Science of the Total Environment 470–471 (2014) 26–33

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Application of the Multi-Attribute Value Theory for engaging stakeholders in groundwater protection in the Vosvozis catchment in Greece

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HIGHLIGHTS

- We use Multi-Attribute Value Theory (MAVT) to investigate stakeholder's preferences and beliefs in a deteriorating ecosystem.
- A modified MAVT application — two stage process was applied.
- We use MAVT method to design a sustainable groundwater management strategy.
- MAVT analysis led to an agreement based on the stakeholder's preferences.

ARTICLE INFO

Article history:
Received 9 June 2013
Received in revised form 9 August 2013
Accepted 3 September 2013
Available online 10 October 2013

Editor: Damia Barcelo

Keywords:
Groundwater management
MAVT
Multi-criteria
Public participation
Stakeholders

ABSTRACT

Multi-Attribute Value Theory (MAVT) was used to investigate stakeholders' preferences and beliefs in ameliorating a deteriorating ecosystem, i.e. Vosvozis River and Ismarida Lake in Northeastern Greece. Various monetary and environmental criteria were evaluated with scores and weights by different stakeholder groups and key individuals such as farmers, fishermen, entrepreneurs, residents and ecologists to elicit their preferences concerning alternative protection scenarios. The ultimate objective was to propose policy recommendations for a sustainable water resources management for the case study area. The analysis revealed an overwhelming agreement among stakeholders regarding the dire need for immediate actions in order to preserve and enhance Vosvozis ecosystem. With a two stage evaluation process, the MAVT analysis led to a high consensus among the stakeholders on the alternative that favors water recycling from the wastewater treatment plant combined with small dams for rainwater harvesting.

1. Introduction

Water resources management decisions are often complex, especially when there are conflicting opinions on how the water should be used in the area. In such cases, an experts' involvement could help in solving any disputes and reaching an agreement for the optimum social utility benefit. To this direction, several techniques have been used so far involving Multi-Criteria Decision Analysis (MCDA) (Goosen et al., 2007; Paneque Salgado et al., 2009; Straton et al., 2010). Initially, the focus was on providing optimization and modeling tools. Nowadays the emphasis is laid on tools not only addressed to assist decision making processes but also for negotiation purposes directly among stakeholders (Kodikara et al., 2010). Improved water planning is achieved by stakeholders' involvement for evaluating alternatives and most of the times conflicting water allocation scenarios (Bruen, 2008).

The MCDA is a field of operational research and a quantitative method for evaluating multiple and usually conflicting criteria when making a decision (Ryu et al., 2009). It is widely applied to problems of water management systems that serve multiple uses. In recent years with the consideration of an environmental and ecological component in water resources management, MCDA is one of the practical management tools for decision making (Ananda and Herath, 2009; Huang et al., 2011; Sorvari and Seppälä, 2010; Udías et al., 2012; Weng et al., 2010). MCDA assumes the formulation of all criteria related to the decision process in quantitative terms (Kiker et al., 2005). In general, several approaches have been proposed for MCDA (Lai et al., 2008). Among them is the Single Synthesizing Valuation Method, in which all criteria are aggregated into a single value. Multi-Attribute Value Theory (MAVT) is such a method. This method includes Multi-Attribute Utility

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http://dx.doi.org/10.1016/j.scitotenv.2013.09.008

Theory (MAUT) or Multi-Attribute Value Theory (MAVT). Other widely used methodologies are: Analytical Hierarchy Process (AHP) (Lai et al., 2008), Technique for Order Preference by Similarity of Ideal Solution (TOPSIS) (Behzadian et al., 2012) and Simple Multi-Attribute Rating Technique (SMART) (Mustajoki et al., 2005). Buede and Maxwell (1995) report from a comparison they have undertaken, that similar results were concluded from the application of AHP and MAVT.

The purpose of this study was to investigate stakeholders' preferences for ameliorating a deteriorating ecosystem, namely Vosvozis catchment area in Northeastern Greece. The MAVT method was used to elicit preferences from different stakeholder groups in order to propose policy conclusions towards a sustainable water resources management strategy.

2. Materials and methods

MAVT application involves different amelioration alternatives which are ranked by the stakeholder groups involved aiming at finding the "best" solution. Interviews from representatives of stakeholder groups help to reveal their preferences. The aim is to connect the value of alternative management options that represents the stakeholders' preference, taking into account all the criteria. The simplest and most used aggregation method in MAVT is the additive model (Belton and Steward, 2002; Hostmann et al., 2005):

$$V(\alpha) = \sum w_i v_i(a_i) \quad (1)$$

where:

$V(\alpha)$: the total value of the alternative α;
$v_i(\alpha_i)$: the simple attribute value function reflecting alternative α's performance on attribute i; and
w_i: the importance weight for each criterion assigned by the stakeholders.

One of the advantages of MAVT method is that it provides a structured approach to address the problem using both quantitative and qualitative data. The clarification of alternatives, objectives and attributes helps the user to understand the environmental problem and participate in its solution. Another advantage is that MAVT helps to conclude in accepted solutions and policy recommendations as the value function considers the user's preference. Furthermore, it can be used as a tool to facilitate the negotiations by shedding light into the advantages and disadvantages of the alternative policies and to bring stakeholders to an agreement. Finally, it is simple in application with no need to use sophisticated software. Sensitivity analysis is also applicable to test the robustness of the results. Participants weight each criterion regarding its contribution to the ultimate goal, such as sustainable and fair water allocation. The weights attributed by each stakeholder group are averaged. The performance assessment of each alternative strategy in the achievement of the ultimate goal is based on both the aggregation of the value of each criterion under each alternative scenario and its average weight. According to the decision analysis literature (Reichert et al., 2007) the general procedure adopted by decision analysis techniques can be described in nine steps shown in Fig. 1, starting from the "Establishment of the decision context" and ending with "Policy Conclusion".

Step 1 is a crucial step in which the articulation of the decision context and the definition of the problem are defined. In Step 2 the identification of objectives and attributes takes place. Objectives are the alternative scenarios that the stakeholders would like to be implemented while the attributes are measurable characteristics used to quantify the objectives. In Step 3 the identification and pre-selection of alternative scenarios are completed to conduct the analysis and simplify the analysis procedure. For the next step (number 4), once the alternative options have been selected as the most feasible approaches to solve the certain problems, the consequences of these options should be analyzed. In Step 5 the preferences of stakeholders are elicited. In order to quantify the preferences of stakeholders there are several quantification approaches that can be used, such as value or utility function approaches (Amanda and Heralth, 2003). The weights of each criterion are also elicited from the stakeholders. The results from Steps 4 and 5 are integrated in order to rank the alternative scenarios (Step 6). In Step 7 the results are assessed and evaluated. Sensitivity analysis (Step 8) is undertaken for testing the sensitivity of ranking the alternative scenarios in relation to parameters with expected variation within a certain range (Reichert et al., 2007). Finally, policy conclusions (Step 9) are recommended. This step is the outcome of the analysis of the applied methodology. These conclusions can be utilized by the decision makers for the establishment of a sustainable water resources strategy plan. However, whether these recommendations are adopted, it is a matter of political will.

This MAVT application is not a mere stakeholder involvement, as a typical legal requirement. It provides case study information on how to make this involvement efficient. An efficient involvement is essential in overcoming obstacles resulting from competitive uses for applying specific policies. This can be achieved only by strengthening the awareness among the stakeholders of the importance, the benefits and the costs of the proposed projects (OECD, 2001). Therefore the goal is not to just rank the alternative projects but also to safeguard the consensus of all (or as much as possible) stakeholders on the policy mutually acceptable. The methodological innovation of this study lies upon the double application of the method, which involves a second sorting and ranking of alternatives after the detailed presentation of the problem as depicted in the right panel of Fig. 1. Effectiveness of this intervention to locals was profoundly assessed by their consent (after the second phase of the procedure) although conflicting interests apply. If the first stage had been omitted it would have been difficult to access this intervention to the stakeholders. Furthermore, the stakeholder group had to bear in mind all the advantages and disadvantages of each alternative scenario from the point of view of all the other stakeholder groups. From the efficient discussion among the stakeholders, the initial ranking changed as they were requested to rank again the alternatives. This means that all the stakeholders tend to converge their preferences for a better integrated water management plan. Thus the methodology tends to become more an interactive tool rather than a strict decision making process.

3. Case study identity

3.1. Description

Vosvozis catchment area is located in Northeastern Greece in the region of Thrace (Fig. 2). The main urban center is the town of Komotini with the surrounding agglomerations which has a total population of 70,000 inhabitants. The area is a typical Mediterranean region with warm summers and mild winters. The main land uses are agriculture, cattle breeding, industry and urbanization. The total area covers 340 km^2 and it comprises two very important ecosystems Vosvozis River and Ismarida Lake. The lake and the surrounding wetland ecosystems belong to Natura 2000 network and should be protected by the Ramsar Convention of 1974 as well as from the Greek Ministry of Environment (1986, 1996). Vosvozis River originates from Rhodope mountain chain, which forms the Greek–Bulgarian borders. It has a total length of 40 km and mean annual discharge of 0.78 m^3/s. Vosvozis River provides both domestic and irrigation water for local communities, but it also supplies small local activities. Besides the direct abstractions from the river, domestic water supply is also provided by the Komotini well field. The origin of the water extracted from the aquifer in the Komotini well field is the nearby river, i.e., Vosvozis River, rain infiltrated directly into the aquifer, and lateral inflows from the northern mountains (Moutsopoulos et al., 2008).

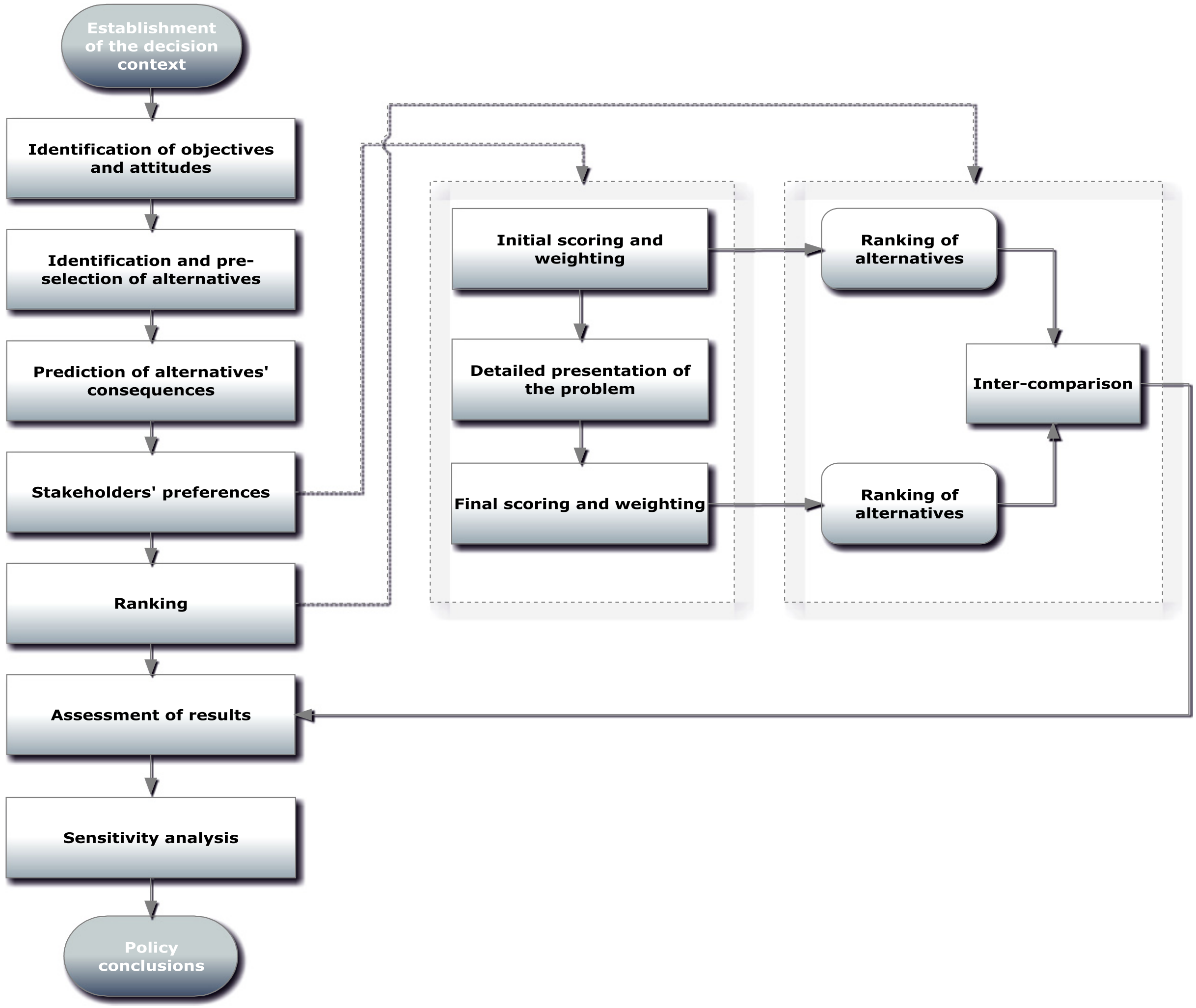

Fig. 1. Research approach flowchart.

Ismarida Lake is a shallow lake with mean depth of 1.5 m. In the past, flooding events were frequent so the local authorities tried to drain the wetland area by the construction of an artificial channel that connected Ismarida Lake with the sea. However, this did not have the desired effects, because in summer, the seawater enters the lake converting the originally freshwater to a brackish ecosystem. Currently Ismarida Lake is a freshwater ecosystem in the winter and in the summer it is a mixture of freshwater–saltwater ecosystem. Gemitzi and Stefanopoulos (2011) showed that there is a direct interaction between Ismarida Lake and the nearby groundwater, known as Neon Sidirochorion aquifer. Comparing satellite images of Ismarida Lake from 2003 to 2009, Gemitzi and Stefanopoulos (2011) showed that it had lost approximately 30% of its total area. The main reason for this is the overpumping during summertime for irrigation. Farmers actually pump the lake water that is brackish, thus causing salinization of agricultural lands with a subsequent loss of production. The climate and the plain terrain create favorable conditions for agriculture. Furthermore, the region has professional fishing activities. There is a fishing co-op founded in 1950 that formerly numbered over thirty members, but currently it has only six members. The total production is 15 to 20 t/y and the main captured species are crabs, carps (*Cyprinus carpio*), eels (*Anguilla Anguilla*) and gilt head breams (*Leuciscus cephalus*). There is limited industrial activity in the case study area. However, the industrial activities from the north catchment area as well as from Komotini's wastewater treatment plant deteriorate the quality of freshwater. The main environmental action organization in the case study area is the "Ecological Group of Rhodope" which is a non-profit organization founded in 1990. It is worth noting that the Management Body of Nestos River, Lakes Vistonida and Ismarida is the principal authority responsible for the management of this ecosystem (Management Body of the River Basin, 2013).

3.2. Stakeholders

At the beginning of this study, a stakeholder analysis was performed to identify the main groups with interests in water management in the case study area. This analysis identified different groups and key individuals, such as farmers, fishermen, entrepreneurs, residents and ecologists. Individuals and representatives of these groups were contacted to inform them about the research targets. In order to elicit stakeholders' preferences, a stakeholder meeting was held in the City Hall of Neon Sidirochorion where twelve representatives from all stakeholder groups participated in this meeting. The synthesis of the stakeholder meeting is presented as follows:

- *Farmers*. The case study area is an agricultural area, and the majority of the people is composed of farmers cultivating mainly cotton. The president of the local union and two management committee members have participated.
- *Fishermen*. In the past decades, there was intense fishing activity in Ismarida Lake, but the community of fishermen has recently decreased significantly due to the decreased fish populations, forcing fishermen to move to other fishing areas or to change its economic activities. The president of the local union and three management committee members have participated.

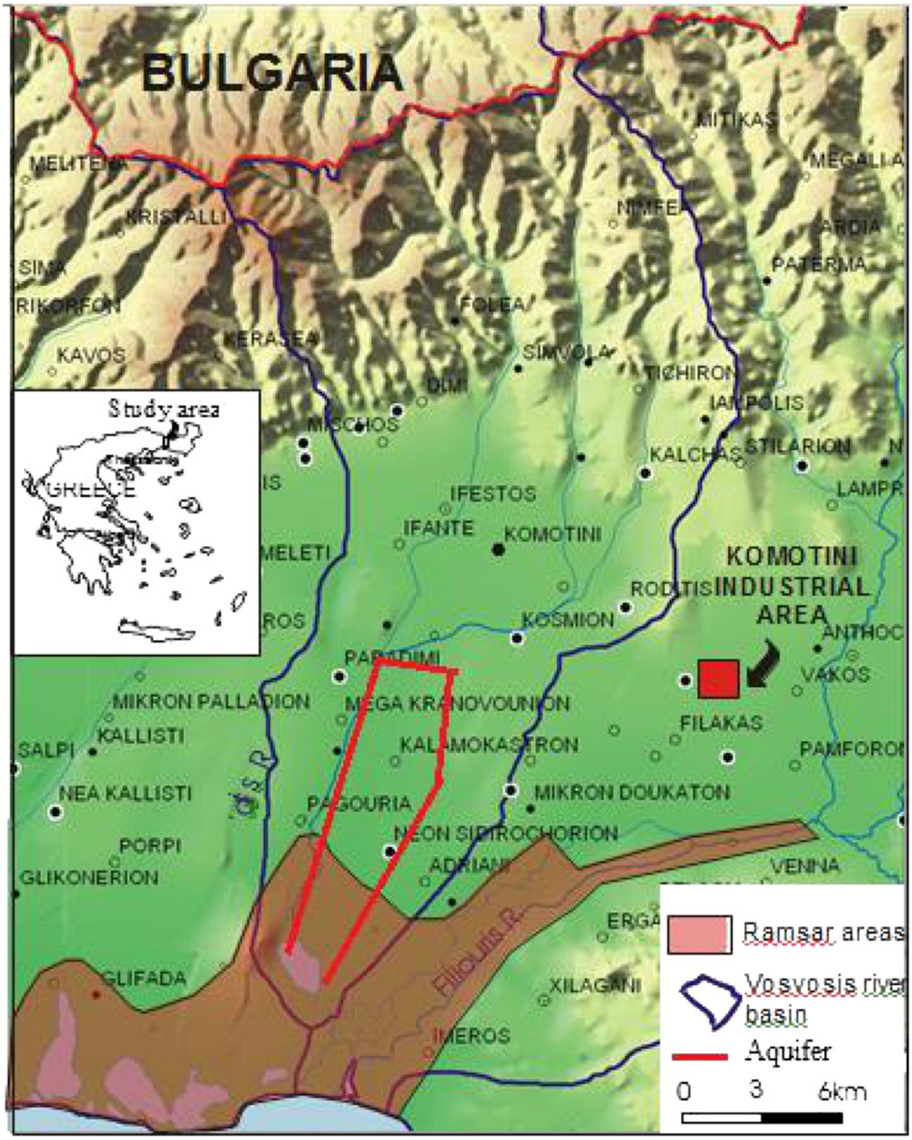

Fig. 2. Vosvozis catchment area.

- *Industry*. There are several agribusinesses for cotton, meat and milk. There are also some technical companies for infrastructure such as gravel and cement. A representative from the cotton agribusiness industry and a representative from the infrastructure sector participated.
- *Ecologists*. In the case study area there are several small environmental groups. The main authority responsible for the management of the lake is the Management Body of Delta Nestos, Lakes Vistonida and Ismarida. One member from the Management Body has participated.
- *Urban residents*. The main urban center is the town of Komotini and its surrounding agglomerations. A city council member (alderman) and the local city council elected representative have participated.

3.3. Alternatives for improving the situation

Initially, the decision context was defined i.e., the need of a sustainable water management strategy. The next stage was the identification of objectives and attributes as well as the pre-selection of alternatives and the likely consequences of these alternatives. From previously conducted surveys in the case study area, five alternative options were identified as more appropriate. These alternatives were selected among many suggestions that have been proposed by local decision makers and experts in public forums. Some of them have been also put forward to receive EU funds for implementation in different calls. These are the only ones, which were based on previous published works. The data provided for the five alternatives are based on the authors' calculations and relevant studies (2012 prices). The alternatives are discussed as follows:

1. Efficient irrigation and irrigation reduction (EI–IR).
   One feasible option is to improve irrigation techniques (European Commission, 2012). In particular, changing the sprinkler irrigation to dripping irrigation, which is commonly used by the farmers in the area, would result in significant savings in groundwater and increase crop production as well. Furthermore, the irrigation water reduction could be achieved by changing the cultivated crops to less water demanding. The proposed scenario was to cultivate wheat over 30% of the total cultivated area and the rest cultivated with other crops. Concerning the case study area, the total cost of this option was estimated at 3.9 million € with a saving of about 7.8 million m^3/yr of groundwater.
2. Efficient household water consumption by using specific saving devices (EHWC).

There are practical solutions for efficient household consumption. These solutions are associated with specific devices for household taps like flushers and bath saving taps. It has been estimated that 17,000 m^3/yr groundwater could be saved and a total cost of this scenario is 43,000 € for the residents of the study area.

3. Water recycling from the wastewater treatment and small dams for rainwater harvesting (WR–SD).
Another feasible solution is to install infiltration basins for Komotini's wastewater treatment plant and achieve groundwater recharge. The cost of this solution is 240,000 € including the costs of purchasing the land and could save approximately 3,285,000 m^3/yr groundwater. An additional measure under this option is the construction of rainwater harvesting dams. Four rainwater harvesting dams could be installed, amid the agglomerations, saving 1,600,000 m^3/yr groundwater with a construction cost of 320,000 € in total. The total costs for this alternative was 560,000 € resulting in 4,885,000 m^3/yr groundwater savings.
4. Construction of a dam in Ismarida Lake (DI).
This involves the construction of a lock gate that will close the artificial canal which connects Ismarida Lake with the sea. This intervention will prevent the direct intrusion of seawater in Ismarida Lake, and then to the aquifer. Although the dam would not affect the groundwater capacity, it would improve the groundwater quality by lowering groundwater electrical conductivity values. The construction would cost 10,000 € and would have a positive effect on a farmers' annual family income.
5. Business as usual scenario (BAS).
Finally, business as usual was offered, as an option which means that no action is taken in the catchment area and consequently the situation would remain as it is now. Regarding groundwater, both capacity and quality will remain in the same dire situation or even worsen. By selecting business as usual, the stakeholders are going to pay nothing.
The evaluation matrix was developed for the five scenarios based on estimates and expert opinions. Table 1 shows a summary of the five options regarding the quantity of groundwater saves, the costs for each option, the realization times, the measure efficiencies and the income changes. The selected attributes reflect better the diversification of the alternatives. The values presented in Table 1 were calculated by the authors and associates with experience of the case study area. It is important to stress that these are presented in a comprehensive way to non-technical audience using also qualitative scales of measure. Measure efficiency indicates the qualitative effectiveness of the measure in terms of water savings and improvement in water quality.

3.4. Modified MAVT application — two stage process

The modified MAVT process was applied by two-stage interviews/workshops. In the first phase of the meeting, the stakeholders were requested to fill in the initial scores based on their existing knowledge of the problem and no information was given. They were also requested to assign weights for each criterion to reflect their relative importance on a scale from 0 to 100 (corresponding to "no importance" and "high importance", respectively) based on their own knowledge about the problems in the case study area. Each group argued on the alternative scenarios from their point of view. Therefore, it was inevitable that conflicting interests would emerge during the discussion. The stakeholders' preferences were identified by this first stage ranking of the alternative scenarios. Thereafter, a comprehensive and detailed presentation of the problem, highlighting the advantages and disadvantages of each alternative scenario was given. All stakeholders were informed in-depth about the problems in the case study area. Specifically, they were informed about the quality and capacity of the groundwater, and the associated costs, realization times, the measure efficiencies and the incomes that accrue from each alternative scenario. A constructive conversation between the representatives of the stakeholders' groups was achieved. Then, the scores and weights were requested for a second time. In this evaluation, the stakeholder groups had to bear in mind all the positive and negative consequences of each alternative scenario which emerged from the previous discussion. Like during the first phase, each member was requested to assess the value of each criterion for each alternative scenario using the same scoring scale.

Table 1
Alternative options (scenarios) and attributes in Vosvozi's case study.

Options	Attributes				
	Groundwater save (m^3/yr)	Cost (€)	Realization time (yr)	Measure efficiency	Income
Alternative 1	7,800,000	3,900,000	2	Excellent	(+/−)
Alternative 2	17,000	43,000	2	Poor	(+)
Alternative 3	4,885,000	560,000	3	Very good	(+/−)
Alternative 4	0	10,000	1	Good	(+)
Alternative 5	0	0	0	Very poor	(−)

4. Results and discussion

Initially, the ranking of the alternatives was presented, followed by a sensitivity analysis. Finally, policy recommendations for sustainable water resources management were proposed.

4.1. Ranking of the alternative options

Table 2 displays the initial weights that were derived from the stakeholders' responses. In addition, it displays the final assessment for each stakeholder group after the information session. The detailed calculations are presented in Appendix A.

Based on Table 2 and the procedure described in the Materials and Methods section, the rankings of Fig. 3 were calculated. Fig. 3a displays the rankings of the alternative options as proposed by each stakeholder. The best option among all the alternatives was the "Water Recycling" from the wastewater treatment plant of Komotini and Small Dams for rainwater harvesting (WR–SD). In particular, three groups (farmers, fishermen and urban) ranked it as the first possible option, while the Dam in Ismarida Lake (DI) came in second place. The third option was the "Efficient Irrigation" and "Irrigation Reduction" (IR–EI). The fourth option was the "Efficient Household Water Consumption" by using specific saving devices (EHWC) and "Business As Usual" (BAS) was ranked as last option. A remarkable observation is that the option 'business as usual' was ranked as the last option by all the groups which means that all the stakeholders were aware of the problem in their area and they wanted to take action in order to mitigate the problems in the case study area. Moreover it is worth noting that the fishermen and farmers ranked the options in exactly the same order which may be explained by the fact that fishermen also own agricultural land. Fig. 3b shows the ranking of the alternative options in the second process after the extensive discussion. The first option remained the WR–SD but this option was also chosen by all the groups except for the industry group. The second option was IR–EI where all groups seemed to agree entirely. Four groups ranked DI as the third possible option, while the industry group regarded this option as the most effective. EHWC and BAS were unanimously ranked in fourth and fifth places respectively.

The change of stakeholders' preferences through the two stages of the stakeholder meeting is worth remarking. Regarding farmers, WR–SD remained their first option, but they changed their preference with regard to the second and third alternative scenarios. Actually, they might have changed their options because they were informed about the irrigation systems and the water demands for cultivation. This change indicates that after illustrating and providing arguments, the efficiency improvement comes before new investments for recycling and

Table 2
Initial and final attribute weights related to stakeholder's responds.

Attribute weights	Farmers		Fishermen		Ecologists		Industry		Urban	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Groundwater save	0.19	0.22	0.20	0.25	0.29	0.25	0.24	0.25	0.20	0.21
Cost	0.17	0.16	0.18	0.19	0.17	0.20	0.20	0.24	0.18	0.18
Income	0.21	0.21	0.19	0.18	0.11	0.15	0.17	0.04	0.22	0.20
Measure efficiency	0.22	0.18	0.20	0.24	0.29	0.25	0.27	0.28	0.20	0.21
Realization time	0.21	0.22	0.23	0.14	0.14	0.15	0.12	0.19	0.19	0.19

water harvesting projects. We regard this as a positive influence of the information session. Therefore, they preferred IR–EI than the DI. Although they believed that EHWC is a remarkable alternative, they ranked it in fourth place, while BAS was constantly in the last place. Fishermen's group has exactly the same preferences as the farmer's group. The similar change fishermen had with farmers is also a sign of the positive influence of the information session in favor of improving efficiency. It is not surprising that fishermen and farmers behaved the same way in terms of ranking. There is an interrelation of activities by those groups with members of the same family doing one or the other activity, or even both of them. On the other hand, for the ecologists, BAS remained in fifth place in the second phase, while they changed all the other preferences. Before receiving more detailed information they believed that the best solution was IR–EI, in second place was EHWC, third was WR–SD and fourth was DI. After the information and the conversation with all groups, they ranked the WR–SD as the best alternative followed by IR–EI, DI and EHWC. Although someone would expect ecologists to be constant in their ranking, this was not the case for this application. It is the efficient supervised (by experts) discussion and first time in-depth interaction with other stakeholders that has led the most related with the environmental and ecological problems of the area to comprehend and revise their initial understanding. Regarding the industry group, they did not change their first preference DI and their last one BAS. Initially they ranked in second place WR–SD, third was EHWC and fourth was IR–EI while in the second phase they ranked IR–EI in second place, third was WR–SD and in fourth place was EHWC. The industry group, although insisted in their first selection, they upgraded the efficiency irrigation by two ranks (to second). An explanation for retaining the option with major works first can be explained by the fact that the technical firm involved foresees benefits from constructing new projects in their region. Urban group ranked WR–SD in first place followed by IR–EI, DI, EHWC and BAS. It is very interesting that it's the only group that did not change their preferences and they did not change anything in the final ranking. This indicates that urban residents have an overview of all agricultural, ecological, and aquacultural activities and in fact they interact with those involved in all those activities due to the not densely populated area.

4.2. Sensitivity analysis

For more in-depth analysis of the results, it is very important to investigate whether the results are robust given the uncertainty in the input information. When more than one person is interviewed for a stakeholder group, large uncertainty is reported when scores vary too much. In groups where scores do not vary too much, a low uncertainty is reported. To this end, a sensitivity analysis was conducted. In this analysis there are two pieces of input information: the attribute values and the ranking. Regarding the attribute for the initial and final values there was a great variation especially in the industry group as depicted in Figs. B1 to B5 (Appendix B). This observation may be explained by the fact that each representative comes from different industry sectors. On the other hand ecologists have no uncertainty since scores come from one person.

For the majority of the stakeholder groups, the uncertainty can result in changes only in adjacent ranks (e.g. change between ranks 1 and 2 or between ranks 4 and 5, Figs. 4 and 5). There is not immense substantial change in the rankings. In other words, the most preferable alternative does not become the least preferable alternative and vice versa.

Also, it is important that the ranking of the alternatives is more vigorous for some stakeholder groups than others, such as farmers and fishermen.

4.3. Policy recommendations for sustainable water resources management

Sustainable water management and groundwater protection framework is provided by the EU WFD 60/2000 and Directive 2006/118/EC. Greece has enforced WFD with 3199/2003 law. It is obvious and legally supported that all stakeholders should be involved when regulations and policies are being implemented (OECD, 2001). Nevertheless, Greece has not adopted river basin management plants yet, which means failure to fulfill obligations of 60/2000 EU directive. Greece was convicted at the European Court for this failure (Official Journal of the European Union, 2011). Furthermore, Greece failed to submit any data concerning the threshold values for the quality of groundwater according to the European groundwater Directive 2006/118/EU

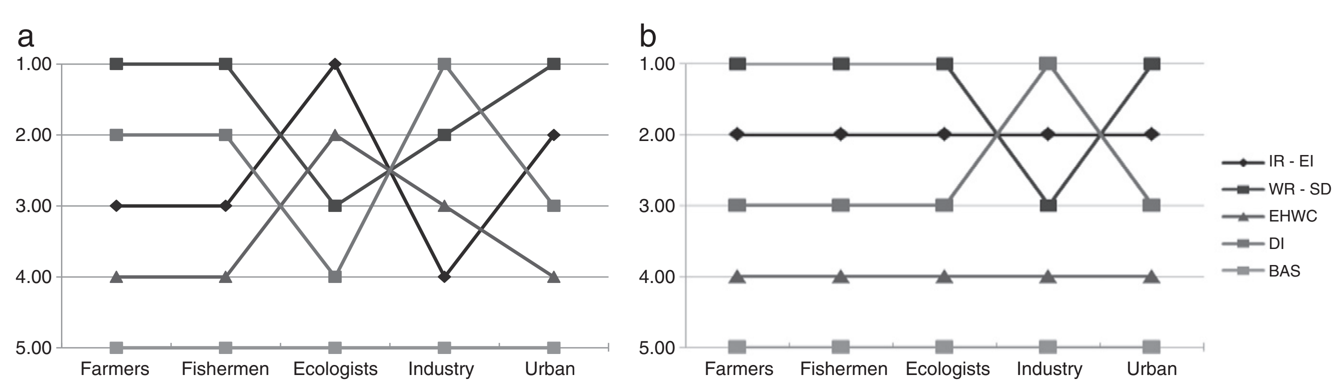

Fig. 3. Initial (a) and final (b) ranking related to stakeholders' responds.

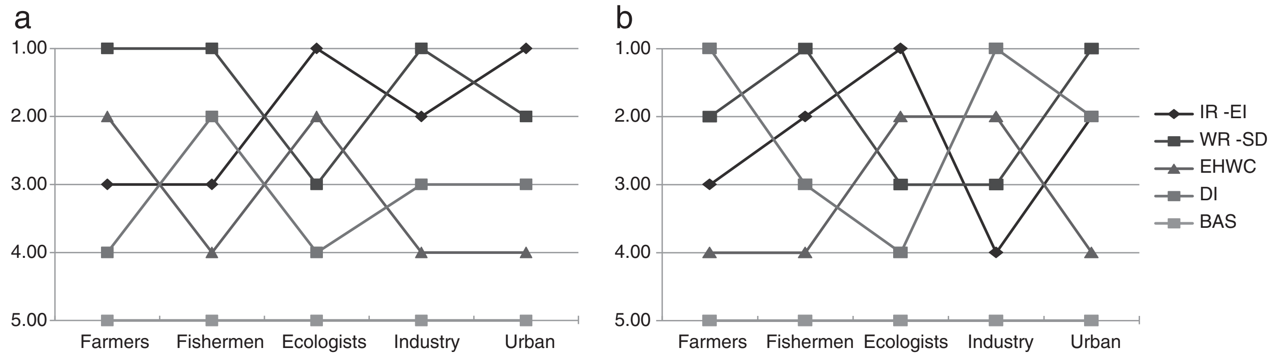

Fig. 4. Sensitivity analysis concerning the uncertainty in the estimation of initial ranking (a) lower boundary corresponds to more balanced comparisons and (b) upper boundary corresponds to more extreme comparisons.

(European Commission, 2010). In the case study area, several alternatives for the region have been proposed in order to plan a sustainable water resources strategy. From the application of MAVT two of them were accepted from the great majority of the stakeholders (first or second alternatives in this study): water recycling from the wastewater treatment plant and small dams for rainwater harvesting as well as the efficient irrigation and irrigation reduction. These alternatives remain also in favor of the stakeholders after the sensitivity analysis. For a sustainable management plant, the local authorities should adopt both of these but essential environmental terms should accompany them. First of all the installation of discharge gauges in each borehole should be enforced to ensure that no over-pumping takes place. This will help to both monitor the quantity of groundwater and to make data available to scientists for surface and groundwater modeling of water reserves. In addition, although the groundwater recharge with treated wastewaters will increase water availability, limitations according to irrigated areas and pumped quantities should be enforced to safeguard that a surplus of water for groundwater recharge is available. Furthermore, previous works in the study area (Gemitzi and Stefanopoulos, 2011; Gemitzi et al., 2013) have shown that the lock gate that will act like a dam in Ismarida Lake is the most effective measure for the improvement of groundwater quality, as it will prevent saltwater intrusion to the aquifer system. These recommendations will lead to the improvement of the water resources quality and quantity based on scientific analysis, measurement of physical parameters and application of numerical models presented in previous works (Gemitzi, 2012; Gemitzi and Stefanopoulos, 2011; Gemitzi et al., 2013). The proposed policy interventions can be fully assessed/measured after the implementation and after considerable time has elapsed.

5. Conclusion

MAVT method is a very useful tool to rank and support the choice of various alternatives in complex environmental problems. In its simple additive form, it is relatively easy to be explained and also to be used. One of the main advantages of the method is that it can be used for policy processes. Furthermore, it can be used to evaluate the sustainability of a policy taking into account the three dimensions of sustainability, the social, the environmental and the economic one. In this study the MAVT method is used to design a sustainable groundwater management strategy, based on the beliefs and preferences of different stakeholders' groups in the Vosvozis catchment area. Usually, a large amount of data is required for a better description of the problem and the attributes. MAVT can administrate both qualitative and quantitative data. If quantitative data were not available, the impacts could be estimated by experts' judgment. Experts were also needed to set the value function and the structure of the problem. Several software programs for MAVT method were applied to help the interaction and the reliability with the users. Most of these programs can also support sensitivity analysis in order to test the robustness of scores and weights. Some constructive conclusions can be drawn by this study. First of all, there was an overwhelming agreement among participants (different stakeholders) regarding the dire need for immediate action in order to preserve and enhance both Vosvozis and Ismarida Lake ecosystems. Secondly, despite the fact that there was a range of alternative scenarios and attributes, MAVT analysis facilitated an agreement among the stakeholders with converging opinions. Thirdly, the MAVT analysis, scientific support, evidence and guidance played a crucial role in eliciting stakeholders' preferences. Fourthly, the two-stage rankings are a methodological improvement in the MAVT analysis for decision support. In this study,

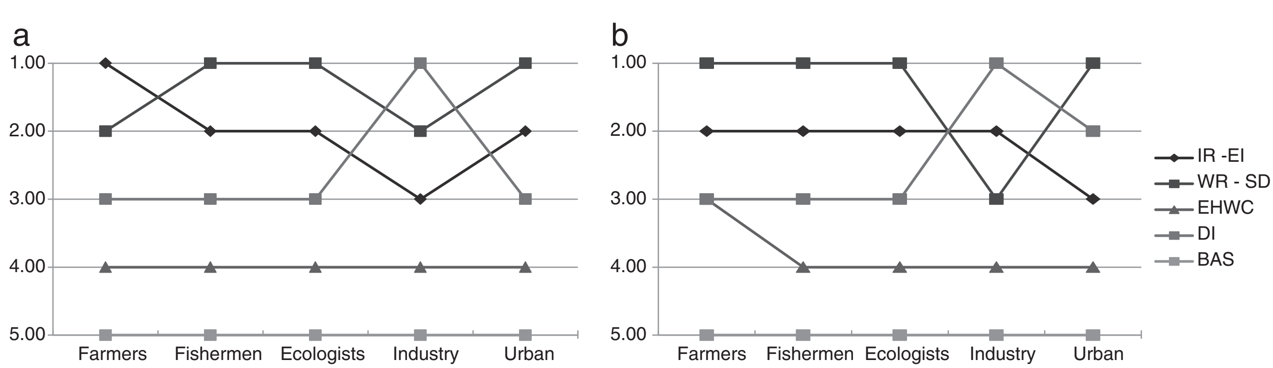

Fig. 5. Sensitivity analysis concerning the uncertainty in the estimation of final ranking (a) lower boundary corresponds to more balanced comparisons and (b) upper boundary corresponds to more extreme comparisons.

the first phase of evaluation of stakeholders' preferences was based on their previous knowledge of the environmental problems in the case study area. Stakeholders were informed about the current condition of Vosvozis River and Ismarida Lake ecosystems and the possible restoration alternatives and then were asked to reassign weights and scores for the attributes. A new ranking was synthesized based on the improved understanding of the stakeholders. Finally, this case study shows that the conflicting interests of different stakeholder groups were not necessarily obstacle to achieve sustainable water resources management objectives.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.scitotenv.2013.09.008.

Acknowledgments

This work is developed within the frames of the European FP7 project GENESIS (Groundwater and Dependent Ecosystems: New Scientific and Technical Basis for Assessing Climate Change and Land-use Impacts on Groundwater Systems). Grant agreement no.: 226536 — GENESIS CP-IP.

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