AGGREGATION OF STAKEHOLDER PREFERENCES IN SUSTAINABLE FOREST MANAGEMENT USING AHP

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Abstract: The Analytic Hierarchy Process (AHP) is the most often applied approach to modelling strategic forest management problems. When dealing with Multiple Criteria Decision Making, AHP allows one to take social, economic and environmental criteria of sustainability concept, as well as public participation, into account. We carried out a workshop to validate a decision hierarchy for Sustainable Management in Mediterranean forests, as well as two surveys to elicit social priorities. Stakeholder and expert judgments were integrated using the geometric mean to obtain group preferences. We applied this method to develop empirical research into sustainable forest management in a Mediterranean region, where the environmental and social services of the forest are more important than the economic ones. We quantified weights of criteria, objectives and management strategy priorities and discuss the obtained results.

1 THE PROBLEM

The environmental problems and decision making in this area are issues that governments, companies and citizens are more aware of each day. Over the last decade, Sustainable Forest Management (SFM) has emerged as a dominant forest management paradigm (Ananda, 2007). An accepted definition of SFM is the following: The management and use of forests and forest lands in such a manner and at such a rate that they can maintain their biodiversity, productivity, regeneration capacity, vitality and the potential to fulfill, now and in the future, important ecological, economic and social functions at local, national and global levels without causing damage to other ecosystems (Ministerial Conference on the Protection of Forests in Europe, 1993). This definition implies the inclusion of environmental, economic and social criteria in the decision making at every level, whether strategic, tactical or operative. This is the reason for using Multiple Criteria Decision Making (MCDM) tools.

Nowadays public participation is also, in general, an essential part of sustainable forest management particularly in Europe. Public participation means that citizens are involved in decision-making that has an effect on natural resources. In addition, the legitimacy of the final decision may be better, when the different stakeholders are involved in the decision making (FORSYS, 2011). For this reason, Group Decision Making (GDM) is also necessary. However, from the Operations Research field, we know that the inclusion of the preferences of the stakeholders in public decision making is not an easy problem to solve, given the conflict of interests that usually appears between the stakeholders. The application of GDM methods in forestry from a multicriteria perspective is a relatively new area of research (Diaz-Balteiro and Romero, 2008).

In past decades forest management has been the source of many problems in decision making, mainly related to the wood industry (Martell, Gunn and Weintraub, 1998). For that reason, publications refer to the principal productive zones: North America, Latin America, Scandinavia, Australia and New Zealand. We can state that the situation is still

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the same, as demonstrated by Ananda and Herath (2009). In addition, these authors show that theoretical developments have moved faster than empirical applications of MCDM.

The Mediterranean forest is one of the more vulnerable ecosystems (IPCC, 2007) and is one which plays an essential role as a regulating element of water resources and climate change, as well as minimizing advancing of erosion and biodiversity loss. Nevertheless, we do not see, in the scientific literature, studies which deal with decision making at a regional level, the inclusion of public participation and the concept of sustainability in forest management. In regional planning, the works of Ananda (2007) and Ananda and Herath (2008) presented a real application integrating MCDM and GDM approaches in the North East Victoria region (Australia). In Europe, studies concentrate on specific, limited, areas (Diaz-Balteiro, González-Pachón, J. and Romero, C., 2009; Nordström, E.M., Romero, C., Eriksson, L.O. and Öhman, K., 2009; Nordström, E.M.; Eriksson, L.O. and Öhman, K., 2010).

The objective of this study is to develop a model for the sustainable forest management at a regional level for the Mediterranean forest that takes public participation into account as well as the relevant objectives, integrating both aspects to inform public policies, using Analytic Hierarchy Process (AHP).

We have organized the paper as follows: In section 2 we present the most relevant data of the Valencian Community forest, the decision making hierarchy that we have developed, as well as the process for validating it with the stakeholders and elicit their preferences. In section 3 we explain how we aggregate the preferences and expert knowledge through geometric mean. Following that, we present the results about criteria, objectives and strategies of management. Finally we highlight the conclusions and the future lines of research.

2 METHODOLOGY: STAKEHOLDERS, DECISION HIERARCHY, WORKSHOP AND SURVEYS

2.1 Mediterranean Forests in Valencian Community and Forest Stakeholders

The Valencian Community is located on the Mediterranean coast of Spain. It is an Autonomous Region of the Spanish State with its own authority for strategic forest management. Nowadays, the relevance of the Mediterranean forest is mainly due to the services that it provides and not to the traditional production of wood and cattle where its productivity is very low compared when to the Atlantic forest, characteristic of the North of Spain and Europe. The Valencian forest surface, covers almost 60% of the territory, but contributes barely 0.03% of the GNP. The Valencian Community has a total forest area of 1,323,465 hectares (PATFOR, 2011) and 4.5 million people, a population density higher than the European Union average.

The regional government annually distributes an important quantity of money amongst different lines of action, dedicating as much to private as to public forest. In 2010, the budget was more than 147 million Euros of which more than 70% was spent on fire prevention and extinction, mostly the latter. The public forest is approximately one third of the total and is mainly managed by the forestry administration.

Several authors consider that MCDM must adopt a more participatory posture at all levels of the modeling process. Stakeholders must be able to participate and contribute actively to modeling (Mendoza and Martins, 2006). The main role of stakeholders in sustainable forest management has also been highlighted in other recent studies which focused on regional forest programs in Finland (Kangas et al, 2010).

In our case, we have identified the following stakeholder groups in the Valencian Community: Administration, Professional Engineering Associations, people involved in Forest Research and Education, Hunting and Fishing Federations, Forest Owners (private owners and municipalities), Companies and Land Stewardship, Environmentalist and Conservationist Groups. Representatives of these groups are the ones previously invited by the Regional Government to collaborate in developing new forest programmes in the Valencian Community.

2.2 Decision Hierarchy and Workshop

In developing our value tree or decision hierarchy we tried to construct the simplest possible model, while taking into account several other important considerations. We tried to balance completeness (wherein all important aspects of the problem are captured) with conciseness (keeping the level of detail to a minimum), two conflicting requirements in defining criteria and objectives for our problem. Another important characteristic of the work as an

operational model is to take into account that the volume of information and the demands on the people involved should not be excessive (Belton and Stewart, 2003).

We organized an all day workshop (April 2010) with representatives of all stakeholder groups to test the criteria, objectives and management strategies we had proposed and previously discussed with several experts. In this workshop, with almost 200 participants, we carried out a round table with stakeholder's representatives, followed by a colloquium and general debate between all participants. We had previously presented principal statistical data on Valencian forests and maps with public and private forest areas, as well as the decision hierarchy. Figure 1 synthesizes the goal, the criteria, the objectives and the management strategies, finally adopted after this workshop. Group participation with knowledgeable people is a good way to ensure that the decision hierarchy is a logical and complete structure (Saaty and Shih, 2009).

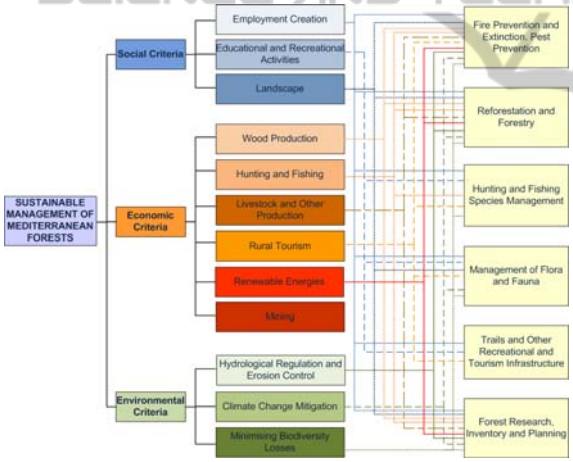

Figure 1: Decision hierarchy for Sustainable Management of Mediterranean Forests.

The lowest level of the decision hierarchy is for management strategies at regional level:

1. Fire prevention and extinction. Pest prevention.
2. Reforestation and forestry.
3. Hunting and fishing species management.
4. Management of flora and fauna.
5. Trails and others recreational and tourism infrastructure.
6. Forest research, inventory and planning.

The model represented in Figure 1 intends to be a strategic model for the public administration to inform sustainable forest management, both public and private, at a regional level. For this reason it has been structured with the same objectives for all stakeholders. We consider that this is the proper structure for a regional model which can be used as a general framework for small scale planning, such as, demarcation, regional, municipal or areas such as protected natural parks, etc. This differentiates the model from those which focus on a specific piece of forest, such as the one developed for an urban forest in Nordström et al. (2009), in which each group of stakeholders has different interests and it is not possible to define a structure that everybody accepts.

2.3 Surveys, Questionnaires and Matrix Consistency

In the three first levels of figure 1, the stakeholders might have a different opinion, for example, in the importance that the social criteria might have in the sustainable forest management. Thus, some might assign greater importance to social criteria, other might emphasize the environment and the owners would probably be more interested in economic objectives. We can see that whether we consider that job creation or the landscape is the attribute which contributes more to the social criteria is a subjective question. After accepting the hierarchical structure of the model, the participation of the stakeholders consists in defining their preferences for the first three levels. With this objective we made a first survey of the representatives of all the 7 groups of stakeholders considered.

In the workshop we explained Saaty´s basic scale of comparisons between pairs of criteria with the objective that stakeholders could respond to a questionnaire. We carried out a first survey to elicit the preferences of stakeholder groups for criteria and objectives. 46 stakeholders generated 5 pairwise comparison matrices each, where each element in an upper level is used to compare the elements in the level immediately below with respect to it (Saaty, 2006). We obtained 2 matrices that contain the preferences of each person surveyed on the contribution of the social, economic and environmental criteria to the sustainable management of the Mediterranean forest. One matrix refers to all forests of the region and another specifically for public forest. The other 3 matrices refer to the contribution of the third level objectives to the criteria of the second level (social, economic and environmental). We asked the stakeholders to complete the top half of the comparison matrix and we assumed a reciprocal matrix.

The contribution of the strategies from the lowest level of the hierarchy to the objectives from the third

level is not a subjective question of stakeholder preferences rather it is a technical matter. The lack of data about the contribution of each strategy to each objective lead us to propose a second survey using the same methodology as in the first one, but this time consulting only the experts who participated in the first survey. We have grouped the alternatives in six categories, due to the methodology of pairwise comparison. A greater number of strategies would imply a greater number of questions and thus less consistency in the resulting matrices. In this second phase we obtained 17 completed questionnaires, with 11 matrices in each one, and their distribution amongst the groups of forestry experts is as shown in table 1. As the mining activity does not receive public money from the forest administration it is not necessary to obtain a matrix for this objective. Nevertheless, we have considered it necessary to include it explicitly in the model given that it economically benefits the owners.

We have analyzed the consistency of the answers to both surveys with SuperDecisions Software (2010) and we have only taken into consideration those that have an Inconsistency Index less than or equal to 0.1, which is considered acceptable when using AHP (Saaty, 2006). The percentage of matrices with an Inconsistency Index less than or equal to 0.1 in the first survey is 67% when stakeholders compare 3 criteria and 50% when 6 criteria were involved in pair comparisons. Inconsistencies are not unexpected, as making value judgments is difficult (Keeney, 2002).

Table 1: Distribution of questionnaires among stakeholder groups (first survey) and expert group (second survey).

Stakeholder Groups	Number of questionnaires	
	First survey	Second survey
Administration	17	9
Professional Engineering Associations	5	3
Forest research and education	8	3
Hunting and fishing federations	3	-
Forest owners	4	-
Forestry companies	6	2
Land stewardship, environmentalist and conservationist groups	3	-
TOTAL	46	17

The second questionnaire was conducted amongst the experts that had answered the first survey consistently. The consistency of these matrices is greater than in the first questionnaire and does not depend so much on the number of strategies to be compared. The percentage of consistent matrices has been between 71 and 82% with 3, 4, 5 and 6 strategies to compare. Only in climate change (65%) and renewable energies (53%) did the percentage decrease, which would seem to be related to the newness of these criteria.

3 AGGREGATION OF PREFERENCES USING GEOMETRIC MEAN

The weighted geometric mean is the most common group preference aggregation method in the AHP literature. If judgment matrices M^1, M^2,..., M^n given by stakeholders or experts are of perfect consistency, then their group consensus matrix is of perfect consistency. In addition, the consensus matrix is of acceptable consistency (Inconsistency Index ≤ 0.1) on the condition that each individual matrix is of acceptable consistency (Xu, 2000).

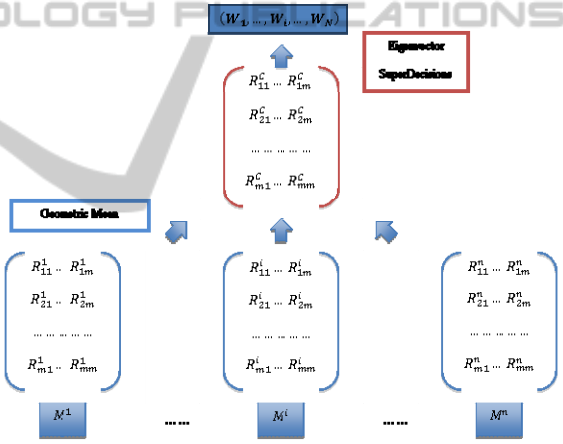

Figure 2: Aggregation of individual preferences to obtain group consensus matrix and weight vector.

In Figure 2 we can see the procedure for integrating the values R^i_{jk} of the individual stakeholder matrices into the values R^C_{jk} of the consensus matrix for each group. As we only use matrices of an acceptable consistency in the AHP method, the consensus matrices that represent the preferences of the group have been obtained by the geometric mean and also have an acceptable consistency. We consider that all people are equally important. The priorities that reflect those preferences are the values of the eigenvector, obtained using SuperDecisions software (Saaty and Peniwati, 2008). We have used this procedure to obtain the priorities that each group of stakeholders gives to the criteria and objectives considered in the

model, as well as to synthesize the knowledge of the experts in the second survey. In this last case the synthesis of the opinions of all the experts allow us to estimate how much each management strategy contributes to each of the considered objectives. We should emphasize that in the survey we highlighted that the comparison between each pair of strategies supposes that we spend the same amount of money on each of them.

4 RESULTS

4.1 Preferences of Stakeholder about Criteria and Objectives

All the experts have traditionally assigned great importance to the multiple functionality of the forest. Nevertheless, the best way of integrating this characteristic into strategic management at a regional level, taking into account the preferences of the stakeholders, is a complex decision making problem. Nowadays, we should also add that the concept and measurement of forest sustainability is still an open problem (Diaz-Balteiro and Romero, 2008). We have to start by quantifying the weight that society wishes to assign to the three basic criteria of the SFM and the attributes from the ones we measure. In this section we present the main results obtained in our first survey to learn the preferences of all of the groups of stakeholders and of society as a whole.

Figure 3 shows that, in general, the most important criteria is the environmental one except for some of the groups that represent economic interests, such as land owners and forestry companies, for whom the economical criteria are the most relevant. The associations of forest engineers give the greatest weight to social criteria, as do as the Land Stewardship, Environmentalist and Conservationist Group (LSEC group), even though we will later see that this is due to different objectives. We also want to highlight the low weight of economic criteria for all of the groups in general and for forestry administration in particular.

In Figure 4 we can observe the relative weights of the different criteria, referred only in this case to public forest. The public forest represents one third of the forestry surface and the majority of it is managed by the forestry administration. The relative weights are very similar to those obtained for all of the forests in general. Nevertheless, the importance of environmental criteria rises slightly in the public forest for the priorities of the administration, the land owners, the companies and the LSEC group. Something similar occurs with social criteria, while the economic criteria have even less importance.

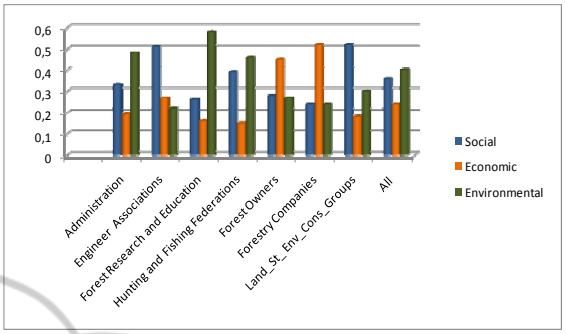

Figure 3: Priorities of social, economic and environmental criteria in sustainable management of Valencian Forest by stakeholder groups.

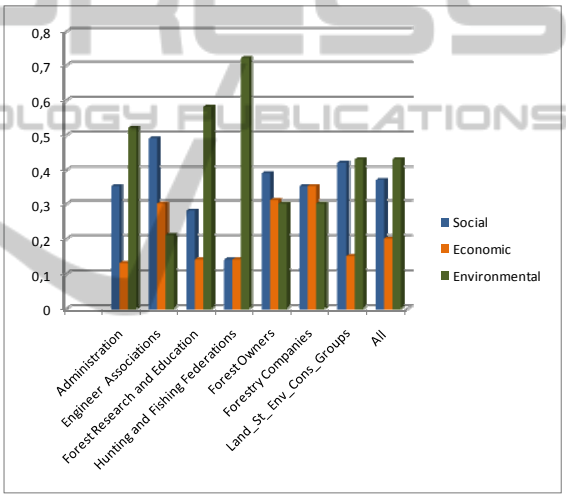

Figure 4: Priorities of social, economic and environmental criteria in sustainable management of Valencian Public Forest by stakeholder groups.

The distribution of the preferences of the social criteria between the three considered attributes can be observed in Figure 5. Globally as well as individually, the groups give more weight to employment, with the exception of the LSEC group. In this case, recreational and educational activities are the objectives with greatest priority. Even though at a regional level there are landscape regulations and programs, these are the objectives with less weight, except for the group of forest research and education, which gives greater importance to the landscape than to educational and recreational activities.

Even though economic criteria are not very relevant in the Mediterranean forest, some activities and services have more importance than the rest.

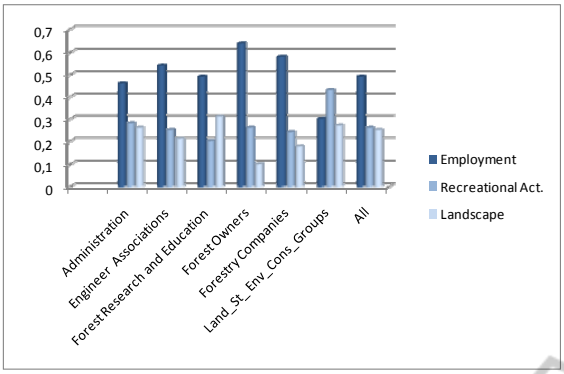

Figure 5: Priorities of Social Objectives of Valencian Forest by stakeholder groups.

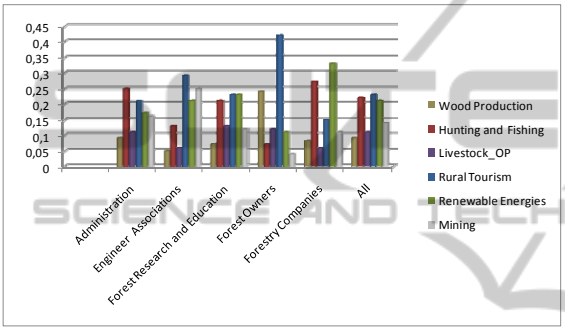

Figure 6: Priorities of Economic Objectives of Valencian Forest by stakeholder groups.

Rural tourism, hunting and fishing and the income from renewable energies (biomass and wind energy) are the greatest ones as we can see in Figure 6. This figure also shows the not at all negligible economic interest of the quarries (clay, gravel, sand…), that nowadays overtakes the productivity of more traditional activities of wood and livestock production.

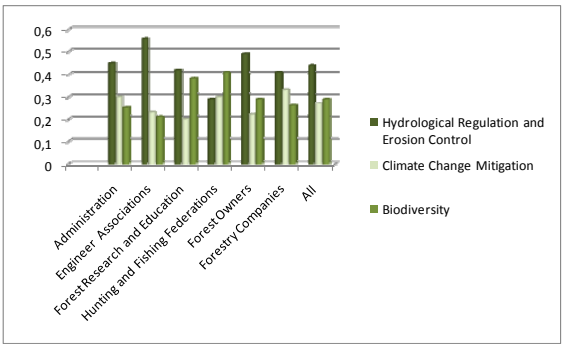

Figure 7: Priorities of Environmental Objectives of Valencian Forest by stakeholder groups.

Figure 7 represents the weights obtained for the environmental attributes. Hydrological regulation and erosion control stand out above the others. Climate change mitigation and the minimization of biodiversity loss have similar weights individually and globally for all of the considered groups. In this case we do not have consistent surveys from the LSEC group, which is the reason why this group does not appear in Figure 7.

4.2 Global Priorities of Management Strategies

As the contribution of management strategies to the objectives of the third level of the decision hierarchy (Figure 1) is not a matter of preference, but of technique, our second survey was conducted only among experts in forest management; from the administration services, people who are dedicated to research and university teaching and people in positions of responsibility in forest enterprises.

Experts who participated in this second survey also responded consistently to the first survey. In this case they made judgments comparing pairs of management strategies (the fourth level of the hierarchy, Figure 1) establishing their relative contribution to the corresponding objective of the third level, on the assumption that the same amount of money is spent on both. We assumed that the matrix was reciprocal and only used the consistent matrices.

First, we calculated the local priorities of the strategies for each of the objectives, except for mining as this is an industrial activity which is not funded by the forestry administration. We then obtained the overall priorities of the strategies in a distributive mode weighting the local priorities with the weights obtained in the first survey to the criteria and objectives of the second and third levels of the hierarchy. The sum of all global priorities of strategies is, therefore, equal to 1 (Saaty, 2006).

In Figure 8 we can see the results of the overall priorities of management strategies for each stakeholder group. Reforestation and forestry are the most important lines of action, followed closely by fire prevention and extinction and pest control. In all groups both of these lines of action account for over 50% of the global priority. The third is Forest research, inventory and planning, their weight varying amongst the groups, between 15 and 20% approximately. The overall weight of the other three strategies varies from one group to another. In the global ranking the first strategy is the management of hunting and fishing, followed by the flora and fauna and finally the lowest priority is trails and other recreational facilities with a weight below

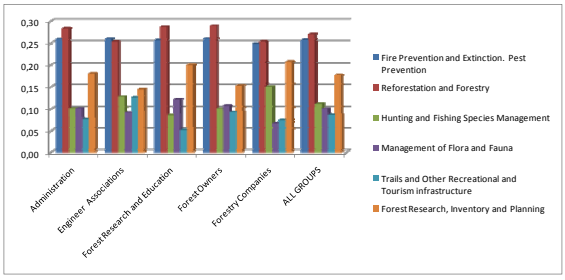

Figure 8: Global priorities of strategies by stakeholder groups.

10%. Global priorities, referring only to public forests, are similar, given the small difference between the weights of the social, economic and environmental criteria for public and for all forests.

In 2010 over 147 million Euros were spent in the forest management of public and private forests. Preventing and extinguishing fires, pest prevention amounted to 76% of the total. Excluding funding for forest fire fighting, if we have into account the budget distribution between different forest management strategies, we find a distribution closer to the reflecting the priorities of the social groups considered. However, we can observe the following considerations. About 43% of the budget is dedicated to the prevention of fires and pests, occupying the first place, while the money for reforestation and forestry is 24% of the total. In priorities, the order in the ranking is reversed and slightly more for reforestation and forestry. The priority of forest research, inventory and planning is 18%, while receiving only 3.5% of the budget. However, the situation in trails and other recreational and tourism infrastructure is the reverse, receives 17% of the overall budget and give stakeholders a priority only 9% obtained with AHP method. The management of hunting and fishing also receives less funding (3%) than would result from taking into account the priority of the stakeholders (11%). Finally, management of flora and fauna receives a percentage of funds (9.4%) very similar to the value of priority obtained for all groups together (10%).

5 CONCLUSIONS

We have used the Analytic Hierarchy Process to develop a sustainable forest management model that will allow us to adequately inform public policies in a region with an important part of the territory of which is formed of Mediterranean forest. This ecosystem is one of the most vulnerable and its current importance lies in the environmental services provided, along with the social and economic ones other than the traditional wood and livestock services. AHP is a powerful and useful method that easily allows the integration of the concept of SFM and public participation through the preferences of stakeholders and also allows the quantification of the priorities that characterize the various stakeholders.

The empirical model that we have developed has allowed us to quantify the increased importance of environmental and social criteria compared with the economic criteria in the Mediterranean forest. We have also highlighted that stakeholder groups show very few differences between the strategic management of public forests and that of forest land management in total. This is a very interesting result, given that two thirds of the forest are privately owned and currently give little or no economic return to most of the owners.

Job creation is the most important social goal for most stakeholders, with a total contribution close to 50%. However, there are differences between groups; the other half is divided between recreation activities and landscape. We have quantified a greater contribution of hunting and fishing to the economic criteria than the traditional activities of timber production and livestock. Quarries are also of greater importance than timber and livestock. Rural tourism and renewable energies such as biomass and wind energy are the most important objectives along with hunting and fishing. The stakeholders have shown that the role of forests in water regulation and prevention of desertification has a higher priority than its role in mitigating climate change and loss of biodiversity. With regard to the priorities for the action plans, we can say that society places a higher priority on reforestation and forestry than the prevention and extinction of fires, which is where the forest administration spends the greater part of its budget. Forest administration also spends proportionally more on promoting recreational activities than is suggested by the priorities obtained using AHP. On the other hand, the stakeholders place greater importance on furthering investigation, carrying out forest inventories and supporting adequate planning than is indicated by the funds actually invested in these activities.

Finally, we wish to say that it would be very interesting to compare the results of this research with the analysis of the data using other multiple criteria techniques, such as goal programming and outranking methods. An analysis that studied the subject using various different approaches would help to give greater credibility to, and help promote

the acceptance of, the conclusion which we have obtained.

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