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ORGEST: Regional guidelines and silvicultural models for sustainable forest management

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Abstract

Aim of study: To develop regional guidelines for sustainable forest management.

Area of study: Forests of Catalonia (NE Spain).

Material and methods: The process of developing the forest management guidelines (FMG) started by establishing a thorough classification of forest types at stand level. This classification hinges on two attributes: tree species composition and site quality based on ecological variables, which together determine potential productivity. From there, the management guidelines establish certain objectives and silvicultural models for each forest type. The forest type classifications, like the silvicultural models, were produced using both existing and newly-built growth models based on data from the National Forest Inventory (NFI) and expert knowledge. The effort involved over 20 expert working groups in order to better integrate the expertise and vision of different sectorial agents.

Main results: The FMG consist in quantitative silvicultural models that include typical silvicultural variables, technical descriptions of treatments and codes of good practice. Guidelines now cover almost all forest types in Catalonia (spanning up to 90% of the Catalan forest area). Different silvicultural models have been developed for pure and mixed stands, different site quality classes (2–3 classes per species), and even- and multi-aged stands.

Research highlights: FMG: i) orient the management of private and public forests, (ii) provide a technical scaffold for efficient allocation/investment of public subsidies in forest management, and (iii) bridge forest planning instruments at regional (strategic-tactical) and stand (operational) level.

Additional keywords: forest types; site quality; expert approach; National Forest Inventory; multifunctionality; fire prevention; best forest management practices.

Abbreviations used: FMG (Forest Management Guidelines); NFI (National Forest Inventory); ORGEST (Sustainable Forest Management Guidelines for the Catalonia region, NE Spain).

Authors´ contributions Conceived, designed and performed the work; coordinated the project and obtained funding; wrote the paper: MP. Analyzed and interpreted the data: MB, PV and MP. Revised the manuscript: PV and MB.

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Introduction

Forest management has become progressively more complex and subject to sharper and wider social demands (Behan, 1990; Wiersum, 1995), creating a need for new tools to address the challenge (Puettmann, 2011; Piqué & Vericat, 2014). Catalonia (NE Spain) is no exception, as sliding profitability, threat of forest fires, global change and the mosaic of social demands have resulted in a comprehensive, cross-sectorial legal framework requiring a multifunctional and sustainable vision of forest management (Saura & Piqué, 2006).

Forest systems, especially Mediterranean systems, provide a number of extremely valuable and varied functions, from timber and non-wood forest products to soil protection, biodiversity, landscape, CO_2 fixation, water regulation, habitat, and more. Furthermore, climate change is expected to have deep consequences for the conservation and functionality of Mediterranean forests (Palahí *et al*., 2008). There is therefore a pressing need for tools to orient forest management to meet these different functions while remaining sustainable and coping with climate change.

Forest management guidelines (FMG) are widely used technical tools for improving sustainable forest management. Many countries have forest management guidelines or directives: Canada has issued "Guidebooks" (*i.e.* BCMF, 2002; Delaney, 2003), France has issued "Silvicultural Guides" (*i.e.* ONF, 1999; Gauquelin & Courbaud, 2006) as well as "Regional Schemes of Silviculture Management" (*i.e.* CRPF, 2001; 2004; 2011), and there are other examples in Europe and the US.

Guidelines provide practical, applicable and updated information to forest managers at operational level. They usefully inform multifunctional forest planning and decision-making, including the efficient allocation of public resources, and in the wider picture, they serve as a scaffold for adapting forest management decisions and practices to climate change.

In parallel, a key management focus for Mediterranean forests is the integration of forest fires as the main disturbance (Costa *et al.*, 2011), making it necessary to develop guidelines combining the objectives of forest production and wildfire prevention.

In 2004, the Forest Ownership Centre (Catalan Ministry of Agriculture) commissioned the elaboration of Sustainable FMG for the Catalonia region, NE Spain (ORGEST) to ensure sustainable and multifunctional forest management in today's context of global change.

The objectives established for the FMG were: guiding the management of private- and public-owned forests in Catalonia; giving technical information for efficiently meeting management objectives; bridging forest planning instruments from regional level (strategical natural resources planning) to stand level (applied forest management planning); ensuring the continued ecological and socioeconomic value of the forests; providing a technical scaffold for efficient allocation of public funds within forest management policies.

The main aim of the present work was to expose the general process to elaborate the ORGEST and present the main silvicultural models and tools developed to guide sustainable forest management in Catalonia region.

Material and methods

Process of elaborating the ORGEST

Forest types

Prior to creating the FMG, we developed a classification of forest types at stand level, based on analysis of National Forest Inventory (NFI) data (ICONA, 1994; DGCN, 2005), comprehensive bibliographic review, and expert knowledge (enrolling 20-odd working groups). The classification was based on two attributes: i) tree species composition and related density variables (number of trees per hectare, basal area and crown cover), and ii) site quality, based on ecological variables, which determines species adaptation, vitality and potential productivity.

The combination of forest types (species composition and site quality at stand level) with other relevant indicators reveals the stand's vocation and; from there, the main objectives and appropriate FMG to assign (Fig. S1).

Concerning species composition (Fig. 1), we elaborated a classification of pure (when one species accounts for at least the 80% of total basal area) and mixed forests (stands with more than one species, none of which dominate more than 80% of total basal area). Data from 11,859 NFI plots highlighted the huge importance of mixed stands, which represented 46% of total forest cover in Catalonia.

Concerning site-quality classifications, experts determined that only two or three quality classes need to be differentiated for most species, based on the premise that it is only rational to set different

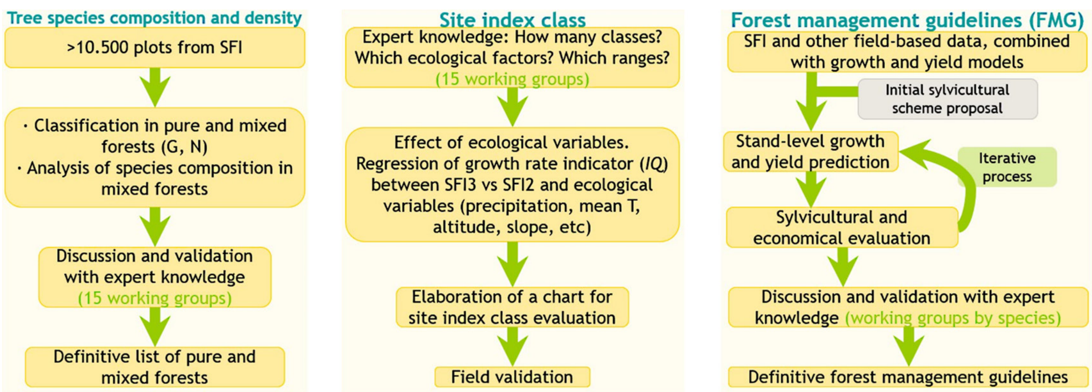


Figure 1. Scheme of the ORGEST elaboration process. From left to right: species composition analysis, site index classification, and management guidelines creation (G, basal area; N, stand density).

site qualities when they lead to different goals and management schemes.

The process of defining site-quality classes for each species based on ecological variables involved two stages. First, we led expert-panel group sessions to establish the number of classes needed and identify the key ecological variables related to site quality, including their relative importance and ranges. Second, we ran statistical analyses on the relationship between growth indicators obtained from the NFI and certain ecological variables readily identifiable by managers (*i.e*. Vericat *et al*., 2013). This process resulted in site quality charts that serve to assign a quality class based on environmental variables.

Forest management guidelines (FMG)

Silvicultural models and FMG were also developed based on NFI data and other field-base data, combined with complete bibliographic review of growth and yield models (*i.e*. Bravo *et al*., 2011) and literature on the main species (*i.e*. Serrada *et al*., 2008), and expert knowledge (same working groups were involved). As an example, see Beltrán *et al.* (2012) who described the case of Pinus sylvestris FMG elaboration. Further work was done with the NFI data to fill the gap in growth models for certain minor species.

Initially, we established a set of scenarios combining site quality, fire risk, stand structure and different objectives. Then, draft silvicultural schemes were developed for each scenario in an iterative elaboration process starting with a design of the different stand stages. Stand parameters were calculated at each stage based on site index, mortality and growth models, allometric relationships, and competition indexes.

Inside the iterative process, we led an economic and silvicultural evaluation of each proposed scheme. Treatments and products obtained were valuated, and the behaviour of the whole management cycle was assessed using a common framework. Strength tests were carried out by varying the price increase rate and the production output obtained. The working groups discussed and validated the schemes to help settle on the final silvicultural models. Fig. 1 schematizes the process followed to construct the FMG.

We further integrated wildfire prevention into the guidelines. To do this, we developed keys for ranking crown fire hazard based on the main forest stand variables that play a significant role in crown fires (Piqué *et al*., 2011). In addition, based on these fire risk assessment keys, we elaborated specific silvicultural models with the main objective of reducing crown fire hazard at stand level (results not shown).

Results and discussion

ORGEST “Sustainable forest management guidelines”

ORGEST consists in a set of FMG covering almost every conifer and broadleaf species-dominated forest in Catalonia (including pure and mixed forests), which together represent over 90% of Catalonia’s forest area. The Forest Ownership Centre has published the ORGEST FMG as manuals through its open-access website (see ags.ctfc.cat/?p=649 for the links).

For each species-dominated forest considered, ORGEST offers site quality charts and different guidelines for various management scenarios. They were built considering 2–3 site quality classes (depending on species), high or low risk of large wildfires in the area, even- or multi-aged forest structure, and different objectives such as timber production, non-wood forest products, wildfire prevention, or enhancing forest vitality and resilience.

Site quality charts

Site quality charts developed for the main species (Piqué *et al*., 2014) allow forest managers to quickly and objectively assign the most likely site quality class at stand level through readily identifiable ecological factors.

Fig. 2 shows an example of a site quality chart for *P. sylvestris*, where A is best site quality class (the species is well adapted and shows good growth) and C is poorest class.

Silvicultural models included in the FMG

ORGEST introduces silvicultural models and FMG for pure forests, including even- and multi-aged stands (Fig. 3), but also guidelines for mixed forests based on previous models for pure forests “reference models”, and specific silvicultural models for crown fire prevention (results not shown).

The silvicultural models for even-aged stands give a table with typical forest variables (dominant height, mean diameter, density, basal area, volume, etc.) plotting time–course evolution, including extracted basal area and volume when silvicultural treatments are applied (Fig. 3). Silvicultural models for multi-aged stands give a reference distribution of basal area and density among diametrical classes grouped

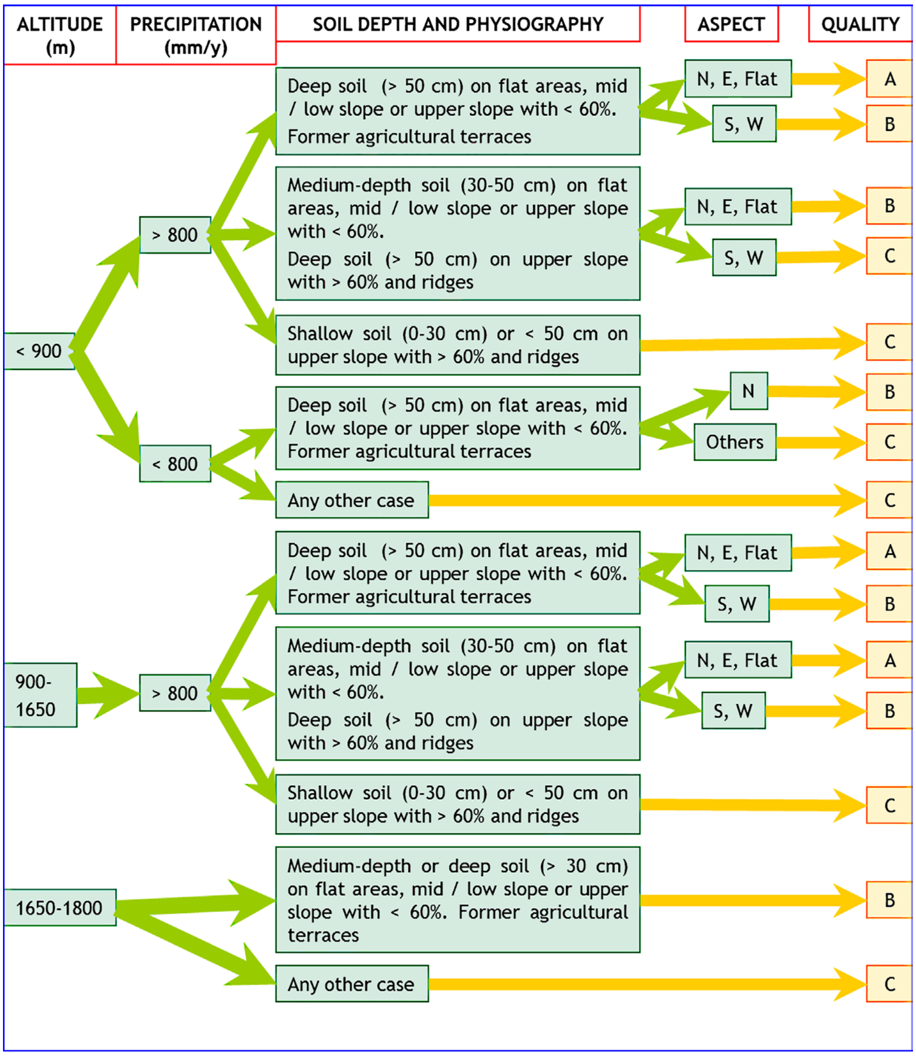


Figure 2. Site quality chart for *Pinus sylvestris* (NE Spain) based on ecological factors (A, high site quality; B, mid-range site quality; C, low site quality).

as small, medium and large trees, and an expected evolution until the next selection felling should be done. Extracted basal area and volume data are also included (Fig. 3).

Moreover, the FMG also include a complete and applied description of all treatments (clearing, thinning, regeneration cutting, selection felling, etc.) and a code of best forest practices in order to ensure correct implementation of the silvicultural models.

Applicability of the ORGEST

Both the forest types classification and FMG provide forest administrators and managers with technical information for achieving management objectives and more efficient allocation of public funds in forest management.

Forest types provide information that helps reduce inventory costs and may ease strategic planning at larger scales (promoting certain objectives depending on forest types). The site quality charts based on ecological factors enable site quality to be classified fast, despite the current stand conditions used. The ORGEST approach enables stand-level-adaptable forest management, which is vital in our context due to the huge diversity of species, structures, site qualities and objectives involved at stand level.

In summary, the methodology used, combining expert knowledge, NFI data analysis, existing growth and production models, and in-field validation with stakeholder participation has proven to be very useful not just for establishing the forest types and FMG but also in driving acceptance of the guidelines by practitioners and forest technicians. We anticipate that our methodology could be replicated to other forested regions and that the silvicultural models and FMG could be directly

Site quality	*Fire risk*	*Stand structure*	*Primary objective for the stand*	*Model features*	
HIGH	LOW	Regular	High- quality timber with target Ø ~ 50 cm	Selection thinning	Ps01
			High-quality timber with target Ø ~ 50 cm	Low thinning	Ps02
			Intermediate quality timber with target Ø ~ 35 cm	Low thinning, short rotation	Ps03
		Irregular	High-quality timber with maximum Ø ~ 55 cm	Selection system in small groups	Ps04
			Intermediate timber with maximum Ø ~ 35 cm	Selection system small groups	Ps05
			High-quality timber with maximum Ø ~ 50 cm	Selection system in medium-sized groups	Ps06
	HIGH	Regular	High-quality timber with target Ø ~ 50 cm Increasing resistance vs. fire	Low thinning	Ps07
		Irregular	High-quality timber with maximum Ø ~ 50 cm Increasing resistance vs. fire	Selection system in medium-sized groups	Ps06

MODEL Ps01

Model parameters

H0 (m)	N (trees/ha)	D (cm)	G (m²/ha)	OBV (m³/ha)	Age (years)	Treatment	Nf (trees/ha)	Competitors per target tree	OBVf (m³/ha)	Gf (%)
6	>4.000	6	-	-	13-16	Selective clearing; radius > 1m	>1.900	-	-	-
11,5	2.100	13	27	141	23-28	Selective thinning + pruning	700	2	-	15
15,5	1.400	20	42	294	32-40	Selective thinning + pruning	700	2	94	31
18,5	700	28	42	346	42-53	Intermediate selective thinning	350	1,75	110	31
21,5	350	40	43	421	57-71	Intermediate selective thinning	150	0,75	146	33
23,5	200		41	449	72-90	Preparatory cutting	95		213	46
24,5	105	~50	24	256	83-103	Seed cutting	60		146	54
25	45		11							

Treatments

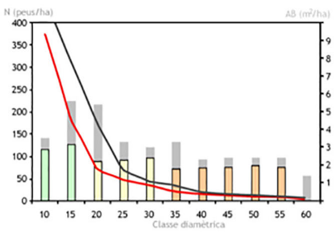
Selective clearing. Selection
sociologic differentiation. A
pruned, up to 1,5-2 m if qual

First thinning, selective. Tw
complemented with a low thi

Second thinning, selective.
chosen, and will be those to
thinning. If selected trees are

MODEL Ps04

General parameters of control



Size class	DC	Reference N	Reference G	Reference % G	Before intervention N	Before intervention G	Before intervention % G	To fell N	To fell G	To fell % G
Small	10-15	554	6	27%	768	9	26%	214	3	24%
Medium	20-30	151	7	31%	283	12	33%	132	5	38%
Large	≥35	64	10	42%	95	14	41%	31	5	38%

Treatments

Selection system cutting. Selection system is applied on 1.000-3.000 m² groups evenly distributed. Each intervention includes thinning in groups with small and medium size diameter classes and final felling on groups with large diameter classes, creating gaps for natural regeneration. Cutting is done preferably on poorly conformed and dominated trees until achieving the desired distribution of basal area organized by groups (or other parameters of control).

Optionally, each intervention can include pruning on 45 trees/ha of DC20 to increase the value of the future product, when reaching 40

Figure 3. Example of management scenarios and forest management guidelines for even-aged and uneven-aged stands, case of *Pinus sylvestris,* NE Spain (Ho, dominant height; N, stand density; D, mean diameter; G, basal area; OBV, mean volume; Nf, stand density after treatment, DC, diameter class).

applied in other areas with similar conditions, mainly within the Mediterranean basin.

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