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Groundwater Valuation and Quality Preservation in Iran: The Case of Yazd

Abedi, Z.[1], Fattahi Ardakani, A.[2], Hanifnejad, A.R.[1*], and Dashti Rahmatabadi, N.[3]

[1]Faculty of Environment and Energy, Department of Environmental Economics, Science and Research Branch, Islamic Azad University, Tehran, Iran

[2]Department of Natural Resources, Yazd University, Yazd, Iran

[3]Faculty of Persian Literature and Foreign Languages, Islamic Azad University, South Tehran Branch, Tehran, Iran

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ABSTRACT: Groundwater can be used directly or indirectly and any decline in its quality or quantity may negatively impact the environment. Through groundwater valuation, people are made aware of the fact that groundwater is not free of charge and therefore the significance of groundwater preservation is established. In this study, groundwater quality preservation value has been estimated for the city of Yazd based on the contingent valuation method (CVM). The methodology used consisted of field study and library research. After determining the sample size using Cochran's formula, the distributed questionnaires were filled by the inhabitants of the city of Yazd. Thereafter, the results were analysed using Excel and EViews. Finally, people's willingness to pay for the preservation of Yazd groundwater quality was estimated to be US$18.5 annually per capita, which is a remarkable value. Hence, it was determined that groundwater quality preservation was of great value to the inhabitants of Yazd.

Key words: Conservation value, Groundwater, Contingent valuation method (CVM), willingness to pay (WTP), Yazd

INTRODUCTION

Yazd is located in the Central Iranian Plateau and is situated above the water source of Yazd-Ardakan. This water source is replenished by rainfalls mainly in the high Shir Kuh Mountains. There is no perennial river in the Siah Kuh water-wash desert. The surplus seasonal river water during heavy rainy seasons reaches the Taft and Mehriz Basins from the mountain areas and replenishes the Yazd-Ardakan catchment areas via groundwater. This water catchment source covers an area of 11,775 km2, not exceeding 10% of the Yazd area. However, density-wise it covers over 70% of the Yazd population. This area includes 4,117 km2 main plain, 3000 km2 highlands, 845 km2 low hills and marshlands, and 2,723 km2 isolated and marginal plains. There are 827 aqueducts (Qanat) in the Yazd-Ardakan plain with an average water flow of 9 litres per second and a maximum of 250 lit/sec. In addition, there are 49 water springs with an average water flow of 39 lit/sec and a maximum of 1,875 lit/sec. There are also 255 semi-deep water wells with an average water flow of 6 lit/sec and a maximum flow of 46.2 lit/sec. Moreover, there are 1067 deep water wells with an average water flow of 19 lit/sec and a maximum water flow of 97.2 lit/sec. In Figure 1, the distribution of the wells in the Yazd-Ardakan region is displayed.

The Yazd-Ardakan basin has been facing a decline in its water balance and groundwater level for a long time due to unpermitted and excessive utilizations such that it has become a prohibited plain since 1966 and any exploitation development in this area has been limited. This issue has negatively affected the quantity and quality of Yazd groundwater. Previously, because of the absence of permanent rivers, Yazd used to receive all its water supply from underground water tables. However, during the past decades, Yazd has been transformed into an industrialized and populated centre and therefore, the water resources of the area fail to meet the increasing requirements of industries, urban consumption and agriculture. This has severely damaged the environment of Yazd. During the past few years, numerous researches have been carried out on the supply of water to Yazd from Zayandeh Rud

*Corresponding author E-mail: a.r.hanifnejad@gmail.com

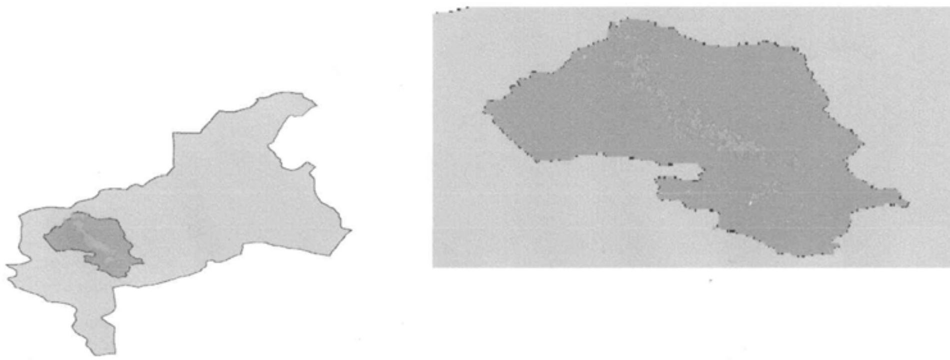

Fig. 1. Distribution of wells in the Yazd-Ardakan region

headwaters in Esfahan. Transfer of water from the mentioned headwaters to Yazd has reduced the hazards to the environment.

One reason why people overlook the importance of preservation of groundwater quality is that they are uninformed about its value. Hence, it appears that the most important issue in the area of preservation of the groundwater quality is keeping the people well informed about the value of quality preservation in this regard. Several studies have been conducted on groundwater valuation and quality preservation (Solino *et al.*, 2013; Madani *et al.*, 2012; Romanelli *et al.*, 2011; Martinez-Paz and Perni, 2011; Belkhiri *et al.*, 2011; Praveena *et al.*, 2010; Baghvand *et al.*, 2010; Nasrabadi *et al.*, 2009; Sadashiva Murthy *et al.*, 2009; Joarder *et al.*, 2008; Mehrdadi *et al.*, 2007). In a study by Maji et al. (2012) the effect of groundwater contamination has been analysed. In another study also related to groundwater (Sun *et al.*, 1992), the benefits of groundwater contamination control were determined. In a study on groundwater conducted by Danh (2007), the economic value of groundwater protection in the Mekong Delta has been analysed. For this purpose, the mean willingness to pay was estimated using the contingent valuation method (CVM). With regard to groundwater contamination, Holmes and Lillicrap (2011) have analysed the environmental processes causing groundwater acidity in Western Australia's wheat belt. Diwakara (2005) has studied the effect of some variables, including age and household trust, on the households' attitudes towards groundwater sharing and community prosperity. Shoham (2006) in a study conducted in Boston has examined how the city, state, and community organizations can pool their resources to prevent further damage to wood pilings and permanently increase groundwater levels in the city. In a study by Pulido-Velazquez et al. (2010), a hydro-economic modelling framework for selecting sustainable cost-efficient measures and management strategies to achieve the good groundwater status of the EU area has been introduced. Hasler et al. (2005) have used the CVM and Choice Experiments for valuation of groundwater protection in Denmark. Mahumani, B.K. (2009) has conducted a socio-economic study that centred on determining the economic value of groundwater in rural and agricultural uses. Christantoni et al. (2011) have compared primary data derived from a Contingent Valuation survey that was conducted to estimate households' WTP for protecting groundwater resources to secondary data predicted by value transfer. Turner et al. (2004) have produced a review on water resource valuation issues and techniques specifically for the appraisal and negotiation of raw water resource allocation for agricultural development projects. In a study by Steward et al. (2009) the natural association between groundwater wells and agricultural parcels is employed to couple models simulating groundwater hydrogeology and open modelling interface protocols. Bulatewicz et al. (2010) have integrated multidisciplinary models related to agriculture, groundwater, and economy using the Open Modelling Interface. Day and Mourato (1998) in a study titled "Willingness to Pay for Water Quality Maintenance in Chinese Rivers" based on the economical valuation techniques and the multilayer market of Beijing in China found that the environment surrounding the rivers was of great value to the people of the area. Another research was done in 1998 by Rosado titled "Willingness to Pay for Drinking Water in Urban Areas of Developing Countries" in which a Multidimensional Logit model was presented for estimating the families' welfare for supply of healthy drinking water in southern Brazil.

Casey et al. (2005) in a research titled "Willingness to Pay for Improved Water Service in Manaus, Amazonas, Brazil" investigated the amount people were willing to pay for access to clean and potable water. In a research done by Kaliba et al. (2003) titled

"Willingness to Pay to Improve Domestic Water Supply in Rural Areas of Central Tanzania" based on the Logit model, the WTP of the inhabitants of rural areas of Tanzania for improving the water quality was investigated. Researches were conducted throughout 30 villages by using questionnaires. Lichtenberg and Zimmerman (1999) have conducted a survey of 1611 farmers to estimate their WTP to prevent leaching of pesticides into groundwater. Ojeda et al. (2008) estimated the recreational value of Yaqui River in Mexico and determined the average amount people were willing to pay per month to be 73 pesos throughout 40 towns. In Iran too, limited studies with regard to the estimation of the recreational value of water have been conducted. In 2006, Amirnejad et al. investigated the preservation value of Sisangan Park and estimated the WTP of the inhabitants for the conservation value of the park and the recreational value to be 6365 and 2477 Rials, respectively. Peron and Esmaili (2010) calculated the average WTP for visiting the Hera Jungle to be 3491 Rials. Furthermore, in a separate study, Dashti and Sohrabi (2008) estimated the recreational value of Nabovat Park located in Karaj city to be 3300 Rials. Kavousi and Khodaverdizadeh (2011) in estimating the recreational value of Sahoolan Cave estimated people's WTP as 4235 Rials. Finally, Saleh and Moulaie (2010) in assessing the recreational value of Darreh Si Park in Arasbaran Jungles estimated the average WTP as 3908 Rials.

MATERIALS & METHODS

The CVM is a flexible valuation method that is widely used in cost benefit analysis and assessment of environmental effects. It was first introduced by Ciriacy-Wantrup in1947 who believed that prevention of soil erosion in nature can be estimated through quantitative non-market valuation. Davis (1963) for the first time used CVM empirically and estimated the profit obtained by hunters from wild geese hunting. This method is usually useful for two important values, i.e., existence value and option value. CVM has been used by Hashemi (2011) to determine the recreational value of tourism in Masouleh village in Iran. In order to determine the model for measuring the WTP, it is assumed that the person accepts or rejects the amount suggested for the determination of non-market values of a natural resource based on maximizing its utility function under specific conditions:

$$\Delta V = \Delta U + (\varepsilon_1 - \varepsilon_0) \quad (1)$$

where U is the indirect utility achieved by a person. In the following equations, Y and A are the income and suggested amount, respectively. S represents other socioeconomic characteristics which are influenced by personal taste. ε_0 and ε_1 are random variables which have been distributed equally and independently. The difference of utility (ΔU) can be illustrated as follows:

$$\Delta U = U(1, Y - A; S) = U(0, Y; S) \quad (2)$$

$$\Delta V = U(1, Y - A; S) - U(0, Y; S) + (\varepsilon_1 - \varepsilon_0) \geq 0$$

$$\Delta U \geq -(\varepsilon_1 - \varepsilon_0)$$

$$\varepsilon = \varepsilon_0 - \varepsilon_1 \qquad (\varepsilon_0 - \varepsilon_1) \leq \Delta U$$

$$-(\varepsilon_1 - \varepsilon_0) \leq \Delta U \qquad (\varepsilon_1 - \varepsilon_0) \geq -\Delta U$$

$$\Delta U = \alpha + \beta A + \gamma Y + \theta S \qquad F_\eta(\varepsilon) = \frac{1}{1 + e^{-\Delta u}}$$

$$\Pr(\varepsilon) \leq \Pr(\Delta U) \qquad \varepsilon \leq \Delta U$$

The questionnaire format in CVM consists of a dependent variable with binary selection which requires a qualitative selection model. Usually, Logit and Probit models are used in qualitative selection methods. If the Logit model is used for estimating the effect of variables on the amount of people's WTP for determination of non-market values, the probability (pi) that a person accepts one of the suggestions (A) is calculated as follows:

$$F_\pi(\Delta U) = \frac{1}{1 + \exp-\{\alpha - \beta A + \gamma Y + \theta S)\}} \quad (3)$$

where:

$$F_\eta(\Delta U) \qquad \theta > 0, \gamma > 0, \beta \leq 0$$

In order to estimate the amount of WTP, a method called Truncated Mean WTP is used in which the expected value of WTP is calculated by numerical integration in the range of zero to infinity. The Logit model parameters are estimated by using the Maximum Likelihood Method, which is one of the most commonly used techniques. Thereafter, the expected value of WTP is calculated using numerical integration within the range of zero to the highest suggested amount (A) as illustrated below:

$$E(WTP) = \int_0^{Max.A} F_\eta(\Delta U)dA$$

$$= \int_0^{Max.A} \left(\frac{1}{1 + \exp\{-(a^* + \beta A)\}}\right)dA \quad (4)$$

E (WTP) is the expected value of WTP and α^* is the adjusted intercept which was added to the original intercept (α) by the socio-economic statement:

$$[a^* = (\alpha + \gamma Y + \theta S)]$$

In order to collect the needed data, first a questionnaire was prepared. Thereafter, 45 questionnaires were filled as pre-test. The questions were designed in four categories. The first group related to general information and socio-economic characteristics of the respondents. The second group was concerning the environmental views of the respondents through which the respondents' knowledge of environmental issues related to Yazd was determined. The third group related to people's opinions on groundwater and issues involving the environmental aspect of groundwater based on which their degree of approval in this regard was specified. Finally, in the fourth group, the value people place on their access to groundwater and their WTP for having access to higher quality water—based on intrinsic value of groundwater and preservation of its quality—was determined. The number of questionnaires designed for three areas of Yazd city was 466, which were filled in proportion with the population of these areas. The most important difference between the pre-test questionnaire and the final version was that in the pre-test version the respondents would be asked about their WTP without suggesting any figure to them. The sample size was calculated using Cochran's formula as follows:

$$\rightarrow n = 466 \quad n = \frac{1.96^2 \times 1.1^2}{0.1^2} \qquad (5)$$

In the present study, it is presumed that the Islamic Republic of Iran has decided to conserve Yazd groundwater resources more rationally and to prevent their quality deterioration. Such a decision is taken through assigning this role to a non-governmental organization. Furthermore, it is presumed that the only way to preserve groundwater resources is through people paying certain amounts of money to this non-governmental organization. Such an organization can supply high quality water to the inhabitants of Yazd by purchasing water purification machines. Obviously, the foregoing requires investment by the mentioned organization, which will be returned through people's annual water bills. The main question in the pre-test for determining the price in this regard was, "What is the maximum annual amount you are willing to pay this organization through a mechanism similar to your water bills having considered the intrinsic value of groundwater?" Thereafter, for the purpose of determining the suggested price, the payment card method—in which the amounts were set based on the data obtained from the pre-test—was used. The amounts specified for people's WTP in the final questionnaire were US$9, US$18, and US$36 and the people of Yazd were asked which of the foregoing amounts they were willing to pay to the organization for the preservation of the quality of groundwater.

RESULTS & DISCUSSION

In order to estimate the expected WTP for the respondents who replied "yes" to the question, "Are you willing to pay A Rials for the conservation of the intrinsic groundwater value?" the indirect utility function $V_1 = V(M - A, 1) + \varepsilon_1$ was used, where 1 shows the conservation of the intrinsic value of groundwater. For the respondents who gave negative answers, the utility function was specified as $V_0 = V(M, 0) + \varepsilon_0$ in which zero showed that the respondents refused to accept the amount suggested for the preservation of the intrinsic value of groundwater. A positive response yields higher utility than when the proposed amount is rejected. Therefore:

$$PR(Yes) = PR(V_1 + \varepsilon_1 > V_0 + \varepsilon_0) \qquad (6)$$

$$= PR(\varepsilon_1 - \varepsilon_0 > V_0 - V_1)$$

$$= PR(-\varepsilon_1 + \varepsilon_0 \le V_1 - V_0)$$

$$= PR(\varepsilon \le \Delta V) \qquad F(\Delta V) = V_1 - V_0,$$

$$\varepsilon = \varepsilon_0 - \varepsilon_1$$

$$= F(\alpha + \beta A)$$

where F is the Logit Cumulative Distribution Function shown as $Cdf = F(A)$. The indirect utility difference is shown as ΔV illustrated below:

$$\Delta V = \alpha + \beta A \qquad (7)$$

Some characteristics of the respondents have been used in the Logit function estimation, which include sex (S), family size in numbers (X), level of education in years (D), and monthly income (Y). In addition, some variables such as other important factors relating to water according to the respondents (W), the level of significance of the environment in the view of the respondents (Z), and the destruction of the vegetation cover around the city (U) are used. The indirect utility difference function is estimated for each respondent through the Logit Model as follows:

$$\Delta V = \alpha + \beta A + b_0 S + b_1 X + b_2 D + b_3 Y + b_4 W + b_5 Z + b_6 U \quad (8)$$

The results outlined in Tables 1 and 2 showed that most respondents, consisting of 178 persons, were 25–36 years old and the fewest number of respondents were over 55 years old. The majority of the respondents were male, approximately 3 times more than females. Most participants consisted of families with 3–6 members comprising 70% of the total population. The number of married respondents was three times that of single participants. The number of respondents who were heads of households was approximately two times more than those who were not. This means that improvement of the quality of water and preservation of water is more important to the heads of families and hence their WTP was closer to reality. Concerning education level, the lowest percentage of respondents were those who were illiterate and those holding bachelor's degrees comprised the highest proportion of the population. Most participants had monthly incomes of between US$363 and US$545. The lowest percentage of income related to those earning monthly incomes of above US$727. Four percent of the participants did not accept any of the suggested amounts. Out of the 96% who accepted the amounts, 35% were willing to pay US$9, 47% were willing to pay US$18, and 15% were willing to pay US$36 annually per every member of their family to a non-governmental organization for water purification and supply of higher quality water to the people. The family size coefficient has been statistically made meaningful at a level of 1% and the negative sign indicates that increases in the family size cause the acceptance of the suggested amount to decrease. The income coefficient of the respondents has been made meaningful at 1%. The positive sign indicates an increase in the possibility of acceptance of the WTP for preservation and maintenance of water quality with increases in income. The results of estimation of the Logit model indicate that the suggested variable is meaningful at 1% and the negative sign shows that if the suggested price increases, the possibility of acceptance of the suggested amount by the respondents decreases. The estimated coefficient of the importance of the environment indicates that this variable is meaningful at 5% and the negative sign explains that those who agree with preservation of the quality of groundwater and the maintenance of its value are willing to pay higher amounts.The estimated coefficient of destruction of vegetation cover due to incorrect water consumption is positive and meaningful and it indicates that if this incorrect trend continues, the process of destruction of the vegetation cover will persist. The marginal effect pertaining to gender indicates that in Yazd the possibility for men to accept the suggested amount for maintenance of the groundwater quality is higher compared to women. In other words, the possibility for acceptance of the suggested amount by men is 0.4 times more than women. The coefficient sign of education indicates a direct (positive) relation between education level and WTP. In other words, higher levels of education increase the respondents' WTP.

Table 1. Descriptive results of quantitative variables

Variables	Minimum	Maximum	Mean
Age in years	18	71	34
Family size in numbers	1	11	3.8
Education in years	0	18	13.9
Monthly income (US$)	27	1362	413

Table 2. Results of qualitative variables

	Sex		Marital Status		Head of Household		Destruction of Cover		Acceptance of Suggestion	
	Male	Female	Married	Single	Yes	No	Yes	No	Yes	No
Number	339	127	354	112	284	182	442	24	449	17
Percentage	73%	27%	76%	24%	61%	39%	95%	5%	96%	4%

Table 3 Estimated WTP model

Variables	Coefficient	T-Statistic	Elasticity at Means	Marginal Effect	Meaningful Level
Sex	0.19	1.3	0.074	0.048	0.1542
Family size	-0.1	-2.3	-0.22	-0.27	0.0444
Education	0.38	1.5	0.014	0.096	0.5158
Monthly income	$0.9\text{x}10^{-8}$	0.4	0.022	$0.2\text{x}10^{-8}$	0.4472
WTP	$-0.49\text{x}10^{-4}$	-7.3	-0.56	-0.00001	0.0000
Other values of water	0.43	1	0.21	0.1	0.1080
Importance of the environment	-0.14	-1.7	-0.32	-0.36	0.2015
Destruction of vegetation cover	0.61	1.7	0.3	0.14	0.0503
Constant coefficient	0.82	1.4	-	-	-
Percentage of right predictions=0.60 Likelihood statistic= -610			ESTRELLA R^2= 0.04 MADDALA R^2= 0.07 CRAGG-UHLER R^2= 0.1 MCFADDEN R^2= 0.05		

As the aim of this study was to estimate the expected amount of WTP, A is considered to represent the major variable and other variables are considered at the mean level. Finally, it was determined that $\Delta V = 0.94 - 0.000049A$.

The logistic function can be summarized as follows:

$$F(\Delta V) = \frac{1}{1+e^{(-\Delta V)}} \quad = \frac{1}{1+e^{-(\alpha+\beta A)}} \qquad (9)$$

Furthermore, the expected WTP is determined based on the following equations:

$$E[WTP] = \int_0^{MAXA} F(A)dA \qquad (10)$$

$$E = \int_0^{40000} \frac{1}{1+e^{-0.94+(-0.000049}A_1)} dA = 20375 \qquad (11)$$

Therefore, the average WTP of the inhabitants for the preservation of the quality of Yazd groundwater was calculated to be US$18.5 per capita annually. Taking into consideration that the average size of families in the population was 4 people, the mean WTP for preservation of the quality of Yazd groundwater was US$74 annually. As the number of households in the city of Yazd was 138,200, the total amount of the WTP for Yazd inhabitants for preservation of the quality of groundwater was determined to be US$10,226,800 annually. Therefore, the monthly amount the people of Yazd were willing to pay for preservation of the quality of Yazd groundwater was US$852,233.

CONCLUSION

Groundwater usage in different agricultural, drinking, industrial, and environmental sectors impacts its quantity and quality to a great degree. Lack of attention to the output of each of these sectors severely damages the sector, other sectors, and the environment in general. Through better management in water consuming sectors, groundwater preservation both in terms of quantity and quality will be possible. The value determined based on the information obtained from the inhabitants of Yazd with regard to the preservation of Yazd groundwater indicated that even the slightest changes in the quality of groundwater was not acceptable to them. Based on the suggested prices, it was concluded that the present quality of Yazd groundwater was at an acceptable level and the value obtained showed an increase in the quality of Yazd groundwater in the recent years, mainly because of the water transfer plan from the Kuhrang area to the city of Yazd. It appears that through the implementation of the second phase of this plan, the quality of Yazd groundwater will further improve. Based on the results of the present study and estimation of the elasticity, it was determined that the respondents' incomes had a meaningful effect on the preservation of the quality of groundwater. Therefore, it seems that improvement in the income level of the inhabitants of Yazd will lead to higher values of groundwater quality preservation. As the effect of the level of education on the acceptance of the suggested amounts is positive, hence, increase in the public education level will have an effective impact on the awareness of the inhabitants with respect to Yazd groundwater quality preservation value. The high amount of WTP of the people of Yazd for the groundwater quality preservation indicates the significance of this vital element for the people. Therefore, employing legal and managerial tools for the conservation of groundwater appears to be crucial. As the family size increases, the possibility for acceptance of the suggested amount decreases. With the addition of one person to the family size, the possibility for acceptance of the suggested price decreases by 0.02 units. Therefore, it is suggested that in order to calculate the groundwater price, the family size should be taken into account. Coordinating different sectors which consume groundwater requires integrated management. Hence, it is suggested that appropriate water consumption policies in different sectors should be considered in regional environmental and economic development plans so that payment by each sector (agriculture, industry, and drinking) is based on the amount of groundwater they use. It seems that the knowledge of the inhabitants of Yazd about the correct manner of water usage and the methods of enhancing its consumption is at a low level. It is suggested that the people of Yazd be made aware in this regard through employing different means, such as installing signboards throughout the city and also through television programs. The estimated coefficient of the destruction of the vegetation cover due to incorrect usage of water is positive and meaningful, which indicates that if this trend continues, the destruction of the vegetation cover will persist. Therefore, it is suggested that economical valuation be conducted in this regard and the depreciation expenses resulting from destruction of the vegetation cover surrounding the city of Yazd calculated through the green accounting system. Considering people's awareness of water scarcity and groundwater quality decline in Yazd and taking into account their positive response for adding the preservation value to the water price, it appears that including the suggested price in the water bills to some extent may reduce inappropriate water consumption by the people of this city. This article estimates the preservation valuation of groundwater quality in Yazd using CVM. Further researches in estimating water valuation based on different techniques are recommended.

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