The important role of multifunctional forests in society: a methodology for stands delimitation

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Abstract. Forest planning and management must be conceived in accordance with the circumstances and needs of the moment. Nowadays, the forest does not have a single and exclusive productive use but responds to multiple demands. The stand management method, with a broad approach, has been recently well adapted to this type of multipurpose management. This study proposes a methodology for delimiting stands which led to manage different uses in forests in protected areas. The methodology consists of six phases: (i) create permanents units (ii) initial identification of forest typologies, (iii) image analysis, (iv) identification of tree types within the forest typology, (v) detailed inventory and (vi) formation of stands. An example is presented for the "Monte Paris" forest, located a few kilometers from Madrid, which combines protective, livestock and recreational use. For the protection use, pruning and thinning will be carried out, for the livestock use, supplementation, meadow sowing and enclosures, and for the recreational use, the design of an environmental center and five ecological trails are proposed. The organization in time and space of the activities planned in the stands allows a correct and satisfactory management of the multiple uses that occur in this forest.

1. Introduction
The multiple use forest management planning concept has improved rapidly over the last couple of decades and harmonizes the ecological, economic and socio-cultural values of forest ecosystems. The solo timber production-oriented approach is no longer appropriate as the multiple use forest management concept has gained increased attention [1]. Current forest planning and management demands ecological and social requirements according to the needs of society and its current problems [2]. Both depend on the circumstances of the moment, as well as on the international environmental obligations assumed by the country in question. Firstly, it is necessary to reconcile economic development with the forest environment, as already announced at the United Nations Conferences. Secondly, the establishment of protection networks, such as the Natura 2000 network in Europe, reinforces the conservation and restoration of the biodiversity of habitats and species [3]. In this Natura 2000 sites, the concept of the multifunctionality of forests emerged more strongly giving the forest several uses: environmental, protective and climate change mitigation, cultural, scenic or recreational, in addition to the traditional productive use [4, 5]. The harmonized use of forests must be reconciled for both owners and society in Natura 2000 sites [6].
For all these reasons, current forest management methods must be flexible and adapted to current demands. One of the management methods best suited to current needs is the "stands management method". It had its origin in the work published by Judeich (professor at the Tharand School) between 1871 and 1893 in Germany. The method did not have much impact at the time. Recently, a new approach [7] has been given to this method and the characteristics of the stands are: (i) the minimum permanent dasocratic unit can be subdivided into more than one stands and (ii) the stand is a temporal unit and constitutes the ultimate unit of the inventory, as well as the silvicultural unit of management. It is defined in each management according to the actual stand condition, the objectives at the forest level and the management needs. Related to this stand level, several authors have used optimal control theory in stand-level optimization. These approaches have been mainly in the theoretical way incorporating models such as Faustmann into market analyses or deterministic and stochastic methods [8]. Others works address stand delineation in automatic analysis, using only satellite image or Lidar [9].

In the last few decades, it became increasingly obvious that timber is not the only resource offered by a forest ecosystem. There are many other resources and ecosystem services offered by forests, such as: prevention of soil erosion, balancing the water regime, protection of wildlife habitats and natural biodiversity, fight against climate, land for recreation [10]. Several examples of multifunctional forest management approach have been presented with mainly protection use, for example controlling severe soil erosion in dryland regions [11], recreational uses in protected areas [4, 5], livestock [10] and the traditional timber use among other uses [12].

On the other hand, in a more practical way, our research group “Technologies and methods for sustainable management” have worked planning forest management plans in several Natura 2000 [13] using the new stand concept of González Molina et al., 2006. In each of these forest management planning work, we have created an own methodology to obtain the stands. We now, with our previous experiences, the objective of this paper is to propose a methodology for stands delimitation to manage multiple uses. In this case, our work takes place in a Natura 2000 site, “Monte Paris” in Madrid, Spain, which presents an example of multiple uses (protection, livestock and recreational-educational). This methodology will let forest managers have a very useful tool for decision making in a practical way.

2. Methodology

2.1. Study area

The study area is called Finca "Monte Paris" located in the west of Madrid, Spain (40°29'17.2"N 3°51'02.2"W). It has a surface area of 463 hectares and is privately owned, belonging to the "Tatiana Pérez de Guzmán El Bueno Foundation" (figure 1). The Foundation's mission is to manage the estate inherited after the death of the Countess after whom the Foundation is named and to conserve nature (protected use). There is not timber exploitation (not production use). In addition, its objectives are to develop environmental education activities and to promote research (educational use) and nature walks (recreational use). Monte Paris is located within the Cuenca Alta del Manzanares Regional Park, 20 km far from the center of Madrid city.

The study area has an altitude of approximately 718 metres above sea level. The climate is continental Mediterranean with cool winters and mild summers (average annual temperature of 13°C, minimum of -5 °C and reaching 40 °C). Rainfall varies between 500 and 600 mm, concentrated between autumn and winter. In terms of fauna, 150 deers (Cervus elaphus), 30 fallow deers (Dama dama) and 20 wild boars (Sus scrofa) are present in the study area (figure 2). There is no hunting that brings income to the property. There is an extensive farm (500 sheep), which allows keeping clear the forest avoiding fires. It is the only economic use (livestock use).
It is necessary to supplement forage in summer due to low rainfall. There are also species listed in Annex II of Directive 79/409/EEC: black vulture (*Aegypius monachus*), black stork (*Ciconia nigra*), booted eagle (*Hieraaetus pennatus*). The vegetation is composed of holm oak groves (*Quercus ilex*) on sandy substrates. The holm oak itself gives way to shrub formations constituting the first stage of forest replacement, which are sometimes mixed with broom (*Retama sphaerocarpa*) and, when the soil is very poor, prickly rockrose (*Cistus ladanifer*) and rosemary (*Rosmarinus officinalis*). The habitats of Community interest present are: 5330 Thermo-Mediterranean and pre-stepic scrublands, 6220 Sub-stepic areas of grasses and annuals (*Thero - Brachypodietea*), 6310 Evergreen meadows of *Quercus* spp and 9340 Forests of *Quercus ilex* and *Quercus rotundifolia*.

2.2. Methodology

Our proposed methodology for stands delimitation to manage multiple uses in forests has six phases:

(i) To arrive at the division of the forest into stands (temporary division), we will first divide the forest into **blocks and compartments** (permanent division). The blocks are the large property units that are subdivided into compartments. The compartments are delimited through field and office work, with the help of a Geographic Information System (ArgGis 10.1). It is proposed to overlap the cartography of orientations, slopes and the general topographic plan.

- Definition: blocks are roughly homogeneous territorial units in terms of ecological characteristics, seasonal quality and with easily identifiable boundaries on the ground (supported by natural or artificial lines such as roads, trackways...).

(ii) In the first field visit an overview of the whole forest is obtained, and various vegetation groups (initial forest typologies) repeated in the forest, are identified.

(iii) Then, in the office, an **image analysis** of the forest is carried out, dividing it into parts according to tonality, density and texture. In addition, the image provides us with the degree of ground cover by the vertical projection of the crowns, canopy cover (CC).

(iv) Therefore, a provisional location of the typologies is obtained. A second and exhaustive field visit is carried out, in which different **types of trees within each forest typology** are also characterised.

(v) Then, an **inventory** is carried out, quantifying the tree types defined in each typology. The result is compiled in a definitive map of forest typologies. The overlapping of the forest typologies with the blocks gives the division into provisional **stands**.

- Definition: a stand as a temporary territorial unit established in each management project, according to the characteristics of the stand or other variables. Its shape and extent may vary from this management to later revisions, depending on the evolution of the stand [7].

(vi) Finally, after a new field visit, the definitive **stands** are delimited, carrying out some slight modifications to the provisional stands, taking into account the drainage network and the roads, to adjust the surface area of some of them. In each stand, the appropriate inventory or descriptive study will be
applied. In addition, the stand is studied (species of interest, dead wood, fauna, etc.) to maintain and preserve the biodiversity present.

3. Results and discussion
Now we present the results of the application of the methodology applying the proposed methodology:

(i) Blocks or compartments were delineated.

(ii) Initial forest typologies: the holm oak (*Quercus ilex*) typology is scattered, in some places quite degraded into broom (*Retama sphaerocarpa*), small agricultural areas (traditionally cultivated) and some buildings.

(iii) An image analysis: divided according to the canopy cover (CC) in three simple and clear groups, (figure 3):

- CC: 70% < CC < 100% Full forest typology.
- CC: 40% < CC <70% Open forest typology.
- CC < 40% Clear tree forest typology.

(iv) Tree types within the forest typology:

- *Quercus ilex* well-shaped tree_ type 1: *Quercus ilex* over 1.30 m tall and diameter at the breast high (dbh) greater than 20 cm -High forest- with single trunk or bifurcated into two in which the trunk and crown are clearly differentiated. The crown is well defined.

- *Quercus ilex* stump_ type 2: Stems originated from stump* or root*, with variable diameters, bigger than 2 meters tall. There is a main stem or stems that are clearly differentiated from other tortuous stems that arise from the stump.

- *Quercus ilex* creeping shrub_ type 3: Stems originated from stump* or root*, with variable diameters, not bigger than 2 meters tall. They are eaten recurrently by animals. They are wider at the base than at the top.
(v) Inventory: To characterize the tree in forest typologies, band plots (20 m x 100 m) were established in each of them as required in the National Spanish inventory for this 9340 habitat, staked out in the field with the Laser hypsometer "True pulse" and/or with the ultrasonic hypsometer "Vertex III" and GPS (for the location of the plots). A total of 9 plots were surveyed (3 for each type, table 1. In these plots, the tree types defined above were counted.

| Tree mass typology | Type 1 | Type 2 | Type 3 |
|--------------------|--------|--------|--------|
| full               | 1983   | 2583 (9833*) | 400a   |
| open               | 1066   | 1633 (4267*)  | 117a   |
| clear              | 600    | 450 (2450*)   | 50a    |

aStems originated from stump or root.

(vi) Final stands:
In the figure 4, we can appreciate the 22 stands resulting from the described methodology.

3.1. Forest management proposal for multiuses compatibility.

3.1.1. Protective use. To provide the forest with this use we proposed the following forest management measures in the tree types:

-Quercus ilex well-shaped tree_ type 1: Management proposal: pruning- elimination of branches, both live and dead, so that the branches receive more light and adopt a prefixed shape that favors acorns production. Branches larger than 12 centimeters in diameter should not be cut. It is advisable to contact a woodcutter close to the farm, to obtain some economic benefit and facilitate the removal of the pruning. If it is not possible to remove them in this way, it is suggested to use a hammer brush cutter (figures 5 and 6).

-Quercus ilex stump_ type 2: Management proposal: thinning- a certain number of trees are removed in order to eliminate competition. In this way the trunks will become wider, the crowns will develop more and produce a greater number of seeds (acorns). The treatment should favor the tree straightest, with the largest diameters and the best crown shapes. This is a flexible silviculture, in which the approximate rule of thumb is to eliminate 33%-25% of the trees (figures 7 and 8).

-Quercus ilex creeping shrub_ type 3: Management proposal: no action. It is decided not to take any actions at the present time because at this stage the trimming and/or pruning are considered unnecessary expenses due to the abundant regrowth that occurs. It is preferred to wait that some resprouts outline as
trees that in the future may be acorn producers (for example, due to their vigorous crown, straight trunk, etc.) (figures 9 and 10).

Stands: 3.a and 4.a, during the forest special plan (10 years).

3.1.2 Livestock use. The problem in the study area is the deer population which is in the limit of the carrying capacity. We had to tackle two main issues, damage of the soil causing d and problems for reproduction by acorns. To reduce these effects, several management actions are proposed:

– Rotation of supplementation points, both to avoid damage due to overgrazing, nitrification and trampling, as well as to take advantage of the pasture-improving effect of livestock grazing.
– Improvement and seeding of pastures by amendment and fertilization (stands 3a and 4a).
– Enclosed areas, to promote the nascence of acorns that will allow the emergence of seedlings.
– Use of livestock as a tool to control regrowth and control the height of grasses that can cause fires (figure 11).

3.1.3 Recreational and educational use. The target is designing an Environmental Reference Center in which an exhibition model and content would be shown to visitor. For this purpose, five ecological trails showing flora and fauna interests of each trail will be explained and a series of dynamic brochures with
questions for visitors to answer during their tour enliven the visit. For the correct development of the recreational use proposals, parking areas have been located to reduce the environmental impact.

The Environmental Reference Center would be located in a facility that the property already has (figure 12) and the interior has been designed (figure 13), with screens, panels and projection rooms. There will also be rooms for meetings and workshops. Visitor groups will be a maximum of 25 people and a visit in advance should be arranged for the best program organization.

The trails: an important field work has been developed for the design of its route. Thus, we determined which are the most interesting routes, their length, the time required and their degree of difficulty. Table 2 shows the five trails.

| Trails | Length  | Duration   | Level   |
|--------|---------|------------|---------|
| 1      | 1.25 km | 50 min     | Medium  |
| 2      | 4.35 km | 1 h 40 min | Difficult|
| 3      | 1.6 km  | 30 min     | Easy    |
| 4      | 3.20 km | 1 h        | Difficult|
| 5      | 5 km    | 2 h        | Medium  |

Figures 14 and 15 show two of the five proposed routes. The topics would be sustainable management, fauna, flora, uses of the forest, etc.

**Figure 14.** Proposed route number 2.  
**Figure 15.** Proposed route number 5.

Stands: Environmental reference center in stand 3.e, and routes through several stands during the forest special plan (10 years).

The weak point of the traditional management methods is their excessive temporal, spatial and silvicultural rigidity, which makes their application sometimes difficult [7]. They were based more on guaranteeing the persistence of the forest for timber production purposes than on considering multifunctionality. For these reasons in the last decades have been different multifunctional forestry approaches, for example five principles to distinguish between dominant, important, and general functions. The dominant functions should be first and foremost guaranteed, while minimising the negative effects on other important or general functions [11]. When there is a political debate about multifunctional management, the terms of integration and segregation are of high importance have been include, especially when there is a debate about conflicting interests, such as wood utilization vs. protection of biodiversity (e.g., dead wood) [12]. “Inclusion” means that different interests can be fulfilled on the same spot without conflicts, for example coppice with standard systems were an example for the inclusion of interests for firewood and timber. In this case there are no clear boundaries between
areas of prioritization. However, in this approach exclusion means that certain functions are completely suppressed by the dominant function within the area of interest [10].

In the present proposed methodology in this paper we integrated all the uses at the same level and we highlight the flexibility of responding to the requirements of today's society, including all the instruments to improve biodiversity. In our case, protective use requires flexible silviculture (pruning and thinning) capable of harmonizing all the uses present in the forest. Livestock use is a management tool to control the regrowth preventing fires. This use not only benefits the biodiversity of the grasslands, but also, if well managed, it is beneficial for the different insect biotopes and for environmental and landscape diversity, and especially for fire risk control. Recreational use promotes the educational use of the forest in the Environmental Reference Center and five routes of varying degrees of difficulty.

4. Conclusions
Nowadays, society demands multiple uses of forests. The forest is not only used for production but also for protection, recreation, education, research and maintenance of the landscape mainly in Natura 2000 sites. These uses are combined with others and that is the reason for adapting forest management methods. The stand level approaches in other works are very theoretical [8, 9] and are not adequate for the real and practical Natura 2000 management. For these reasons we propose a methodology for stands delimitation to manage multiple uses in forests has six phases. The advantages of implementing such a proposed methodology are:

- An adequate delimitation of stands, homogeneous and temporary units, which allow the management of multiple uses (in this case protective, livestock and recreational uses). This a very useful tool for forest managers.
- Each stand is perfectly defined. The forest typologies can be defined according to the management objectives, and the stands will constitute the ultimate and temporary units. The proposed methodology perfectly characterizes stands to apply the necessary silviculture in each one of them.
- Flexibility capable of responding to the requirements of today's society, including all the instruments to improve biodiversity.
- The main disadvantage is that characterization of the stands requires a lot of field and office work. Provisional stands are delimited by joining forest typologies with compartments and will become definitive when the information is confirmed in the field. This process can be very time consuming.

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