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INTEGRATING HUMANS IN ECOSYSTEM MANAGEMENT USING MULTI-CRITERIA DECISION MAKING[1]

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ABSTRACT: The Ecosystem Management (EM) process belongs to the category of Multi-Criteria Decision Making (MCDM) problems. It requires appropriate decision support systems (DSS) where "all interested people" would be involved in the decision making process. Environmental values critical to EM, such as the biological diversity, health, productivity and sustainability, have to be studied, and play an important role in modeling the ecosystem functions; human values and preferences also influence decision making. Public participation in decision and policy making is one of the elements that differentiate EM from the traditional methods of management. Here, a methodology is presented on how to quantify human preferences in EM decision making. The case study of the National Park of River Nestos Delta and Lakes Vistonida and Ismarida in Greece, presented as an application of this methodology, shows that the direct involvement of the public, the quantification of its preferences and the decision maker's attitude provide a strong tool to the EM decision making process. Public preferences have been given certain weights and three MCDM methods, namely, the Expected Utility Method, Compromise Programming and the Analytic Hierarchy Process, have been used to select alternative management solutions that lead to the best configuration of the ecosystem and are also socially acceptable.
(KEY TERMS: negotiation group; expected utility method; analytic hierarchy process; compromise programming; ecosystem management; sustainable development.)

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INTRODUCTION AND BACKGROUND

Ecosystem management (EM), as adopted mainly in the USA, is an approach to the management of land and natural resources that integrates the human, the biological, and the geomorphologic/landscape dimensions. EM can be applied in any region considered an ecosystem. From this point of view, EM can be applied within a watershed, which defines the boundaries of the ecosystem, or in an ecoregion limited to a part of a watershed or comprising a number of watersheds (Pavlikakis and Tsihrintzis, 2000a). To achieve solutions that are socially acceptable and lead to the sustainable development of a region, EM methodology follows certain steps, which include, among others: investigation of issues, participation of the public, scientific research, planning, application, monitoring, and evaluation.

EM differs from the traditional methods of management (Pavlikakis and Tsihrintzis, 1999a, 2000b) in that: (1) it aims at long term sustainability; (2) it has an objective of protecting the ecological integrity instead of the welfare of a single species; (3) it considers humans as ecosystem components and integrates their activities along with the conservation of nature; (4) it includes political, economic, and social values (this means that there is a need for awareness and education of the public and collaboration between landowners, agencies, scientists, engineers and managers, and population involved in the procedure); (5) the EM approach, in contrast to the traditional one, is sensitive to the particularities and the needs of the public (development of a region and the quality of life of the inhabitants are also EM objectives); and (6) EM has a scientific basis and uses reliable modern tools such as models and Geographic Information Systems (GIS).

According to Rauscher (1999), EM remains a philosophical problem that has to be formulated. He proposes three levels of organization in the EM decision

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process: (1) the decision environment; (2) the decision making organization and processes; and (3) the EM Decision Support System (DSS). Since the ecosystems operate in several spatial and temporal scales, EM has a multi-scale concept. Therefore, management decisions affecting ecosystems must be concurrently examined in these multiple space and time scales. The boundaries of the ecosystem are defined operationally by decision makers (DMs), managers, or scientists (Pavlikakis and Tsihrintzis, 2000a). The consideration of humans and their activities as a part of the ecosystem, and the involvement of the public in decision making, are also factors that influence the EM process. This reality requires a public reassessment of both the goals for natural resource management within a sustainable way of thinking, and the position of the society on public welfare and development.

The EM process belongs to the category of Multi-Criteria Decision Making (MCDM) problems. The development of the appropriate decision support is a need in EM to define and achieve management goals. In an EM-DSS, "all interested people" would be involved in the decision making process, which uses high quality scientific information and modern software tools. Biological diversity, health, productivity, and sustainability are critical environmental values that have to be studied; they play an important role in modeling the ecosystem functions. Human values and preferences also influence decision making. Questions arise, such as, what is the boundary of the region that will be managed, what are the main issues to be studied, how can these issues be quantified, how can public goals and preferences be taken into account, and is it possible to quantify these preferences. Managers need some answers to these questions before deciding to propose alternative solutions or make final decisions.

A major question concerns the existence of the appropriate mathematical formulation and procedure to integrate the public opinion in the decision making process. Is that possible? What are the constraints? This paper tries to answer these questions, the main objective being the integration of humans in a holistic EM process with the use of MCDM methods. Emphasis is given to: (1) the human factor, which has been incorporated in the management of the ecosystems (human behavior is usually mirrored in the natural condition of the ecosystem, but in this study, human preferences, goals, conflicts, etc., have been taken into account in the EM process); (2) the delineation of a general procedure in the management of natural resources, which has an interdisciplinary character; (3) the meaning of the collaboration between all involved people; and (4) the use of a holistic approach and MCDM methods.

This study presents the following approach to EM decision making problems (Figure 1). (1) All "interested people" form a negotiation group, which is invited to define and weigh the issues to be studied and the criteria needed for the alternative solutions that will be proposed. This can be accomplished through a workshop where all aspects will be discussed. In some cases, electronic discussions and voting with the aid of the appropriate software facilitates this process. (2) The results of the negotiation group process, historic data about the region, field measurements, and use of GIS and other scientific methods, provide the DMs with the appropriate information to define the final criteria and their weights and propose alternative solutions. (3) An MCDM method is used to select the best configuration for the ecosystem. (4) The negotiation group can judge the final ranking of the alternatives. (5) The DMs are free to decide about the alternative to be followed in the EM process.

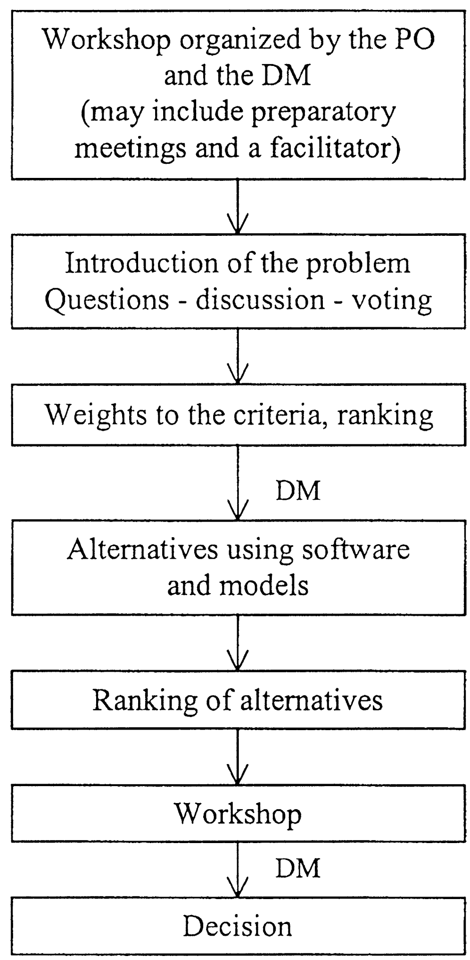

Figure 1. The Procedure of Decision Making.

The National Park of River Nestos Delta and Lakes Vistonida and Ismarida is a sensitive ecosystem of great significance in northeastern Greece. Progress is being made in the management of the region, but there are many conflicts and the procedure seems to be far from an EM one (Pavlikakis and Tsihrintzis, 2000b). This ecosystem has been used herein to apply the described methodology. Hypothetical weights of the public's preferences and values of different criteria, such as gross agricultural income, use of fertilizers and pesticides, water sufficiency, and development of the region have been used in three MCDM methods – namely, the Expected Utility Method (EUM), Compromise Programming (CP), and the Analytic Hierarchy Process (AHP). The theoretical results showed how the direct involvement of the public, the quantification of its preferences, and the DM's attitude influence the selection of alternative management solutions that are also socially acceptable.

THE PUBLIC INVOLVEMENT IN EM

Humans are part of the ecosystem and their activities are integrated along with the conservation of nature. The public's role in EM enters in three levels: (1) human behavior influences ecosystem function and, for this reason, it must be taken into account in the management plan; (2) public involvement in the policy process is needed to overcome conflicts and to achieve socially acceptable solutions; (3) public participation, which takes place in working groups and activities in the field, is a basic element in EM methodology (Pavlikakis and Tsihrintzis, 1999a, 2000b). The success of an EM program is directly connected to the collaboration between all interested people in the region. The role of training and education through schools, universities and organizations is important to that success. The mass media, national and local governmental agencies, and private organizations must be involved to increase public awareness and knowledge (Pavlikakis and Tsihrintzis, 1999b). U.S. legislation, such as the National Environmental Policy Act (1969), the Coastal Zone Management Act (1972), and the National Forest Management Act (1976) allows for citizen involvement into the policy making process through comments and public hearings (Steelman and Ascher, 1997).

During the last decade, public participation has been increased through advisory committees and detailed referenda (Steelman and Ascher, 1997; Steelman, 1999; Steelman and Maguire, 1999), although the problem of how direct public participation and citizen involvement can be expressed in the management plan remains unsolved. Steelman and Ascher (1997) identify four types of public involvement: (1) standard representative policy making, (2) referenda, (3) nonbinding direct involvement, and (4) binding direct policy making by nongovernmental representatives. They present two examples of public involvement in the decision making process concerning timber management practices. The first example concerns the Monongahela National Forest planning process in West Virginia, where a nonbinding direct involvement failed to describe how public preferences would be measured and weighted in the decision. The second, Maine's clear cutting referendum, defined explicitly the public's role in the decision making process. The method that was followed in the Monongahela National Forest included letters, phone calls, and face-to-face communication in a six-month period. The main problems identified were: (1) the decision rules were unclear; (2) there were complaints from the timber industry that all the participants were considered as equivalent, so the opinion of the specialists was given less weight; and (3) the public comments spanned from simple letters to technical notes. Six working meetings with open participation followed, and finally a round table discussion took place where the participating stakeholders accepted a consensual decision. In Maine's clear cutting case, a referendum was written and circulated by the members of the Green Party and signed by 58,000 voters. This referendum helped in clearing decision rules and illustrated the advantages of direct voting.

It can be seen that it is difficult to quantify public opinion and preferences to achieve a decision that satisfies all interested parties. Q-Methodology, suggested by Steelman and Maguire (1999), is an alternative method for investigating and estimating public preferences and interests. It is a technique for studying human subjectivity and can contribute to a better problem identification and definition, and an effective selection, implementation, and evaluation of different policies. Q-Methodology is concerned with patterns of subjective perspectives across individuals and is quite representative and democratic, but the problem of quantifying the preferences still remains. The methodology of the negotiation group in combination with MCDMs, presented in the following paragraphs, is an attempt to overcome this problem.

METHODS

The Negotiation Group

The complexity, the various interest groups involved, and the interdisciplinary character of EM classify it as a complex technical policy and social problem. Such problems include a technical and a policy component (DeTombe, 1999), and should be handled by groups of people. Several roles can be distinguished in complex problems, such as the problem owner (PO), the DM, and the participants. The PO is the one who is obliged by himself, or by the task he has, to solve the problem. Problem owners may be state or local authorities, or a private organization. The PO entrusts the DM to handle the problem and find a solution. The DM may be a public agency, a university, a private company, or an individual. The participants form the negotiation group, which includes all "interested people" and stakeholders, such as local authorities, public agencies, scientists and specialists, managers, farmers and land users, ecological or other nongovernmental organizations, special interest group members, and the public at large. The role of the negotiation group is to support the DM in selecting the alternative management solution, which is acceptable by the majority, respects the interests and expectations of the people living in the region, and leads to the protection and/or the improvement of the ecosystem functioning.

The negotiation group is invited by the DM to define and weigh the issues to be studied and the criteria needed for the alternative solutions that will be proposed. This can be done through a workshop organized by the PO and guided by the DM or his/her representative, or a facilitator who collaborates with the DM. Information about the region and its problems can be sent to the participants a few weeks before the workshop. DeTombe (1999) describes the preparation of such a workshop and the support that can be given to it to meet its objectives. The results of the workshop are very important for the DM because they include the human desires and aims when managing a region and help to avoid conflicts. During the workshop: (1) the problem is introduced by the DM or his/her representative; (2) the participants are introduced; (3) a small number of questions are answered to formulate the problem and generate the issues to be studied; (4) answers are read; (5) verbal comments are made; (6) voting takes place; and (7) voting is evaluated.

Suppose G1, G2, G3, G4, and G5 are the interested groups participating into the negotiation group. The DM presents the problem, its historical data, and the current situation. Then the participants answer some questions, such as: (a) What is the main problem in using the land in the study area? (b) Who are the other interested people? (c) Are you satisfied with the development of the area? (d) Are there conflicting interests? (e) What kind of solution do you suggest? The invited participants are representatives of various groups with different interests and backgrounds. For this reason, the questions must be general and limited to a small number, and they should aim at formulating the problem and generating a discussion that leads to the issues to be studied. The time limits of the workshop are also a factor that confines the number of questions. After reading the answers and a brief discussion, the issues I1, I2, I3, I4, and I5 to be studied are introduced. The groups then vote for ranking the issues regarding their importance. An easy way to rank the issues is to give them marks that correspond to their order (e.g., among the five issues, the first preference takes 5 points, the second 4, the third 3, the fourth 2 and the last 1). A hypothetical result of the voting is shown in Table 1.

TABLE 1. Results of the Negotiation Group's Voting.

	Mark				
Group	**5**	**4**	**3**	**2**	**1**
G1	I1	I2	I3	I4	I5
G2	I2	I1	I4	I3	I5
G3	I2	I3	I5	I4	I1
G4	I4	I1	I2	I3	I5
G5	I3	I2	I1	I5	I4

If all the groups are considered as equivalent, the total points of an issue will determine its rank. Thus, for the given issues the rank is I2, I1, I3, I4, and I5. In fact, the interested groups may not be equivalent, as some of them are specialists or already have management projects in the region, and present an exceptional activity. In this case, a more precise method must be used for ranking the issues and giving the group's preferences the appropriate weight. Prato and Hajkowicz (1999) propose simple or more complicated methods of weighing preferences. The AHP (Saaty, 1980), which is described later in this paper, can be used for this purpose. The estimation of the importance of a group is done by the DM, which introduces some subjectivity in the procedure, depending upon the DM's experience and other factors. To reduce subjectivity, it is proposed that the DM is a few-member team of very experienced experts and not a single person. Research on the local population could also be helpful to recognize the interest groups, so they can be invited to participate in the negotiation group. The ranking of the groups by the DM is an additional step, which does not conflict with the methodology of AHP, as the issues and possibly the alternatives are judged by the participants in the workshop. Assuming that the importance of the groups, in our case, is G2 > G1 > G3 > G4 > G5, the AHP gives the results shown in

Table 2. The scale used here is 1 to 5 following the number of issues. Prato and Hajkowisz (1999) indicate that there is no substantive reason for using the scale 1 to 9 proposed by Saaty (1980). The ranking obtained is I2, I1, I3, I4, and I5.

TABLE 2. Weights Expressing the Negotiation Group's Preferences.

Issues	I1	I2	I3	I4	I5
Weights	0.240	0.293	0.191	0.178	0.098

A sensitivity analysis was performed to see how sensitive the issue ranking results are on group importance (which is a DM's judgment). The computations were repeated considering all possible group importance ranking (a total of 120 permutations). The results showed that issue I2 ranked always first, I3 and I4 interchanged position in 30 percent of the cases, I1 and I3 interchanged position in 20 percent of the cases, and I5 ranked always in the last position. These changes in position were only observed when the first or the second group became fourth or fifth, which shows that the results are quite stable regarding the DM's judgment.

Multi-Criteria Decision Making Methods

The results of the negotiation group process, historic data about the region, field measurements, and use of GIS and other scientific methods (Tsihrintzis *et al.,* 1996) provide the DM with appropriate information to define the final criteria and propose alternative solutions.

The issues correspond to measurable criteria. For example, the quality of drinking water can be expressed by the quantity of pesticides used in agricultural activities, the quality of aquatic systems by the quantity of nitrogen and phosphorus in runoff and soil erosion, and the development by the value of the agricultural or industrial production. In the literature one can find ways of aiding decision making with a set of alternatives (Miettinen and Salminen, 1999). In any case, which of the alternatives is ranked as the best depends upon the weights and the DM's ability.

The DM can judge the different alternatives by using several methods that include:

1. **The Expected Utility Method** (Prato and Hajkowisz, 1999). The following optimization problem must be solved:

$$\text{Maximize } U(z)$$

$$\text{Subject to: } z = f(x) + e,\ x \geq 0 \qquad (1)$$

where $U(z)$ is defined as the utility function; z is an n-dimensional vector of normalized criteria; x is an m-dimensional vector corresponding to m alternatives and representing variables such as the acreage, the agricultural income, the quantity of fertilizers and pesticides used, etc. The function $f(x)$ is a deterministic component and e represents a random component, which implies that the values of the criteria depend upon random variation such as market prices, weather, and natural condition, etc. The value of $U(z)$ gives the expected utility of the criteria. The alternative with the maximum expected utility is ranked as the best. The utility function proposed by Prato and Hajkowisz (1999), is:

$$U(z) = \sum_i w_i z_i^{1/2} \qquad (2)$$

where w_i is the weight of the ith criterion and z_i is the mean value of the ith normalized criterion, $\sum_i w_i = 1$ and $w_i \geq 0$ for all i.

This function is less restrictive than a linear one and implies that the decision is risk neutral. The interactions among the ecosystem components and the complexity of the ecosystem issues require a less restrictive concave utility function, so changes in the criteria will cause small changes in its values (Prato and Hajkowisz, 1999). Normalization of the criteria is done to overcome incommensurability. That is, all the criteria must be measured in the same units. In this study the summation normalization was used, where the value of each criterion is divided by the absolute value of the sum of the values of all the criteria. When the variables are measured in different units, their simple summation will cause biases towards the objectives with a larger magnitude. There are different normalization techniques, such as percentage normalization, Euclidean normalization, summation normalization, and zero one normalization (Tamiz *et al.,* 1998).

2. **Compromise Programming**. Given a set of alternatives, the best among them has the minimum metric $Lp(A)$ that gives the least distance of a value from an ideal one (Srinivasa Raju and Pillai, 1999). The problem to be solved is now formulated as:

$$\text{Minimize } Lp(A) = \left[\sum_i w_i^p \left| \frac{x_i^* - x_i}{M_i - m_i} \right|^p \right]^{1/p} \qquad (3)$$

where $Lp(A)$ is the metric for the alternative A, x_i is the value of the alternative A for the criterion i, M_i and m_i are the maximum and the minimum values of the criterion i, x_i^* is the ideal value of the criterion i, and p is the parameter reflecting the DM's attitude. Attitude here implies experience, capability, subjectivity, and impartiality in judgment. The higher the value of p, the more experienced and capable and more objective is the DM. The difference $M_i - m_i$ stands as the normalization constant. The alternative with the minimum value for Lp is considered as the best.

3. **The Analytic Hierarchy Process.** AHP is a tool in multi-criteria decision making with which the DM's or others' preferences can be formally incorporated in the solutions. Two important components of AHP are (Schmoldt and Peterson, 1997): (1) the problem is structured into a hierarchy, which consists of goals and subordinate features of the problem, such as objectives, scenarios, events, interested people, and alternatives. These features are arranged into different levels of hierarchy. The alternatives, which are the final choices in the problem solution, are placed at the lowest level. (2) Pairwise comparisons are made between the elements at each level, according to preference, importance, or possibility of the elements considered.

As it is already seen, the DM's preference and ability weighs the relative importance of the groups participating in the negotiation group. The application of AHP in the second stage of the decision making process, after the negotiation group, incorporates and uses the weights that have resulted to define the relative importance of the criteria. The goal "select the alternative" is at the top of the hierarchy. The criteria, such as agricultural income, quantity of fertilizers expressed by the quantity of nitrogen and phosphorus in runoff, quantity of pesticides in surface water, water sufficiency, and development of the region, are placed at the second level. The alternatives to be considered appear at the lowest level. The scale 1 to N, where N is the number of alternatives, is used for comparison. The relative importance of the alternatives regarding the different criteria is determined by ranking them according to the importance each issue has in each alternative. For example, if issue I1 is favored by Alternative A2, is second for A3, third for A4 and fourth for A1, then the rank of the alternatives is A2, A3, A4, and A1 for issue I1. This procedure can be followed by the DM, but to increase objectivity, a new workshop is proposed to take place to make the final decision, or, alternatively, the negotiation group can judge the final ranking of the alternatives. The decision may lead to new legislation or follow the already existing one. In any case, the DM hears all the opinions and makes the final decision.

THE CASE STUDY

The National Park of River Nestos Delta and Lakes Vistonida and Ismarida is situated in northeastern Greece. In the same area, in addition to the three main water bodies, there are also two smaller lakes, six lagoons, the torrents Kossynthos, Kompsatos, Travos, Filiris, and Vosvozis and other smaller riparian streams.

The area has high biological significance, because there are a large number of habitats of great interest (breeding places for rare aquatic birds, resting places for migrating species), 307 species of birds (among them 34 endangered and strictly protected rapacious species), rare vegetation, forests, and many species of mammals, reptiles, and insects. The ecosystem contains wetlands of international interest protected by the Ramsar Convention of 1971, by the Bern Convention, and by the European Community's Directives and is considered by legislation a protected area (Greek Ministry of the Environment, 1986). It is also included in the network Natura 2000 of the European Union concerning the regions of special environmental interest (Dafis *et al.,* 1997).

The region is characterized by a nearly flat topography and within it there exists one town, 81 villages, and two cities (capitals of prefectures). The population of the major area is about 190,000 people. Inside the park area live 44,783 people, of which 17,147 are economically active. The main occupation of people living in the region is agriculture and livestock, but there are also some fisheries and small industries. Tables 3 and 4 summarize information about population and cultivated land (Greek Ministry of the Environment, 1996). It can be seen that a significant part of the agricultural income results from dynamic cultivation of cotton, corn, and vegetables. This means economic risk, use of large quantities of fertilizers and pesticides (Table 5), and overdrawing of water.

The Greek Ministry of the Environment hired a consulting firm in May 1996 to develop a study and a plan for the management of the ecosystem, to protect and restore it. The developed study has many weaknesses and the proposed procedure seems to be far from an EM one. Progress is being made in the management of the region, but there are many conflicts (Pavlikakis and Tsihrintzis, 2000b).

The stresses on the ecosystem are excessive pumping of ground water for irrigation, increase of water demanding cultivation such as cotton and corn, decline of water quality, transformation of forests to

TABLE 3. Demographic Information About River Nestos Delta and Lakes Vistonida and Ismarida (Greek Ministry of the Environment, 1996) (Total Area = 146,680 ha; Cultivated Land = 73,330 ha; Urban Land = 4,780 ha; and Surface Water = 16,070 ha).

Area	Population	Economically Active Population (EAP)	Primary Sector (agriculture, livestock fishing, etc.) (percent of EAP)	Unemployment (percent of EAP)
River Nestos Delta	20,035	4,731	58.40	3.86
Lake Vistonida	12,862	7,489	61.40	4.47
Lake Ismarida	11,886	4,927	71.20	4.05
Total	44,783	17,147		

TABLE 4. Agricultural Production and Income in River Nestos and Lakes Vistonida and Ismarida National Park.

Area	Cultivated Land (ha)	Gross Value of the Agricultural Production (EUR/ha) or $/ha)	Dynamic Cultivation					
			Cotton		Corn		Vegetables	
			Cultivated Area (ha)	Income Percent	Cultivated Area (ha)	Income Percent	Cultivated Area (ha)	Income Percent
River Nestos Delta	38,930	2,208	5,120	13.8	13,500	24.4	3,220	36.6
Lake Vistonida	16,780	1,961	5,490	38.1	3,560	15.4	510	12.6
Lake Ismarida	17,620	1,422	8,420	73.4	290	0.0	240	7.7
Total	73,330	1,953*	19,030		17,350		3,970	

*Average.

TABLE 5. Use of Fertilizers and Pesticides and Estimated Loadings in River Nestos Delta and Lakes Vistonida and Ismarida National Park.

Area	Use of Fertilizers Nitrogen-Phosphorus (mt/year)	Use of Pesticides (mt/year)	Nitrogen-Phosphorus in Runoff (mt/year)	Pesticides in Runoff (mt/year)
River Nestos Delta	9,267	240	466	2.88
Lake Vistonida	4,009	103	201	1.23
Lake Ismarida	5,041	110	251	1.31
Total	18,317	453	918	5.42

cultivated lands, construction of hydroelectric dams, destruction of habitats, and building on the coast without a plan. The need for irrigation water and the use of fertilizers and pesticides influence the water quality. Tourism in the region is low. The poor infrastructure and activities (such as uncontrolled hunting) and the lack of well planned, environmentally friendly, tourist activities provoke additional stresses on the ecosystem and do not contribute to the development of the region and to additional income for the local population.

To overcome the difficulties and form a management plan that assures the protection of the ecosystem, but also the development of the region and the welfare of the local population, it is suggested that the methodology described earlier be followed. First, a management organization is formed. The DM can be a person or a group of persons who have been charged with the management plan by the organization. The negotiation group may consist of: (1) representatives of private landowners, farmers, and fishermen, such as the local agricultural associations; (2) scientists and specialists from universities and technical companies; (3) ecological or other nongovernmental organizations; (4) representatives of state and local authorities, such as the Ministry of the Environment, the prefecture, and the municipalities; and (5) representatives of industry owners and other groups, such as hunters, etc. It is hypothesized that these special interest groups correspond to the groups G1, G2, G3, G4 and G5, respectively, with the relative importance G2 > G1 > G3 > G4 > G5. After the presentation, discussion and voting the issues I1, I2, I3, I4, and I5 to be studied may be respectively: (1) agricultural income; (2) quality of aquatic systems; (3) quality of drinking water; (4) sufficiency in water quantity; and (5) economic development of the area. The AHP, as described previously, gives the weights that correspond to these issues (Table 2).

The DM analyzes the results of the negotiation group process and the historic data about the region, and then defines the final criteria and proposes alternative solutions. The use of GIS (Tsihrintzis *et al.,* 1996) and other scientific methods also provides the DMs with the appropriate information. In the present case, the measurable criteria that correspond to the issues mentioned above are the following:

1. I1: Agricultural Income/Criterion C1. Value of the agricultural production.
2. I2: Quality of Aquatic Systems/Criterion C2. Quantity of nitrogen and phosphorus in runoff.
3. I3: Quality of Drinking Water/Criterion C3. Quantity of pesticides in surface water.
4. I4: Sufficiency in Water Quantity/Criterion C4. Good, average, and insufficient.
5. I5: Economic Development of the Area/Criterion-C5. High rate, average, and insufficient.

For the first three criteria, real values have been used (Greek Ministry of the Environment, 1996), while for Criteria C4 and C5, an estimation scale 3-2-1 stands for good or high, average, and insufficient, respectively.

The proposed alternative management solutions, based on the values of the different criteria, are the following:

1. **Alternative A1.** The condition remains unchanged, trying to control the water use and protect the wetlands. The water sufficiency is considered at an average level, but the development of the region is very low. This is the current condition in the region.

2. **Alternative A2.** The use of fertilizers and pesticides is reduced by 10 percent. This causes a decrease in the agricultural income by 1 percent, but other development activities, such as eco-tourism, may make up for the loss.

3. **Alternative A3.** The use of fertilizers and pesticides is reduced by 10 percent, but alternative solutions, such as a shift to less water demanding crops, a variety of cultivated plants, and the development of eco-tourism, provoke an increase in the agricultural income by 3 percent (estimated national inflation 2 percent), improvement of water quality and quantity, and a high rate of development.

4. **Alternative A4.** There is a reduction of fertilizers by 5 percent, the quantity of pesticides used remains unchanged while alternative cultivation and activities result in significant increase in the agricultural income by 5 percent and a high rate of development.

The payoff matrix for the alternatives shown in Table 6 is obtained from Tables 4 and 5 and the alternatives mentioned above.

Three methods have been used for ranking the alternatives. The EUM using Equation (2), the CP using Equation (3) for three values of the parameter p ($p = 1$, $p = 2$, $p = 100$), and the AHP. In the EUM, the summation normalization has been used for normalizing the different criteria. Table 7 shows the parameters required for the calculation of Lp metric for Alternative A1 and Figure 2 presents the AHP applied. The results of ranking the alternatives are shown in Table 8. It can be seen that Alternative A3 is favored by most methods and Alternative A1, which describes the current condition, is placed in the last position.

The different MCDMs can also be judged and ranked (Srinivasa Raju and Pillai, 1999). The selection of the appropriate MCDM constitutes by itself a multi-objective problem. Criteria, such as consistency, confidence of the results, strength of the solution, and other factors can be used in a new AHP. The consistency of the results is given by the consistency ratio (Taha, 1997). This ratio compares the ranks obtained with each method. In this case study, the value of this ratio was less than 0.1 for all the methods, so the results can be considered as satisfactory and the methods equivalent. The confidence of the results is evaluated by the number of times each alternative occupies the same rank. The strength of the solution is based on the number of times the best alternative is in the first place. From this point of view the methods used here are equivalent. Another factor, which

TABLE 6. Payoff Matrix of the Alternatives.

Alternative	Gross Value of the Agricultural Production (EUR/ha or $/ha)	Nitrogen Phosphorus in Runoff (mt/year)	Pesticides in Runoff (mt/year)	Water Sufficiency	Development of the Region
A1	1,953	918	5.42	2	1
A2	1,934	826	4.88	2	2
A3	2,012	826	4.88	3	3
A4	2,061	872	5.42	2	3

TABLE 7. Parameters Required for Calculation of Lp Metric for the Alternative A1.

		Gross Value of the Agricultural Production (EUR/ha or $/ha)	Nitrogen-Phosphorus in Runoff (mt/year)	Pesticides in Runoff (mt/year)	Water Sufficiency	Development of the Region
Maximum Value	M_i	2,061	918	5.42	3	3
Minimum Value	m_i	1,934	826	4.88	1	1
Ideal Value	x_i^*	2,061	826	4.88	3	3
Difference	M_i - m_i	127	92	0.54	2	2
Value for the Alternative A1	x_i	1,953	918	5.42	2	1
Weight	w_i	0.240	0.293	0.191	0.178	0.098

permits the comparison of the different methods, is the spearman rank correlation coefficient, R (Gibbons, 1971; Srinivasa Raju and Pillai, 1999). It is defined as:

$$R = 1 - \frac{6\sum_{i}^{N}\left(U_i - V_i\right)^2}{N\left(N^2 - 1\right)} \quad (4)$$

where *Ui* and *Vi* are the ranks of the alternative *i* for two methods, *i* = 1,2,…,N; and N is the number of the alternatives. R takes values between 0.0 and 1.0. The closer the R value is to 1.0, the more comparable are the results of the two methods.

The results of the ranking from Table 8 were used in Equation (4) to compute the correlation coefficient R between all three methods (Table 9). It can be seen that R varies between 0.80 and 1.00, so the results of all methods are comparable. The agreement of the results by the three methods shows the importance of the contribution of public opinion to the DM's judgment, since the final decision is based on public opinion about the most important issues concerning the ecosystem, as expressed by the appropriate weights.

DISCUSSION AND CONCLUSIONS

The participation of the public in the decision making process is a main element of the EM methodology. The direct input in policy formation aims at achieving solutions that are socially acceptable, economically feasible, and ecologically sustainable. The increase in public input over the last decades resulted in confusion over its purpose and intent. The quantification of the public's preferences is a way to overcome the differences, which have emerged by the numerous methods of public involvement. It is obvious how the human preferences, as they are expressed by the appropriate weights, can influence the selection of a management plan. The DM's abilities and experience also play an important role in decision making. It is proposed that the DM is a few member team of very experienced experts and not a person to avoid subjectivity, as the ranking depends upon the DM's ability and experience. The parameter p in CP (Equation 3) was chosen to show the DM's low (for p = 1 and p = 2) or high (for p = 100) experience, capability, subjectivity and impartiality. Theoretically, the DM's high experience stands for p = ∞, but this value cannot be managed in calculations, so any high value can be chosen for p. There were values of p checked from 0.1

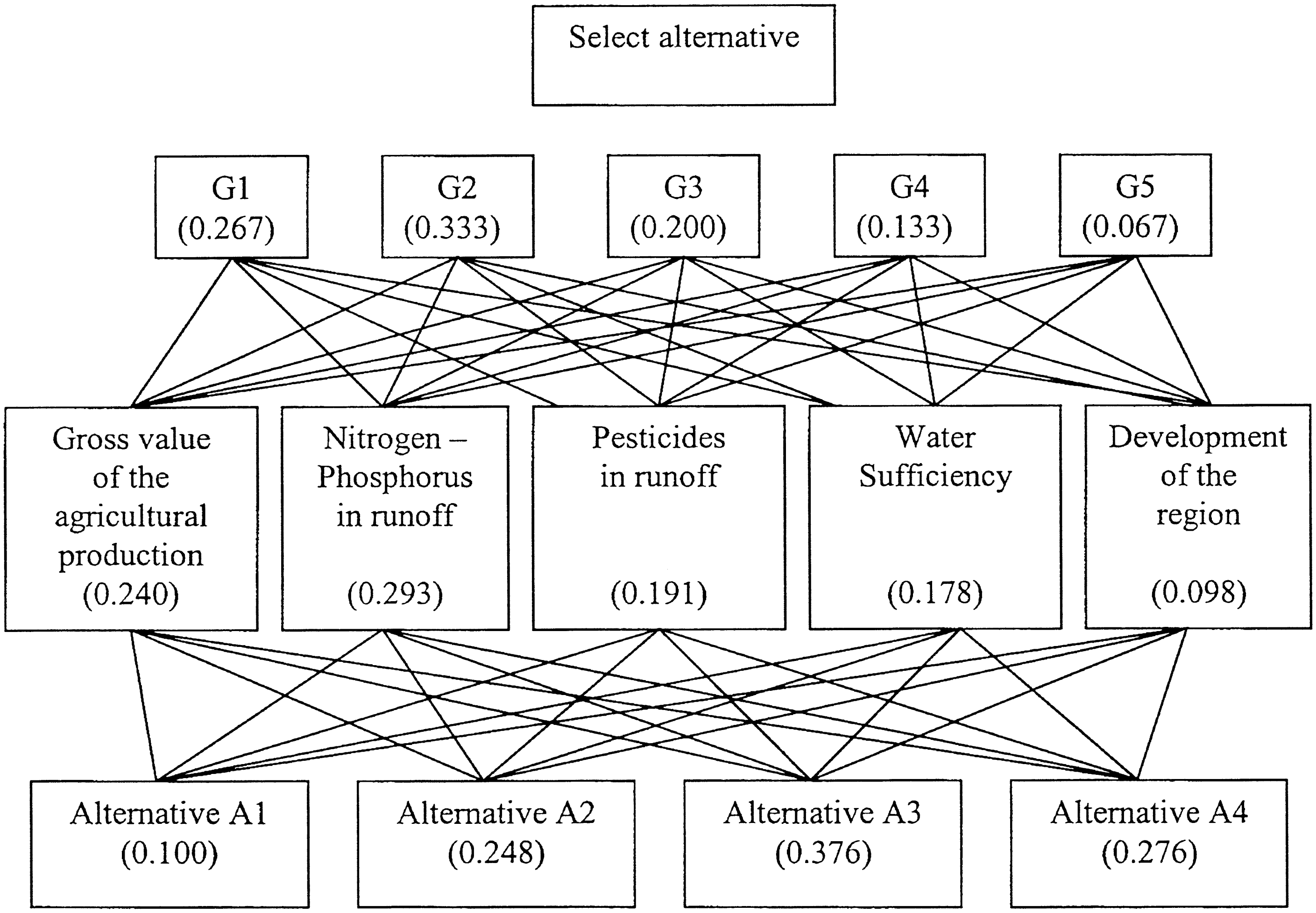

Figure 2. Hierarchy Levels and Pair Comparison of the Criteria in the Analytic Hierarchy Process.

TABLE 8. Ranking of the Alternatives.

	Compromise Programming									
	p = 1		p = 2		p = 100		EUM		AHP	
Alternative	Metric *Lp*	Rank	Metric *Lp*	Rank	Metric *Lp*	Rank	*U(z)*	Rank	Weight	Rank
A1	0.963	4	0.453	4	0.293	4	0.485	4	0.100	4
A2	0.467	2	0.303	3	0.240	3	0.485	3	0.248	3
A3	0.092	1	0.092	1	0.092	1	0.517	1	0.376	1
A4	0.516	3	0.299	2	0.191	2	0.508	2	0.276	2

TABLE 9. Correlation Coefficient R Values Between the Three Methods CP, EUM and AHP.

	CP (p = 2)	CP (p = 100)	EUM	AHP
CP (p = 1)	0.80	0.80	0.80	0.80
CP (p = 2)		1.00	1.00	0.80
CP (p = 100)			1.00	1.00
EUM				1.00

to 1,000,000. It has been observed that for p values less than 1.0, *Lp* approaches 1.0, and for values of p greater than 500, *Lp* becomes 0.0. For values of p from 15 to 500, the value of metric *Lp* was the lowest constant, nonzero value, which is the closest to the ideal value. Thus, the values p = 1 and p = 2 correspond to a relatively inexperienced DM and lead to a conservative solution, which may be preferable in the case where the DM is only one person. The value p =

100 is in the range of the constant, nonzero value of *Lp*, and represents an experienced DM or a small DM group. For high values of p the objectivity increases.

The use of multi-criteria decision making methods that integrate the human factor form an effective DSS required by EM and provides it with a strong tool. Regarding the three methods used, it can be seen that their results were equivalent, and it is not easy to propose one of them as more suitable than the other. The choice of an MCDM can be by itself a multi-criteria problem. In brief, it can be noted that the AHP seems to be a suitable method to rank the different methods, based on the results. Some of the criteria that can be used are (Srinivasa Raju and Pillai, 1999): (a) the consistency of the results, which is given by the comparison of the ranks obtained by the different methods; (b) the robustness of the results based on the effect of changes in the parameter values; (c) the strength of the solution, which is based on the number of times the best alternative is in the first place; and (d) the confidence of the results, which is evaluated by the number of times each alternative occupies the same rank. Studies in progress consider as many as 23 criteria for seven multi-criteria decision making methods (Srinivasa Raju and Pillai, 1999). Regarding data requirements, there are no great differences among the three methods. Accurate values of the criteria are needed for CP and EUM. AHP depends on the consideration of the interest groups, which define the most critical issues in the ecosystem. For this purpose, research based on the local population, through questionnaires, seems to be suitable. In general, CP and EUM are easier to apply, and AHP is more time consuming. In summary, although the three methods can be used independently, in this work, it is proposed to use all three methods and compare the results using R (Equation 4). The most suitable alternative solution is the one favored by most methods.

The procedure may take a considerable amount of time but: (1) EM is a long term process, and (2) the procedure resolves the problem of the quantification of the public's preferences. As EM deals with large spatial and temporal scales, it is difficult to have short term results. The case study presented above is an effort to manage a very significant and sensitive ecosystem in Greece by following EM principles. There are many problems because of conflicts and different interests. The negotiation group will help to assure the support of the local population, the local authorities, and the politicians. The use of field data may change the weights of the various criteria and will improve the methods used.

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