Assessing the economic viability of alternative water resources in water scarce regions: The roles of economic valuation, cost–benefit analysis and discounting

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1. Introduction

The necessity of estimating the entirety of values generated by environmental goods and services for cost-benefit analysis (CBA) of policies and projects has long been advocated (Pearce, 1993). Coined as the total economic value (TEV) , the notion is based on the argument that environmental goods and services not only generate direct use values, but also indirect, non-use, option and existence values, which should be captured (i.e., quantified in monetary units) in order to be weighed against the costs of conservation or provision of such goods and services in a classic CBA framework. In addition the "sustainability" context pertaining to the long run and inter-generational equity issues regarding environmental goods and services, require appropriate discounting of the costs and benefits of conservation or provision of such goods and services. Recent advances in the discounting literature propose the use of econometrically estimated time declining trajectory of discount rates in order to be able to judge better the sustainability of plans which propose to conserve or provide such environmental goods and services (Gollier et al, 2008).

The aim of this paper is to document a comprehensive methodology which would allow for the assessment of the viability of an environmental management plan which has long-run economic and ecological impacts. The plan under consideration is an aquifer management plan which proposes to replenish a depleting aquifer with treated wastewater in a water scarce region of the world, namely Cyprus. It is expected that the results of the study will provide the policy makers with policy recommendations which might help them with the sustainable management of Cyprus' scarce water resources and the timely implementation of the European Union's (EU) Water Framework Directive (WFD (2000/60/EC)).

To this end, one of the main aquifers in Cyprus, namely the Akrotiri aquifer is used as a case study. Through literature reviews, focus group discussions and informal interviews with experts and general public in the area, the main stakeholders who would be benefiting from such a plan were identified as the local farmers and the residents of the nearby city of Limassol. Farmers located in the area derive use values as well as option values from the aquifer as they irrigate their farms with water from the aquifer. Limassol residents on the other hand derive indirect use values through the consumption of locally produced vegetables, as well as non-use values from the ecological status of the local environment and from the employment in agricultural sector supported by the aquifer. Two distinct choice experiments were employed with randomly selected members of these two stakeholder groups to estimate the use and non-use economic benefits that may arise as a result of the proposed aquifer management plan.

These estimated benefits are aggregated over the relevant populations and weighed against the costs of the provision of such an intervention. Since the costs and benefits of this plan are expected to have impacts well into the future, a long run CBA was conducted and different discount rate schemes (constant and declining discount rates) were used. The results of this long-run CBA reveal that the net benefit generated by the aquifer management plan is positive and significant well into the future, regardless of the discount rate scheme used. The net benefit trajectory estimated with the declining discount rate is however higher than those estimated with the constant discount rates. Moreover, the benefits under the declining discount rate trajectory take thrice as long to come to a plateau. The results therefore have implications in terms of using declining discount rates for evaluating project, policies or plans with long term impacts in general, and in terms of informing efficient water resources management in Cyprus in particular. The methodology developed would especially benefit those EU Member States which obligated to implement the WFD, since the Directive specifically calls for application of long run CBA and consideration of the sustainability criterion when developing and adopting the appropriate measures and technologies to achieve good water status for the European water resources.

The rest of the paper unfolds as follows: The next section describes the case study. Section 3 introduces the choice experiment approach, design and implementation of the two experiments and their results. Section 4 reports the results of the cost benefit analysis and discusses the use of different discount rates for public projects which have long run impacts. The final section concludes the paper and draws policy implications.

2. The Akrotiri Aquifer case study

Efficient management of its scarce water resources has historically been one of the most important resource challenges in Cyprus (Koundouri, forthcoming). As a member of the EU, Cyprus is obligated to adopt and implement the WFD which aims to achieve "good [ecological, chemical and physical] status" for all European waters by 2015. Article 11(3)(c) of the Directive emphasizes the need to find sustainable solutions, by specifying that measures to promote and efficient and sustainable water use must be introduced in order to safeguard environmental objectives. Furthermore the Directive calls for the economic estimation of the costs and benefits of various measures (both economic and technological) and conducting of thorough CBA in order to determine the most efficient, effective and equitable means of achieving the good water status. The key elements of the Water Framework Directive have been adapted to national legislation through the “Water Protection and Management Law of 2004” and similarly to several other Member States, implementation of the Directive is currently underway (Koundouri, forthcoming).

The case study presented in this paper is the Akrotiri aquifer, a common-pool resource and the third largest aquifer in Cyprus. This coastal aquifer is extremely important for the local economy and ecological stability. Extending over 42 km^2, the Akrotiri aquifer not only provides local farmers with irrigation water, but also supports the largest inland aquatic system in the country which hosts unique ecological habitats and biodiversity riches (Birol et al., 2008). The Akrotiri wetland, a product of aquifer runoff, is recognized as a wetland of national and international importance by the Ramsar Treaty (site no: 1375); an important bird area by Birdlife International, and as a special protected area by the Barcelona Convention (Kailis, 2005). The 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 aquifer faces serious water quality and quantity problems, which are expected to have significant adverse effects on the livelihoods of the local farmers as well as on the ecological conditions in the area in the not too distant future. After the construction of the Kouris River dam, water inflow has decreased significantly resulting in a lower water table (Mazi et al., 2004). This has lead to saltwater intrusion to maintain its hydrological balance. Water quality in the aquifer is deteriorating further because of the intensive use of fertilizers and pesticides in agricultural production in the area. 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. Decreased water availability and deterioration of water quality imply limits on the household use of aquifer water, which translate into increasing frequency and duration of water shortages and increasing residential water prices. Moreover, in combination with the decreased precipitation rates as a result of climate change, aquifer depletion is expected to cause desertification, leading to the deterioration of ecological conditions in the area.

In order to mitigate the adverse effects of reduced water availability and deteriorating water quality in the aquifer, its replenishment with treated wastewater from Limassol and nearby villages has been proposed. Among the water scarcity alleviation technologies, wastewater treatment and reuse is a promising technology especially in water scarce regions (Fetter et al, 1974; Paling, 1987; Bouwer, 1992; Barnett et al 2000; Scott et al., 2004). Large scale wastewater treatment has already been initiated in the Limassol prefecture 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 ecological conditions and overall water resources management (Papaiacovou, 2001). So far the wastewater treated in this plant has been discharged in the Mediterranean Sea.

Recently, the Government has been considering implementation of the plan to recharge the rapidly depleting Akrotiri aquifer with treated wastewater, in order to reduce the effects of seawater intrusion and to ensure sustainability of the current water quality and quantity levels in the aquifer. The case study presented in this paper aims to assesses the economic viability of such a plan, by estimating the total economic value of the use and non-use benefits that will be generated by this plan and weighing these benefits against the costs of implementing this plan, using different discount rates.

3. Valuation of the benefits of treated wastewater

3.1. Choice experiment design and survey development

Focus group discussions, expert consultations and thorough review of the literature revealed two main stakeholders groups which derive economic benefits from the Akrotiri aquifer. The first is the local farmers, who use the aquifer as an irrigation source. This stakeholder group is assumed to derive mainly use and option values from the aquifer. The second group is the public located in the nearby Limassol city. This stakeholder group is assumed to derive indirect use values through the consumption of locally produced food, as well as non-use values from the conservation or improvement of the ecological status of the local environment and from the employment in agricultural sector supported by the aquifer. Two distinct choice experiments were carried out in order to capture the different components of economic value accrued by these two stakeholder groups.

The key attributes of the environmental plan that is being valued, i.e., the "aquifer management plan", and the levels these might take with and without the replenishment of the aquifer with treated wastewater were identified following consultations with hydrologists, ecologists, and local water policy makers, as well as focus group discussions with local farmers and Limassol residents. The selected attributes and the levels they encompass for each one of the choice experiments are reported in Table 1.

[Insert Table 1 around here]

In the farmer choice experiment, water quality and quantity attributes were specified to have two levels: current level and low level. It was explained that currently water quality and quantity levels in the aquifer are at a medium level. The water quality at the aquifer can indefinitely be maintained at its current level if high quality treated wastewater is used for its replenishment. If however no action is taken to replenish the aquifer, then within the medium run the quality of water is expected to deteriorate to a low level due to increasing salinity, and remain in this condition in the long run. Low water quality due to increasing salinity would indicate that farmers cannot continue cultivating the same crops as they do today, which are mainly vegetables. In that case farmers would need to cultivate those crops that are tolerant to saline water (e.g., sugarbeet, durum wheat, potato, maize and sunflower) (Katerji et al., 2000).

For the water quantity attribute, it was explained that currently the aquifer table is at a medium level. If, however, extraction of water continues at the current rate and if no projects are undertaken to replenish the aquifer with treated wastewater then the water quantity in the aquifer is expected to decrease to a low level, and remain at that level. Low level of water in the aquifer would imply that farmers' pumping costs would increase to one and a half to twofolds of what they are today.

The employment attribute refers to the number of part time and full time farmers employed in the area. Currently there are approximately 1500 local farmers who benefit from the aquifer. If the current conditions of uncontrolled water extraction prevail, it is expected that agricultural employment in the area will decrease by 20% (to 1200 farmers) in the medium to long run and remain at that level in the future. If, however, the plan to replenish the aquifer with treated wastewater is implemented, then employment in agriculture would continue to decrease, however by lower levels, to 1455, 1380 or 1275, depending on the quantity and quality of water available in the aquifer, as well as complimentary government agricultural policies.

Finally the monetary attribute which is necessary for estimating the welfare changes is defined as the price of m^3 of water extracted from the aquifer. The price of water under the aquifer management plans is expressed as a percentage increase on the current average price paid by each farmer. Under an aquifer management plan, the price of water currently paid by the farmers could remain the same or increase by 50%, 25% or 10%. Information on farmers' current per m^3 water costs was collected in order to be able to convert these percentage levels into monetary levels for each farmer.

The selected attributes for the resident choice experiment implemented in Limassol included water quality, ecological conditions, employment in agriculture and water price (Table 1). The definition of the employment in agriculture attribute was the same in the resident choice experiment as in the farmer choice experiment. This attribute was included in the resident choice experiment to test the hypothesis that the public may derive economic benefits from social and economic factors in addition to the ecological factors (Portney, 1994). Several previous choice experiment studies have included social and economic factors, such as number of people employed or living in the countryside, in order to capture the economic benefits enjoyed by wider public from provision of such factors (e.g., Morrison et al., 1999; Bennett et al., 2004; Othman et al., 2004; Colombo et al., 2005; Bergmann et al., 2006; Birol et al., 2006b).

The water quality attribute was defined to have impacts on the type of crops cultivated by farmers in the area, as described in the farmer survey. This attribute is also expected to have indirect economic impacts on the residents in terms of the availability and diversity of locally produced vegetables. The ecological condition attribute refers to the possible effects of desertification that may take place in the region due to decreased water availability and increased water salinity. Current habitats and biodiversity riches supported by the Akrotiri aquifer and the wetland are expected to be lost as a result of desertification. If the aquifer is replenished with treated wastewater, ecological conditions in the wetland are expected to remain at their current conditions. On the other hand, if replenishment plans are not implemented, the aquifer and the wetland will be drained as a result of excessive extraction, and local ecological conditions will deteriorate. The payment vehicle was selected to be a percentage increase in the price of m^3 of water used by a household. The price could remain the same as today or increase by 50%, 25%, or 10%. Similarly to the farmer survey information on residents' current expenditure on m^3 of water was collected in order to be able to convert these percentage levels into monetary levels for each consumer.

A large number of unique aquifer management plans descriptions can be constructed from this number of attributes and levels. Statistical design methods

(Louviere et al., 2000) were used to structure the presentation of the levels of the four attributes in choice sets. Specifically, for both choice experiments an orthogonalization procedure was employed to recover only the main effects, consisting of 16 pair wise comparisons of profiles. These were randomly blocked to two different versions each with eight choice sets in each experiment.

Both experiments were implemented with face-to-face interviews. Each respondent was presented with eight choice sets, each containing two aquifer management plans and an "opt out" alternative by selecting neither of the profiles presented to them. The opt-out alternative was a "business as usual" scenario, defined as the situation that would prevail within the next decade if no interventions are implemented.

3.2. Survey administration and sampling

The choice experiment surveys were implemented in February and March 2008. The farmer survey was conducted in seven villages that use aquifer water for irrigation while the public survey was conducted in the city of Limassol. A sample of 160 farmers (i.e., almost 11% of the approximately 1500 farmers in the Akrotiri aquifer area) was envisaged for the farmer survey. In each village, the farming households were listed with the use of the Census data and 12-15% of these were randomly selected and contacted to arrange appointments for in-person interviews. Those that agreed to participate in the survey were subsequently interviewed the following day. The respondents were by and large those household members who were responsible for making farming decisions. The response rate was as high as 94% resulting in 150 completed questionnaires. Among them eight protestors were identified and excluded from the sample and the final sample consisted of 142 farmers.

The public choice experiment was conducted in Limassol. Currently, there are 31,648 households in the city of Limassol. A quota sample of 350 households (i.e. 1.1% of the population) was within the budget and time constraints of the project. The survey was administered to be representative of the Limassol population, and hence data were collected from four neighborhoods stratified according to the distance to the aquifer, income level and main residential water source. Streets in each neighborhood and buildings in each street were randomly selected. Face to face interviews were conducted with 300 heads of households, resulting in an 85.7% response rate. 14 households were identified as protesters of the aquifer management plan and removed from the sample resulting in a final sample of 286 respondents.

Both surveys begun by stating the aim of the overall project, which was to investigate farmers' and residents' perceptions on the implementation of a plan which proposes to use treated wastewater for replenishment of the Akrotiri aquifer. This was followed by the description of the survey (e.g., its duration, kind of questions that will be asked, that their answers will be treated in the strictest confidence and there are no right or wrong answers).

Following this, respondents were read a statement describing current water conditions in Cyprus in general and in the Akrotiri aquifer/wetland area in particular. They were reminded that there is an ever increasing scarcity of water quality and quantity in the Akrotiri area mainly due to the uncontrolled pumping, which will result in increasing salinity and eventual desertification of the fertile agricultural lands, as well as irreversible impacts on the ecology (i.e., habitats and biodiversity supported by) the wetland. Respondents were then explained that according to the EU WFD the government aims to provide long-term water security and safety for farmers, as well as to minimise ecological impacts of water shortages. One of the means through which this aim could be achieved was the implementation of the 'aquifer management plan', which would channel treated wastewater from Limassol and the nearby villages, into the aquifer in order to replenish its groundwater supplies. The respondents were then acquainted with the definition of treated wastewater, its potential uses, as well as its potential disadvantages.

Following this introduction, respondents were read the descriptions of the attributes valued used in the choice experiment and their levels. Respondents were then presented with the eight choice sets and were asked to state their preference in each choice set. Debriefing questions were asked to discriminate between protestors and those with a true zero value among those who selected the business as usual alternative in all choice sets. Comparison of the descriptive statistics of the farmer and Limassol residents' sample averages to their population statistics reveal that in terms of household size, age of the household head and income, the samples are representative of their respective populations (Census of Agriculture and Cyprus National Statistics, 2003)

3.3. Results of the choice experiments

The choice experiment was designed with the assumption that the observable utility function would follow a strictly additive form. The model was specified so that the probability of selecting a particular aquifer management plan is a function of plan attributes. The results of the Conditional Logit Model (CLM) for 1136 choices elicited from 142 farmers are reported in the second column of Table 2 and the CLM results of the 2288 choices elicited from 286 residents are reported in the third column of the same table.

[Insert Table 2 around here]

The overall fit of the farmer CLM, as measured by McFadden's ρ^2, is satisfactory by conventional standards used to describe probabilistic discrete choice models (Hensher et al., 2005). The results of the CLM reveal that all attributes included in the definition of the aquifer management plan are highly significant determinants of aquifer management plan choice. The positive coefficients on the quality, quantity and agricultural employment attributes indicate that farmers are more likely to choose alternatives that maintain the current conditions of those attributes. The coefficient on water price is negative as predicted by economic theory implying that farmers are more likely to choose aquifer management plans with lower water prices. The magnitudes of the coefficients on the binary attributes water quality and quantity indicate that amongst these, the most important determinant of farmers' choice is water quantity followed by water quality.

Overall, the CLM estimates reveal that there are significant economic benefits to be gained from the maintenance of water quantity and quality at their current levels through the replenishment of the aquifer with wastewater treated to a high quality. At the same time, the low number of protestors (approximately 6% of the sample) suggests that the plan to replenish the aquifer with treated wastewater is widely accepted by farmers. Nevertheless, it is worth noting that the surveys were implemented following one of the worst droughts experienced in the area in recent history. This could have biased farmers' attitudes in favor of aquifer replenishment with wastewater, even if under normal circumstances they would have regarded treated wastewater as a last resort to help tackle the water scarcity problem.

For the residential choice experiment, the fit of the CLM is satisfactory and the results of the model indicate that similarly to the farmer choice experiment all of the attributes are highly significant determinants of aquifer management plan choice. Residents are more likely to select alternatives that maintain current water quality. Residents also tend to select alternatives with higher employment in agriculture and those that maintain current ecological conditions in the area. The magnitude of the estimates indicates that among the binary attributes, water quality is the most important determinant of individual choice. The coefficient on the price attribute is significant and negative indicating that residents are more likely to choose those aquifer management plan alternatives which have lower water prices.

The implicit prices that farmers and residents assign to each one of these attributes can be calculated as the ratio of coefficient on each attribute to the coefficient on the monetary attribute, which represents the marginal rate of substitution between price and the plan attribute in question, or the marginal willingness to pay (WTP).

Table 3 reports the implicit prices, or marginal WTP values, for each of the aquifer management plan attributes for the farmer and residential choice experiments, estimated using the Wald procedure (Delta method) in NLOGIT 3.0.

[Insert Table 3 here]

The table reports that an average farmer is WTP CYP 0.014 per m^3 of water and CYP 0.028 per m^3 of water in order to maintain the current levels of water quality and quantity in the aquifer, respectively. Furthermore, farmers are WTP CYP 0.0002 per m^3 of water to for each job maintained in the agricultural sector. Residents are on the other hand WTP CYP 0.131 per m^3 to maintain current water quality, CYP 0.054 per m^3 to maintain current ecological conditions and CYP 0.0004 per m^3 to maintain an extra employment position in agriculture. When farmers' and residents' WTP for the common attributes are compared with a t-test, it is observed that farmers and residents do not have significantly different valuation of agricultural employment. This implies that the altruistic values of the non-farming respondents roughly correspond to the altruistic and use values of the farmers themselves. For water quality, on the other hand, residents are WTP significantly higher prices to ensure water quality in the aquifer is maintained at its current levels, revealing the importance of the ecological benefits the wetland generates.

Compensating surplus (CS) values are calculated for the aquifer management plan which proposes replenishment of the aquifer with sufficiently high quality and quantity of treated wastewater to ensure the current water quality and quantity and the resultant ecological conditions are sustained, and the highest possible number of farmers remain employed (1455). Under this scenario, the CS of an average farmer is 0.333 CYP per m^3 of water, and the CS of an average resident in the Limassol area is 0.767 CYP per m^3 of water.

4. Cost benefit analysis and long run discounting

4.1. Theory of long run discounting

The realization that actions taken today can have long term consequences, presents a new challenge to decision makers in assessing the desirability of policies and projects, a challenge summarized as the goal of `sustainable development'. In the classical CBA the economic efficiency of policies and projects with costs and benefits that accrue in the long term is often assessed with the net present value (NPV) rule. The use of the classical NPV rule is however problematic especially when constant socially efficient discount rates are used for all times, thereby eliminating the influence of the welfare of future generations on the outcome. The deleterious effects of exponential discounting ensure that projects that benefit generations in the far distant future at the cost of those in the present are less likely to be seen as efficient, even if the benefits are substantial in future value terms. In other words, from the perspective of social choice, the present yields a dictatorship over the future, undermining intergenerational equity, an important component of sustainable development concept.

Recently, many EU Member States (e.g., France and the UK) have decided to use smaller rates to discount costs and benefits occurring in the distant future. This tends to favor the distant future compared to projects with benefits occurring in the shorter term. Moreover, recent economic literature proposes the use of a discount rate which declines with time, according to some predetermined trajectory (Groom et al, 2005). In comparison with the use of a constant discount rate, using a declining discount rate (DDR) raises the weight attached to the welfare of future generations.

In a deterministic world, the social time preference rate δ, is commonly characterized by the Ramsey equation (Ramsey, 1928):

$$\delta = \rho + \mu g. \tag{1}$$

This reflects two characteristics of individual preferences which provide a rationale for discounting the future: 1) the pure rate of time preference, ρ, and 2) the aversion to consumption fluctuations, reflected by μ. ρ is commonly known as the utility discount rate and reflects the preference of individuals for present utility over the future utility. When utility is the *numeraire*, ρ is the appropriate Social Discount Rate (SDR).

It is often overlooked that the Ramsey rule provides a complete description of the term structure of the interest/discount rates. More specifically, when the growth rate of the economy is certain and constant, the discount rate should be independent of the time horizon. It is easy to generalize the Ramsey rule to risk-free economies with time-varying growth rates. In that case, we obtain that

$$\delta_t = \rho + \mu g_t, \qquad (2)$$

where δ_t is the discount rate associated to time *t*, and where g_t is the annualized growth rate of the economy over period [*0,t*]. It implies that the discount rates should be decreasing with maturity in an economy with decreasing expectations, i.e., when the growth rate is expected to go down in the future.

It is of course very difficult to predict the distant future. This is why all recent attempts to justify a decreasing time structure of discount rates relied on introducing uncertainty into the picture. Once the context shifts to one of uncertainty, the case for DDRs becomes compelling. In the relevant theoretical studies of Gollier (2002a, 2002b) and Weitzman (2007), it is mainly persistence combined with uncertainty that leads to decline in discount rates over time. The existence of persistence is an empirical question and it is the degree of persistence in the series that determines the rate of decline of the certainly equivalent discount rate. Newell et al (2003), Groom et al. (2007), and Hepburn et al. (2008) show how empirical work can measure the relevant parameters of a sequence of an aggregate DDR required for the case study. A convenient proxy for the uncertainty in social discount rates is arguably the uncertainty in the risk-free interest rate on government bonds[1]. In an important paper on discounting under uncertainty, Newell et al (2003) make effective use of this proxy. Employing a simple autoregressive model of US interest rates, they derive a working definition and estimation of the certainty-equivalent forward rate for use in CBA. Their analysis confirms that the CER is largely declining through time, and that the rate of decline is a function of the uncertainty and also the persistence in past interest rates. Recently Groom et al. (2007), Hepburn et al. (2008), and Gollier et al (2008), have argued that such a simple autoregressive model is unlikely to be sufficiently versatile to reproduce the empirical regularities typically found long-run in interest rate series. They emphasize the importance of econometric model selection for both the estimation of the schedule of empirical discount rates appropriate for CBA in many countries.

4.2. Application of the long run cost-benefit analysis to the case study

The CS values calculated in section 3 reveal that the maintenance of the current water quality and quantity, as well as employment and ecological conditions in the Akrotiri wetland area are likely to generate significant (direct and indirect) use and non-use benefits. Majority of the direct use values are expected to be appropriated by the local

[1] This is not to suggest that the appropriate social discount rate is the risk-free market interest rate. On the contrary, there are several reasons why the social discount rate should be based on the social rate of time preference, with an adjustment for the shadow price of capital. See for example Lind (1982).

farmers who will be the sole users of the aquifer water once the recharge takes place. Hence, the total use value of the recharge is given by the product of the CS of the average farmer for the aquifer management plan (CYP 0.333) and the total treated wastewater that will be used to replenish the aquifer, which is expected to be 6,000,000m^3 per year. The annual direct use values are therefore estimated at CYP 1,998,000. Non use and indirect use values are enjoyed by the general public. Since data collection focused on the city of Limassol, the non-use and indirect use benefits are calculated as the product of the CS of the average member of the public for the aquifer management plan, and the total consumption of water in Limassol, which was estimated at 12,743,735 m^3 per year. The annual indirect use and non-use values are therefore calculated to be CYP 9,774,445 per year. The total economic value of the aquifer management plan is therefore calculated to amount to CYP 11,772,444.75 per year.

The cost of the aquifer recharge plan includes the fixed costs of infrastructure development needed to recharge the aquifer with the treated wastewater, as well as the variable costs of treatment of wastewater. The fixed costs of infrastructure development are estimated at CYP 100,000 and include the pipes and the construction of borehiles for the recharge. Capital cost and operation cost (including transportation of wastewater) are estimated at CYP 0.07 and CYP 0.05per m^3 of wastewater treated, respectively. For 6,000,000 m^3 of wastewater treated, variable costs amount to an overall cost of CYP 720,000 per annum (Aeoliki foundation, personal communication).

The next step is to use these cost and benefit figures to conduct a thorough long-run CBA to determine whether the implementation of the aquifer management plan is a Pareto improvement. The ecological and economic impacts of the proposed aquifer management plan are expected to reach far in to the future. According to our consultations with the hydrologists, ecologists and local water policy makers, if the aquifer management plan is implemented and sustained, the current ecological, water quality and quantity as well as employment conditions in the area can be maintained in the long run, extending to approximately 200 years. Our approach on the future net benefits is conservative since we assume that the cost of the recharge will not decrease due to technological change and that water consumption will remain constant. We also assume that the benefits to farmers and residents will remain constant over time. The classic NPV rule is applied and three constant discount rates (4, 5 and 6%) are used to calculate the NPV by using the average, upper and lower bound CS for farmers and residents. The results are reported in the second, third and fourth columns of Table 4.

[Insert Table 4 about here]

Due to the absence of long-run data on Cyprus discount rates, we use the optimal 'world' trajectory of the DDR estimated by Gollier et al (2008), to assess the long run economic viability of the aquifer management plan under consideration. Gollier et al estimated country-specific DDRs trajectories and then construct a weighted 'world' average DDR, based on the GDP of each country measured in Purchasing Power Parity (PPP) terms. Specifically, the weight for each country equals the ratio of its GDP over the sum of the GDP of all countries under consideration. The DDR estimated by Gollier et al. starts at 4.5% and declines sharply during the first decade. Then it declines gradually for the next 190 years until it reaches approximately 2% at year 200. Figure 1 illustrates the DDR trajectory used in this paper.

[Insert Figure 1 about here]

The NPVs for average, upper and lower bound CS values are estimated with the DRR and reported in the final column of Table 4. Under the DDR the average NPV is CYP 355,114,487 approximately 1.28 times the NPV under the lowest constant exponential discount rate of 4%. The NPV under DDR is approximately 1.6 times the NPV under the 5% constant discount rate while it is 1.9 times the NPV under the 6% discount rate. The NPVs for the lower and upper bound CS estimates follow the same pattern.

Overall the CBA results reveal that the aquifer management plan generates substantial economic benefits (i.e., use and nonuse values) resulting in positive NPV irrespectively of the discounting scheme implemented. The NPV under the DDR are however significantly higher. This illustrates the importance of using DDR for projects and policies which have impacts far into the future, and the significance of weighing the economic benefits that will be appropriated by the future generations. As illustrated in figures 2 to 4 below, the NPV under constant exponential discounting becomes noticeably flat after the first 60 years. NPV under the DDR net benefits come to a plateau after 180 years.

[Insert Figure 2 about here]
[Insert Figure 3 about here]
[Insert Figure 4 about here]

These findings are especially important in the context of the implementation of the WFD since the Directive promotes the notion of "sustainability" and the need to capture the entirety of the costs and benefits and the necessity to do thorough CBA of various measures and technologies to ensure the adoption of the most economically efficient instruments in different countries, under different circumstances, for different water resources.

5. Policy Implications and Conclusions

This paper demonstrated a comprehensive framework for assessment of the viability of an environmental management plan which has long-run economic and ecological impacts. The environmental management plan under consideration was an aquifer management plan, which proposes to replenish a depleting aquifer with treated wastewater. The case study was the Akrotiri aquifer in Cyprus, a water scarce region of the world. The framework was implemented in three stages.

First the main stakeholders that would bear the costs of and derive the benefits from this plan were identified through various qualitative methods (including focus group discussions and informal interviews with the public, and consultations with experts and policy makers) as well as through thorough literature reviews on aquifer management in water scarce regions in general and on Akrotiri aquifer in particular. The key stakeholder groups that benefit from the aquifer were identified to include local farmers and residents in the nearby city of Limassol. The former was found to derive use and option values from the aquifer as they depend on the quality and quantity of water for their livelihoods, whereas the latter was found to derive indirect use values through the consumption of locally produced vegetables, as well as non-use values from the ecological status of the local environment and from the employment in agricultural sector supported by the aquifer.

Second, two distinct choice experiments were implemented with these two stakeholder groups in order to capture the specific economic values that each one of these stakeholders derive from such a plan. In the farmer choice experiment the aquifer management plan was defined in terms of the quality and quantity of water in the aquifer and the number of farmers that can be employed in agricultural sector in the area. For the resident choice experiment, the aquifer management plan was defined in terms of water quality, agricultural employment and ecological conditions in the area. In both experiments the payment vehicle was an increase in the price of m^3 of water consumed by the farm/household. The results of the choice experiments reveal that on average farmers and residents are not opposed to an aquifer management plan which proposes to replenish the aquifer with treated wastewater. Both stakeholder groups exhibit significant compensating surplus values revealing that such a plan would generate both use (direct and indirect) and non-use values.

Third, the long run economic efficiency of implementing such a plan was assessed. To this end a cost benefit analysis was conducted and the estimated economic values (benefits) accrued by these two stakeholder groups were aggregated over their relevant populations, and added to capture the total economic value (i.e. total economic benefits) generated by this plan. The calculated total economic benefits were weighed against the total (fixed and variable) costs of implementing such a plan. Since this proposed plan is expected to have long run impacts on the local economy and ecology, the sustainability of the plan was tested by a long run cost benefit analysis, and the net present value of the plan was estimated using different discount rate schemes, namely constant and declining discount rates.

The net present value results reveal that the net benefit generated by the plan is positive and significant well into the future, regardless of the discount rate scheme used. Therefore implementation of this plan would be a welfare (or Pareto) improvement, which would not only increase economic benefits to all the stakeholders both in the short run and in the long run; but also help Cyprus in its endeavors to meet the EU WFD requirements by 2015.

The net present value results however reveal that the net benefit trajectory estimated with the declining discount rate is higher than those estimated with the constant discount rates. Moreover, the net benefits under the declining discount rate trajectory take thrice as long to come to a plateau. These findings have implications in terms of using declining discount rates for evaluating projects, policies or plans with long term impacts in order to ensure sustainable development goals are reached.

Overall this methodology is recommended for the assessment of any environmental plans which has long run economic and ecological impacts that would affect various stakeholders (including future generations). In particular this framework would be useful for the EU member states who are obligated to implement the WFD which explicitly calls for estimation of the total economic value; consideration of the costs and benefits and that accrue to different stakeholders and application of the thorough cost benefit analyses which takes sustainability into account.

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Tables and Figures

Table 1: Attributes and levels used in the two choice experiments

Attribute	Definition	Attribute levels
Farmer Choice Experiment		
Water quality	Quality of water in the aquifer	Current water quality vs. Lower water quality *
Water quantity	Quantity of water in the aquifer	Current water quantity vs. Lower water quantity
Agricultural employment	Number of farmers employed in the area	1200, 1275, 1380, 1455
Price	Percentage increase in the price per m^3 of water pumped from the aquifer by the farmer	Current price vs. 50% increase, 25% increase, 10% increase in price
Resident Choice Experiment		
Water quality	Quality of water in the aquifer	Current water quality vs. Lower water quality
Agricultural employment	Number of farmers employed in the area	1200, 1275, 1380, 1455
Ecological conditions	Ecological conditions in the area, including habitat health and biodiversity conservation	Current ecological conditions vs. Desertification and
Price	Percentage increase in the price per m^3 of water used by the household	Current prices vs. 50% increase, 25% increase, 10% increase in price

*Underlined levels depict the status quo situation

Table 2. Results of the CLM estimations of the farmer and resident choice experiments

	Farmer CE	Resident CE
Attributes	Coeff. (St. Err.)	
Water quality	0.23*** (0.06)	1.061*** (0.056)
Water quantity	0.47*** (0.06)	-
Agricultural employment	0.003*** (0.0004)	0.003*** (0.0003)
Ecological conditions	-	0.441*** (0.051)
Price of water per m^3	-16.73*** (1.58)	-8.098*** (0.797)
Log likelihood	-1039.91	-2182.625
ρ^2	0.138	0.137
No. of obs	1136	2288

Source: Akrotiri Aquifer Farmer Water Management and Resident Water Valuation Surveys, 2008; (*)10% significance level; (**)5% significance level; (***)1% significance level with two-tailed tests.

Table 3: Farmers' and residents' WTP for aquifer management plan attributes (in CYP/per m^3 of water/per household) (95% C.I. in parentheses)

Attribute	Farmer WTP	Resident WTP
Water Quality	0.014*** (0.01-0.018)	0.131*** (0.121-0.141)
Water quantity	0.028*** (0.024-0.032)	-
Ecological conditions	-	0.054*** (0.047-0.061)
Agricultural employment	0.0002*** (0.00017-0.00023)	0.0004*** (0.00036-0.00043)
Compensating surplus for the aquifer management plan which provides highest levels of all attributes	0.333 (0.2814-0.3847)	0.767 (0.692-0.828)

Table 4: Net present value (in CYP) for 200 year horizon and varying discount rates

	Constant 4%	Constant 5%	Constant 6%	Declining
Average CS	276,102,793.18	220,936,112.03	184,105,812.36	355,114,487.33
Lower bound CS	244,420,715.61	195,581,975.80	162,976,327.15	314,369,305.83
Upper bound CS	303,251,341.52	242,662,212.27	202,211,785.68	390,029,259.81

Figure 1: Trajectory of the Declining Discount Rate over 200 years

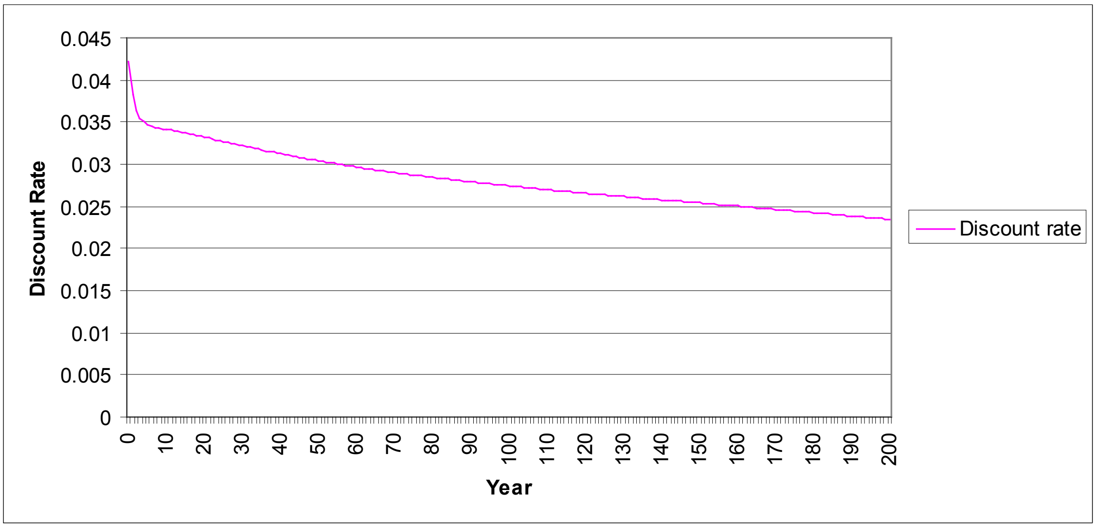

Figure 2: NPV for Average CS in the next 200 years

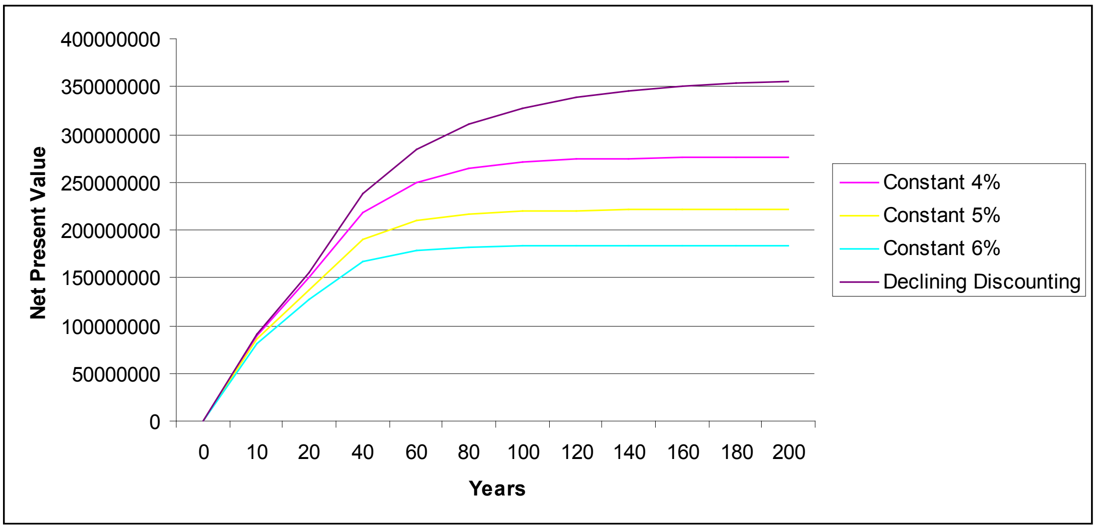

Figure 3: NPV for Lower Bound CS in the next 200 years

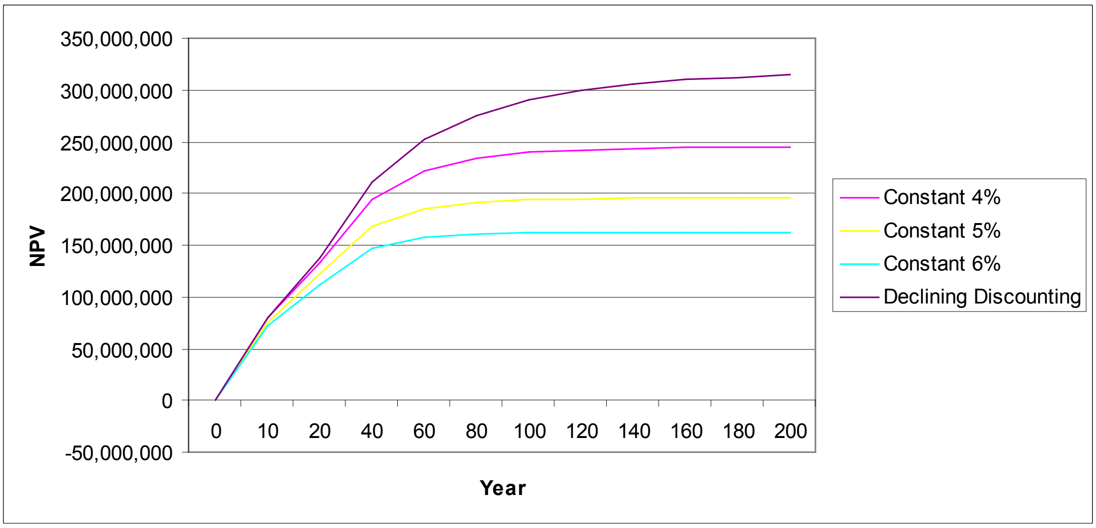

Figure 4: NPV for Upper Bound CS in the next 200 years