Multi-functional approach in forest landscape management planning: an application in Southern Italy

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Abstract

Forest Landscape Management Plan (FLMP) is intended to have an intermediate role between forest management plans on a regional level and forest management on a unit level. FLMP addresses long-term management issues, with special attention to social and environmental functions, normally not meticulously considered when working on a single forest property level. This paper presents a method to evaluate forest multifunctionality, in order to define management guidelines and support forest planning. A FLMP was conducted in a district of the Basilicata region (Italy). A total of 92 inventory plots comprising the main forest types: i) turkey oak, Hungarian oak, and sessile oak forests (*Quercus cerris* L. dominant), ii) downy oak forests (*Quercus pubescens* Willd. dominant), iii) Mediterranean evergreen oak forests (*Quercus ilex* L. dominant), were considered. Technicians evaluated the multifunctionality of each area by estimating — in the context of an Index of Importance of Function (I) — the capacity of each forest to fulfil different functions. The index was successively aggregated according to forest type and forest system (high forest and coppice). The results showed that the higher level of multifunctionality was found in the high forests. According to the synthetic indicators of multifunctionality, the turkey oak forests obtained the highest values among all forest types. The last part of the paper illustrates an approach to multi-functional forest management, analysing how different silvicultural systems are able to fulfil the main forest functions. This method, as shown in the results, seems to provide a useful support for technicians to evaluate multifunctionality related to forest types and different silvicultural treatments.

Key words: forest multifunctionality; forest landscape management plan; index of function importance; silvicultural system; Collina Materana district (Italy).

Resumen

Multifuncionalidad en la planificación del paisaje forestal: una aplicación/un estudio de caso en el Sur de Italia

El Plan de Manejo del Paisaje Forestal (PMPF) tiene un papel de intermediario entre los planes de manejo forestal a nivel nacional y regional y los planes de ordenación forestal a nivel de cada propriedad forestal. El PMPF toma en consideración de aspectos de gestión a largo plazo, con especial atención a las funciones sociales y ambientales, que por lo general no son consideradas cuidadosamente en caso de planificación a nivel de propriedad forestal individual. El trabajo presenta un método para evaluar la multifuncionalidad del bosque, con el fin de definir las directrices de gestión y de apoyar el proceso de planificación forestal. En un distrito de la región de Basilicata, en el Sur de Italia, un PMPF ha sido desarrolado y levado a cabo. En el Plan se consideraron un total de 92 áreas de estudio que abarcan los principales tipos de bosques: i) bosques de roble turco, roble húngaro y roble albar (*Quercus cerris* L. dominante) ii) bosques de roble pubescente (*Quercus pubescens* Willd. dominante), y iii) bosques de robles mediterráneos siempreverdes (*Quercus ilex* L. dominante). Los técnicos evaluaron la multifuncionalidad de cada zona mediante la estimación — Índice de Importancia de la Función (I) — de la capacidad de cada bosque respectiva para cumplir diferentes funciones. El índice ha sido agrupado en función del tipo de bosque y del tipo de sistema forestal (monte alto y monte bajo). Los resultados de un estudio de técnicas que muestran el nivel más alto de la multifuncionalidad es para el

monte alto en comparación con el monte bajo. Teniendo en cuenta el tipo de bosque los bosques de roble turco han obtenido los más altos valores de multifuncionalidad. La última parte del documento describe un caso de gestión forestal con un enfoque multifuncional y analiza cómo los diferentes sistemas silvícultural cumplen las principales funciones del bosque. De acuerdo con los resultados observados, el método parece ser de gran ayuda para los técnicos para evaluar la multifuncionalidad relacionados con diferentes tipos de bosques y tratamientos silvícolas.

Palabras clave: multifuncionalidad forestal; plan de manejo del paisaje forestal; índice de importancia de la función; sistema silvícultural; distrito Collina Materana (Italia).

Introduction

Ecosystem functions refer to habitat, biological or system properties or process of ecosystem that produce, directly or indirectly, benefits for human populations (Costanza *et al.,* 1997). The ecosystem functions available to society can be interpreted to represent the natural capital of that society (Barbier, 2000) and it can be defined as the capacity of ecosystems to supply goods and services (De Groot, 1992; Ansink *et al.,* 2008). Natural capital refers to the creation of value through the transformation of the natural world (biophysical and geophysical processes) into means of production and products themselves (Tacconi, 2000). The ecosystem functions represent, in the classical economic theories and in the subsequent neoclassical variations, the "land" used in combination with the other factors of production (labour and capital) to create value (Butcher, 2006). The functions of the ecosystem are diverse. Taking into account the economic aspect, for instance, this multifunctionality is expressed by the fact that an economic activity may have multiple outputs and, as a consequence, may simultaneously contribute to the many requirements of society. Multifunctionality is thus an activity oriented concept that refers to specific properties of the production process and its multiple outputs (OECD, 2001).

The conceptual origins of multifunctionality in forest management date back to Heinrich von Cotta. In 1820 he stated that forests should be treated in different ways according to the benefits that need to be acquired. This vision was spread during the following decades in the main industrialized countries which have progressively abandoned a mono-functional perspective — exclusively focused on maximizing the wood production — towards a multi-functional perspective aimed to value simultaneously all forest functions (Kennedy and Koch, 1991; Harshaw and Tindall, 2005).

A conceptual-theoretical definition of multifunctional forestry dates back to the explanation of the "theory of forest functions" by Dieterich (1953) expressed in the text *Forstwirtschaftspolitik* (Hytönen, 1995). In this theory, three main groups of functions were described (utility, protection and recreation), and thus integrated, refined and improved by many authors over the following decades. The modifications implemented included: production, option, regulation and information functions (Vos, 1996), or utility, realization, perception and protection functions (Fernand, 1995).

As the multifunctional forestry concept spread out and the environmental awareness after the Rio de Janeiro Conference (1992) changed, forest planning in Europe shifted from a model mainly based on wood and timber production (Farcy, 2004) to multipurpose planning. Such change has led to the establishment of a new management paradigm called "sustainable forest management" to the detriment of the traditional "sustainable yield" (Szaro *et al.,* 2000; Farrell *et al.,* 2000). The sustainable forest management is a concept in permanent evolution both in time and space (Angelstam *et al.,* 2005; Straka, 2009). The multi-functional forest management planning — which is the operative basis of the sustainable forest management — aims to integrate in decision making the non productive aspects of the forest, just as well as the socio-cultural and environmental issues (Vincent and Binkley, 1993; Kangas and Store, 2002). The logical process that leads to the choice in such planning approach becomes considerably complicated (Pukkala, 2002). The most unambiguous, reproducible and economically sound definition and experimentation of a methodology regarding the plan process is therefore necessary.

Forest planning in Italy has been regulated since a few decades ago by a national law. It used to be small property oriented with a prevalent productive focus and a strong attention to hydrogeological protection. In the last decades, the planning and the related regulations have been transferred at a regional level and, therefore, a landscape level planning is being locally developed. The development of planning systems on a landscape scale is the proper tool to analyse all the forest features

and define the management guidelines (Kant, 2003; Kennedy and Koch, 2004; Farcy and Devillez, 2005; Cubbage *et al.,* 2007; Schmithusen, 2007).

Forest landscape management plan (FLMP) is an integrated tool to address forest management guidelines on a broad scale only providing details when considered either useful or necessary. The system has a hierarchical approach between a medium and detailed level of planning (Bettinger *et al.,* 2005). Thus, a distinction, but also a continuity, is created in forest planning between strategic and operational levels (Bachmann *et al.,* 1996; Kurttila and Pukkala, 2003). FLMP has an intermediate role (tactical level) between forest management plans at a national or regional (i.e. administrative) level and at a forest management unit level (Baskent and Keles, 2005). FLMP addresses long-term forest management issues, with special attention to land and environmental aspects (such as watersheds, biodiversity, etc.) that cannot be properly considered by referring to a single forest management unit (i.e. single forest ownership). In addition, FLMP provides management recommendations and silvicultural guidelines, according to forest type and forest system. These are then divided and adapted for every function.

On the basis of these preliminary considerations, the main objective of the paper is to define a methodology capable to assess forest multifunctionality from a technical-managerial point of view. In the framework of field surveys, forest technicians evaluate the multifunctionality of each sampling point by estimating the capacity of each respective forest type to fulfil different functions. In the second part, starting from this preliminary evaluation, the paper focuses on a comparative analysis aimed at evaluating the ability of different silvicultural treatments to influence the fulfilment of the functions required by forest formations. This research was conducted in the frame of a FLMP realized in 2006-2007 in a district in Southern Italy.

Material and methods

Study area

The Comunità Montana Collina Materana (40° 29' 30'' N; 16° 09' 20'' E), located in the central-western part of the Matera Province in the Basiliata region, southern Italy, was chosen as the study area (Fig. 1). The territory of the Comunità Montana occupies about 60,784 ha, which are divided into seven

municipalities (Municipality of Accettura, Aliano, Cirigliano, Craco, Gorgoglione, San Mauro Forte and Stigliano).

Generally, an oro-mediterranean climate prevails, characterised by a warm and dry summer and a cold winter with the highest precipitation; the dry season is between the end of June and the half of September. We can recognize two different zones: (1) the North-western part of the Collina Materana district where the average annual temperature is 12.5°C, with 885 mm of rainfall per year, (2) the South-eastern part of the district where the average annual temperature is 16.5°C, with about 600 mm of rainfall per year (Costanza *et al.,* 2004).

The demographic density is low, 22.2 people/km², compared to a national average of 200.1 people/km². The rural sector covers a rather important role in the economic structure of the Comunità Montana, employing 24% of the active population, whereas the national average is 8% and the European average is 4-5%. Conversely, the industrial sector is extremely weak as well as the tourist sector which has not shown a significant development so far, as demonstrated by the very scarce presence of factories operating in this sector.

Forests cover a surface of 22,221 ha (14,900 ha forests and 7,321 ha shrubs lands), comprising 36.6% of the territory. The large diversity of forest formations is to be attributed to the great variability in morphology, altitude and lithology of the area. In the eastern part of the territory, the forests are more scattered, providing space for agricultural lands, shrub lands and bad lands.

At the higher altitudes of the North-western sector a diffuse presence of turkey oak (*Quercus cerris* L.) dominant forest, either associated or alternated with nearly pure groups of Hungarian oak (*Quercus frainetto* Ten.), is observed. At lower altitudes, the turkey oak forests are gradually replaced by mixed thermopile oak forests with downy oak (*Quercus pubescens* Willd.)

Figure 1. Basilicata Region and Comunità Montana Collina Materana.

dominant. Decreasing further, especially in the South-western area, Mediterranean evergreen oak forests with holm oak (*Quercus ilex* L.) dominant are found (Fig. 2).

The land which is still devoted to agriculture is essentially concentrated in the area of Pliocene hills on sand deposits. The forest distribution is generally limited to those areas where the slope and/or thin soils did not allow either cultivation or husbandry in the past.

The forest types considered for the analysis of multifunctionality were (EEA, 2006):

— turkey oak, Hungarian oak, and sessile oak forest *(Quercus cerris* L. dominant*)*;

— downy oak forest *(Quercus pubescens* Willd. dominant*)*;

— Mediterranean evergreen oak forest *(Quercus ilex* L. dominant*)*.

A substantial balance between coppices and high forests was observed in terms of extension. Taking into account also the high stands with asexual origin, high forests were slightly more represented than coppices, being 50.3% and 42.3% respectively. The forest system of 7.4% of forest formations was classified as "undefined".

The downy oak forest is the most represented in coppices, being 2/3 of the sample, while coppices with turkey oak and/or Hungarian oak dominant were rare (Savini, 2007).

From the ecological and economic point of view, the opportunities for the Collina Materana forest formations are strictly dependant on their past management.

The actual structures of forests are: i) coppice with standards for firewood production; ii) mixed management wood-pasture with release of a great number of standards for timber and acorn production; iii) conversion from coppice to high stands in the less productive coppices in order to obtain high stands with asexual origin. At today the main use of wood is for fuelwood production to heat houses and the most part of annual cuttings is bought by local population.

Forest grazing has been practiced in the Materana Mountain since the Middle Ages, as in other areas of Europe. It is essentially a system of land management where trees are grown, but with grazing by large herbivores (Rackham, 1980; Vera, 2000). It is a very important, traditional activity deeply rooted in the local culture; seemingly bound to ancient forms of management system in a "multifunctional landscape" (Rotherham, 2007) where crops, pastures, wood-pastures, forests, and grazed forests represent the elements of a mosaic in which livestock is a key component.

Grazing by livestock still represents an important use of certain forest types in Southern Italy; these forests produce palatable forage for summer grazing, supplementing the limited amount of spring-fall grassland range.

In the Collina Materana, oak forests are the most suitable forest formations for this type of grazing as they are characterised by a well-developed herbaceous and shrubby undergrowth, sufficient to feed the livestock.

Concerning forest grazing two different aspects have to be considered: the relationship with forest fire and with forest degradation. The first is very important, in fact there is an high risk of forest fire but it is under control thanks to stockbreeder that watch forests (Gutman *et al.,* 2001). On the other side forest grazing have a negative effect on the forest's ecosystem; continued forest grazing is very closely connected to the presence of forest formations degraded with irregular structures, and species reduction and simplification (Ainalis *et al.,* 2010). The widespread phenomenon of soil compaction and damage caused by animal paths can likewise be imputed to an overabundance of livestock (Quezel and Medail, 2003).

Assessment of multifunctionality

The structure of the plan is provided by the study of the forest and pastureland and the related social and economic aspects through interdependent steps of analysis (Agnoloni *et al.,* 2009). Considering the various phases of the Plan (Fig. 3), the assessment of forest
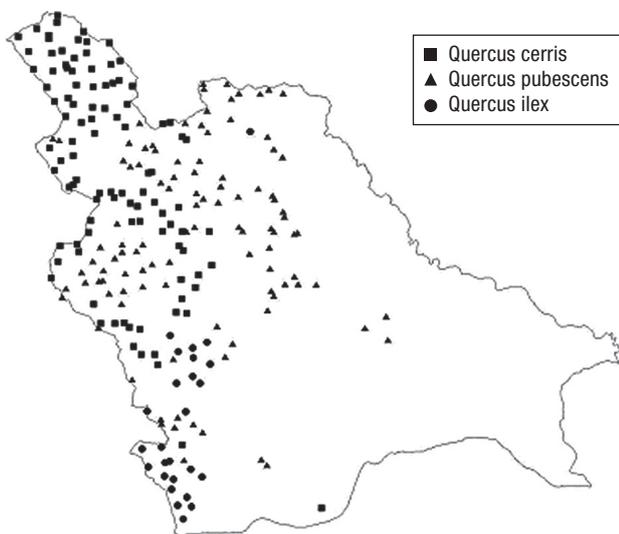

Figure 2. Typological classification of sampling points.

Stage of Plan

Preliminary evaluation
The analysis of existing cartography and bibliography, the planning tools in force and the legislative context provided a snapshot useful for the further development of the Plan.

Basic cartography
A typological-cultural forest map of the Comunità Montana was elaborated on the basis of the existing typological-cultural forest regional map.

Field investigation (description and quantitative surveys)
Field surveys were conducted through stratified sampling (349 sampling areas).

The resources of pasturelands
A qualification of natural resources of pasturelands was realized thanks to the definition of an original expeditious method with respect to the classical survey methods of herbaceous resources (Argenti *et al.,* 2006).

The participative process
The participative method was conducted through the consultation method. The involvement of the local community regarded the whole of the planning process, from the preliminary investigations to the definition of the management guidelines contained in the Plan. A number of 63 structured interviews among institutional actors and stakeholder was realized and evaluated through the SWOT analysis.

Evaluation of forest productive chain
The analysis of the forest productive chain regarded the investigation of the sectors involved in logging activities and primary and secondary wood transformation. The method was based on direct interviews and bibliographic researches.

Study on landscape
The survey considered the evolution of forest cover in order to orientate either conservation or recovery actions of a certain landscape design. The method was based on a multitemporal analysis of land use in order to identify the areas with a long lasting presence of forest formations, to follow their evolution in terms of forest cover and therefore to define the actions to undertake for their natural development.

Tourist-recreational analysis
The recreational and tourist activities present in the territory were assessed with the help of interviews and bibliographic investigations. The data were elaborated in order to identify new tourist trail for different typology of visitors and therefore increase the tourist offer of the area.

Figure 3. Phases of FLMP "Collina Materana".

multifunctionality is related to the phase of field investigation. Infact, in the framework of field surveys, technicians evaluate the multifunctionality of each sampling point.

The CORINE land cover (EC, 1993) European classification until level III was adopted as a reference classification system for the basic cartography. A specific classification was assembled for the forests which was based on the use of a homogeneous cultivation subcategory. This feature was ranked as an intermediate between the forest category and the forest type, and took into account both the forest system and possible treatments of the wood. This classifica-

tion was obtained according to the existing regional forest types (Costantini *et al.,* 2006) and was coherent with higher reference systems (Italian National Forest Inventory, European Nature Information System - EUNIS, CORINE).

For what concerns the qualitative and quantitative description of forest formations (woodlands, shrublands, pasturelands and uncultivated lands) — in Italy planning and management of forests and pastureland are assigned to the same administrative subject — the survey of woodlands and shrublands was carried through stratified sampling descriptions based on homogeneous cultivation subcategory, while extensive surveys were realized for pasturelands and uncultivated lands.

Field surveys were carried out by 4 teams, composed by 2 technicians each. With the aim of harmonizing their evaluations, technicians were previously trained, both with field workshops and class lessons. All technicians had a degree in Forestry with high professional experience in the Collina Materana district or other similar environmental context.

A circular sampling area of 0.5 ha was chosen for forests and shrub lands. The features sampled were harmonized, where possible, to both the National Forest Inventory Standards (Tabacchi *et al.,* 2007) and the Sustainable Forest Management (SFM) (Secco *et al.,* 2006).

The territory was stratified according the existing regional forest types map (Costantini *et al.,* 2006), and a total of 349 descriptive areas (plots) were classified — it equates to 1 plot every 63,67 ha — 122 assigned to shrub formations, and 227 to forest formations. The information, retrieved from sampling, was then entered in a Geographical Information System (GIS) built on the regional forest map. In Fig. 2, the sampling point locations of the main forest types (considered for the analysis) is reported. The distribution analysis showed the differences between the north-western and the south-eastern sector of the Comunità Montana. These differences were a direct consequence of the diverse geo-pedological conditions.

The forest types considered for the analysis of multifunctionality were (EEA, 2006):

— turkey oak, Hungarian oak, and sessile oak forest *(Quercus cerris* L. dominant*)*;

— downy oak forest *(Quercus pubescens* Willd. dominant*)*;

— Mediterranean evergreen oak forest *(Quercus ilex* L. dominant*)*.

We consider them because they represent the 91.2% of total forest area, respectively 48.2%, 34.9% and 8.1%.

Considering the benefits as the tangible product — expressed in terms of goods and services — of the capability of forest ecosystem to provide different functions (Ansink *et al.,* 2008), the multifunctionality of each sampling point was evaluated by technicians estimating — in the context of an Index of Importance of Function (I) — the capacity of each respective forest type to fulfil different functions. This index was calculated by providing a score for each function. The score was assigned for each function following a few key-indicators (i.e. for habitat conservation: quantitative and qualitative presence of deadwood, species composition, for timber and firewood production: volumes allocated on the quality of the stem, distance from forest road, for hydrogeological protection: slope, roughness, etc.). A scale ranging from 0 to 10 was utilized. A value of 10 was assigned to the most prevalent function, with each decreasing value (9, 8, 7 etc.), respectively, signifying those functions with an increasingly minor importance. Functions that were not applicable in the context, were given a score of 0. The functions, reported in the literature, had to be adapted to the Collina Materana context because of the characteristics specific to that territory.

In particular, the functions were defined and codified before the survey phase since these were based on the result of the synthesis of the data gathered from both the first phase of the participation process and information already owned by the technicians (including: cartography, previous management plans, etc.). The functions considered were therefore seven: fuelwood production, timber production, hydrogeological protection, tourism and recreation, habitat conservation, landscape conservation and environmental protection.

The sampling points were aggregated according to forest system and forest type and then compared with indicators measuring the level of multifunctionality. The indicators were:

a) the average number of functions fulfilled by each forest type $\bar{N}_{fft}$ calculated as the mean of the functions of all sampling points related to the forest type.

$$\bar{N}_{fft} = \frac{\sum_{i=1}^{i=n} f_i}{n} \qquad [1]$$

n = total of sampling points per forest type
f_i = number of functions fulfilled in a sampling point i

b) the average value of each function associated to a forest type $\bar{v}_{fft}$

$$\bar{v}_{fft} = \frac{\sum_{i=1}^{i=n} I_i}{n} \qquad [2]$$

n = total of sampling points per forest type
I_i = index of importance of function in a sampling point i

c) the mean total value of all functions $\bar{V}_{F\,FT}$ referred to each forest type

$$\bar{V}_{F\,FT} = \frac{\sum_{j=1}^{j=m} \bar{v}_{fft\,j}}{m} \qquad [3]$$

m = total of functions
$\bar{v}_{fft\,j}$ = average value of a forest type for the function j

The analysis of the three indicators provided a synthesis of the actual level of multifunctionality for system and forest type, a starting point for the investigation of future silvicultural guidelines.

In general, these indicators can be used together with dendrometric data in order to highlight the functional and structural characteristics of stands. In particular, the assessment of each forest functions provides indications for a zone-oriented forest landscape management. In this planning scheme (large-scale segregation), the selected areas are designated for priority purpose, being all other functions subordinated within any one area (Helliwell, 1987). *Viceversa* the total value of multifunctionality associated with number of functions is more useful in a complete integration planning scheme, where different goals can be fulfil for each area of forest district.

Given that the number of observations was not particularly high and the results provided a non-normal distribution, non parametric tests were applied in order to investigate the differences. The Kruskall-Wallis test was applied in order to analyze differences between the three main forest types, whereas the Mann-Whitney test was utilized to investigate the differences between the two forest system and among each function.

Silvicultural system and multi-functional forest management approaches

The technicians were asked to evaluate the capability of the different silvicultural treatments to fulfil the required functions, in particular to which degree each

treatment might influence the pursuing of functions in a short term (the validity of a management plan) and mid-long term (beyond the biological life of the actual forest).

The silvicultural systems taken into account were:

For coppices:

— Coppicing: the cutting down of the stand with release of "standards" with the presumed function of seed dispersal and hydrogeological protection (Perrin, 1954). In Southern Italy coppices had in the past a double function: firewood production and pastureland. Thus, the standards provided also shelter and fodder, with acorns for the animals (Zanzi Sulli and Di Pasquale, 1993);

— Coppice conversion into high forest: all the preparatory techniques for the conversion of a coppice into a high stand. The treatments lead the coppice to assume the appearance of a high forest (Bernetti, 2005; Gonzalez Molina, 2005);

— Absence of treatments: natural evolution of the stand.

For high forests:

— Variable extension clearing for natural regeneration in even aged forests: shelterwood cutting, strip or group felling (Kimmins, 2004).

— Treatments aimed to obtain a high forest with permanent regeneration: selection cutting for an uneven aged structure, progressive shelterwood felling and shelterwood-strip felling for an uneven aged structure by small groups (Helms, 1998).

— Absence of treatments: natural evolution of the stand.

The evaluation was conducted for each silvicultural treatment by using a seven class scale which attributed a synthetic assessment on the capability to fulfil a certain function (Table 1). The numeric index *SFi* expressed the capability of the silvicultural treatment S to carry out the function F in the point *i*. The N.V. class was used when a certain silvicultural treatment was not able to fulfil a specific function (i.e. firewood production associated to the option "natural evolution"). The N.A. class, instead, was utilized whenever a treatment was not applicable to a specific function (i.e. coppicing in a forest of conifers).

The evaluations were carried out considering the effects of each treatment both in short term (validity of a management plan, equal to ten years), and in mid-long term (20-30 years).

A degree of function fulfilment of each silvicultural system was calculated for every forest type through the

Table 1. Scores for the index $C_{ss\,ft\,f}$

Capability to fulfil a certain function	Score
G = Good	5
MG = Medium - Good	4
M = Medium	3
MS = Medium - Scarse	2
S = Scarse	1
N.V. = Not viable	0
N.A. = Not applicable	0

Capability of Function Fulfilment Index, generically defined as $C_{ss\,ft\,f}$, calculated as the mean of the product between index of importance of function and capability of the silvicultural system to fulfil the function of all sampling points related to the forest type:

$$C_{ss\,ft\,f} = \frac{\sum_{i=1}^{i=n} I_f i \cdot c_s\ i}{n} \qquad [4]$$

where:

n = total of sampling points per forest type

$I_f i$ = index of importance of function f in the point i

$c_s i$ = capability of the silvicultural system in the forest type to fulfil the function f in the point i

The evaluation of the technicians acquired a particular importance for forest planning, since they assessed the possible effects of the different silvicultural treatments in regard to the functions that forest ecosystems might provide. The results regarding the capability of the silvicultural system to fulfil the function were used in the plan drafting phase. Specifically, the planners proceeded, for each forest area, as follows: firstly, they selected the forest function which was worth of enhancement, secondly they applied the Capability of Function Fulfilment Index in order to identify the most appropriate silvicultural treatments.

Results

Forest system, forest type and multifunctionality

The indicators of multifunctionality were employed for the analysis of the sampling points and aggregated by forest type and forest system. The N_f indicator which was related to the average number of functions for each sampling point, highlighted that the turkey oak forests performed the highest number of functions, $N_f = 3.42$,

Table 2. Average values of function importance ($\bar{v}_{fft}$) and average number of functions (N_f) per forest type

Functions/Forest type	Turkey oak forests	Mediterranean evergreen oak forests	Downy oak forests
Habitat conservation	1.52	0.00	0.34
Fuelwood	7.94	4.00	7.45
Roundwood	0.00	1.40	0.00
Tourism and recreation	0.55	0.00	0.34
Environmental protection	5.91	7.00	1.79
Landscape conservation	8.18	9.00	5.59
Hydrogeological protection	7.06	9.60	8.79
Mean (V_t)	**4.45**	**4.43**	**3.47**
St. dev.	**3.62**	**4.14**	**3.72**
Mean (N_f)	**3.42**	**3.40**	**2.62**

Table 3. Average values of importance of function ($\bar{v}_{fft}$) and average number of functions (N_f) per forest system (U = 28249.0, Expected value = 26754.0, p-value 0.251, α = 0.05)

Functions/Forest system	High forest	Coppice
Habitat conservation	1.61	0.28
Fuelwood	7.97	6.97
Roundwood	0.00	0.19
Tourism and recreation	0.90	0.00
Environmetal protection	5.71	2.92
Landscape conservation	8.03	6.33
Hydrogeological protection	6.71	9.11
Mean (V_t)	**4.32**	**3.82**
St. dev.	**4.63**	**4.59**
Mean (N_f)	**3.32**	**2.90**

the Mediterranean evergreen oak forests scored N_f = 3.40, while the downy oak forests showed the lowest values with N_f = 2.62. The V_t indicator, (Table 2), regarding the overall average value of all functions, showed the highest score in the turkey oak forests followed by the Mediterranean evergreen oak forests and the downy oak forests.

The non parametric test of Kruskall-Wallis applied to the three forest types did not highlight significant differences. Taking into account the results of each individual function, turkey oak forests and downy oak forests fulfilled seven functions. In both formations the timber production function was absent. In the Mediterranean evergreen oak forests, instead, the habitat conservation and the tourism and recreation functions were not found.

Considering the average values per function, the timber production, the habitat conservation and the tourism and recreation function showed either very low scores or were absent in all forest types. Conversely, landscape conservation and hydrogeological protection displayed high values for each forest type; fuelwood production was secondary only in the Mediterranean evergreen oak forests, while environmental protection gained a certain importance in both Mediterranean evergreen oak forests and turkey oak forests.

The first multifunctionality indicator, relative to the number of functions fulfilment applied to the forest system, underlined a remarkably high number of functions per point in the high forests (N_f = 3.32) compared with the coppices (N_f = 2.90). The V_t indicator (Table 3), expressed as the average value of all functions calculated in the totality of the points falling in a certain forest system, resulted equal to V_t = 4.32 (st. dev. = 4.63)

in the high forests and V_t = 3.82 (st. dev. = 4.59) in the coppices. Non statistically significant differences emerged between the two forest systems (U = 28249.0, Expected value = 26754.0, p-value 0.251, a = 0.05) by applying the non parametric test of Mann-Whitney.

Taking into account the individual functions per forest type, roundwood production, habitat conservation and tourism and recreation function showed either very low values or were absent in both forest systems. The non parametric test of Mann-Whitney, applied to each function, showed significant differences for habitat conservation, remarking that in the Collina Materana context the valorisation of these functions is basically realized in high forests rather than in coppices. The hydrogeological protection appeared to have priority in the coppices of the Collina Materana, although it was important even for high stands. Conversely, the landscape conservation and the fuelwood production was a priority in the high forest even though it was considered relevant also for the coppices.

To conclude, the turkey oak forests, among forest types, obtained the highest values for the two synthetic indicators, while the downy oak forests received the lowest scores. The landscape conservation and the hydrogeological protection assumed great relevance, as well as the fuelwood production, except for the Mediterranean evergreen oak forests. The only statistically significant differences were observed for the environmental protection function between downy oak forests and the other two forest type (turkey oak forests: U = 734.0, Expected value = 495.0, p-value 0.0, α = 0.05; Mediterranean evergreen oak forests: U = 29.0, Expected value = 75.0, p-value < 0.0001, α = 0.05) and for the landscape conservation function between downy

Table 4. Objectives-treatments matrix for turkey oak dominant forests

Functions/Forest type	Simple Coppice system		Conversion		Even aged		Uneven aged		No silvicultural system (coppice/high forest)	
	Short	Med.	Short	Med.	Short	Med.	Short	Med.	Short	Med.
Habitat conservation	–	–	–	–	–	–	–	–	–/10.9	–/10.9
Fuelwood	16.8	9.1	24.8	10.7	7.9	16.4	1.0	13.5	–/–	–/–
Roundwood	–	–	–	–	–	–	–	–	–/–	–/–
Tourism and recreation	–	–	–	–	–	2.2	–	2.2	–/2.2	–/1.7
Environmental protection	2.6	1.8	3.9	8.7	6.1	7.1	3.3	9.0	7.7/27.6	8.6/27.6
Landscape conservation	8.5	2.7	18.8	7.8	8.0	14.3	3.7	17.0	25.8/35.7	21.7/35.7
Hydrogeological protection	13.2	8.2	23.5	10.8	5.3	16.7	2.2	20.7	31.3/28.5	28.1/28.0
Total	5.9	3.1	10.1	5.4	3.9	8.1	1.5	8.9	9.3/15.0	8.3/14.8

oak forests and turkey oak forests (U = 311.0, Expected value = 495.0, p-value 0.008, α = 0.05). In addition, a difference was found for the hydrogeological protection function between downy oak forests and turkey oak forests (U = 345.0, Expected value = 495.0, p-value 0.028, α = 0.05). Statistically significant differences between forest type were not observed for the other forest function.

The high forest highlighted for each indicator higher values than the coppices, apart from the hydrogeological protection function. Even for those functions which had obtained low scores, such as the habitat conservation function, the high forest appeared to be the most suitable for their valorisation.

Silvicultural system and multifunctionality

The data regarding the capability to fulfil a function applied to each silvicultural treatment, showed that the turkey oak dominant forests (Table 4) obtained very high values for the hydrogeological protection if associated to the silvicultural option of natural evolution. This result was highlighted in the short term for both coppices and high forests. Such solution was confirmed even in the medium term, although with slightly lower average values. Furthermore, the natural evolution resulted the best solution for the technicians, who had compiled the matrix, also for the valorisation of the habitat conservation, environmental and landscape conservation and hydrogeological protection.

Regarding the downy oak dominant forests (Table 5), the fuelwood production function might achieve excellent results in both short and medium terms with the application of a simple coppice system. The conversion might successfully accomplish the landscape conservation and hydrogeological protection function as well as the firewood production function. According to Table 5, the downy oak dominant forests improve the hydrogeological protection when no treatment is applied and/or with even aged treatments, in the latest case especially in the medium term. This kind of intervention, independent from the management period, is the most interesting for the functional improvement of

Table 5. Objectives-treatments matrix for downy oak dominant forests

Functions/Forest type	Simple Coppice system		Conversion		Even aged		Uneven aged		No silvicultural system (coppice/high forest)	
	Short	Med.	Short	Med.	Short	Med.	Short	Med.	Short	Med.
Habitat conservation	–	–	–	–	–	–	–	–	2.4/–	2.4/–
Fuelwood	22.5	19.0	21.5	15.7	8.3	23.4	1.1	2.3	–/–	–/–
Roundwood	–	–	–	–	–	–	–	–	–/–	–/–
Tourism and recreation	–	–	–	–	3.8	3.8	–	–	–/–	–/–
Environmental protection	0.4	–	3.0	–	8.8	8.8	–	–	2.4/5.0	2.4/5.0
Landscape conservation	5.9	0.8	11.5	2.7	14.4	28.6	5.0	10.0	19.5/19.6	19.9/20.6
Hydrogeological protection	16.7	12.5	25.1	16.9	12.5	34.4	6.3	12.5	33.9/30.6	35.2/30.6
Total	6.5	4.6	8.7	5.0	6.8	14.1	1.8	3.5	8.3/7.9	8.6/8.0

Table 6. Objectives-treatments matrix for Mediterranean evergreen oak forests (only coppice)

Functions/Forest type	Simple coppice system		Conversion		No silvicultural system	
	Short	Med.	Short	Med.	Short	Med.
Habitat conservation	–	–	–	–	–	–
Fuelwood	12.0	–	–	8.0	–	–
Roundwood	–	–	–	–	–	–
Tourism and recreation	–	–	–	–	–	–
Environmetal protection	5.0	1.8	3.6	13.4	17.2	17.2
Landscape conservation	6.8	3.6	5.4	15.2	25.4	27.2
Hydrogeological protection	9.6	6.0	4.0	17.0	28.0	30.0
Total	4.8	1.6	1.9	7.7	10.1	10.1

the environment protection and the tourism and recreation function. The medium term is the most suitable for firewood production.

The natural evolution appears the best solution both in short and medium term for the majority of the functions (environmental, landscape and hydrogeological protection) in the Mediterranean evergreen oak forests (Table 6). Only the fuelwood production is optimized through a simple coppice system in the short term and the conversion to high forest in the medium term.

Discussion and conclusions

From the ecological and economic point of view, the opportunities for the Collina Materana forest formations are strictly dependant from their past management and, consequently, their actual structure.

The oak forests, especially those with turkey oak and downy oak dominant, show dendrometric and structural features which are directly influenced by the under storey grazing of domestic animals, mainly bovines. As in the large majority of the Southern Apennines, this practice, associated with the occasional and not rationally planned logging of either firewood or, more rarely, timber, used to be the main forest function until a few decades ago. As a matter of fact, woodlands used to provide shelter from solar radiation and fodder with grass, fruit, shrubs and sprouts. This type of management has determined, in sites with Mediterranean climate, cultural features that vary from open forest to woodland pasture, characterized by individual trees with branchy stems and expanded crowns, absence of both intermediate and shrub storey and abundance of herbaceous cover (Massa and La Mantia, 2007; San Miguel, 2005).

This brief reference frame is necessary in order to read correctly the results coming from the functional analysis of the forest in which the planning was carried out.

The actual structure of the forest as well as the lack of a specific silvicultural tradition in the territory influence deeply any silvicultural options. The "natural evolution" choice in the short term for high stands as the best solution to fulfil the manifold functions in the different forest types, comes from the remark that the forests have been overgrazed and, consequently, the edaphic component of their soils have been impoverished.

Taking into account these conditions, the technicians considered preferable to adopt a "waiting period", in order to best value all the forest functions, and therefore suspend logging, at least in the medium term. On the other hand, interventions aimed to ameliorate the stands may be conducted, where necessary, especially through preparatory thinning oriented to natural renovation. The most appropriate treatment to renovate the oak forests may be evaluated in the long term. Productive functions may be therefore enhanced in the most fertile sites where the renovation of the forest is guaranteed. At the same time, a negative impact on the other functions, especially the hydrogeological protection, should be avoided because of the desertification hazard of the territory.

Natural evolution was considered the best option for the fulfilment of the large majority of functions, also for coppices. In this case, wherever the maintenance of this management system would not be either economically convenient or ecologically sustainable, it was considered to leave the forest to natural evolution and convert to high forest only particularly favourable situations such as very fertile coppices or oak forests mixed with valuable species.

The importance of the landscape valorisation function, especially for high forests, was an interesting output to be considered in the plan. As a matter of fact, the cultural landscape of the oak forest devoted to pasture has a considerable landscape value. It ought to be maintained locally through specific silvicultural treatments as well as with a fine regulated grazing in those areas which are particularly suitable for tourism.

The synthetic indicators of multifunctionality provided adequate outputs: the value of overall multifunctionality increased with the altimetric gradient, from Mediterranean and downy oak forests at low altitudes to turkey oak forests at greater heights.

The degradation of low altitude oak formations is high, especially because of the combination of drought and soil constipation due to overgrazing. Thus, these forests showed scarce values for production, tourism and recreation and landscape conservation function, maintaining the only soil protection function as confirmed by the indicators.

As it was expected, the analysis demonstrated that the economic value of the Collina Materana forests has a low value, and it is limited to firewood production. The indexes confirmed that the high stand management system provided the fulfilment of the highest number of functions, especially for the turkey oak forests, being the formations with greater potentiality (Del Favero 2008). The analysis showed that conversions from coppice to high stand may increase the overall value of the Collina Materana forests because of the increment of protective, tourism and productive functions, in the most fertile sites.

In conclusion, this method enabled to gather and elaborate useful information in order to evaluate multifunctionality in forest formations. The information retrieved and the evaluations thus acquired, provided a useful support for planning managers to establish guidelines.

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