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RESEARCH ARTICLE

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Criteria and indicators for sustainable forestry under Mediterranean conditions applicable in Spain at the forest management unit scale

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Abstract

Aim of study: to identify criteria and indicators (C&I) of sustainable forest management (SFM) under Mediterranean conditions. The indicators are meant to monitor changes in the provision of ecosystem services at a local scale (forest management unit, FMU). We support that if a forest provides a bundle of ecosystem services its management can be considered sustainable; thus, we adjust C&I to an ecosystem services classification.

Area of study: La Hunde y La Palomera, a public FMU in the region of Valencia (east of Spain), 100km southwest of the city of Valencia.

Material and methods: first, a literature review of the following themes took part: SFM, features of Mediterranean forests, ecosystem services and C&I. Some C&I were proposed and, later on, a participatory process in Ayora, the municipality where the mentioned FMU is located, was carried out with different stakeholders (forestry professionals, users for recreation, hunters, environmentalists and professionals of cultural and rural development activities) in order for them to value the C&I proposed according to their management preferences for *La Hunde y La Palomera*.

Research highlights:

– 15 criteria and 133 indicators were identified: a balance has been achieved among economic, social and ecological concerns.
– People value the ecological issues associated to forestry on top and the economic ones at the bottom.
– Results suggest that SFM under Mediterranean conditions is based on more than one product and on the provision of several ecosystem services.

Key words: Sustainable forest management; ecosystem services; local scale, literature review, participation.

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Introduction

The concept of sustainable forest management (SFM) was first used at the *Earth Summit* held in Rio de Janeiro (UNCED, 1992) in reference to a type of management that considers social and environmental values of forests and other products apart from wood (Wijewardana, 2008). However, there is not a universal definition of SFM (Varma *et al.*, 2000); the relative importance of the different aspects that SFM covers varies depending on the natural and anthropogenic influences on each type of forest (Castañeda, 2000; Barbati *et al*., 2007). Criteria and indicators (C&I) constitute a tool to spread an understanding of SFM: they provide the means to translate sustainability principles into measurable goals and achievements (Wijewardana, 2008).

Monitoring and evaluation processes through C&I depend a lot on the subjectivity of the one who carries out the evaluation, its experience, values and interests.

To overcome this weakness of existing C&I standards[1], Pokorny & Adams (2003) suggest that the meaning of C&I has to be clear, which means that their writing should be simple, understandable and specific.

There is general agreement that international C&I standards cover the following thematic areas: (1) area of forest resources, (2) biodiversity conservation, (3) forest health and vitality, (4) and (5) productive and protective functions of forests, (6) social functions, and (7) legal, political and institutional framework (FAO, 2006). They are particularly weak in the social and cultural areas. This fact likely reflects the strong emphasis that forestry has traditionally placed on natural sciences and a perceived division over responsibility for the social elements of SFM (Gough *et al*., 2008).

Context

As aforementioned, the literature on SFM suggests that its objectives and strategies change depending on the type of forest; this fact is especially relevant under Mediterranean conditions, which have to be in mind to evaluate forestry practices (Osem *et al.*, 2008). These conditions have been summarised by Scarascia-Mugnozza *et al*. (2000), Fabbio *et al*. (2003) and Madrigal (2003), as follows (Valls *et al*. 2012):

Adaptation to a specific climate: a pronounced biseasonality with dry and hot summers, occasional heavy rains, a large year-to-year variability of total precipitation and strong winds that favour the spread of forest fires.
Species richness: the presence of a high diversity of plant and animal species, the Mediterranean area harbors around 25000 plant species whereas in the rest of Europe around 6000 plant species can be found. 50% of the Mediterranean flora is endemic.
Anthropogenic influence: the diversity of vegetation types, land-uses and landforms, results in a landscape that consists of a mosaic of patches. This is the result of a very long history of human occupation and overlaying of new elements without elimination of the old ones.
Fragility: due to heterogeneity, instability and low profitability. Heterogeneity is caused by diversity of species and habitat conditions (climate, soils). Instability results from summer drought, heavy rains, poor soils, and forest fires. Low profitability is derived from low productivity of Mediterranean forests.

These forests provide a diversity of goods and services, all of them known as ecosystem services (MA, 2005). The goods include edible products (fungus, pine nuts and other fruits), resins, cork or aromatic plants (rosemary). Forests in this region also provide ecological and social services, like protecting soil from erosion, keeping and improving the visual aspect of landscapes and serving as spaces for recreation (Scarascia-Mugnozza *et al*., 2000). These services are essential for rural development and for the well-being of urban populations (EFI, 2010).

Spain constitutes a case where Mediterranean conditions take place in most of the forests. Besides the features mentioned, forestry in this country presents some peculiarities which are described next:

Decentralization: regional governments have the authority in forest regulation (MMA, 1999). The decentralized model allows for adapted forest policies, but results in an uneven development in terms of budget, schedule and so on (MARM, 2008).
Property structure: most of the forest area is private (65%) and the forest management units (FMUs) are on the average small-sized (less than 3ha). This discourages many land owners to manage their land as they cannot harvest regularly (Tolosana *et al*., 2004).
Socio-economic conditions: there has been a depopulation of rural areas a few decades ago, so that the management of much land including forest has been abandoned (Marraco, 2004). The main forest product is timber, which together with firewood accounts for a 47.1% of the total forest production in Spain (Tolosana *et al*., 2004). Most of the timber produced goes to low added value industries like packing cases (Plana & Meya, 1999). Besides, the average price of one m^3 of wood in Spain to be paid to the forest owner in the year 2005 was of 46.49€, which is very low for a small property (MARM, 2010).

This research develops a case study in the region of Valencia (east of Spain). For this region a forestry plan has been elaborated: *Plan de Acción Territorial Forestal de la Comunitat Valenciana* (PATFOR). This plan proposes a forest management that stems from ecosystem services. Nowadays, most of the ecosystem services provided by Mediterranean forests do not result in any incomes to the forest owners. Besides, PATFOR states that the forests of this region go through an eco-

[1] Standard or set refers to a group of criteria and indicators that has been developed to monitor and assess the performance of forest management for specific ecological, social and economical conditions.

nomic, social and environmental crisis. The economic crisis derives from the low productivity of these ecosystems. The ecological and the social crisis are connected: the abandonment of forest management increases the density of vegetation favouring the spread of forest fires. The social crisis is also affected by a lack of organisation among the forest actors, bad communication with the society, and conflicting interests between forest owners and users (Generalitat Valenciana, 2011a).

The low productivity and the abandonment of forest lands represent a danger for the continuity in the provision of ecosystem services. It becomes then necessary to identify and define C&I for SFM that take into account ecosystem services together with their economic valuation (Generalitat Valenciana, 2011a).

Another pillar over which PATFOR builds forest management is the inclusion of participatory processes for decision making. This is to make the forest sector closer to people, to achieve a common vision among stakeholders and to share responsibility with society (Generalitat Valenciana, 2011a).

Aim and Objectives

The aim of this research is to answer this research question: "what has to be considered for SFM under Mediterranean conditions?" The specific objectives of this research are:

1. To identify C&I of SFM for Mediterranean forests, applicable at the scale of FMU and adapted to an ecosystem services framework, under the hypothesis that if forestry is oriented to maintain and improve the provision of ecosystem services it can be considered sustainable.
2. To test the realism and comprehensiveness of the issues covered by the C&I identified by means of a participatory process.

Material and methods

In order to adapt a typology of ecosystem services to Mediterranean conditions, different studies proposing them were revised. The inputs came mainly from the *Common International Classification on Ecosystem Services* (CICES) document (UN, 2010) and PATFOR (Generalitat Valenciana, 2011a). The first of them is a proposal of a United Nations expert committee. PATFOR adapts other existing frameworks to Mediterranean forests. Tables 1, 2 and 3 constitute a classification with examples of ecosystem services, and the references consulted. Then, to identify forestry criteria that maintain and improve their provision, those examples and kinds of the classification whose supply was considered that could be improved through management actions[2] were transformed into criteria (Table 4).

It was considered that the provisioning services category could be associated to the economic pillar of sustainable development, the regulating one to the ecological pillar and the cultural category to social issues. The criteria were classified in three groups: economic, social and ecological, according to the ecosystem services categories. The criteria are indicated next:

- Economic criteria: persistence and stability of forest resources, profitability of forest resources, diversified exploitation of forests.
- Social criteria: employment and working conditions, recreation, visual character, historical and cultural heritage, participatory processes, education, research.
- Ecological criteria: biodiversity and habitats, hydrological regulation, mass flows, forest fires, carbon storage.
-

It can be seen in Table 4 that the criteria *employment and working conditions* and *participatory processes* have not been associated to any ecosystem service kind or example. This is because they constitute requirements of forest management and thus have to be included as criteria, even though they do not maintain or improve the provision of any ecosystem service. On the other hand, no criteria have been associated to the following ecosystem services kinds:

- Service group *air flow regulation.*
- Service group *noise pollution reduction*.
- Service group *air quality regulation*.
- Service type *regional and local climate.*
- Service group *water quality regulation*.
- Service group *nutrient cycling.*
- Service type *fishing*.

The reason for not including them is because they happen either in specific situations or as a result of the management for providing other ecosystem services. The first situation corresponds to *noise pollution reduction*, *air quality regulation* and *fishing.* The first two

[2] Management actions refer to all the procedures and activities of forestry: from planning goals to silvicultural treatments.

Table 1. Provisioning ecosystem services: this category corresponds to tangible benefits that people get from forests with either material purposes (food, construction or decoration) or energetic. This table shows the sources where the ecosystem services kinds and examples are taken or inspired from. The ecosystem services examples that are relevant in Mediterranean forests are underlined.

S. Class	S. Group	Service Type	Examples
Nutrition (UN, 2010)	Edibles from terrestrial plants and animals (UN, 2010)	Livestock (UN, 2010)	Pastures, meat, milk and other edibles coming from animals (UN, 2010; Chiabai et al., 2011; Generalitat Valenciana, 2011a)
		Plants, wild animals and other wild living beings and their products (UN, 2010)	Mushrooms, truffles, honey, snails, wild asparagus, berries and seeds (pine nuts, sloes, acorns, arbutus fruits, blackberries, etc.) (Generalitat Valenciana, 2011a)
	Freshwater edibles (UN, 2010)	Animals (UN, 2010)	Macro invertebrates (UN, 2010)
		Plants (UN, 2010)	Water cress (UN, 2010)
Non-edible materials (UN, 2010)	Biotic (UN, 2010)	Plant origin (UN, 2010)	Wood, splinters, paper, cardboard, esparto, cork, resins (de Groot et al., 2010; Chiabai et al., 2011; Generalitat Valenciana, 2011a)
		Animal origin (UN, 2010)	Leather, furs, waxes (Chiabai et al., 2011)
		Ornamental resources (UN, 2010)	Flowers, stones, gems, ornamental and aromatic plants (moss, holly, mistletoe, rosemary, thyme, lavender, etc.) (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)
		Medicinal resources (UN, 2010)	Plants, active ingredients (de Groot et al., 2002; de Groot et al., 2010; Generalitat Valenciana, 2011a)
	Abiotic (UN, 2010)	Mineral resources (UN, 2010)	Salt (subsurface assets not included) (UN, 2010)
Energy (UN, 2010)	Renewable biofuels (UN, 2010)	Plant based resources (UN, 2010)	Firewood, peat, forest biomass (UN, 2010; Generalitat Valenciana, 2011a)
		Animal based resources (UN, 2010)	Dung, fat, oils (UN, 2010)
	Renewable abiotic (UN, 2010)		Wind, hydro, solar, thermal (UN, 2010)

Table 2. Regulating ecosystem services: this category refers to different ecosystem processes that are relevant for life itself and for humankind. This table shows the sources where the ecosystem services kinds and examples are taken or inspired from. The ecosystem services examples that are relevant in Mediterranean forests are underlined.

S. Class	S. Group	Service Type	Examples
Flow regulation (UN, 2010)	Air flow regulation (UN, 2010)		Windbreak, air circulation (UN, 2010)
	Water flow regulation (UN, 2010)	Natural drainage and irrigation (de Groot et al., 2002)	Directing the flow of water towards rivers and ravines (de Groot et al., 2002)
		Runoff regulation (UN, 2010; Generalitat Valenciana, 2011a)	Flood frequency and magnitude reduction and attenuation of discharge rates (UN, 2010; Generalitat Valenciana, 2011a)
		Water storage (UN, 2010)	Wetlands, natural springs, lakes, reservoirs and aquifers (UN, 2010; Generalitat Valenciana, 2011a)
	Earth flow regulation (UN, 2010)	Erosion control (de Groot et al., 2010; Generalitat Valenciana, 2011a; UN, 2010)	Minimise soil losses (de Groot et al., 2010; Generalitat Valenciana, 2011a)
		Mass flows regulation (UN, 2010)	Landslides, avalanches (UN, 2010)

Table 2 (cont.). Regulating ecosystem services: this category refers to different ecosystem processes that are relevant for life itself and for humankind. This table shows the sources where the ecosystem services kinds and examples are taken or inspired from. The ecosystem services examples that are relevant in Mediterranean forests are underlined.

S. Class	S. Group	Service Type	Examples
Physical environment regulation (UN, 2010)	Noise pollution reduction (de Groot et al.,2002)		
	Air quality regulation (de Groot et al., 2010)		Dust and chemicals capture, air oxygenation (de Groot et al., 2002; de Groot et al., 2010)
	Climate regulation (UN, 2010; Generalitat Valenciana, 2011a)	Global climate (UN, 2010; Generalitat Valenciana, 2011a)	Greenhouse gases, hydrological cycle (UN, 2010; Generalitat Valenciana, 2011a)
		Regional and local climate (UN, 2010; Generalitat Valenciana, 2011a)	Temperature, humidity, rainfall (UN, 2010; Generalitat Valenciana, 2011a)
	Water quality regulation (UN, 2010)	Water purification and oxygenation (UN, 2010)	Nutrient retention in buffer strips, nutrient translocation and water purification in wetlands (UN, 2010)
	Soils and their formation (UN, 2010)	Formation (de Groot et al., 2010)	Physical, chemical and biological pedogenesis (de Groot et al., 2010)
		Fertility (UN, 2010)	Organic residuals, N-fixing plants, activity of soil organisms (UN, 2010)
		Structure (UN, 2010)	Activity of soil organisms (UN, 2010)
	Nutrient cycling (Costanza et al., 1997)	Nutrient cycles in the ecosystem (Costanza et al., 1997)	Nutrient acquisition, cycling, processing and storage (Costanza et al., 1997)
		Regulation of wastes (recovery of mobile nutrients and reduction or removal of excess nutrients or compounds) (Costanza et al., 1997; de Groot et al., 2010; UN, 2010)	Plant and microorganism bioremediation, dilution, filtration of particulates and aerosols, and nutrient sequestration and absorption (UN, 2010)
Biotic environment regulation (UN, 2010)	Life cycle maintenance (UN, 2010)	Reproduction (Costanza et al., 1997; de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)	Pollination, seed dispersal, habitat for reproduction and bringing up (Costanza et al., 1997; de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)
		Other functions of living beings (Costanza et al., 1997; de Groot et al., 2010; UN, 2010)	Refuge and feeding habitat (Costanza et al., 1997; de Groot et al., 2010; UN, 2010)
	Pest and disease regulation (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)		Biological control by plants, animals and other microorganisms (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)
	Biodiversity maintenance (Costanza et al., 1997; de Groot et al., 2010; Generalitat Valenciana, 2011a)		Regulation of species populations, maintenance of species diversity and genetic diversity (Costanza et al., 1997; de Groot et al., 2010; Generalitat Valenciana, 2011a)
Forest fires regulation (Generalitat Valenciana, 2011a)			Species, vegetation and landscape structures that avoid fire spread and favour recovery after the fire (Generalitat Valenciana, 2011a)

services are relevant for humans in forest that are close to urban and industrial areas; *fishing* takes place in forests located next to a river, and the management of fish populations is a competence of the Central Government (Gobierno de España, 2001). *Air flow regulation*, *water quality regulation* and *nutrient cycling* occur in forests where vegetation and soils are kept in good conditions; these conditions are taken into account in other criteria, therefore, there is no need to consider them explicitly.

Further references and legislation were revised for describing and explaining the criteria (*Table 5*). Later on, some forest management experts were consulted about the criteria and their descriptions. They were both invited to participate and explained what the research was about and which the objectives of the consultation

Table 3. Cultural ecosystem services: this category includes psychological benefits (tranquility, reflection, isolation) and social benefits (group activities, maintenance and improvement of cultural heritage, promotion of science and education). They are difficult to measure and subjective in many cases. This table shows the sources where the ecosystem services kinds and examples are taken or inspired from. The ecosystem services examples that are relevant in Mediterranean forests are underlined.

S. Class	S. Group	Service Type	Examples
Symbolic and inspirational (UN, 2010)	Cultural heritage and aesthetic (UN, 2010)	Visual landscape (UN, 2010)	Aesthetic significance and information, outstanding features of the landscape, general appearance (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)
		Cultural landscape (UN, 2010)	Sense of place, <u>physical features (natural or manmade) holding a cultural/historical meaning</u> (de Groot et al., 2002; UN, 2010; Generalitat Valenciana, 2011a)
	Spiritual and religious (UN, 2010)	Naturalness (UN, 2010)	Tranquility, isolation (UN, 2010)
		Sacred character (UN, 2010)	Sacred places or species (UN, 2010)
		Intellectual development (Generalitat Valenciana, 2011a)	Experience and spiritual enrichment (meditation, yoga, reflection) (de Groot et al., 2010; Chiabai et al., 2011; Generalitat Valenciana, 2011a)
		Creativity (de Groot et al., 2002; de Groot et al., 2010)	Inspiration for culture, art and design (books, films, paintings, etc.) (de Groot et al., 2002; de Groot et al., 2010)
Information and knowledge (UN, 2010)	Leisure activities (UN, 2010)	Sports (de Groot et al., 2010; Generalitat Valenciana, 2011a)	Land, air and water sports (de Groot et al., 2010; Generalitat Valenciana, 2011a)
		Ecological-kind (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)	Fauna, flora and natural habitats observation and enjoyment (de Groot et al., 2010; UN, 2010; Generalitat Valenciana, 2011a)
		Hunting and fishing (UN, 2010; Generalitat Valenciana, 2011a)	Small and big game hunting, trout (UN, 2010; Generalitat Valenciana, 2011a)
		Recreation (de Groot et al., 2010; Generalitat Valenciana, 2011a)	Use of infrastructures (camping and recreation areas) (de Groot et al., 2010; Generalitat Valenciana, 2011a)
		Social relationships (MA, 2005)	Implicit in all leisure activities when practiced in groups (MA, 2005)
	Knowledge (UN, 2010)	Scientific research (de Groot et al., 2002; UN, 2010)	Pollen records, tree ring records, genetic patterns (UN, 2010)
		Education (MA, 2005; UN, 2010)	Educational excursions, seminars (de Groot et al., 2002)

Table 4. Criteria of SFM identified in this research as a result of the association of management actions to the different classes, groups, types and examples of ecosystem services that appear in the classification adapted for this research. Notice that all of the *economic criteria* are associated to the *provisioning services* category. The rest of the criteria are associated to specific ecosystem services kinds and examples.

Ecosystem services	Criteria of SFM
Provisioning services	Economic criteria
Service group *leisure activities*	Recreation
Service types *visual landscape*, *intellectual development* and *creativity*, and the example *sense of place* from the service type *cultural landscape*	Visual character
Service type *cultural landscape*, and service group *spiritual and religious*	Historical and cultural heritage
Service type *education*	Education
Service type *scientific research*	Research
Service class *biotic environment regulation*	Biodiversity and habitats
Service groups *water flow regulation* and *soils and their formation*, and service type *erosion control*	Hydrological regulation
Service type *mass flows regulation*	Mass flows
Service class *forest fires regulation*	Forest fires
The example *greenhouse gases* (only refers to CO_2), from the service type *global climate,* from the service group *climate regulation*	Carbon storage

were. Attached to the e-mail via which they were contacted, a file with the criteria was sent so that they were able to correct and comment on them. A total of 4 experts participated: 2 university academics and 2 civil servants. They were asked the following questions:

1. *Do these criteria cover the relevant issues of SFM in the Mediterranean region at the FMU level?*
2. *Are these criteria applicable?*
3. *Rephrase or comment on the writing of the criteria and their definitions if you think they could be improved.*

Next, to identify indicators of SFM, existing international C&I standards were revised: ATO/ITTO, 2003; UNDP/FAO/SADC, 1999; Montréal Process, 2007; ITTO, 2005; FAO, 1999; FAO, 1997; International Expert Meeting on Monitoring, Assessment and Reporting on the Progress towards Sustainable Forest Management, 2001; Kotwal *et al*., 2008; SFI, 2010; GTC-FSC, 2007; AENOR, 2007a; AENOR, 2007b. Other studies that propose C&I were also consulted (Table 7).

All the indicators taken from the review were classified according to the criteria identified. After this, indicators were rephrased to be simple and easily understandable, as recommended by Pokorny & Adams (2003). The last task consisted of proposing new indicators in the issues for which less attention had been paid in the literature.

Later on, a participatory process in *Ayora*, a village located 100km southwest from the city of Valencia, was carried out. Its objective was to test if the topics included by the C&I identified are comprehensive and realistic. For this step, and in order to facilitate the process to participants, the indicators were grouped into aspects, which are defined as the specific issues covered by a criterion. Their meaning is broader and their writing less technical than that of the indicators.

The process was open to anyone living there. Participants were asked to value the criteria and, for each criterion, the aspects that it covers. They valued according to their management preferences for a public forest located in the municipality of the village, which is called *La Hunde y La Palomera*. Several authors of academic papers propose to identify and pre-select C&I based on relevant literature, followed by a process of verification or refinement by stakeholders (Kurka & Blackwood, 2013).

The participatory process was publicly announced hanging papers on walls and shop windows, and it was advertised in the local radio. Local associations whose interests are related to forest management or forest conservation were personally contacted (via telephone or face-to-face) in order to get a representation of the different stakeholders involved.

Figure 1 displays the structure of the proposed standard for this research. Every participant received a questionnaire with 19 questions, each of them containing a list of elements to value: 15 questions to value the aspects of each criterion, 3 questions to value the criteria of each group and 1 question to value the three groups of criteria.

The weighting method selected corresponds to a multi-criteria analysis (MCA) technique described by

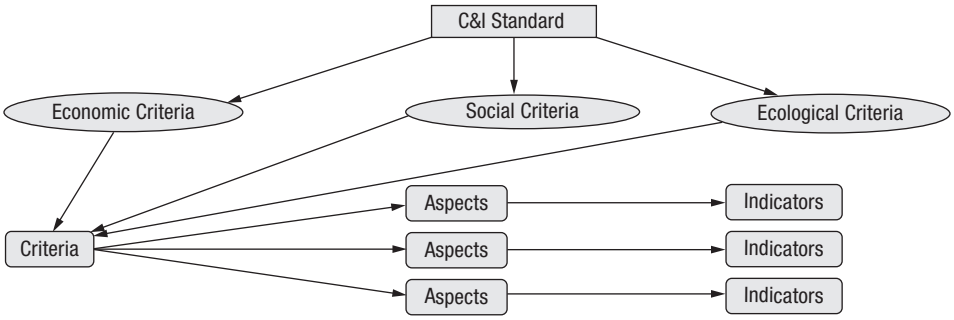

Figure 1. General structure of the criteria and indicator standard developed in this research. There are three criteria groups: economic, ecological and social; each group consists of several criteria, every criterion is made of various aspects, and a few indicators correspond to every aspect.

Table 5. Description of the criteria identified and references consulted (1) for the identification.

Criteria	Descriptions
Persistence and stability of forest resources	Management guarantees that a certain quantity of the forest resources stays in the FMU all the time and that it continues when biotic or abiotic disturbances occur (pests, fire).
Profitability of forest resources	Income generation (in-kind or money) as a result of the management, annual or periodic, variable or regular.
Diversified exploitation of forests	Inventory and determination of best use of present and potential forest goods and services.
Employment and working conditions	The number of job posts in the FMU is suitable to the activities necessary to carry out for the management, workers receive suitable training and there exist health and safety measures.
Recreation	There are infrastructures for the social use in its different kinds: taking a rest, trekking, fauna observation, camping, sports or hunting.
Visual character	Maintenance of the identifying visual properties of the FMU that make it attractive and improvement of them if they have been degraded.
Historical and cultural heritage	Management preserves the features and places of the FMU holding a historical or cultural meaning, either tangible (charcoal kilns) or intangible (pilgrimages), natural or artificial.
Participatory processes	Take account of stakeholders and affected people's experience and points of view in forest management decisions.
Education	Forest management favours society's education and awareness on the cultural, environmental and economic significance of forestry and natural areas.
Research	The use of forests as an object of scientific studies, either to improve the management (and the information on its goods and services) or to increase the knowledge of other disciplines (ecology).
Biodiversity and habitats	Management keeps species and habitats diversity and habitats conectivity in order to maintain and improve forest capacity to recover after disturbances.
Hydrological regulation	An important element of the hydrological cycle is vegetation that increases infiltration and reduces the quantity and speed of runoff. This attribute of vegetation offers important services: controls erosion, reduces the number and magnitude of floods and refills aquifers. The aim of this criterion is to maintain and improve these services through the management of vegetation structure and composition.
Mass flows	Management prevents landslides and avalanches.
Forest fires	Management prevents forest fires and facilitates extinction, so as to keep the frequency, intensity and consequences of forest fires in an ecologically sustainable and socially acceptable level.
Carbon storage	Forest management contributes to global climate change mitigation through maximising biomass synthesis and maintaining soil carbon storage capacity.

(1) AENOR, 2007a; Ayala *et al*., 2006; Deshler, 1979; EC (1992, 2000); EU, 2010; Euroquality &ASEMFO, 2002; FAO (2002, 2005); Generalitat Valenciana (1993, 2004, 2009, 2010, 2011a, 2011b); Gobierno de España (1985, 2002, 2003, 2006, 2007, 2011); ILO (1998, 2005); Mackay, 1949; Madrigal, 2003; Pemán & Navarro, 1998; Ruano, 2003; Thompson, 2011.

Gómez-Orea (2002) that is applied when participants are asked to value the elements of a list according to a predetermined scale whose values can be repeated. The elements of any question are valued giving a 1 to the most important for the participant and so progressively. As mentioned, the weighting method allowed participants to repeat values: for example, in a question comprising 7 elements, these could be valued 3-4-2-2-1-5-1; this would mean that for that participant there are two elements in the first order of importance and two in the second.

The aggregated weights of every aspect and every criterion, which take into account the values from all participants, are calculated following the method recommended by Gómez-Orea (2002). This method implies that the higher the value the better. However, in this research the lowest value (1) is the best. Therefore, the scale of the answers was inverted like this: value 1 changes into the number of elements of the list and it reduces progressively (this way the answers look like participants had valued according to a scale that equals the number of elements of the list). In the example aforementioned, it would be like asking participants to value 7 elements in a scale from 1 to7, the inverted scale would be:

1→7
2→6
3→5
4→4
5→3
6→2
7→1

The previous scheme shows for this example how would the values of the answers change when inverting the scale: on the left are the old values and on the right the new ones. The result would be 5-4-6-6-7-3-7. The inversion of the scales was done for all the questions of all the participants. Next, aggregated weights were calculated according to the method indicated, which consists of the following steps:

1. In every question a table was made that put the elements in rows and the participants in columns. The table was fulfilled with the inverted values from participants.
2. The sum of the inverted values of each participant was calculated at the bottom of each column.
3. Every number that fulfilled the table was divided by the sum of the inverted values that corresponded to its column.
4. The aggregated weight of each element was calculated summing all the new numbers in a row (calculated in step 3) and dividing this sum by the number of participants. The sum of the weights of all the elements in a question should be equal to 1.

Results

SFM criteria

A brief description of the resulting criteria and the bibliography consulted is provided in Table 5. A complete description appears in Suppl. file S1 [PDF on line].

A total of 15 criteria were identified: 3 economic, 7 social and 5 ecological. They take account of the multiple products (*diversified exploitation of forests*) and services of forests (*recreation*, *historical and cultural heritage, biodiversity and habitats*). Mediterranean features are considered in criteria like *forest fires* or *biodiversity and habitats*. The applicability of the criteria at the FMU scale can be seen in the fact that no consideration has been given to rural development and regular revenues, which are desirable outcomes of SFM but have to be considered at a regional level because they require association and coordinated actions among several forest owners (Madrigal, 2003). Besides, rural development needs the input of other sectors apart from forestry.

Indicators and aspects of the criteria

The number of indicators identified was 133; a subgroup of 24 indicators was proposed. The indicators have a simple writing, and a specific content. There are both quantitative and descriptive indicators. Many indicators serve to evaluate the state of the forest, but there are also indicators saying how to carry out certain management actions. Finally, there are indicators that encourage managers to innovate, like the ones referring to thinking of potential recreation activities and studying their demand.

The aspects that resulted from grouping the indicators to facilitate the participatory process are displayed in Table 6; this table allows an overview of what issues this research proposes to be relevant for sustainable management of Mediterranean forests. The indicators proposed together with the bibliography reviewed are in Table 7. In Suppl. file S2 [PDF on line] appears next to each indicator the references consulted for its identification.

Table 6. Aspects of the criteria and their descriptions.

Criteria	Aspects	Descriptions
Persistence and stability of forest resources	*New plants*	Management facilitates the establishment and growing of new tree individuals.
	Tree layer	Maintenance and improvement of its quantity and quality.
	Species diversity	Tree layer made of more than one species if possible.
	Genetic diversity	Among the individuals of any tree species population present in the forest.
	Non-wood products	Management for their persistence and stability: honey, fungi, etc.
	Pest treatments	Preventative and healing treatment of pests, diseases and other disturbances.
Profitability of forest resources	*In-kind incomes*	Management increases the quantity of forest resources in a given amount of time.
	Money incomes	Forest management products are sold and generate revenues to the owner.
	Demand	Study local demand and possible buyers of forest products prior to management.
Diversified exploitation of forests	*Diversification*	Forest incomes have to come from more than one product.
	Efficiency	Management based in the more profitable product combination.
Employment and working conditions	*Job posts*	The number of workers in the forest is suitable to the activities carried out.
	Training	Of workers and managers suitable to job post and to SFM objectives in general.
	Contract conditions	Timetables, responsibilities, salary, contract length, etc. have to be specified.
	Health and safety	Work risk prevention plans and measures.
Recreation	*Social use*	Users and frequency of use of recreational infrastructures.
	Infrastructures	Existence and quality of recreational infrastructures.
	Diversity	Recreational activity focused in more than one kind of activity.
	Demand	Study demand of new activities prior to their introduction.
	Hunting fauna	Provide proper habitats for this fauna as well as sustainable captures per year.
Visual character	*Outstanding elements*	Conservation of attractive elements due to their natural or human induced aspect.
	Watching areas	Existence of places where people can enjoy the visual landscape.
	Views	Quality of the views from the watching areas.
	Diversity	Visual landscape diversity in all the forest, which increases its quality.
	Visual integration	Human new affections on the visual landscape have to be integrated to keep the visual character.
Historical and cultural heritage	*Elements*	Human made items that lost their function and so represent traditional past activities (charcoal kilns, etc.).
	Traditions	Intangible items that people are used to practice regularly in specific moments.
	Places character	Conservation of the character of certain places holding a sacred or inspirational singnificance.
Participatory processes	*Representation*	All the stakeholders are represented.
	Leadership	Developers keep discussions on a track and make sure that input is evenly distributed among participants.
	Information	Participants have enough context information to give valuable and documented opinions.
	Objectives	Time, location and objectives of the process are clarified before it takes place.
	Transparency	Participants know and understand how decisions are made during or after the process.
	Acceptance	Participants accept the results of the process.
	Impacts	Participants perceive their input in the results.
	Social relationships	New relationships (work, friendship) or reinforcement of existing ones as a result of the process.

Table 6 (cont.). Aspects of the criteria and their descriptions.

Criteria	Aspects	Descriptions
Education	*Activities*	Promoting formative actions: excursions, information sessions.
	Infrastructures	Panels, information points to promote forest ecologic, economic and social values.
Research	*Monitoring*	Periodic monitoring and reporting on the state of the forest and the management.
	Research projects	Promote research to improve management and science knowledge.
Biodiversity and habitats	*Flora diversity*	Maintenance and improvement of the number of flora species in the forest.
	Fauna diversity	Maintenance and improvement of the number of fauna species in the forest.
	Endangered species	Maintenance and improvement of the populations of endangered species in the forest.
	Alien species	Control the entrance and propagation of exotic species.
	Habitats	Variety and conservation of existing habitats in the forest.
	Ecological connectivity	Connectivity among habitats and vegetation formations.
Hydrological regulation	*Erosion*	Minimise soil losses.
	Soil productivity	Maintenance and improvement of this soil capacity.
	Soil pollution	Avoid pollution due to fertilisers and pesticides.
	Aquifer filling	Vegetation structure that favours aquifer filling.
	Floods	Vegetation structure and infrastructures that avoid or control floods and reduce their devastating effects.
Mass flows	*Infrastructures*	Number and conservation state of preventative infrastructures (contention walls, etc.).
	Vegetation	Vegetation structure that prevents mass flow.
Forest fires	*Preventative silviculture*	Horizontal and vertical fuel discontinuities.
	Extinction aid silviculture	Creation of firebreak areas.
	Extinction infrastructures	Water deposits, tracks and other infrastructures that help fire extinction.
Carbon storage	*Vegetation*	Vegetation structure and composition that favour biomass synthesis.
	Soils	Maintain and improve soil capacity to store carbon.

Results of the participatory process

A group of 34 people participated. Their profiles were analysed and they were classified in the following groups: users for recreation (14 participants), environmentalists (9), hunters (2), forestry professionals (4, both with and without a university degree) and professionals of cultural and rural development activities (5).

The aggregated weights of the elements in most of the questions are similar. None of them receives a very low weight compared with the others of the same question. In this chapter only the answers to the questions showing meaningful differences for the aggregated weights of their elements are shown and analysed; these are presented in Figures 2, 3 and 4. Graphs showing the aggregated weights for the elements of all the questions are in Suppl. File S3 [PDF on line]. Besides, participants have not suggested adding any new elements to the standard.

Generally, the results show that participants value ecological issues on top and economic ones at the bottom. This is visible in the question in which they are asked to value the *groups of criteria* (Figure 4), but also in questions like the ones to value the aspects of the criteria *mass flows* and *profitability of forest resources* (Figure 2). In the case of *mass flows*, participants value prevention through *vegetation* (60%) more than through *infrastructures* (40%); whereas in the other case, they value *in-kind incomes* (43%) more than *money incomes* (24%). This preference towards ecological concerns is also visible in the valuation of the *economic criteria* (Figure 3), for which the highest

Table 7. Indicators identified for each criterion and references consulted (1) for the identification.

Criteria	Aspects	Indicators
Persistence and stability of forest resources	*New plants*	Number of new plants in harvested area a certain time after harvesting.
	Tree layer	Number of tree plants per area unit.
		Vigour/vitality of the trees of each species.
	Species diversity	Number of trees of each tree species per area unit.
	Genetic diversity	Number of individuals of the population of each tree species.
		In case of reforestations and enrichment plantations, the trees or seeds employed must be labelled and authorised.
		In case of reforestations and enrichment plantations, trees or seeds come from the same region where the forest is located.
		In case of reforestations and enrichment plantations, the origin of trees or seeds must be varied.
		Thinnings are not focused just on fast-growing individuals or those with a favourable morphology.
	Disturbances	Area affected by disturbances.
		Species are adapted to site conditions (soil and climate).
		A maximum time for harvest remainders is to stay in the forest is detrmined.
		Integrated pest management: chemical treatments are not used in a preventative manner and always used when there is no possible alternative way.
		Forest managers notice and inform on the existence of pests and diseases in their forests.
Profitability of forest resources	*In-kind incomes*	Current value of resources present in the forest.
		Percentage of forest managed for production.
	Money incomes	Incomes resulting from selling forest resources produced.
		Expenses resulting management operations.
		Incomes due to subsidies and other sources different from forest resources produced.
	Commercialisation	Demand estimation for the forest resources produced.
		Existing selling contracts.
Diversified exploitation of forests	*Diversification*	Forest area managed for the provision of each of the existing forest resources.
		Identification of possible resources to manage and sell.
		Demand estimation of possible resources to manage and sell.
	Efficiency	The exploitation of forest resources respects the maximum quantity per period that management plans establish.
		Estimation of the exploitation of possible resources to manage and sell.
		Estimated value of possible resources to manage and sell.
Employment and working conditions	*Job opportunities*	Number of employees in the forest.
		Number of job posts is suitable to the activities required for the management.
	Training	Workers' training is suitable for their posts.
		Training programs for workers and managers.
	Contract conditions	Salaries and incentives respect collective agreements and are in accordance with regional standards.
		Working hours and extra work incentives are established in the contract.
		Types of contracts depending on contract length and number of contracts of each type.
	Health and safety	There is a work risk prevention plan.
		Number of working accidents in a certain time period.
		Number of working diseases produced in a certain time period.

Table 7 (cont.). Indicators identified for each criterion and references consulted (1) for the identification.

Criteria	Aspects	Indicators
Recreation	*Hunting fauna*	Hunting species inventory. Captures number per species and time period. Hunting fauna infrastructures inventory.
	Social use	Forest area managed for recreational use. Number of visits for recreational purposes.
	Infrastructures	Recreational infrastructures inventory.
	Diversification	Types of recreational activities offered in the forest.
	Demand	Study potential recreational activities. Estimate demand of potential recreational activities.
Visual character	*Outstanding elements*	Visual outstanding elements inventory.
	Watching areas	Main watching areas inventory.
	Views	Watching areas views valuation by means of participatory processes.
	Diversity	Total forest area harvested the previous year. Length of tracks and firebreaks in the forest. Inventory of human elements (aerials, constructions, surveillance towers). Forest area not covered by trees. Forest area covered by trees. Forest area covered by scattered trees.
	Visual integration	Visual integration of recent human activities a little time after they have occurred. Unpleasant visual contrasts inventory.
Historical and cultural heritage	*Elements*	Tangible heritage elements inventory (natural o artificial).
	Traditions	Customs, traditions and resource rights of use inventory. Customs, traditions and resource right of use maintenance valuation by means of participatory processes.
	Places character	Inventory of places holding a religious, spiritual or inspirational value. Valuation by means of participation of the maintenance of the character of the places holding a religious, spiritual or inspirational value.
Participatory processes	*Representation*	Number of participating stakeholder groups. Participants number (total and by stakeholder groups). Management issues whose decision making includes participatory processes.
	Leadership	Conflicts and their causes. Solved conflicts. Topics addressed in the participatory process. Stakeholder groups or participants that have actively participated in the discussions. Agreements achieved.
	Information	Quality of the information on the topics to decide that participants have received.
	Objectives	Quality of the information on the objectives and expected development of the process that participants have received.
	Transparency	Participants understand how decisions are made when they do not take part in the final decision.
	Acceptance	Participants' level of acceptance of decisions made, once different points of view and process difficulties are understood.
	Impact	Participants perceive their input in the final decisions.
Education	*Activities*	Number of visits per time period with educational objectives. Number of informative sessions per period time. Existing agreements for educational visits and informative sessions.
	Infrastructures	Forest educational infrastructures inventory.
Research	*Monitoring*	Regularity in data gathering for monitoring. The information on the monitoring process is publicly reported.
	Research projects	Forest area where research projects take part. Existing agreements for research projects.

Table 7 (cont.). Indicators identified for each criterion and references consulted (1) for the identification.

Criteria	Aspects	Indicators
Biodiversity and habitats	*Flora diversity*	Flora species inventory (diversity and abundance).
		Vegetation layers in each vegetation formation.
	Fauna diversity	Wild fauna species inventory (diversity and abundance).
	Endangered species	Rare, endangered and endemic species inventory (species and abundance).
		Biodiversity conservation sites inventory.
	Alien species	Exotic species inventory.
		Study on the convenience and dangers of introducing exotic species.
		Inventory of species affected or disappeared because of exotic species.
	Habitats	Habitat conservation sites invnetory.
		Forest habitats inventory.
		Forest prioritary or relevent habitats inventory.
		Motor vehicles and forest machinery circulation restrictions.
		Presence of wood, dead trees and other habitat elements (stumps) where harvesting activities have occurred.
	Ecological connectivity	Vegetation formations and their limits inventory.
		Continuity/naturalness of vegetation formations limits determination.
		Fauna movement limitations exist to protect new plants or other justified cases.
Hydrological regulation	*Erosion*	Forest area affected by compaction.
		Forest area affected by erosion.
		Determination of the erosion types that occur in each case.
		Erosion vulnerable areas identification.
		Compaction vulnerable areas identification.
		Forest area managed for protection functions.
	Soil productivity	Nutrient inventory in plots regularly distributed in the forest every certain time.
		Pollutants inventory every certain time where fertilisers or pesticides have been applied.
		Restrictions for the application of fertilisers and pesticides: quantity, composition, time of the year and allowed products.
	Aquifer filling	Forest area managed to generate water surpluses for aquifer filling.
		Forest area suffering from soil infiltration problems.
	Floods	Human infrastructures (tracks, bridges) allow free water circulation in hillsides and natural water channels.
		Flood control infrastructures inventory.
		Vegetation quality in areas managed for protection functions.
Mass flows	*Infrastructures*	Mass flow regulation infrastructures inventory.
	Vegetation	Forest cover state in areas managed to prevent mass flow.
	Cartography and inventory	Mass flow risk areas identification.
		Inventory of mass flow events that have taken place.
		Forest area managed to prevent mass flow.
Forest fires	*Preventative silviculture*	Fuel discontinuities (including harvesting remainders) between vegetation layers.
		Bush density.
	Extinction aid infrastructures	Extinction aid infrastructures inventory.
	Affected forest	Forest area per time unit affected by forest fires.
		Types and magnitude of forest fires occurred.
		Forest fires causes.

Table 7 (cont.). Indicators identified for each criterion and references consulted (1) for the identification.

Criteria	Aspects	Indicators
Carbon storage	*Vegetation*	Total biomass in the forest (trunk, branches and leaves).
		Number of trees in young vegetation formations in areas managed to maximise biomass synthesis.
		Number of trees in adult vegetation formations in areas managed to maximise biomass synthesis.
		Bush density in bush formations in areas managed to maximise biomass synthesis.
		Forest area managed to maximise biomass synthesis.
	Soils	Forest area showing dry and cracked soils. Forest area where soil structure has been broken or altered.

(1) AENOR (2007a, 2007b); ATO/ITTO, 2003; Blackstock *et al*., 2007; Commonwealth of Australia, 1998; Eriksson & Lindhagen, 2001; FAO (1997, 1999, 2002); Generalitat Valenciana, 2011a; GTC-FSC, 2007; International expert meeting on monitoring, assessment and reporting on the progress towards sustainable forest management, 2001; ITTO, 2005; Kotwal *et al*., 2008; Madrigal, 2003; Menzel *et al*., 2012; Montréal Process, 2007; Moote *et al*., 1997; Mrosek & Balsillie, 2001; Mrosek *et al*., 2006; Pokharel & Larsen, 2007; Rowe & Frewer, 2000; SFI, 2010; Thompson, 2011; Tuler & Webler, 1999; UNDP/FAO/SADC, 1999.

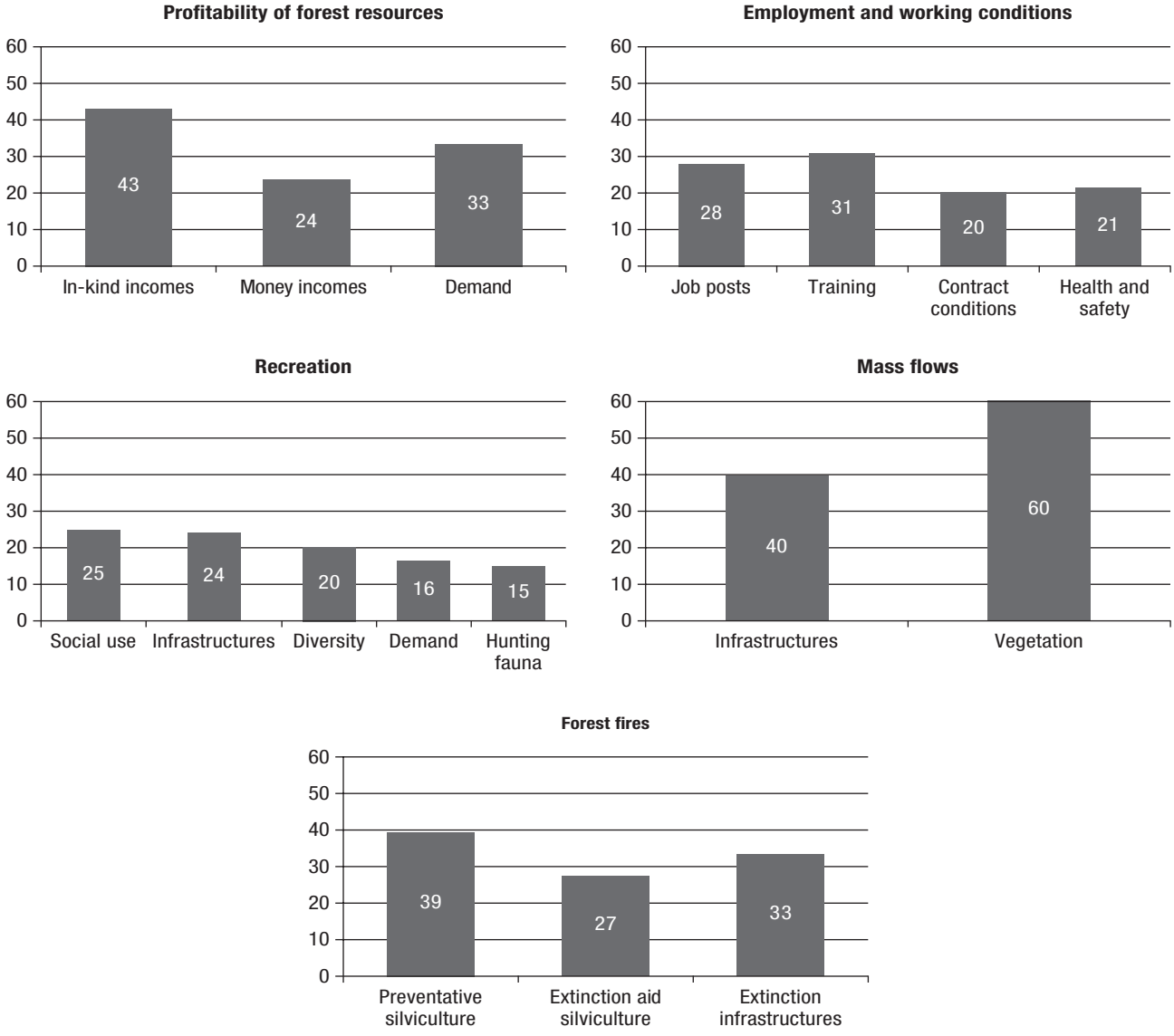

Figure 2. Aggregated weight (%) of the aspects of the criteria *profitability of forest resources*, *employment and working conditions*, *recreation*, *mass flows* and *forest fires.*

aggregated weight corresponds to *persistence and stability of forest resources* (44%) and the lowest one to *profitability of forest resources* (22%).

Concerning the criterion *employment and work conditions* (*Figure 2*), *training* is the aspect that gets the highest aggregated weight (31%) and *job opportunities* stays at a very similar level (28%). *Recreational activity* obtains high values for *social use* (25%) and *infrastructures* (24%). Finally, even though the three aspects of *forest fires* do not differ much, *extinction aid silviculture* has the lowest weight (27%) and *preventative silviculture* the highest one (39%). *Ecological criteria* (*Figure 3*) do not show big differences in their weights, but it can be noticed that *biodiversity and habitats*, *forest fires* and *hydrological regulation* are slightly higher valued (23%, 22% and 21% respectively) than *mass flows* and *carbon storage* (16% and 18%).

Discussion

This research dives into the considerations of SFM under Mediterranean conditions. A collection of 15 criteria applicable at the FMU level have been identified. These criteria intend to maintain and improve the provision of ecosystem services and cover the three pillars of SFM: economic, social and ecological. The existing C&I standards treat mainly ecological and resource quantity topics.

An assortment of 7 of the criteria identified in this research is social. The relevance of this type of issues is emphasized by other works. A similar study developed by Maroto *et al*. (2013) in the same region as this research (Valencia), but applied at a regional scale, highlights that social criteria of SFM are more important than economic ones for most stakeholder groups. Likewise, in a Mexican local community case study, the health of the forest was highly respected because the forest represented community pride, spiritual enjoyment, personal health and family cohesion. The researchers of this case study argued that the social dimensions of sustainability are more important where the economic role of forestry activities is marginal, like in most Mediterranean forests (Rodriguez-Piñeros & Lewis, 2013).

Ecosystem services are important in forests under all type of conditions. However, in Mediterranean forests they gain relevance because their productivity is low but the society appreciates and benefits from these services. Besides, the special characteristics of these forests make some of the ecosystem services, and therefore their associated criteria, very relevant:

- Heavy rains and scattered canopies increase the risk of erosion, mass flows and floods. These issues are considered in the criteria *hydrological regulation* and *mass flows.*
- The risk of big fires and pests make it necessary to manage resistant and resilient forests. This is mainly achieved through biodiversity, which is also worth maintaining because of its high value in Mediterranean forests. These concerns are tackled in the criteria *forest fires*, *persistence and stability of forest resources* and *biodiversity and habitats.*
- The cultural character of the landscape due to many years of intervention, addressed in the criterion *historical and cultural heritage.*
- Diversified exploitation as another means to overcome low profitability and because of the different products offered by Mediterranean forests: resins, truffles or cork; referred to in the criterion *diversified exploitation of forest.*

Apart from the benefits mentioned, applying an ecosystem services classification into the thinking of SFM has the advantage of encouraging an integrated approach with other land uses: a common language across sectors and more explicit focus on trade-offs and synergies. Nevertheless, it could happen that an incom-

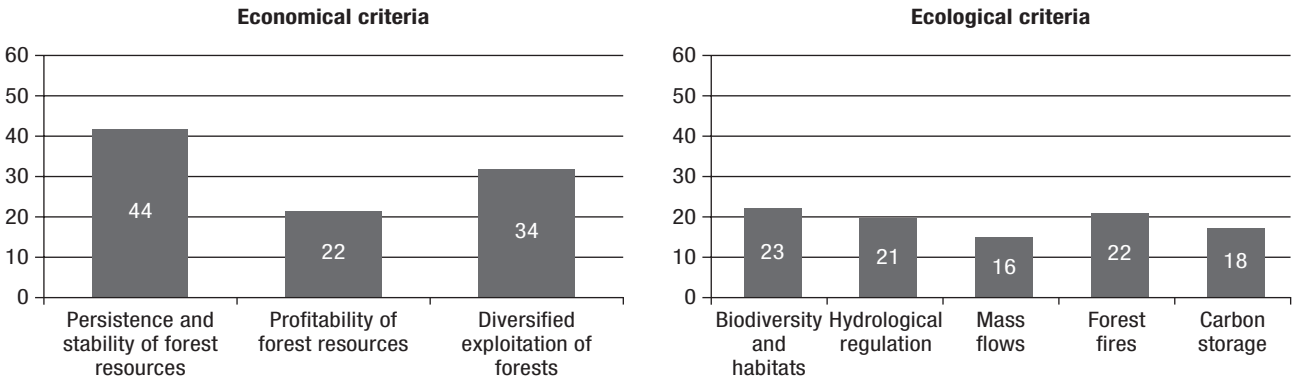

Figure 3. Aggregated weight (%) of the criteria of the groups *economic* and *ecological*.

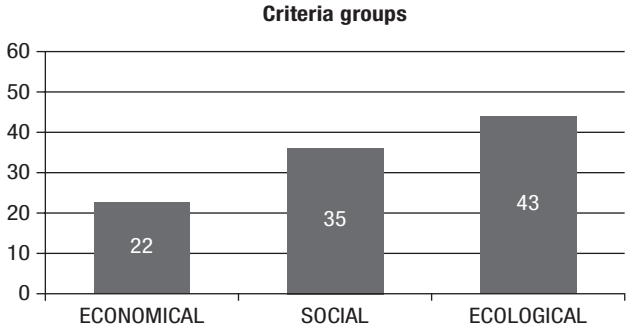

Figure 4. Aggregated weight (%) of the three groups of criteria.

plete valuation of the services pushes attention on the ones that are already quantified and monetised. Besides, emerging markets for single services may discourage multifunctional forests (Quine *et al*., 2013).

Regarding the indicators, an effort has been made for them to be simple and easy to know what has to be measured or considered. These two characteristics are hardly found in existing standards. For example, the indicators of *FSC-Spain* (GTC-FSC, 2007) are perceived as clear in what they refer to but made of very long sentences. On the other hand, the indicators of *PEFC-Spain* (AENOR, 2007a; AENOR, 2007b) are seen like having a simpler wording, quite clear in their objectives, but less clear on what variables or qualities to look at. The standard proposed in this work just intends to offer another option for forest managers that overcomes these perceived weaknesses, but not to stay above the work developed by others.

Concerning the participatory process developed to verify that the issues addressed by the C&I proposed are sensible, the groups of participants are representative of the stakeholders related to the forest. However, the amount of members in each group is not even but, on the whole, the total number of participants is considered enough to draw conclusions. Results reveal that participants value ecological issues on top, followed by social ones, and noticeably economic ones at the bottom. The study by Maroto *et al*. (2013) also acknowledges the lesser relevance of economic criteria and the greater importance of ecological criteria in sustainable and participative management of Mediterranean forests.

With respect to the valuing and aggregation method, Mendoza & Prabhu (2000) conclude that MCA techniques are excellent for prioritizing a list of C&I. They describe two similar methods (*ranking* and *rating*) for establishing a hierarchy among principles and criteria (similar to criteria and aspects, as it has been done in this research). The aggregated weights that result from the participatory process show that participants cannot establish preferences easily. Therefore, few priorities can be made among criteria and aspects but, on the other hand, it suggests that the standard proposed is applicable. Similarly, Mendoza & Prabhu (2000) propose the use of the *Analytic Hierarchy Process* (AHP) as the one *most involved and also providing the most information but also most complex and time consuming*. They recommend the use of AHP to examine the relative weights at the indicator level because *it is there where the principles and criteria are measurable and observable*, and this is how it is intended to proceed with this research in next stages.

A similar study to this one shows that the methods followed is quite common and that the indicators presented here constitute a starting point from which more work is needed. Maes *et al*. (2011) developed an indicator framework to be applied at stand level in Flanders (Belgium). Their framework was set up by the authors and a few experts, resulting in 19 criteria and 157 indicators, which were selected from literature and assigned to a criterion. Later on, a validation step was carried out. In words of Maes *et al*. (2011), only a validation procedure can transform a potential set of indicators into a suitable set. Future steps of this research will consider the performance of the indicators in a specific FMU for different management scenarios.

Conclusions

This research set out to identify C&I of SFM under Mediterranean conditions, adapted to an ecosystem services framework, and applicable at the FMU level. The process followed for the identification includes literature review of themes related to the research topic, an expert consultation to improve a set of criteria previously proposed and a participatory process to verify the issues considered in the C&I set. A standard comprising 15 criteria and 133 indicators has been developed as a result.

SFM is based on the multifunctional use and exploitation of forests and it considers the social and environmental implications and consequences associated to forestry. The concept of SFM and its application have to be adapted to the particular conditions of each case; this is especially relevant in Mediterranean forests due to their specific characteristics.

Existing C&I standards and studies focus on the ecological and productive issues of SFM; social and cultural ones usually appear all together in a single criterion. The development of a C&I standard based on the maintenance and enhancement of the provision of ecosystem services searches for a balance among the three pillars of sustainability: economic, social and ecological. The criteria identified in this research adapt

to an ecosystem services classification and so they cover these three pillars. The indicators proposed overcome another shortfall of existing C&I standards, whose wording is ambiguous and long. A big effort has been done for the indicators to have a simple and specific writing.

The results of the participatory process do not reveal big differences for most of the aggregated weights of the elements of the different questions. This findings make it difficult to establish priorities among criteria and aspects, but also suggest that the topics covered by the C&I proposed are suitable to Mediterranean conditions and that a standard adapted to ecosystem services is applicable.

This work has been conceived as an exploratory research. It has included top-down and bottom-up approaches to develop a proposal of C&I, which serves as a checklist of "what to look at" when managing Mediterranean forests sustainably. However, it remains to be seen whether the selected C&I can be successfully employed for decision making processes, by testing them in different scenarios in a specific case study. Besides, more case studies are needed to develop a general set applicable in Spanish forests under Mediterranean conditions. Nevertheless, this proposed set can serve for similar research or decision making situations as a starting point for C&I pre-selection. C&I constitute a piece of the puzzle; a sustainable management based on ecosystem services depends upon many drivers, not all of them coming from the forest sector (subsidies, payments for ecosystem services).

References

AENOR, 2007a. Gestión forestal sostenible. Criterios e indicadores. Parte 1: Genéricos para la unidad de gestión. Norma: UNE162002-1. Asociación Española de Normalización y Certificación: pp. 18. Madrid, Spain.

AENOR, 2007b. Gestión forestal sostenible. Criterios e indicadores. Parte 2: Complementarios para la evaluación a escala regional. Norma: UNE162002-2. Asociación Española de Normalización y Certificación, pp. 18. Madrid, Spain.

ATO/ITTO, 2003. ATO/ITTO principles, criteria and indicators for the sustainable management of African natural tropical forests. African Timber Organisation and International Tropical Timber Organisation, pp. 27.

Ayala FJ, Olcina J, Laín L, González A, 2006. Riesgos naturales y desarrollo sostenible: impacto, predicción y mitigación. Instituto Geológico y Minero de España. Ministerio de Educación y Ciencia. Madrid, Spain.

Barbati A, Corona P, Marchetti M, 2007. A forest typology for monitoring sustainable forest management: the case of European forest types. Plant Biosystems 1: 93-103. http://dx.doi.org/10.1080/11263500601153842

Blackstock KL, Kelly GJ, Horsey BL, 2007. Developing and applying a framework to evaluate participatory research for sustainability. Ecological Economics 60: 726-742. http://dx.doi.org/10.1016/j.ecolecon.2006.05.014

Castañeda F, 2000. Criteria and indicators for sustainable forest management: international processes, current status and the way ahead. Unasylva 203 (51): 34-40.

Chiabai A, Travisi CM, Markandya A, Ding H, Nunes PALD, 2011. Economic assessment of forest ecosystem services losses: cost of policy inaction. Environ Resource Econ 50: 405-455.http://dx.doi.org/10.1007/s10640-011-9478-6

Commonwealth of Australia, 1998. A framework of regional (sub-national) level criteria and indicators of sustainable forest management in Australia. Montréal Process Framework of Regional Indicators. Commonwealth of Australia. 120 pp.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M, 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260. http://dx.doi.org/10.1038/387253a0

de Groot RS, Wilson MA, Boumans RMJ, 2002 A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393-408.http://dx.doi.org/10.1016/S0921-8009(02)00089-7

de Groot RS, Fisher B, Christie M, Aronson J, Braat L, Haines-Young RH, Gowdy J, Killeen T, Maltby E, Neuville A, Polasky S, Portela R, Ring I, 2010. Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. Chapter 1 of The Economics of Ecosystems and Biodiversity (TEEB) study.

Deshler WO, 1979. Una guía para la aplicación del concepto de uso múltiple. Documento Técnico de Trabajo nº 1. Proyecto FAO/RLAT/TF. Santiago de Chile, Chile.

EC, 1992. Council Directive 92/43/EEC, of 21 May 1992, on the conservation of natural habitats and of wild fauna and flora. European Council. Brussels, Belgium. Official Journal of the European Communities L 206 of 22 July 1992.

EC, 2000. European Landscape Convention. European Council. Florence, Italy. European Treaty Series 176.

EFI, 2010. A Mediterranean Forest Research Agenda 2010-2020 – MFRA. European Forest Institute, Regional Mediterranean Office (EFIMED). Barcelona, Spain.

Eriksson L, Lindhagen A, 2001. A model indicating effects of multipurpose use of forestry on stand level. In: Franc A, Laroussinie O, Karjalainen T (Eds.), Criteria and indicators of sustainable forest management at the forest management unit level. European Forest Institute. EFI Proceedings Nº38, 21-25 March 2000, Nancy (France), pp. 247-260.

EU, 2010. Invasive alien species. Nature and Biodiversity. KH-78-09-558-EN-D. Available at:http://ec.europa.eu/environment/pubs/pdf/factsheets/Invasive%20Alien%20Species/Invasive_Alien_EN.pdf [13 Feb 15].

EUROQUALITY, ASEMFO, 2002. Manual para la asistencia técnica en prevención de riesgos laborales. Sector forestal. European Quality Assurance, Asociación Nacional de Empresas Forestales. Madrid, Spain.

Fabbio G, Merlo M, Tosi V, 2003. Silvicultural management in maintaining biodiversity and resistance of forests in Europe – the Mediterranean region. Journal of Environmental Management 67: 67-76.http://dx.doi.org/10.1016/S0301-4797(02)00189-5

FAO, 1997. Results of the FAO-CCAB-AP experts' meeting on criteria and indicators on sustainable forest management for Central America. Tegucigalpa, Honduras.

FAO, 1999. Practical guidelines for the implementation of criteria and indicators for sustainable forest management in the Near East Region. United Nations Environment Program, Near East Regional Office. El Cairo, Egypt.

FAO, 2002. Captura de carbono en los suelos para un mejor manejo de la tierra. United Nations Food and Agriculture Organisation. Rome, Italy. Informe sobre recursos mundiales de suelos 96. Available at:ftp://ftp.fao.org/agl/agll/docs/wsrr96s.pdf

FAO, 2005. Optimización de la humedad del suelo para la producción vegetal. El significado de la porosidad del suelo. Servicio de Manejo de las Tierras y de la Nutrición de las Plantas. United Nations Food and Agriculture Organisation. Rome, Italy. Boletín de Suelos de la FAO 79. Available at:ftp://ftp.fao.org/docrep/fao/008/y4690s/y4690s00.pdf

FAO, 2006. Global forest resources assessment 2005 – Progress towards sustainable forest management. FAO Forestry paper 147.

Generalitat Valenciana, 1993. Ley 3/1993, de 9 de diciembre, forestal de la Comunidad Valenciana. Valencia, Spain. Diario Oficial de la Generalitat Valenciana, de 21 de diciembre, nº 2168.

Generalitat Valenciana, 2004. Decreto 32/2004, de 27 de febrero, del Consell de la Generalitat, por el que se crea y regula el Catálogo Valenciano de Especies de Fauna Amenazadas, y se establecen categorías y normas para su protección. Conselleria de Territori i Habitatge. Valencia, Spain. Diario Oficial de la Generalitat Valenciana, de 4 de marzo, nº 4705.

Generalitat Valenciana, 2009. Decreto 70/2009, de 22 de mayo, del Consell, por el que se crea y regula el Catálogo Valenciano de Especies de Flora Amenazadas y se regulan medidas adicionales de conservación. Conselleria de Medi Ambient, Aigua, Urbanisme i Habitatge. Valencia, Spain. Diario Oficial de la Generalitat Valenciana, de 26 de mayo, nº 6021.

Generalitat Valenciana, 2010. Pago por servicios ambientales. Una introducción. Conselleria de Medi Ambient, Aigua Urbanisme i Habitatge. Generalitat Valenciana, pp. 16. Valencia, Spain.

Generalitat Valenciana, 2011a. Versión preliminar del Plan de Acción Territorial Forestal de la Comunidad Valenciana (PATFOR). Conselleria de Medi Ambient, Aigua Urbanisme i Habitatge. Generalitat Valenciana, pp. 533. Valencia, Spain.

Generalitat Valenciana, 2011b. Programa valenciano de conservación de recursos genéticos forestales 2011-2020. ECOGEN. Conselleria de Infraestructuras, Territorio y Medio Ambiente. Valencia, Spain.

Gobierno de España, 1985. Ley 16/1985, de 25 de junio, del patrimonio histórico español. Madrid, Spain. Boletín Oficial del Estado, de 29 de junio de 1985, nº 155.

Gobierno de España, 2001. Real Decreto Legislativo 1/2001, de 20 de julio, por el que se aprueba el texto refundido de la ley de aguas. Madrid, Spain. Boletín Oficial del Estado, de 24 de julio de 2001, nº 176.

Gobierno de España, 2002. Plan Forestal Español. Dirección General de Conservación de la Naturaleza. Ministerio de Medio Ambiente. Madrid, Spain.

Gobierno de España, 2003. Ley 43/2003, de 21 de noviembre, de montes. Madrid, Spain. Boletín Oficial del Estado, de 22 de noviembre de 2003, nº 280.

Gobierno de España, 2006. Trabajos forestales. Comisión Nacional de Seguridad y Salud en el Trabajo. Ministerio de Empleo y Seguridad Social. Madrid, Spain.

Gobierno de España, 2007. Ley 42/2007, de 13 de diciembre, del patrimonio natural y de la biodiversidad. Madrid, Spain. Boletín Oficial del Estado, de 14 de diciembre de 2007, nº 299.

Gobierno de España, 2011. Real Decreto 139/2011, de 4 de febrero, para el desarrollo del Listado de Especies Silvestres en Régimen de Protección Especial y del Catálogo Español de Especies Amenazadas. Madrid, Spain. Boletín Oficial del Estado, de 23 de febrero de 2011, nº 46.

Gómez-Orea, D., 2002. Evaluación de impacto ambiental. Mundi-Prensa. Madrid, Spain.

Gough AD, Innes JL, Allen SD, 2008. Development of common indicators of sustainable forest management. Ecological Indicators 8: 425-430. http://dx.doi.org/10.1016/j.ecolind.2007.03.001

GTC-FSC, 2007. Estándares españoles de gestión forestal para la certificación FSC. Grupo de trabajo español para la certificación FSC, pp. 98. Madrid, Spain.

ILO, 1998. ILO code of practice: safety and health in forestry work. International Labour Organisation. Geneva, Switzerland.

ILO, 2005. Guidelines for labour inspection in forestry. International Labour Organisation. Geneva, Switzerland. MELIF/2005/8.

International expert meeting on monitoring, assessment and reporting on the progress towards sustainable forest management, 2001. Tarapoto Process on the Amazon forest's sustainability criteria and indicators, pp 16. Yokohama, Japan.

ITTO, 2005. Revised ITTO criteria and indicators for the sustainable management of tropical forests including a report template. International Tropical Timber Organisation, pp. 41.

Kotwal PC, Omprakash MD, Gairola S, Dugaya D, 2008. Ecological indicators: imperative to sustainable forest management. Ecological Indicators 8: 104-107. http://dx.doi.org/10.1016/j.ecolind.2007.01.004

Kurka T, Blackwood D, 2013. Participatory selection of sustainability criteria and indicators for bioenergy developments. Renewable and Sustainable Energy Reviews 24: 92-102.http://dx.doi.org/10.1016/j.rser.2013.03.062

MA (MILLENNIUM ECOSYSTEM ASSESSMENT), 2005. Ecosystems and Human Well-being: Synthesis. Island Press. Washington DC, pp. 137. United States.

Mackay E, 1949. Fundamentos y métodos de la ordenación de montes. Segunda parte: ordenación técnica, condiciones de

aplicación, inventario dasocrático, métodos de ordenación. Escuela Especial de Ingenieros de Montes. Madrid, Spain.

Madrigal A, 2003. Ordenación de montes arbolados. Dirección General de Conservación de la Naturaleza. MARM. Madrid, Spain.

Maes WH, Fontaine M, Rongé K, Hermy M, Muys B, 2011. A quantitative indicator framework for stand level evaluation and monitoring of environmentally sustainable forest management. Ecological Indicators 11: 468-479. http://dx.doi.org/10.1016/j.ecolind.2010.07.001

MARM, 2008. Anuario de estadística forestal 2008. Dirección General de Medio Natural y Política Forestal. Madrid, Spain.

MARM, 2010. Evaluación de los recursos forestales mundiales 2010. Informe nacional, España. Dirección General de Medio Natural y Política Forestal. Madrid, Spain.

Maroto C, Segura M, Ginestar C, Uriol J, Segura B, 2013. Sustainable forest management in a Mediterranean region: social preferences. Forest Systems 22(3): 546-558.http://dx.doi.org/10.5424/fs/2013223-04135

Marraco S, 2004. Gestión forestal sostenible: retos y dificultades. 7ª edición del Congreso Nacional de Medio Ambiente (CONAMA VII). Madrid, Spain.

Mendoza GA, Prabhu R, 2000. Multiple criteria decision making approaches to assessing forest sustainability using criteria and indicators: a case study. For Ecol Manage 131: 107-126.

Menzel S, Nordström EM, Buchecker M, Marques A, Saarikoski H, Kangas A, 2012. Decision support systems in forest management: requirements from a participatory planning perspective. Eur J Forest Res. 131: 1367-1379. http://dx.doi.org/10.1007/s10342-012-0604-y

MMA, 1999. Estrategia Forestal Española. Dirección General de Conservación de la Naturaleza. Madrid, Spain.

Montréal Process, 2007. Criteria and indicators for the conservation and sustainable management of temperate and boreal forests. Annex F. Third Edition. The Montréal Process, pp. 12.

Moote MA, McClaran MP, Chickering DK, 1997. Theory in practice: applying participatory democracy theory to public land planning. Environ Manage 21: 877-889. http://dx.doi.org/10.1007/s002679900074

Mrosek T, Balsillie D, 2001. Development and testing of a criteria and indicator system for sustainable forest management at the forest management unit level: case study at the Haliburton Forest and Wild Life Reserve Ltd., Ontario, Canada. In: Franc A, Laroussinie O, Karjalainen T (Eds.), Criteria and indicators of sustainable forest management at the forest management unit level. European Forest Institute. EFI Proceedings Nº38, 21-25 March 2000, Nancy (France), pp. 247-260.

Mrosek T, Balsillie D, Schleifenbaum P, 2006. Field testing of a criteria and indicator system for sustainable forest management at the local level. Case study results concerning the sustainability of the private forest Haliburton Forest and Wild Life Reserve in Ontario, Canada. Forest Pol Econom 8: 593-609.http://dx.doi.org/10.1016/j.forpol.2004.11.002

Osem Y, Ginsberg P, Tauber I, Atzmon N, Perevolotsky A, 2008. Sustainable management of Mediterranean planted coniferous forests: an Israeli definition. Journal of Forestry, January/February 2008: 38-46.

Pemán J, Navarro R, 1998. Repoblaciones forestales. Edicions de la Universitat de Lleida. Lérida, Spain.

Plana E, Meya D, 1999. La certificación forestal como instrumento de política forestal, hacia una gestión sostenible de los bosques. IV Forum de Política Forestal (conference). Centre Tecnològic Forestal de Catalunya. Solsona, Spain.

Pokharel RK, Larsen HO, 2007. Local vs. official criteria and indicators for evaluating community forest management. Forestry 80(2): 183-192. http://dx.doi.org/10.1093/forestry/cpm005

Pokorny B, Adams M, 2003. What do criteria and indicators assess? An analysis of five C&I sets relevant for forest management in the Brazilian Amazon. Internat Forest Rev 5(1): 20-28.http://dx.doi.org/10.1505/IFOR.5.1.20.17434

Quine CP, Bailey SA, Watts K, 2013. The UK National Ecosystem Assessment: a practitioner's perspective. Sustainable forest management in a time of ecosystem services frameworks: common ground and consequences. J Appl Ecol 50: 863-867. http://dx.doi.org/10.1111/1365-2664.12068

Rodriguez-Piñeros S, Lewis DK, 2013. Analysis and deliberation as a mechanism to assess changes in preferences for indicators of sustainable forest management: a case study in Puebla, Mexico. J Environ Manage 128: 52-61. http://dx.doi.org/10.1016/j.jenvman.2013.04.051

Rowe G, Frewer LJ, 2000. Public participation methods: a framework for evaluation. Sci, Technol Human Values 25(1): 3-29. http://dx.doi.org/10.1177/016224390002500101

Ruano JR, 2003. Viveros forestales. Manual de cultivo y proyectos. Ediciones Mundi-Prensa. Madrid, Spain.

Scarascia-Mugnozza G, Oswald H, Piussi P, Radoglou K, 2000. Forests of the Mediterranean region: gaps in knowledge and research needs. For Ecol Manage 132: 97-109.

SFI, 2010. Requirements for the SFI 2010-2014 Program. The Sustainable Forestry Initiative Inc, pp. 119.

Thompson I, 2011. Biodiversidad, umbrales ecosistémicos, resiliencia y degradación forestal. Unasylva 238 62 (2): 25-30.

Tolosana E, Ambrosio Y, Vignote S, 2004. Aspectos económicos de la certificación forestal, particularidades del sector (Parte I). Revista del Colegio de Ingenieros de Montes 77: 33-35.

Tuler S, Webler T, 1999. Voices from the forest: what participants expect of a public participation process. Soc Nat Resource 12(5): 437-453. http://dx.doi.org/10.1080/089419299279524

UN, 2010. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. Fifth Meeting of the United Nations Committee of Environmental-Economic Accounting. Department of Economic and Social Affairs. pp. 30. New York.

UNCED, 1992. Non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests. United Nations Conference on Environment and Development. Rio de Janeiro, Brazil.

UNDP/FAO/SADC, 1999. Criteria and Indicators for Sustainable Forest Management in SADC countries within the Framework of the Dry-Zone Africa Process. Meeting between the United Nations Development Program, the Food and Agriculture Organisation and the South African Development Community, pp. 8. Lilongwe, Malawi.

Valls P, Jakesová L, Vallés M, Galiana F, 2012. Sustainability of Mediterranean Spanish Forest Management through Stakeholder Views. European Countryside 4/2012: 269-282.

Varma VK, Ferguson I, Wild I, 2000. Decision support system for the sustainable forest management. For Ecol Manage 128: 49-55.

Wijewardana D, 2008. Criteria and indicators for sustainable forest management: the road travelled and the way ahead. Ecological Indicators 8: 115-122. http://dx.doi.org/10.1016/j.ecolind.2006.11.003