# Abstract

Multiple Criteria and Group Decision Making are powerful techniques for dealing with strategic decision problems from both public and private sectors. These approaches are essential when addressing issues related to the management of natural resources, forests in particular. Strategic forest planning has evolved from regulating the flow of industrial timber resources to its current focus on sustainable forest management. Nevertheless, many Ecosystem Services (ESS) are free and can disappear due to a lack of economic incentive to preserve them.

The main objectives of this research are the following. First, to analyse the models and methods in Decision Support Systems (DSS) for forest management, taking into account the important features which allow forestry related problems to be categorized. Second, to define strategic criteria for the sustainable management of Mediterranean forests, as well as to elicit and aggregate the stakeholders' preferences. Third, to propose a robust methodology to implement collaborative management focused on ESS and to develop indicators for the main functions of ESS.

The methodology is based principally on a workshop and surveys to elicit the decision makers', experts' and other stakeholders' preferences. Several techniques were then used to aggregate individual judgements and determine social preferences, in particular, Analytic Hierarchy Process (AHP) and Goal Programming (GP). In addition, a PROMETHEE based method has been developed to provide indicators of the ESS, classified into provisioning, maintenance and direct to citizens services.

The analysis of DSS for forest management has shown that the best choice of approach to solve a given problem depend on its nature, which can be characterized by the temporal scale (strategic, tactical, operational), spatial context, spatial scale (stand, forest/landscape, regional/national), number of decision makers or stakeholders, objectives (single, multiple) and finally goods and services involved. Simulation methods are related to the spatial context and spatial scale, as well as the number of people involved in taking a decision, more commonly being used on a smaller spatial scale, as well as when there is a single decision maker. On the contrary, there have been

no significant relationships between optimisation and statistical methods and problem characteristics.

With respect to the latest trends, the new generation of evolutionary algorithms gain importance when faced with Integer Programming (IP) solvers, but they require tuning parameters to be competitive and their values are dependent on instance data. Regarding statistical methods there is a need to develop and integrate spatial models in Geographic Information Systems (GIS) tools, which will be a requirement to tackle spatial problems and also to involve stakeholders in participatory processes.

The problems focused on forest products are mainly managed from a technical point of view, while those involving goods and services are related less to expert knowledge than to stakeholder preferences. Approximately 73% of problems have multiple objectives, nevertheless nowadays only 40% of them are solved using Multiple Criteria Decision Making (MCDM) techniques. These data show a strong need and also a great opportunity to improve the capabilities of DSS in this regard. Additionally, the majority of DSS are focused on market products, alone or together with services and a few dealing only with services, and especially with non-market services. It has been confirmed that forest DSS are mainly focused on technical and market economic objectives rather than social and environmental ones.

One of the most vulnerable ecosystems is the Mediterranean forest, according to the Intergovernmental Panel on Climate Change (2007). Valencian forest is a good example of the Mediterranean forest, which provides low wood productivity and also non-wood services. A decision hierarchy for strategic management of Valencian forests has been developed by involving experts during the design phase. This was later validated in consultation with the stakeholders in a workshop and provides the base from which to obtain the social preferences. The results show greater importance for environmental and social criteria and lesser relevance for economic criteria, valid for both public and private Mediterranean forests. 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. New products and services such as rural tourism, renewable energies, landscape, hydrological regulation and erosion control, biodiversity and climate change mitigation are relevant.

This research also proposes a robust methodology to implement collaborative management focused on ESS provided by protected areas and aggregated indicators for their main functions. Decision makers, technical staff and other stakeholders are included in the process from the beginning, by identifying ESS and eliciting preferences using the AHP method. Qualitative and quantitative data are then integrated into a PROMETHEE based method in order to obtain indicators for provisioning, maintenance and direct to citizens services. This methodology, which has been applied in a forest natural park, provides a tool for exploiting available technical and social data in a continuous process, as well as graphical results, which are easy to understand. This approach also overcomes the difficulties found in prioritising management objectives in a multiple criteria context with limited resources and facilitates consensus between all of the people involved. The new indicators define an innovative approach to assessing the ESS from the supply perspective and provide basic information to help establish payment systems for environmental services and compensation for natural disasters.

Finally, a comparative analysis between MCDM and Bayesian Belief Networks (BBN) is also included, pointing out the strengths and weaknesses of both approaches and their great potential for assessing ESS by using them in a hybrid methodology. One of the main strengths of BBN is that expert knowledge can be combined with empirical data, turning it into a useful method for environmental issues as is the case with MCDM. Both approaches allow the integration of qualitative and quantitative data, but availability of reliable data can represent an important challenge in both methodologies. New technologies to capture data will provide an opportunity to overcome this weakness, as well as a challenge to develop new models and methods that are really effective for assessing and managing ESS.