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Sustainable Forest Management in a Mediterranean region: social preferences

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Abstract

Aim of study: There is a lack of empirical research that deals with sustainable forest management in Mediterranean regions, among the most vulnerable ecosystems. The main purpose of this work is to define the strategic criteria and objectives for sustainable forest management and aggregate the preferences of stakeholders in a Mediterranean region, using AHP and Goal Programming.

Area of study: Valencian Community (Spain).

Material and Methods: Firstly, we identified forest stakeholders and structured a decision hierarchy. Then a workshop was carried out to test and validate the proposed criteria and objectives, as well as a survey to determine social preferences. Secondly, another survey was conducted amongst experts to prioritize action plans.

Main results: Stakeholders' preferences gave the greatest importance to the environmental criteria (hydrological regulation and erosion, climate change mitigation and biodiversity) with an average weight of 40%. Social criteria (employment, recreational activities and landscape) had a weight of 38% and 22% the economic criteria case (wood, hunting and fishing, livestock, renewable energies, rural tourism and mining). The results showed that new products and services such as tourism, renewable energies, landscape, hydrological regulation and erosion control, biodiversity or climate change mitigation are very relevant objectives. We also prioritized action plans comparing them with the distribution of the administration budget.

Research highlights: The environmental and social criteria are much more important than the economic ones in the regional planning of the Mediterranean forest, regardless of the method used to aggregate the social preferences and if the forest is public or private.

Key words: multiple criteria decision making; goal programming; analytic hierarchy process; preferences aggregation.

Introduction

Forest Management has been a source of numerous decision-making problems related to principally industry in North America, Latin America, Scandinavia, Australia and New Zealand. Strategic forest planning has evolved from regulating the flow of industrial timber resources to its current focus on sustainable forest management (Martell *et al.*, 1998). The current use of forests is oriented to multiple objectives, and in strategic planning the main idea is to define what is wanted from the forest and often involves numerous stakeholders. They could be the owners of the forests, people connected with tourism, recreation services or nature conservation, as well as forestry companies (Kangas *et al.*, 2008). Nowadays, economic, social and environmental criteria are involved in practically all decision making situations. Within this context, the decision process should explore the conflicting nature of the criteria, the goals set by the decision makers, and the way in which these can be introduced into an appropriate decision model that takes into account the preferences of the stakeholders.

Multiple Criteria Decision Making (MCDM) methods have been widely applied to solving forest ma-

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nagement problems over the past few decades and are a well-established paradigm for addressing many problems in this area. The applications can be classified into harvest scheduling, forest biodiversity conservation, forest sustainability, forestation, regional planning, forestry industry and risk and uncertainty (Díaz-Balteiro and Romero, 2008). The literature review of these authors points out an increasing interest in using Group Decision Making methods (GDM) with a multiple criteria approach.

Ananda and Herath (2009) provide another recent review on forest management and planning using MCDM, confirming that published studies are only applied to cases in countries such as Finland, Canada, USA and Australia. These authors emphasize the importance of empirical applications and suggest areas for improvement in future research such as the process for selecting the decision criteria, as well as a clear definition of criteria.

Analyzing in depth the contributions in these areas over the last decade, we find several studies that focus on regional forest planning referring to the North East Victoria region (Australia). Ananda and Herath (2003a) used Multi-Attribute Value Theory to analyse stakeholder values. They considered a simplified model with 3 attributes (old-growth forest conservation, hardwood timber production and recreation intensity) and 3 hypothetical forest management options or strategies, constructed by taking the status quo as a basis. They interviewed 36 stakeholders from five groups (timber industry, environmentalists, farmers, recreationists and tour operators). Another paper shows that Analytic Hierarchy Process (AHP) can be a tool to formalize public participation in decision making with the same problem as an illustrative example, but they used hypothetical data and thus the results do not have any empirical validity (Ananda and Herath, 2003b). Later, Ananda (2007) and Ananda and Herath (2008) presented a real AHP application for a previous case study involving a greater number of stakeholders.

Kazana *et al.* (2003) used a multiple criteria approach to support decisions in forest management at a tactical level in a National Forest Park in Scotland. Hjortsø (2004) evaluated soft OR to enhance public participation in tactical forest planning with a case study in Denmark. Díaz-Balteiro *et al.* (2009) used Goal Programming (GP) to aggregate the preferences of forestry students, expressed through pairwise comparison matrices, referring to two public forests in Spain, to elicit weights for four objectives. Nordström *et al.* (2009) applied MCDM and group decision making in planning urban forest in Sweden. They designed a hierarchy with 4 stakeholder groups (timber producers, environmentalists, recreationists and reindeer herders), each of which have their own different objectives. GP models are used to aggregate stakeholder preferences and to obtain criteria weights to be used for ranking 12 forest management plans. In Nordström *et al.* (2010) another approach using AHP was applied to aggregate stakeholder preferences for the same urban forest, taking 3 plans into account. Hiltunen *et al.* (2009) tested the Mesta Internet-based decision-support application in strategic planning processes in Finland (Lapland). The main role of stakeholders in sustainable forest management has also been highlighted in other recent studies focused on regional forest programmes in Finland (Kangas *et al.,* 2010).

Decision making and public opinion appears as one of the relevant themes for future research in natural resource management (Petrokofsky *et al.,* 2010). In practice, MCDM methods have been implemented to inform decision problems and public participation and they will continue to be essential in forest and environmental management (Kangas and Kangas, 2005). Nevertheless, several reviews (Mendoza and Martins, 2006; Ananda and Herath, 2009) and an extensive analysis of the literature to date, show a lack of empirical research referring to Mediterranean forest, one of the most vulnerable ecosystems, according to the Intergovernmental Panel on Climate Change (2007).

We can differentiate two main forest zones in Spain: Atlantic and Mediterranean. Atlantic forests have a wood productivity as high as forests in central and northern Europe. In contrast, Mediterranean forests, in general, provide a low wood productivity and non-wood services.Valencian forest is a good example of the Mediterranean forest. Forest land is defined as those areas which present one or more uses which can be considered forestry use. Thus the Valencian Community has a total forest area of 1,323,465 hectares, representing 57% of the total land with the current trend increasing the forest area at a rate of about 3,300 ha/year, mostly through neglected agricultural areas and their subsequent colonisation by forest species. Forest woodlands now occupy 54% of the forest land (PATFOR, 2011).

Management objectives are not always known or, in some cases, they can only be elicited through prior analysis (Schmoldt *et al.*, 2001). This is the case in sustainable management of Mediterranean forest, so expli-

citly specifying all relevant objectives and quantifying their importance in its strategic and sustainable management are very interesting contributions towards developing public policies according to social preferences in Europe.

The decision maker in sustainable forest planning problem is the regional government, which distributes public funds to the different action plans. European public policies must reach a consensus through public participation. Public participation means that citizens are involved in natural resource decision-making that has an effect on them. Public participation is also seen as part of sustainable development (FORSYS, 2011).

The objectives of this article are to define the strategic criteria for the sustainable management of Mediterranean forests, as well as to elicit and aggregate the stakeholders' preferences, using several methods to increase the objectivity and robustness of the results. Finally, we prioritize the action plans of the public administration, taking the social preferences we obtained into account.

In developing the decision hierarchy we tried to balance completeness with conciseness, two conflicting requirements in defining criteria and objectives for our problem. Another important aspect considered is that the information demands on the people involved should not be excessive, following the recommendation of Belton and Stewart (2003). Our hierarchy is logical and includes a complete set of fundamental objectives and has been validated by a large group of experts in a workshop (Saaty and Shih, 2009).

The rest of the paper is organized as follows: The next section describes the public participation techniques and the methods used to aggregate the preferences for sustainable management of Mediterranean forests, in particular for the Valencian region. After that, the results are presented: the decision hierarchy, matrix consistency, social preferences of criteria and objectives as well as the global priorities of the action plans. Finally, the results are discussed and the main conclusions of this empirical research are pointed out.

Material and methods

The Analytic Hierarchy Process and Goal Programming Models

The method developed by Saaty, AHP, is undoubtedly one of those most commonly used to identify and prioritize objectives and alternatives in the field of forest management. Its approach is based on three principles: construction of the decision hierarchy, logical consistency and setting of priorities. The method allows us to incorporate qualitative aspects into the hierarchy definition and to use quantitative aspects to measure preferences and priorities. It also allows group participation in decision-making.

First, the decision hierarchy, for which all the actors involved in decision-making have been identified, is designed. Secondly the individual preferences are obtained by pairwise comparisons, *i.e.* comparing two elements of the same level of the hierarchy with respect to a criterion of a higher level. Comparisons are collected in a matrix that allows us to check the consistency of the preferences.

Each element of the comparison matrix A, a_{ij} represents the relative importance of an element, i to another element, j with respect to a criterion in the upper level. The Saaty fundamental scale is set from 1 to 9, where 1 indicates that the two elements are equally important, 3 moderate importance, 5 strong importance, 7 very strong importance and 9 extreme importance of the first element, i with regard to the second, j. If we were to compare of the second element, j against the first, i, the values would be given inversely (1, 1/2 …1/9). This matrix A is consistent if $a_{ij} = a_{ik}a_{kj}$ for every element i, j and k. That is, if element i has a relative importance of 2 compared to element k and element k has a relative importance of 2 compared to a third element, j then element i should have a relative importance of 4 compared to element j for a consistent response.

From this matrix A we obtain the associated eigenvector, which represents the individual weights w_1, $w_2 \ldots w_n$ for each criterion (Saaty, 2008). To obtain the preferences of a group of people the geometric mean of all pairwise comparisons is used (Saaty and Peniwati, 2008; Xu, 2000).

The Goal Programming Models are an alternative method to AHP for aggregating stakeholder preferences from comparison matrices and obtaining weights of criteria. From individual stakeholder matrices we obtained a consensus matrix for each group using the Extended Goal Programming model developed by González-Pachón and Romero (2007). In the second step, we derived the weights of the relative importance attached by the ith stakeholder group to the rth criterion from the consensus matrix using another Goal Programming model developed by González-Pachón and Romero (2004). Both models are presented in the annex.

Experts, stakeholders, workshop and surveys

In many real problems it is not easy to establish the goals that should inform decision-making and this is particularly true when making government decisions which affect natural resource management and especially in forest management, where public participation is becoming increasingly important. The participation of qualified experts and stakeholders is of paramount importance in defining and selecting regional planning objectives. Expert interviews and workshops are suitable participatory techniques for strategic forest management. Structured surveys allow us to quantify the importance of the objectives and action plans, which can serve as indicators to inform formation and prioritization of public policies.

From both the authors knowledge and exhaustive interviews with experts the following stakeholder groups have been identified: Administration, Professional Engineering Associations, people involved in Forest Research and Education, Hunting and Fishing Federations, Forest Owners (private and municipalities), Companies and Land Stewardship, Environmentalist and Conservationist Groups. Representatives of all these groups have been invited by the Regional Government to collaborate in developing new forest programmes in the Valencian Community.

After identifying the stakeholders, a decision hierarchy with sustainable management of Mediterranean forest as the decision goal at the first level was proposed. The second level consists of social, economic, and environmental criteria, the three basic pillars of the sustainability concept as well as the multifunctional forest. Each of these criteria is divided into specific objectives in the third level with enough detail to include all aspects which are currently relevant to the Valencian region. A decision hierarchy which considers several action plans was completed.

In the next phase, a workshop at the university (2010) was carried out, with representatives of stakeholders to test and validate the proposed decision hierarchy. Presidents of Associations of Public and Private Property, Professional Organizations and Federations, Managers of Public Forestry services, Companies and Land Stewardship, Environmentalist and Conservationist Groups took part, both directors and technical staff. Forestry researchers, teachers and students also participated in the all-day-workshop, which had almost 200 participants. In this workshop we held a roundtable meeting with stakeholder's representatives, followed by a colloquium and general debate between all participants. Principal statistical data on Valencian forests and maps with public and private forest areas, as well as the decision hierarchy for strategic management of Mediterranean forests, in particular the forests of the Valencian Community, was presented following the recommendation from Sheppard and Meitner (2005). In the workshop Saaty's basic scale of comparisons between pairs of criteria (Saaty, 2008) was also explained, with the objective that stakeholders could respond to a questionnaire designed to elicit their preferences.

Then, two surveys were carried out, the first one amongst the stakeholders to determine their criteria and objective preferences. Due to the lack of data, to quantify the contribution of the different action plans of the administration to the objectives included in the decision hierarchy, a second survey was carried out amongst experts. These experts came from the administration, companies and researchers in the forest area. Finally, weights of criteria and objectives were obtained by aggregating stakeholder preferences, using two methods: AHP and Goal Programming models. For both methods, consensus matrices for stakeholder groups were derived. The weights of preferences of criteria and objectives and global priorities of action plans were then determined. The whole process has been represented in Fig. 1.

Results

Decision hierarchy

Fig. 2 synthesizes the criteria, objectives and action plans, adopted after the aforementioned workshop. The first level is the goal of the decision; the second level considers social, economic, and environmental criteria. Social criteria are divided into employment creation, educational and recreational activities and landscape. Environmental criteria have been grouped into hydrological regulation and erosion control, climate change mitigation and minimizing biodiversity loss. In economic criteria we find more traditional objectives, such as wood production, hunting and fishing, livestock and other production (truffles, mushrooms, cork, etc.) and mining. We also include other goods and services, such as renewable energies and rural tourism.

Finally, we completed the decision hierarchy with the following six action plans:

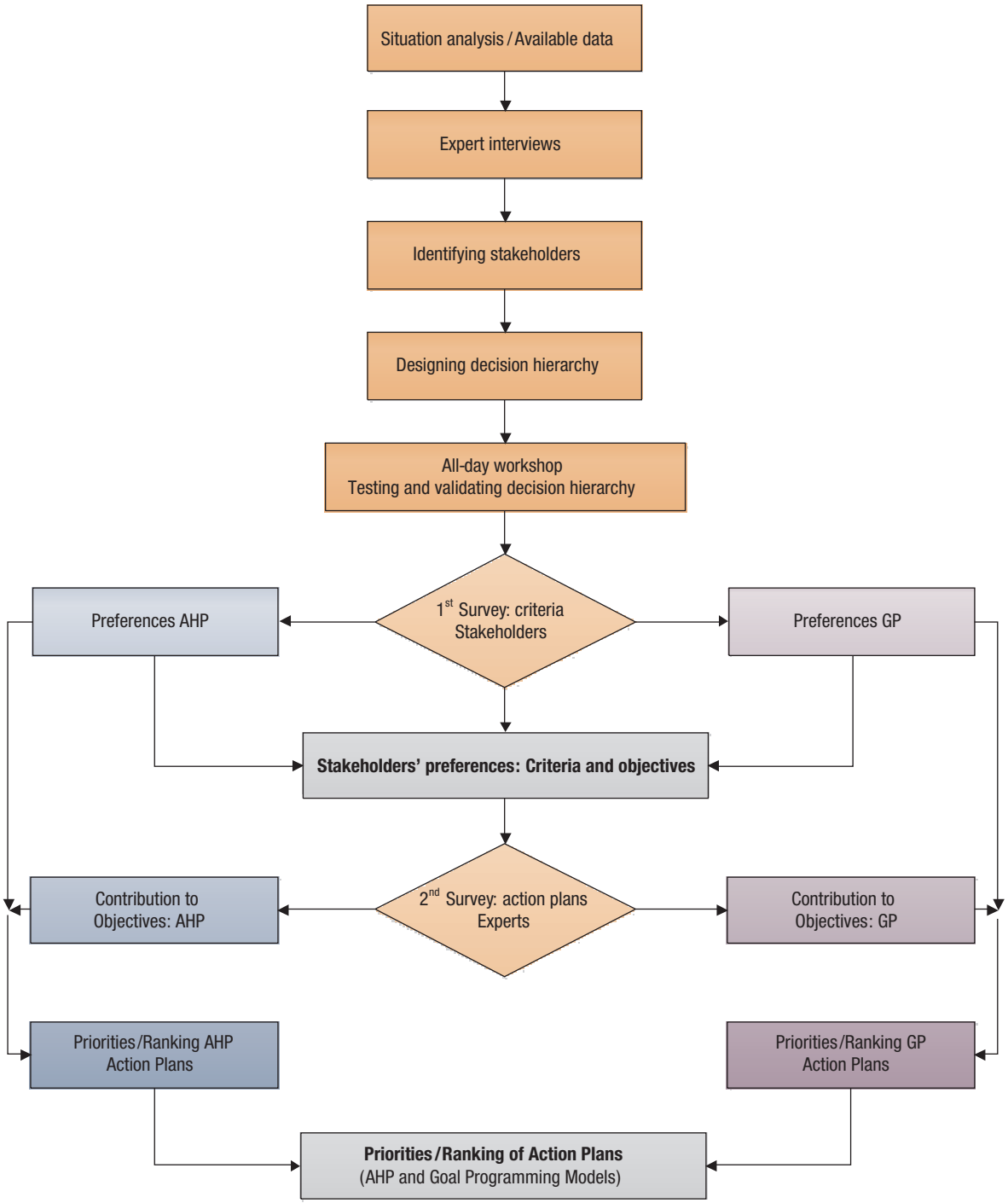

Figure 1. Flow-chart of process to obtain stakeholders' preferences and to prioritize action plans.

1. Fire prevention and extinction. Pest prevention.
2. Reforestation and forestry.
3. Hunting and fishing species management, including the maintenance of game reserves.
4. Management of flora and fauna, conservation of flora micro-reserves, wildlife corridors and enhancement of the Nature 2000 network, in order to preserve the biodiversity of the Valencian Community.
5. Trails and other recreational and tourism infrastructures (recreational areas, cabins, shelters, etc.).
6. Forest research, studies, education programmes, inventory and planning.

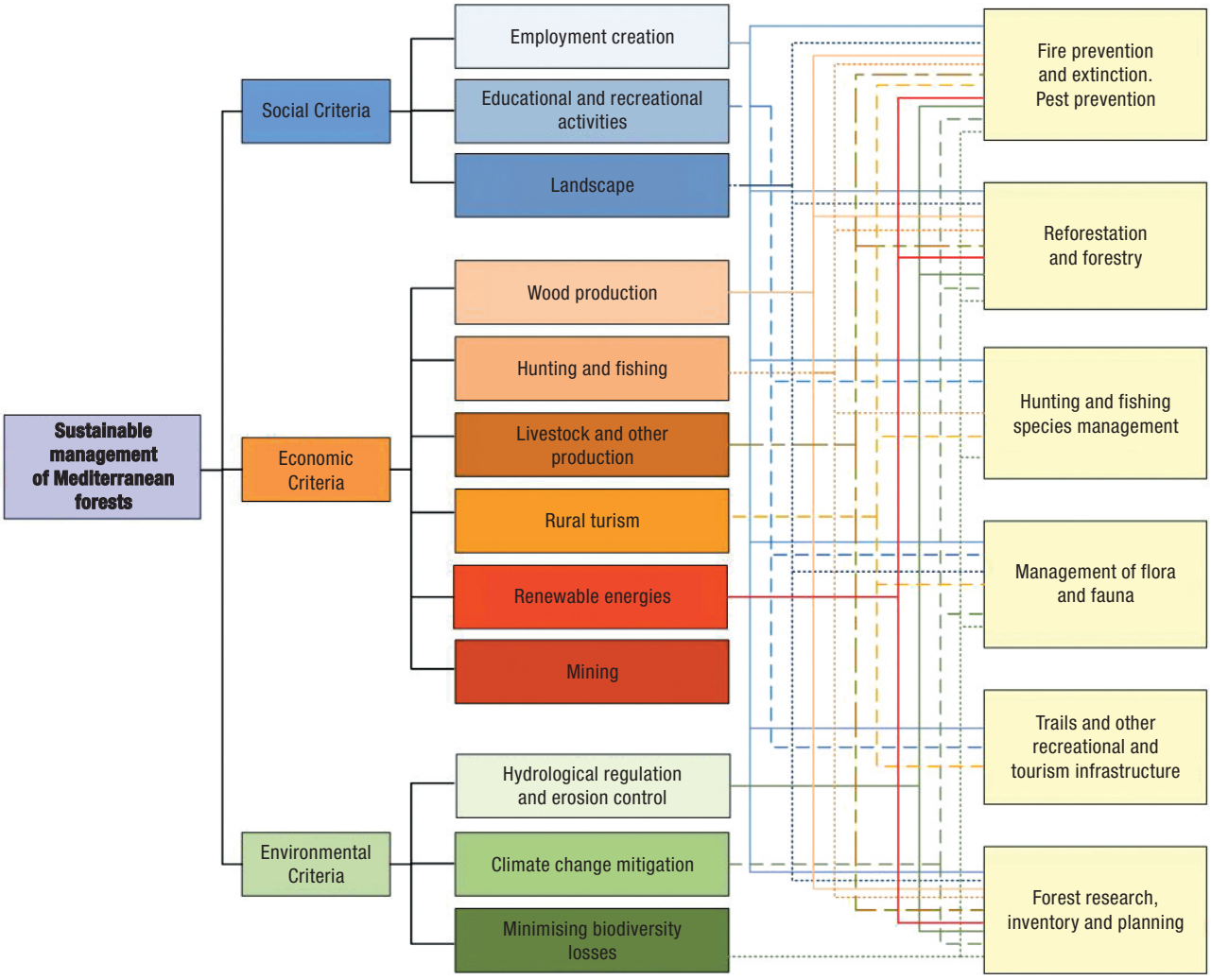

Figure 2. Decision hierarchy for strategic management of Mediterranean forests.

Nowadays all action plans except for Forest inventory and Planning have an administration budget. These budgets are dedicated to financing both public and private forest (the latter through grants to the owners). Some stakeholders at the workshop suggested the inclusion of actions for Forest inventory and Planning, not considered previously. The action plans have been grouped into six categories due to the methodology of pairwise comparison. A greater number of plans would imply a greater number of questions (tedious surveys) and lesser consistency in the resulting matrices.

Surveys and matrix consistency

Mainly due to the large number of criteria and objectives under consideration two phases were planned. A first survey was carried out to gather the preferences of stakeholder groups for criteria and objectives. The second survey allowed us to determine the contribution of action plans to each objective which is a question of a technical nature, not of preferences. Thus, this second phase involved experts who participated in the first one. In both surveys we asked the stakeholders (first survey) or experts (second survey) to complete the top half of the comparison matrix and we assumed a reciprocal matrix.

Table 1 shows the distribution of the 46 questionnaires obtained from the stakeholder groups. Administration was the biggest one, because of the need to balance the different aspects and services involved such as forest management, fire prevention, hunting and fishing and biodiversity conservation.

The second survey asked about the relative contribution of each action plan to each objective, *using the*

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

Stakeholders groups	Number of questionnaires	
	Fist 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

same money for each action plan being compared. In Fig. 2 the links between nodes of third level and fourth level of the decision hierarchy represent the contribution of each action plan to objectives. For exam ple, all six action plans contribute to employment creation, but only four of them contribute to rural tourism. In this second phase we obtained 17 questionnaires and their distribution amongst the groups of forestry experts is as shown in Table 1. We integrated all of them in just one group because the objective is to estimate the contribution of each action plan to each objective by providing expert judgments.

The matrix Inconsistency Index (II) was obtained using Superdecisions Software (2010). In our analysis only matrices having an inconsistency index less than or equal to 0.1, are used (Saaty, 2006). The percentage of consistent matrices is 67 % when stakeholders compare 3 criteria and 50% when 6 criteria were involved in the pair comparisons.

We have 17 experts who responded to the second questionnaire from each of whom we obtained 11 matrices of pairwise comparison. An interesting result of the study is that the consistency of these matrices referring to technical aspects is greater than in the first questionnaire (preferences) and does not depend so much on the number of strategies to be compared. The percentage of consistent matrices was 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.

Preferences of stakeholder about criteria and objectives

In this section the results of stakeholder preferences, obtained with AHP and GP are presented. In this latter case, preference results from the point of view of most of the people are represented in figures. After that, the differences when the opinions of minorities are incorporated into the model are discussed.

Fig. 3 highlights the great importance of the environmental criterion in general, which is the most important for administration, forest research and education, hunting and fishing federations and forest owners. As the latter group is formed of private and public owners, we highlight that this result is due to the preferences of the people representing municipalities. Only engineering associations gave much more importance to social and economic criteria than environmental ones in sustainable management. On the contrary, economic criteria have less relevance in general, but they are the most important for forestry companies.

Analysing the results with respect to public forest the answers highlight the lower relevance of economic criteria and the greater weight of social criteria compared to all the forests. A decrease in economic priorities is compensated mainly by an increase in the weights

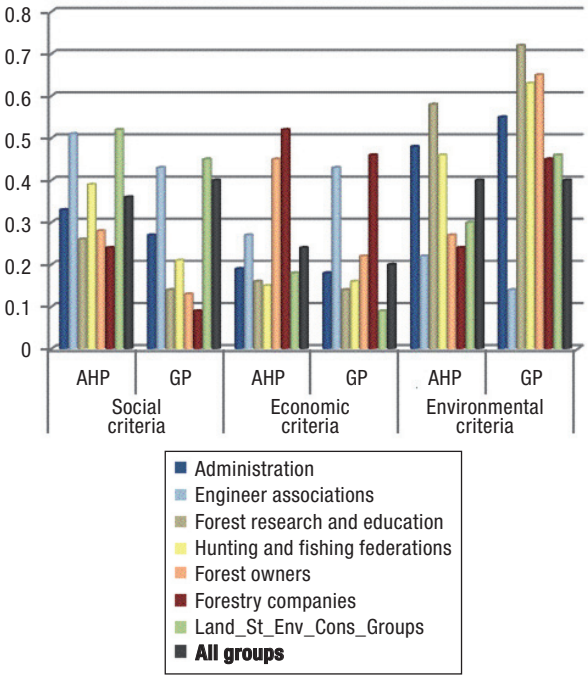

Figure 3. Priorities of social, economic and environmental criteria in sustainable management of Valencian forest by stakeholder groups.

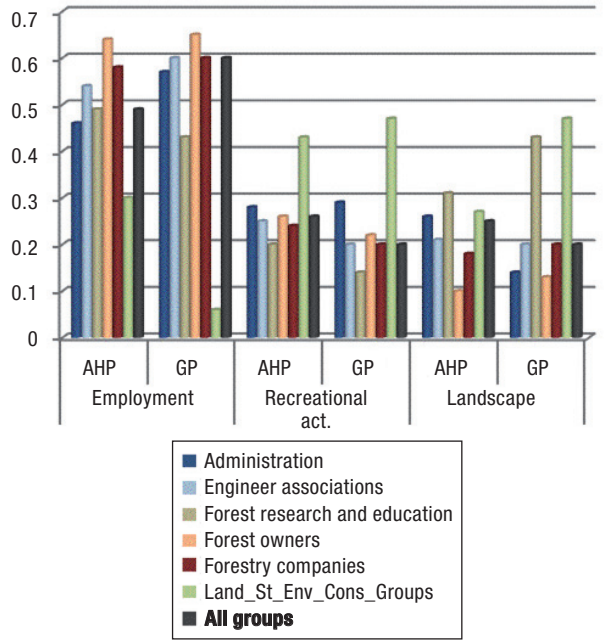

Figure 4. Priorities of social objectives of Valencian forest by stakeholder groups.

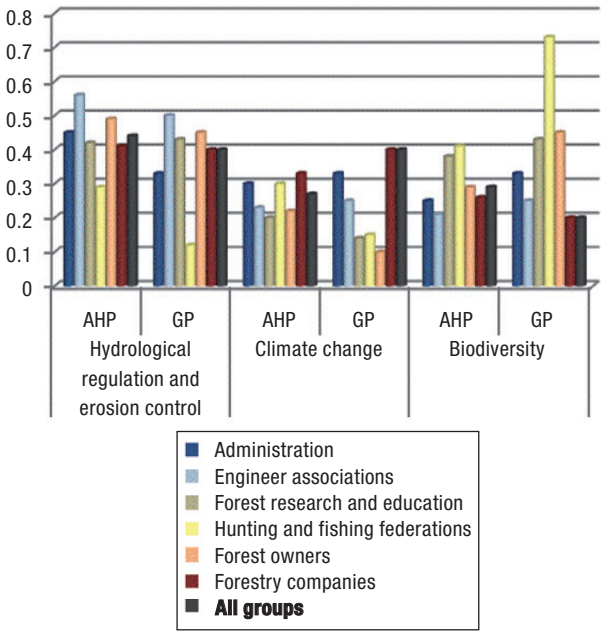

Figure 5. Priorities of environmental objectives of Valencian forest by stakeholder groups.

of social criteria. Stakeholders were also asked if they would change their opinion about the relative importance of the specific objectives (the third level of the hierarchy) for those public forests that are directly managed by the administration. A large majority said no and the percentages do not differ greatly from one stakeholder group to another. The percentage of stakeholders with a negative response is 65%, 28% said yes and 7% did not answer.

The objective contribution to social criteria can be seen in Fig. 4. In general, the employment objective is in the first place, except in the case of land stewardship, environmentalist and conservationist groups. As it could be expected, recreational activities are more relevant for this last group. Results for hunting and fishing federations were not obtained due to the lack of consistent individual matrices.

In Fig. 5 the priorities for environmental objectives can be seen. Hydrological regulation and erosion control are very important to almost all groups. In this case, any individual matrix is consistent for land stewardship, environmental and conservationist group and we only have one from hunting and fishing federations.

Fig. 6 displays the results of the weights of economic objectives from the stakeholders with consistent individual matrices. As it is well known, as the number of elements to compare increases, the difficulty of obtaining consistent matrices also increases. Nowadays, traditional forest products, such as wood production and livestock have less weight in Mediterranean forests, only hunting and fishing activities maintain some

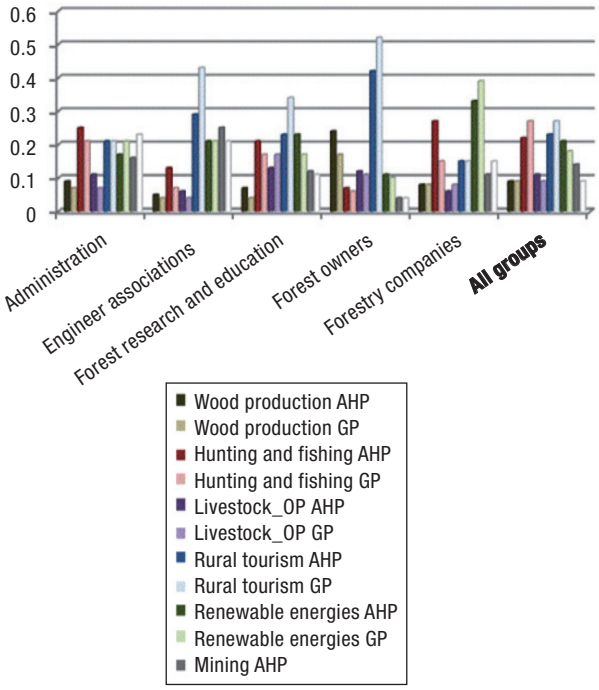

Figure 6. Priorities of economic objectives of Valencian forest by stakeholder groups.

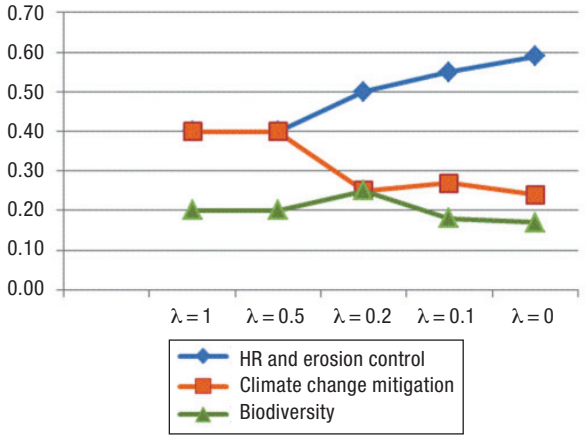

Figure 7. Priorities of environmental objectives when varying the control parameter in the Extended Goal Programming model.

importance. New services and production, such as rural tourism and renewable energies are greater importance in general, with weights of between 15 and 40 per cent, depending on the stakeholder group under consideration. The industrial activity of mining (mainly quarries) is also an important source of income for some forest owners in the Mediterranean area.

Figs. 3, 4, 5 and 6 represent the solution of goal programming models for control parameter $\lambda = 1$, which shows the preferences of the majority. The model has also been solved for all stakeholders when $\lambda = 0$. This solution generates the aggregated preferences when minimizing the maximum deviation of individual preferences regarding the consensus matrix. The model for intermediate values of the control parameter has also been solved as shown in Fig. 7. As it can be seen, the priority of biodiversity varies between 17 and 25%. The variation of preferences is greater in the other two objectives. In giving more weight to the minorities, the priority of hydrological regulation and control of erosion increases. This increase is compensated by lower values for the mitigation of climate change.

By varying the control parameter in the models of social and economic objectives, priorities are very similar for all values of λ. The same applies to the solution of the models that allow us to obtain the aggregated priority criteria, showing a greater preference for the environmental and social criteria than for the economic criteria in the Mediterranean forest, from the point of view of the majority and of the minority.

Global priorities of action plans

Table 2 shows the results of the global priorities of action plans (fourth level of decision hierarchy, Fig. 2) for sustainable and participative management of Valencian forests. Enough questionnaires were obtained to balance the different areas of people's expertise and its distribution among administration, engineer associations, companies, research and education, to try to capture all relevant knowledge.

Due to action plans representing lines of public budget, how much these plans contributed to mining was not asked, because this is a profitable industrial activity and does not receive public funds from the forest ad-

Table 2. Global priorities of action plans by stakeholder groups and public budget

Action plans		Stakeholder groups						Weight of public budget 2010
		Administration	Engineer assoc.	Research and educ.	Owners	Companies	All	
Fire prevention. Pest prevention	GP	0.24	0.24	0.23	0.22	0.24	0.25	0.43
	AHP	0.26	0.26	0.26	0.26	0.25	0.26	
Reforestation and forestry	GP	0.24	0.22	0.23	0.21	0.26	0.24	0.24
	AHP	0.28	0.25	0.29	0.29	0.25	0.27	
Hunting and fishing species management	GP	0.09	0.11	0.05	0.06	0.08	0.07	0.03
	AHP	0.10	0.13	0.08	0.10	0.15	0.11	
Management of flora and fauna	GP	0.13	0.10	0.17	0.16	0.08	0.14	0.09
	AHP	0.10	0.09	0.12	0.11	0.07	0.1	
Trails and other recreational infrast.	GP	0.08	0.17	0.04	0.08	0.05	0.07	0.17
	AHP	0.08	0.13	0.05	0.09	0.07	0.08	
Forest research. Inventory and planning	GP	0.22	0.16	0.28	0.27	0.29	0.23	0.04
	AHP	0.18	0.14	0.20	0.15	0.21	0.18	

ministration. Nevertheless, this economic activity has to be included in the hierarchy because it affects the economic results of forests.

The weights or local priorities of the action plans were obtained from the second questionnaire. We calculated the consensus matrix from all the consistent individual matrices first by using a goal programming model with $\lambda = 1$ (that is, aggregating majority judgments) and afterwards the local priorities by using the second model, as explained in section 2.3. All of the 11 consensus matrices obtained are consistent (inconsistency index less than or equal to 0.10).

Finally, the global priority of each action plan was calculated, weighting the local priorities with the importance of the objectives and the criteria using distribute mode. The sum of all global priorities of action plans is equal to 1 (Saaty, 2006). These global priorities can be used as one of the possible indicators for taking decisions in the distribution of the public budget assigned for the management of the forest, both public and private.

Fire prevention and extinction and reforestation and forestry have similar priorities, occupying the first or second place in all stakeholder groups. Forest research, inventory and planning are notable as they are the most relevant for the following three groups: forest research and education, forest owners and forestry companies (Table 2). These three action plans also occupy the first places for the hunting and fishing federation, with similar priorities. This group is not in Table 2 due to the lack of consistency in some matrices of the second level. The same situation happens with the land stewardship, environmentalist and conservationist groups. These groups are those with the fewest questionnaires. Nevertheless, from the available information from the land stewardship group, the strategy that occupies first place is trails and other recreational and tourist infrastructures. This line is the one that has the least importance for the other stakeholder groups being, globally, that with the lowest priority. Fourth place is occupied by flora and fauna management, followed by hunting and fishing species management. We would like to point out that the decision maker can derive priorities for all society by properly weighting stakeholder preferences. Priorities of *all groups* were obtained by integrating all stakeholder responses in one goal programming model to calculate a general consensus matrix and then using this matrix to derive global priorities.

The priorities of the strategies for the public forest are not very different from those for all forests. This is because there are no important differences between the weights of the objectives and criteria. In this case, forest research, inventory and planning have a slightly higher priority, occupying first place. The priority for the management of flora and fauna also increases slightly and those related to hunting and fishing and trails decrease.

Discussion and conclusions

First of all, we would like to emphasize that the principal results which were obtained from the two preference aggregation methods, geometric mean and eigenvalue and the goal programming are along the same lines, even though each have its own strengths and weaknesses. The eigenvalue technique requires that the index of inconsistency be less than or equal to 0.1, but this is not necessary in the goal programming method. However, in the analysis which we have made, only matrices which meet this requirement have been used so that we could compare the aggregated preferences and the global priorities using the same data.

The geometric mean guarantees that the matrix which represents the preferences or judgements of various persons has an index of inconsistency no greater than that of the individual matrix with the greatest index of inconsistency. However, goal programming models do not assure that the consensus matrices resulting from consistent individual matrices are consistent themselves. In our case study, when the judgements of the experts from the second survey are aggregated, all the matrices obtained were consistent, but this was not the case in all the consensus matrices obtained from the first survey.

Expert responses are generally more consistent than the responses from the other people involved who have less technical knowledge about forestry. In the previous section we commented on the lack of consistent responses from some stakeholder groups where only a few people took part in the survey. Other empirical works revealed similar problems with matrix consistency and have included in their analyses matrices that have higher indexes of inconsistency, up to 0.30 (Nordström *et al.*, 2010).

The investigation shows the greater importance of the environmental criteria over the economic and social criteria in the management of the Mediterranean forest. This result is the same regardless of which preference aggregation technique was used and takes into account

the preferences of the majority of the stakeholders and also the minority opinions furthest from the consensus. The relevancy of the environmental criteria is valid for both public and private forest.

Although there were differences between the values of the priorities obtained using AHP and Goal Programming, these differences decrease as the number of stakeholder surveys taken into consideration increase and, in general, the relative order of the priorities remains.

Experts were involved during the first phase of the design of the decision hierarchy. This was later validated in consultation with the stakeholders. We can improve the legitimacy of the final decision when all the stakeholders are involved in the decision making (FORSYS, 2011).

The public budget distribution during the last 5 years has been analysed. The greater part of the funds is destined for the prevention and extinction of fires, with an emphasis on extinction. It is of interest to note that the responsibility for extinction belongs to the fire service, not to the forest administration. Amongst the reasons for the great amount of budget dedicated to the extinction of forest fires are the high costs of this service, compared with other action plans. Additionally, this Mediterranean region is a high risk for forest fires, many of which present risks to housing and, above all, to human life. In summer, many people live in houses surrounded by forest. This has caused an increase in public spending to this end over the last few decades. For example, the budget was €112,421,579 in 2010, distributed as €86,290,812.86 for fire extinction, €24,785,508.12 for fire prevention and the rest for pest prevention. If we remove the budget for fire extinction from the total, a close relation between the budget dedicated to the different action plans and its relative importance obtained from the stakeholder preferences can be seen (Table 2).

To our knowledge, this is the only proposal at a regional level for the Mediterranean forest. A large number of objectives have been included, taken into account all the relevant aspects of sustainable management. There is a noticeably greater representation of the social objectives in this proposal, compared to works published by other authors for other regions and other scales. Another difference is the use of several multiple criteria techniques to aggregate preferences. The use of several techniques reinforces the results of the work, making them more objective and useful when looking for consensus in strategic decisions.

The model that has been developed could be refined using Analytic Network Process, the AHP generalization which considers dependences between criteria, in order to include things such as the negative effect of mining on the landscape and erosion. It could also be improved by an analysis of sensitivity, weighting the importance of the different groups of stakeholders. The priorities of "All Groups" have been obtained giving all stakeholders an equal value, and so more importance was given to groups with more representatives, such as administration.

In conclusion, this empirical research contributes a model for sustainable regional planning of the Mediterranean forest using a multiple criteria and group decision methodology with a participative process including all stakeholder groups. Our decision hierarchy is a complete model with detailed social, economic and environmental objectives and has been validated by the stakeholders. We have quantified the lesser relevance of economic criteria and the greater importance of environmental criteria in sustainable and participative management of the Mediterranean forest. Social criteria are more important than economic criteria for all stakeholder groups, except for forest owners and forestry companies. It has been demonstrated that this tendency varies very slightly between private and public forest, showing the importance of the environmental forest services to society, regardless of who owns it.

Referring to action plans, fire prevention and extinction and reforestation and forestry have similar global priorities, occupying first or second place for all stakeholder groups. Forest research, inventory and planning occupy third place in the social preferences, although it is the highest priority strategy for people involved in forest research and education, forest owners and forestry companies. Management of flora and fauna is in fourth place, followed by hunting and fishing and finally trails and other recreational and tourism infrastructures.

Finally, our contribution could be a methodological reference for developing decision aid models for strategic forest planning in other regions, in particular the Mediterranean arc, as well as to inform public policies in that area. The model we have developed is a framework within which management models on a lesser scale can be developed, and can also be used to evaluate the environmental services which are provided. In future works it would be interesting to develop, evaluate and compare models and tools for participative multi-

ple criteria decision making for the sustainable management of public forests and natural parks, using face-to-face and internet-based surveys, as well as small deliberation groups and workshops.

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Annex

Goal Programming models to aggregate stakeholder preferences and to derive weights of criteria

In this annex we summarise Goal Programming Models, an alternative method to AHP, to aggregate stakeholder preferences from comparison matrices and to obtain weights of criteria. From individual stakeholder matrices we have obtained a consensus matrix for each group using the Extended Goal Programming model developed by González-Pachón and Romero (2007).The decision variables of this model are the following:

— R_{ij}^{C} = Consensus ratio value that quantifies the aggregated preference when the ith criterion is compared with the jth criterion.

— N_{ij}^{K} and P_{ij}^{K} Negative and Positive deviation variables of the goal when stakeholder K is comparing criteria i and j.

— D = Maximum disagreement of stakeholders with respect to the values of the consensus matrix.

Consensus ratio variables have lower and upper bounds [1], due to Saaty's scale which we have used.

$$0.111 \le R_{ij}^{C} \le 9 \quad i,j = 1,2,\ldots,n \qquad [1]$$

If the consensus ratio value between two criteria is different from a stakeholder K value, this difference is the Negative or Positive deviation variables, as the model goals indicate [2].

$$R_{ij}^{C} + N_{ij}^{K} = R_{ij}^{K} + P_{ij}^{K} \quad i,j = 1,2,\ldots n \;\; i \neq j \quad K = 1\ldots m \qquad [2]$$

The sum of all deviation variables of stakeholder K is equal to or less than D, with as many restrictions as there are stakeholders [3].

$$\sum_{j=1}^{n}\sum_{i=1}^{n}(N_{ij}^{k} + P_{ij}^{k}) \le D \quad i,j = 1,2,\ldots,n \quad \mathrm{k} = 1,2,\ldots,n \qquad [3]$$

The achievement function is the following:

$$MIN\ (1-\lambda)\ D + \lambda\left(\sum_{j=1}^{n}\sum_{i=1}^{n}\sum_{k=1}^{n}(N_{ij}^{k} + P_{ij}^{k})\right) \qquad [4]$$
$$i,j = 1,2,\ldots,n \quad i \neq j \quad k = 1,2,\ldots,m$$

where λ is a control parameter. If $\lambda = 1$ we find the consensus matrix that minimizes the sum of all deviations of all stakeholders and that can therefore be considered in order to obtain the best solution from the point of view of most people. If $\lambda = 0$ we obtain the best solution from the point of view of the minority.

In the second step, we have derived the weights of the relative importance attached by the ith stakeholder group to the rth criterion from the consensus matrix using another Goal Programming model developed by González-Pachón and Romero (2004). In this model decision variables W_{ri} are the weights attached by the ith stakeholder group to the rth criterion. We also have Negative and Positive deviation variables of the goals and ith stakeholder group ($i = 1, 2,\ldots,m$).

We have goals to link criterion weights with the ratio values of the consensus matrix [5] as follows

$$W_{r}^{i} + N_{rs}^{i} = R_{rs}^{Ci}\, W_{si} + P_{rs}^{i} \quad r,s = 1,2,\ldots n \quad r \neq s \quad i = 1\ldots m \qquad [5]$$

We need to add constraints to reflect that the sum of all weights should be 1 for each stakeholder group i.

$$\sum_{r=1}^{n} W_{r}^{i} = 1 \quad r = 1,2,\ldots,n \quad i = 1,2,\ldots,m \qquad [6]$$

The achievement function is minimizing summation of all deviation variables for all criteria [7].

$$MIN \sum_{r=1}^{n}\sum_{s=1}^{n}(N_{rs}^{i} + P_{rs}^{i}) \quad r,s = 1,2,\ldots,n \quad r \neq s \quad i = 1,2,\ldots,m \qquad [7]$$