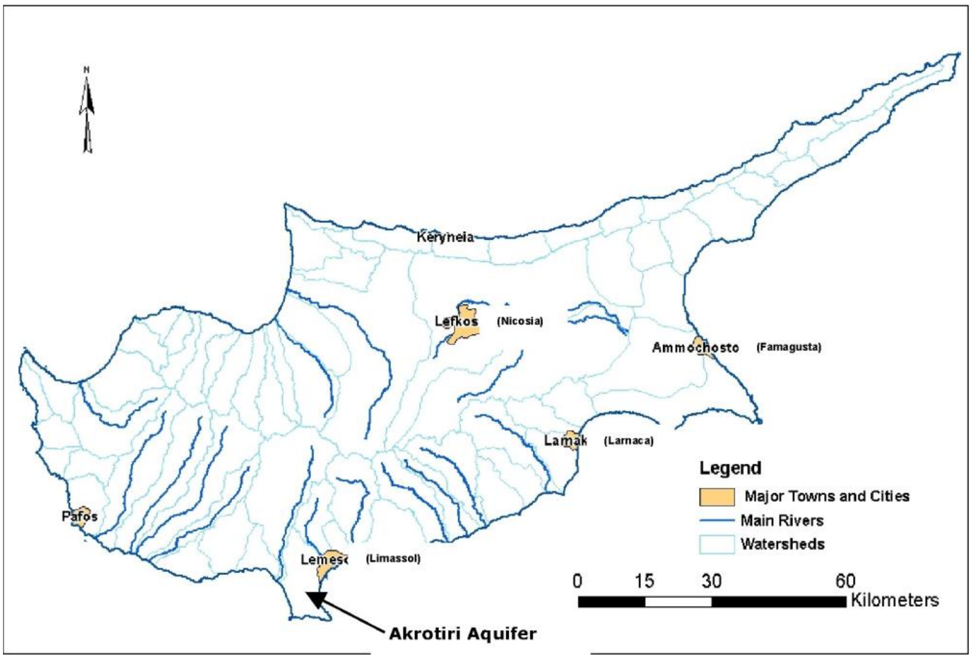
Currently all major cities in Cyprus apply secondary or tertiary wastewater treatment, and treated wastewater is used directly for irrigation. The possibility of reusing treated effluent in the Larnaca area has been investigated as early as 1982. However, treated wastewater use for agricultural irrigation was not deemed cost effective since the particular area had no history in extensive irrigation and there were doubts whether the full amount of effluent could be used. Nevertheless, given sufficient quantities of effluent, approximately 400 ha of land in the city and its environs could be irrigated especially for landscaping purposes. This would not only generate direct economic benefits worth $1,476,000 per annum in fresh water irrigation, but also generate indirect benefits in the form of landscape beautification, which in turn could benefit the tourism industry and improve the local living standards (Mill and Theophilou, 1995). In the Limassol prefecture, where the pilot study presented in this paper is undertaken, large scale wastewater treatment was initiated with the construction of a treatment plant in 1995. The objective of this initiative was to provide a safe and reliable system for wastewater disposal and to improve environmental and water resource management (Papaiacovou, 2001). Most recently, the Water Development Department has been considering the use of the rapidly depleting Akrotiri aquifer as a storage tank, i.e., to recharge the aquifer with treated wastewater, in order to reduce the effects of seawater intrusion. The study presented in this paper aims to help the policy makers by providing information on the farmers' willingness to accept this program, that is the replenishment of the aquifer with treated wastewater, as well as their preferences for the quality and quantity of water used to replenish the Akrotiri aquifer.

3 Contingent Valuation (CV) study on farmers' valuation of treated water in Akrotiri

3.1 The Akrotiri aquifer case study

The case study presented in this paper is the Akrotiri aquifer, a common-pool resource and the third largest aquifer in Cyprus, a semi arid country, which faces chronic water shortages, as explained above. The aquifer is extremely important for the local economy. Extending over 42 km^2, the aquifer not only provides local farmers with irrigation water, but also supplies a significant portion of the water needs of the city of Limassol and the nearby British sovereign bases. The Akrotiri aquifer is replenished with runoffs from the Kouris River; releases from the Kouris River dam; rainfall, and agricultural return flows (Mazi et al., 2004). The location of the Akrotiri aquifer is indicated in Figure 1.

Figure 1 Location of the Akrotiri aquifer



The aquifer faces serious water quality and quantity problems, which are expected to have significant adverse effects on the livelihoods of the local farmers in the not too distant future. After the construction of the Kouris river dam, inflow in the aquifer has decreased significantly resulting in a lower water table (Mazi et al., 2004). This has lead to intrusion of saltwater into the aquifer to maintain the hydrological balance. Water quality in the aquifer is deteriorating further because of the intensive use of fertilisers and pesticides in agricultural production in the area. Recently the Cypriot government has designated the Akrotiri aquifer as a 'Nitrate Vulnerable Area' since nitrate ion concentration was found to be 200 mg/l (Typology and Representive Paradigms of Water Deficient Regions in Southern Europe, 2003; Republic of Cyprus Ministry of Agriculture, Natural Resources and the Environment, 2004). The quantity of water in the aquifer is also adversely affected by uncontrolled and excessive pumping in the area, an artefact of lack of clearly defined property rights, i.e., the open access nature of the aquifer. Table 1 presents the Akrotiri aquifer recharge in the past and more recently in 2003, indicating the substantial increase in seawater intrusion. Furthermore Table 2 indicates the past and more recent outflow of water from the aquifer.

Table 1 Akrotiri aquifer recharge (in Mm^3/year)

	Rainfall	*Riverbed recharge*	*Subsurface inflow*	*Sea intrusion*	*Return form irrigation*	*Return/ diversions*	*Artificial recharge*	*Total*
1968–1978	5.9	15.4	4.2	0.7	4.5	3.5	0	63
2003	4.2	0.5	0.2	3.0	1.1	0.7	3.3	31.0

Source: Typology and Representative Paradigms of Water Deficient Regions in Southern Europe (2003)

Table 2 Akrotiri aquifer outflow (in Mm^3/year)

	Abstraction for irrigation and domestic use	*Evaporotranspiration*	*Rising water*	*Sea/lake outflow*	*Total*
1968–1978	14.5	2.5	2.2	16.0	46
2003	10.8	2.4	0.3	0.5	32.0

Source: Typology and Representative Paradigms of Water Deficient Regions in Southern Europe (2003)

In order to mitigate the adverse effects of reduced water availability and deteriorating water quality in the aquifer, its replenishment with treated effluent from Limassol and nearby villages has been proposed, as explained above. Given that the public good and open access nature of the resource has resulted in its inefficient management, economic instruments, including water pricing have been proposed to enable the efficient and sustainable management of the aquifer.

3.2 Theoretical framework

A CV survey was implemented to estimate farmers' valuation of treated wastewater use programs to be implemented in the Akrotiri aquifer. Following Kontoleon and Swanson (2003) four treated wastewater use programs were valued, where a farmer's valuation (i.e., total WTP) for each program can be defined as the value of simultaneous change in the quantity and quality of water in the aquifer. This survey design, which is also known as scenario difference approach, enables estimation of the values of both the quantity and the quality of the treated wastewater used to replenish the aquifer.

More formally, the valuation exercise presented in this paper takes into account that a treated wastewater use program might have multidimensional impacts on the state, $\boldsymbol{q}$, of the aquifer, affecting both its quantity (water level in the aquifer) and quality (treatment level of the treated wastewater used to replenish the aquifer). The definition of value used in this paper, therefore treats $\boldsymbol{q}$ as a vector (Kontoleon and Swanson, 2003).

Following Kontoleon and Swanson (2003), we assume that $\boldsymbol{q}$ consists of two dimensions, the quantity and quality of the water in the aquifer, $\boldsymbol{q} = (q_1, q_2)$, where the former is measured by the level of treated wastewater used to replenish the aquifer and the latter is measured by the quality of treated wastewater used to replenish the aquifer. A farmer's preference function can be specified as $u = u(x(q_1, q_2))$ where x is the composite good, i.e., water for irrigation. For a multidimensional change in the program that results in the simultaneous change in both dimensions in $\boldsymbol{q}$, the Hicksian compensating welfare measure is the amount of income paid or received that would leave the individual at the initial level of utility subsequent to the multiple impacts of policy. For the change from q^0 to q^1 a holistic measure of value is represented by:

$$\text{WTP}(q^0, q^1) = e(p, q_1^0, q_2^0, u^0) - e(p, q_1^1, q_2^1, u^0). \tag{1}$$

Where $e(\bullet)$ is the standard farmer expenditure function defined for market prices p and fixed utility u^0. Component values can be subsequently defined from (1) by using a simultaneous valuation path that begins at $q^0 = (q_1^0, q_2^0)$ and ends at $q^1(q_1^1, q_2^1)$. The simultaneous valuation path estimates the effect of each element of $\boldsymbol{q}$ as the overall vector changes from q^0 to q^1. The disaggregated expression for (1) is given by:

$$\text{WTP}(q^0, q^1) = \int_{q^0}^{q^1} \left[\frac{\partial e(p, q_1, q_2, u^0)}{\partial q_1} \right] \mathrm{d}q_1 + \int_{q^0}^{q^1} \left[\frac{\partial e(p, q_1, q_2, u^0)}{\partial q_2} \right] \mathrm{d}q_2. \tag{2}$$

where each one of the two components of (2) evaluates a derivative of the expenditure function $\partial e(p, q_1, q_2, u^0) / \partial q_i, i \in \{1, 2\}$ as the overall treated wastewater use program shifts from its initial to post-program level.

3.3 Data collection

Data collection took place during September and October 2006 in four villages located in the Akrotiri area. The sampling frame is comprised of all the farmers located in the area. The results reported in this paper, however, are from a pilot sample, which was envisaged to include randomly selected 100 farmers from the sampling frame. Overall 97% of the pilot sample approached agreed to take part in the survey, and the results reported in the following section are representative of the Akrotiri area.

The CV survey consisted of three parts. In the first part the farmers were informed of the serious water quality and quantity challenges faced by Cyprus. They were reminded of the irrigation water shortages in the Akrotiri area due to uncontrolled pumping from the aquifer. They were also explained that uncontrolled pumping lowers the groundwater level, causing seawater intrusion, and hence increasing water salinity, which makes the groundwater inappropriate for irrigating most crops. Farmers were further reminded that lower levels of water in the aquifer imply higher pumping costs. They were informed that ongoing groundwater overexploitation in the Akrotiri area will eventually result in the permanent desertification of presently fertile areas, thereby causing irreparable economic damage to local and national agriculture and hence to the local and national economy.

In the second part of the survey farmers were presented with the new water resource, namely the use of treated wastewater for replenishment of the Akrotiri aquifer, which they were told would definitely provide long-term water security in the area. They were explained that under the treated wastewater use program, treated wastewater from Limassol and the nearby villages would be channelled into the aquifer to replenish its groundwater supplies. They were further explained in layman terms what treated wastewater is and how the program would work. Finally, the farmers were told that if a treated wastewater use program is implemented, they would be asked to pay a price to the government for each m^3 of water they pump from the aquifer, and the Ministry of Agriculture and Natural Resources would monitor the quantity of water pumped. They were explained that the quality of the treated wastewater used to replenish the aquifer, and the quantity of the water in the aquifer would depend on the price of each m^3 of water pumped from the aquifer.

Farmers were presented with four distinct treated wastewater use programs, characterised in terms of the quantity and quality of treated wastewater used to replenish the aquifer. The definitions of the treated wastewater use programs were based on the focus group discussions and consultations with the policy makers, ecologists and hydrologists at the Ministry of Agriculture, Natural Resources and the Environment. Farmers were explained that the government could choose one of the programs, or none at all depending on the costs and benefits generated by each option. The four treated wastewater use programs and the present situation, i.e., status quo, were defined as follows:

- *Status quo*. This is the present situation in which no treated wastewater use program is implemented to replenish the aquifer. In this case the quantity of water in the aquifer, which is currently at a medium level, will decrease rapidly to a low level within the next ten years, implying that the pumping costs will double. The quality of water will also reach a low level within the next ten years due to the increase in water salinity as a result of sea water intrusion in the aquifer. In the present situation farmers are not expected to pay for the water they pump from the aquifer.
- *Treated wastewater use program A*. In this program low quality treated wastewater is used to replenish the aquifer. Low quality treated wastewater is appropriate for irrigating forestland, albeit in a controlled manner which ensures neither humans nor crops come in contact with the water. The quantity of water in the aquifer will stay at its current medium level and the pumping costs will remain the same during the next ten years. If this program is undertaken, then the farmers are expected to pay for each m^3 of water they extract from the aquifer.
- *Treated wastewater use program B*. Under this program medium quality treated wastewater is used to replenish the aquifer. Medium quality treated wastewater is appropriate for irrigation of trees, such as olive trees, or vineyards, where water does not come in contact with the crops. The quantity of water in the aquifer will stay at its current medium level and the pumping costs will remain the same during the next ten years. If this program is undertaken, then the farmers are expected to pay for each m^3 of water they extract from the aquifer.
- *Treated wastewater use program C*. Under this program medium quality treated wastewater is used to replenish the aquifer. The quantity of water in the aquifer will increase to a high level, implying that the pumping costs will decrease to half or even quarter of what they are now during the next ten years. If this program is undertaken, then the farmers are expected to pay for the m^3 of water they extract from the aquifer.
- *Treated wastewater use program D*. Under this program high quality treated wastewater is used to replenish the aquifer. High quality treated wastewater is appropriate for irrigation of crops whose edible parts do not come in contact with water. The quantity of water in the aquifer will increase to a high level, implying that the pumping costs will decrease to half or quarter of what they are now during the next ten years. If this program is undertaken, then the farmers are expected to pay for the m^3 of water they extract from the aquifer

An 'advanced disclosure' approach was employed, where farmers were presented in advance with all four treated wastewater use programs and the status quo alternative (Kontoleon and Swanson, 2003). The valuation questions consisted of two parts: first the farmers were asked whether they would be WTP some amount of money per m^3 of water in order to move from the status quo to program A. In the case where the farmer was willing to participate in the treated wastewater use program, they were asked for their maximum WTP per m^3 of water, using a payment card with amounts ranging from Cyprus Pounds (CYP) 0.01 (€0.018) to over CYP2 (€3.516). Similarly the farmers were asked whether they would like to participate in treated water use programs B, C and D, and if they were, they were asked to state their maximum WTP to move from the status quo to each one of these programs. Before stating their WTP, the respondents were told to bear in mind how they think the programs described above would affect their current and future production and farm profits. They were also reminded that if the majority of farmers decline the treated wastewater use programs, other measures would have to be imposed, such as obligatory taxation, for water pumping. Five follow-up questions were asked to identify between protest responses and true zero values. These are explained in greater detail in the following section.

The third part of the survey collected information on the farm characteristics, farm management practices, as well as farmers' attitudes and perceptions on how they think consumers would perceive agricultural production which uses treated wastewater, and what they think are the most important agricultural problems in Cyprus. The final section of the survey collected various social and economic data on the farmers and their families, including age, educational level and household size.

4 Results

The sample statistics are reported in Table 3. The main decision makers in the farm are all male and full time farmers. Only 4.4% of them have part time jobs in addition to full time farming. Their average age is 46.1, which is slightly younger than the EU average of 48 years (Eurobarameter, 2000). The main decision-makers' average years of experience in farming is 20.44 years. 82.4% of the farmers have high school diplomas, whereas only 3.3% or less have primary school diplomas, and 4.4% have university degrees. The average farm household in the area comprises of 3.1 members, and the average number of children is one. The total monthly expenditure of households (proxy for income) is CYP1598.8 (approximately €2896). The average total area of land owned by the households (indicator of wealth) in the sample is 64.9 hectares; the average total area they cultivate is 65 hectares, of which an average of 34.7 hectares are irrigated. 48.6% of farmers obtain their water for irrigation from a well located on their land, whereas 41.7% get their irrigation water from dams and reservoirs, and only 9.7% buy their irrigation water from other farmers in the area.

Table 3 Farmer, farm household and farm characteristics

Variable	*Mean* (*std. dev.*)
Age of the main farm decision maker	46.1 (11.6)
Farming experience of the main farm decision maker	20.5 (11.9)
Farm household size	3.1 (1.4)
Number of children in the household	0.95 (0.91)
Total monthly household expenditure (in CYP)	1598.8 (453.4)
Total area of farming land owned by the household (in ha)	64.9 (30.2)
Total area of farming land cultivated by the household (in ha)	65 (29.2)
Total area of irrigated farming land cultivated by the household (in ha)	37.7 (22.6)

Table 3 Farmer, farm household and farm characteristics (continued)

Variable	*Percent*
Education: high school = 1, 0 otherwise	82.4%
Education: University and above = 1, 0 otherwise	4.4%
Education: less than primary school = 1, 0 otherwise	3.3%
Main decision maker has part time job = 1, 0 otherwise	4.4%
Irrigation water from well on land = 1, 0 otherwise	48.6%
Irrigation water from dams and reservoirs = 1, 0 otherwise	41.7%
Irrigation water from other farmers = 1, 0 otherwise	9.7%

Source: Akrotiri Treated Wastewater Use Program Survey (2006)

Farmer perceptions of consumers' attitudes towards food produced with treated wastewater, as well as their perceptions of the most important agricultural problems in Cyprus are reported in Table 4. Whether or not the farmers agree with the statements reported in Table 3 was graded on a Likert Scale (Strongly disagree = 1, Disagree = 2, Neither agree nor disagree = 3, Agree = 4, and Strongly agree = 5). The Likert Scale is converted into dummies (Agree or Strongly agree 1, 0 otherwise) for the purposes of the analysis.

Table 4 Farmer perceptions of consumers' attitudes towards food produced with treated wastewater and most important agricultural problems in Cyprus

Statement	*Percentage agree or strongly agree*
If consumers knew treated wastewater is being used for agricultural production in the area, they would	
Stop consumption of food produced in the area	13.2
Decrease consumption food produced in the area	34.1
Not change their consumption of food produced in the area	35.2
Slightly increase consumption of food produced in the area	13.1
Considerably increase consumption of food produced in the area	4.4
The most important agricultural problem in Cyprus is	
Low food prices	41.8
Low fertility of land	36.3
Low water quantity	53.9
Lack of subsidies to agricultural sector	52.8
High salinity of water	44
Low water quality	45.1

Source: Akrotiri Treated Wastewater Use Program Survey (2006)

When asked how do the farmers think the consumers would react when they know that treated water is used in agricultural production in the area, the consensus is split, as 47.3% of them think that consumers might decrease or stop consumption of agricultural products from the area, and 52.7% think that use of treated water in the area would either have no affect on consumer behaviour or increase consumption of agricultural products from the area. Farmers' perceptions of the most important agricultural problems in Cyprus reveal that about half of them consider water resources related problems, e.g., high water salinity, low water quality and quantity, as the most important agricultural problems in Cyprus.

When asked whether or not they would be WTP in order to move from status quo to the treated wastewater use programs, six farmers stated that they would not be WTP for any one of the programs. In order to differentiate true zero WTP values from protest responses, five follow-up questions in close-ended response format were asked (Haab, 1999):

i I should not be asked to pay for the water under my land

ii I do not believe that the system will succeed in improving conditions

iii I have no interest for water quantity and quality in the aquifer

iv I do not believe that treated wastewater is safe and appropriate for farming

v It is not profitable for me to participate.

Those farmers that have agreed with the statements (i), (ii) or (iv) were classified as protesters of the treated wastewater program and were removed from the sample. Consequently, all of the six farmers, i.e., 6.2% of the sample were classified as protestors, and the remainder of the sample, i.e., 93.8% believe that the treated wastewater use program is safe for farming, it would succeed and they would pay for the water in the aquifer.

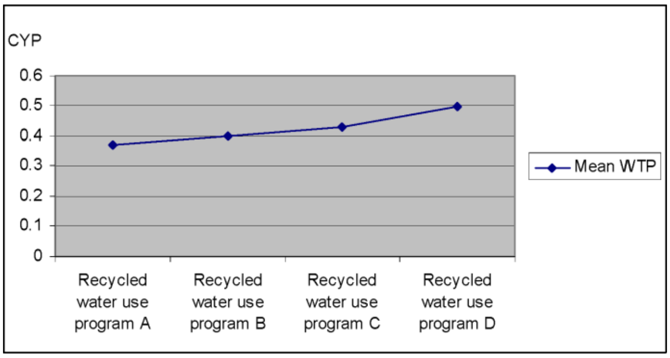
Farmers' mean and median WTP are reported in Table 5 for each wastewater use program. As expected, the average WTP increases with increasing quality and quantity of wastewater used to replenish the aquifer. Accordingly, farmers are WTP CYP 0.3–0.37 per m^3 of water to move from the status quo to program A. This program ensures that within the next ten years, farmers would have as much water as they have now. The quality of treated wastewater in this program is low, therefore this significantly high WTP reveals farmers' concerns with regards to decreasing quantity of water in the aquifer. Farmers are WTP a further CYP 0.025–0.028 per m^3 of water for wastewater use program B, which proposes to replenish the aquifer with medium quality wastewater, and to secure medium quantity of water in the aquifer. Farmers are WTP a further CYP 0.028–0.0312 per m^3 of water for wastewater use program C, which aims to increase the quantity of water in the aquifer to a high level, by replenishing it with medium quality treated wastewater. Finally, farmers are WTP a further CYP 0.065–0.071 per m^3 of water for wastewater use program D, which ensures high quantity of water in the aquifer, as well as the use of high quality treated wastewater for replenishment of the aquifer. Average WTP, therefore, increases with each additional wastewater use program, implying that the WTP values are scope sensitive with respect to the quality and quantity of water used to replenish the aquifer (Kontoleon and Swanson, 2003). Graph 1 illustrates the mid-points of the farmers' upper and lower bound WTP for each one of the treated wastewater use programs.

Table 5 Mean and median WTP values for treated wastewater use programs (in CYP/m^3 of water)

Treated water use program	*Mean* (*std. dev.*)	*Median*
Treated water use program A, lower bound	0.3(0.4358)	0.05
Treated water use program A, upper bound	0.3697(4575)	0.1
Treated water use program B, lower bound	0.3282 (0.4314)	0.1
Treated water use program B, upper bound	0.3947 (0.4566)	0.2
Treated water use program C, lower bound	0.3562 (0.4453)	0.1
Treated water use program C, upper bound	0.4259 (0.4694)	0.2
Treated water use program D, lower bound	0.4209 (0.451)	0.3
Treated water use program D, upper bound	0.4968 (0.4735)	0.4

Source: Akrotiri Treated Wastewater Use Program Survey (2006)

Graph 1 Average of mean upper and lower bound WTP for Treated Water Use Programs A–D



Finally, the relationship between the WTP for wastewater use program and program attributes was further examined by estimating a stacked regression model. In this model the WTP for wastewater use program is specified as a function of the quantity of the water in the aquifer and the quality of treated wastewater used to replenish the aquifer. The sign and significance level of the estimated parameters on the farm and farmer characteristics provide construct validity for the contingent valuation results (Mitchell and Carson, 1989; Arrow et al., 1993).

A random effects interval regression model was employed to estimate the stacked model. This model specification was chosen because the WTP data was collected with a payment card (Cameron and Huppert, 1989), and also to take into consideration the possible correlation between the individuals' four WTP responses for each program (A, B, C and D) (Greene, 1990). The best-fit model is presented in Table 6. In this model WTP was specified to be a function of treated wastewater programme characteristics, including medium and high quality and quantity of treated wastewater (taking low quality and quantity as the status quo, base level), as well as farmer and farm-specific characteristics, including total cultivated area that is irrigated, whether or not the water from irrigation comes from a well on the farm and whether or not the farmer agrees or strongly agrees with the statement that low water quality is an extremely important agricultural problem in Cyprus.

The results of the random effects interval regression model reveal that farmers' WTP significantly increases with the use of high quality treated wastewater used to replenish the aquifer, as well as with medium and high levels of water quantity in the aquifer. As expected, those farmers who have higher total areas of irrigated land, and those who obtain higher percentages of their water from wells on their lands, are WTP more for higher levels of water quantity and treated wastewater quality. Further, farmers who think that low water quality is an extremely important agricultural problem in Cyprus are WTP more for more advanced treated wastewater use programs, thereby revealing construct validity.

Table 6 Random Effects Interval Regression of WTP for alternative wastewater use programs

Variable	*Coefficient* (*Std. Err.*)
Constant	–0.225 (0.087)
Medium quality water	0.0233 (0.0322)
High quality water	0.091** (0.0456)
Medium quantity water	0.3373*** (0.032)
High quantity water	0.367*** (0.046)
Total area of land irrigated	0.0032** (0.0016)
% of irrigation water from well on farm	0.00118* (0.0009)
Low water quality most important problem	0.1033* (0.071)
Number of observations	455
Number of groups	91
Log likelihood	–1128.1388
Wald chi2(7)	256.61
Prob >chi2	0.0000

***1% significance level, **5% significance level and *10% significance level with two-tailed tests.

Source: Akrotiri Treated Wastewater Use Program Survey (2006)

For the purposes of the cost-benefit analysis of the treated wastewater use programs, WTP values for (i.e., benefits generated by) all four wastewater use programs were calculated by employing the significant regression parameters related to treated wastewater use program (i.e., high water quality and medium and high quantity), as well as farm characteristics (i.e., total area of land irrigated and percentage of irrigation water from well on land). Farmer perceptions of important agricultural problems in Cyprus were excluded, since these could not be used for cost-benefit analysis. Furthermore, WTP for wastewater use programs A and B are the same since farmer WTP for medium and low quality wastewater are insignificant.

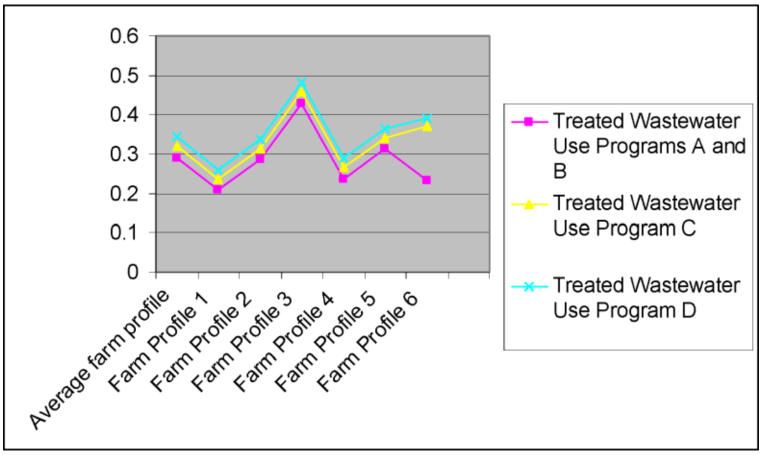
The WTP values resulting from the random effects interval regression model are employed to calculate the sample average WTP as well as the WTP of six farmer profiles. No strong correlation was found between total area of land irrigated and percentage of irrigation water obtained from well on farm. Therefore farmer profiles were created as follows: First, farms were categorised according to size, small size being less than 20 ha, medium ones between 20 ha and 60 ha, and large ones larger than 60 ha. The average sizes of small, medium and large farms were calculated to be 12.94, 36.1 and 77.63 ha respectively. An average small farm is found to obtain 45.26% of irrigation water from the well on their farm, this figure is 48.02% and 55.71% for medium and large farms, respectively. Small, medium and large farms are labelled Farm profiles 1, 2 and 3 respectively. Farm profiles 4, 5 and 6 are categorised according to percentage of irrigation water they obtain from the well on farm. Accordingly, the average of farms that obtain less than 30% of their irrigation from well on farm is 7.97%, whereas the average of farms, which obtain between 30% and 70% of their irrigation from well on farm is 55.65% and the average of farms, which obtain more than 70% of their irrigation from well on farm is 91.67%. The average sizes of these farms are 35.35, 41.55 and 36.97 ha respectively. The WTP values for each one of the wastewater use programs per profile are reported in Table 7 and Graph 2.

Table 7 Farmer WTP for treated wastewater use programs (CYP/m^3)

Farm profile	*Treated wastewater use programs A and B*	*Treated wastewater use program C*	*Treated wastewater use program D*
Average farm profile	0.2909	0.3206	0.3440
Farm Profile 1	0.2074	0.2371	0.2604
Farm Profile 2	0.2852	0.3149	0.3382
Farm Profile 3	0.4280	0.4577	0.4811
Farm Profile 4	0.2355	0.2652	0.2886
Farm Profile 5	0.3118	0.3415	0.3648
Farm Profile 6	0.2313	0.3692	0.3925

Source: Akrotiri Treated Wastewater Use Program Survey (2006)

Graph 2 WTP for treated water use programs for average farm and farm profiles 1–6 (for colours see online version)



The results reported in Table 7 reveal that all of the farmer profiles are WTP higher for higher levels of water quantity and treated wastewater quality used to replenish the aquifer. Farmer profile 1 has the lowest WTP for Treated Wastewater Use Programs A and B, while Farmer profile 3 exhibit the highest WTP for Treated Wastewater Use Program D. These results are expected to aid policy makers in designing efficient and equitable wastewater use programs, since they could be used in cost-benefit analysis of different intensity and scale of wastewater treatment and reuse programs, and could aid in establishment of the price of the water from the aquifer depending on the size of the farm and the extent of extraction of water from the aquifer

5 Policy implications and conclusions

This paper employed the CV method in order to estimate the value of (or economic benefits generated by) a new water resource, namely treated wastewater, so as to inform the policy makers about what quantity and quality of water to provide and which price to charge.

More specifically, a CV exercise was undertaken to examine

- farmers' attitudes towards adoption of this new technology, i.e., the use of treated wastewater to replenish an aquifer used for irrigation
- their WTP for different levels of water quantity in the aquifer, and for different levels of treated wastewater quality used to replenish the aquifer.

The case study is the Akrotiri aquifer, located in Cyprus, an arid country with chronic water shortages, where water scarcity may limit economic development and growth, as well as sustainability of food production in the long run. Therefore, adoption of solutions such as use of treated wastewater for irrigation is essential and urgent for sustainable management for water resources in Cyprus. The Akrotiri aquifer, similarly to several common-pool, open access water resources and public goods, is facing rapid deterioration of its water quality and quantity, and is in need of drastic economic and other measures to ensure its efficient and sustainable management.

The results of this pilot exercise reveal that majority (i.e., 93.8%) of the randomly selected farmers located in the Akrotiri area, are willing to participate in and also WTP significant amount for treated wastewater use programs. Farmers' are WTP higher amounts for those programs, which generate higher water quantity in the aquifer, and use higher quality treated wastewater for the replenishment of the aquifer. Farmers, however, are WTP even for those treated wastewater use programs, which use low quality treated water, revealing the gravity of the water quantity scarcity problem faced by farmers in this area. Furthermore, those farmers who have larger areas of irrigated land, and those who obtain most of their irrigation water from wells on their lands are WTP more for quality and quantity of water in the aquifer, compared to those farmers who farm smaller areas and obtain their irrigation water from dams and reservoirs.

These results could have important implications for efficient and equitable pricing of water in the aquifer, as well as for adoption of the appropriate treated wastewater use program, which maximises the social welfare. In order to be able to draw sound policy recommendations, however, revenues that would be generated under each treated wastewater use program should be compared to the costs of the programs.

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