

Research paper

## Multifunctionality assessment in forest planning at landscape level. The study case of Matese Mountain Community (Italy)

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Received 18/11/2013 - Accepted 20/12/2013

**Abstract** - The main objective is to improve a method that aims at evaluating forest multifunctionality from a technical and practical point of view. A methodological approach - based on the index of forest multifunctionality level - is proposed to assess the "fulfilment capability" of a function providing an estimate of performance level of each function in a given forest. This method is aimed at supporting technicians requested to define most suitable management guidelines and silvicultural practices in the framework of a Forest Landscape Management Plan (FLMP). The study area is the Matese district in southern Apennines (Italy), where a landscape planning experimentation was implemented. The approach includes the qualitative and quantitative characterization of selected populations, stratified by forest category by a sampling set of forest inventory plots. A 0.5 ha area around the sample plot was described by filling a form including the following information: site condition, tree species composition, stand origin and structure, silvicultural system, health condition, microhabitats presence. In each sample plot, both the multifunctionality assessment and the estimate of the effect of alternative management options on ecosystem goods and services, were carried out. The introduction of the term "fulfilment capability" and the modification of the concept of priority level - by which the ranking of functions within a plot is evaluated - is an improvement of current analysis method. This enhanced approach allows to detect the current status of forest plot and its potential framed within the whole forest. Assessing functional features of forests with this approach reduces the inherent subjectivity and allows to get useful information on forest multifunctionality to support forest planners in defining management guidelines consistent with current status and potential evolutive pattern.

**Keywords** - forest multifunctionality, Forest Landscape Management Planning, function fulfilment index, silvicultural system, Matese district (Italy)

### Introduction

The Sustainable Forest Management (SFM) paradigm - defined at the Montreal Process (1987) - aims to balance social, economic, ecological, and cultural needs of present and future generations (Wyder 2001, Tabbush 2004) and to maintain resources based on the multiple use of forests (Garcia-Fernandez et al. 2008).

The theoretical and practical development of multiple use forest management (MFM) started in North America and was re-conceptualized in Europe, giving greater emphasis to the concept of forest functions instead that to the concept of forest use. Nix (2012) referred to MFM as "the management of land or forest for more than one purpose, such as wood production, water quality, wildlife, recreation, aesthetics, or clean air". According to this definition, MFM is an approach that combines two or more uses of forests (i.e. wood production, maintenance of proper conditions for wildlife, landscape effects,

recreation, protection against floods and erosion, and protection of water supplies).

In Europe the concept of forest multifunctionality was born in 1953 in Germany with the elaboration of the "Theory of Forestry Function" by Viktor Dieterich of the University of Munich. In this theory, the concept of multiple-use was developed and widened through a less anthropocentric vision where the functions have an intrinsic importance (vitality and health of ecosystem).

Over the last years, MFM has been envisioned as a promising and more balanced alternative to sustained yield strategies. Some authors emphasize that the inclusion of multiple values and multiple stakeholders might give SFM a much needed social and financial boost (Campos et al. 2001, Hiremath 2004, Kant 2004, Wang and Wilson 2007). The incorporation of multiple forest values in forest management decisions is one of the important dimensions of SFM (Kant 2007). Nowadays a modern forestry vision requires forests to satisfy demands of many

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stakeholder for multiple products and services (Kant 2004, Cantiani 2012).

SFM is a concept in continuous evolution both in time and space (Angelstam et al. 2005, Straka 2009). The multifunctional forest management planning aims to integrate in decision making the non-productive issues of the forest, just as well as the socio-cultural and environmental issues (Vincent and Binkley 1993, Kangas and Store 2002). In such planning approach the logical process that leads to the final management choice becomes considerably complicated (Pukkala 2002). For this reason, the most unambiguous, reproducible and economically sound definition and experimentation of a methodology regarding the planning process is necessary (Paletto et al. 2012).

During the last years, in Italy, forest management planning is not only realized through traditional plans at stand or regional level, but new Forest Landscape Management Plans (FLMP) are gaining importance as well. FLMPs provide alternative scenarios of forest landscape management rather than defining where and when a specific forest practice must be applied (Agnoloni et al. 2009).

Many forest planners have recognized the development of planning systems on a landscape scale as the proper tool to analyse the forest complexity and to define the management guidelines (Kant 2003, Kennedy and Koch 2004, Farcy and Devillez 2005, Cabbage et al. 2007, Schmithüsen 2007).

FLMP addresses long-term forest management issues, with special attention to environmental issues 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 category and silvicultural system (coppice or high forest). These are then divided and adapted for every function (Paletto et al. 2012).

Referring to the method developed by Paletto et al. (2012), devoted to define the forest multifunctionality from a practical point of view to support the forest practitioners, the main objective of this study is to improve this method in several aspects.

Specifically, we implemented the following three issues:

- i) introduction of the priority level of every function. Zero priority function no longer exists; instead a priority ranking will be established among all functions;
- ii) introduction of an index of the forest multifunctionality level. This index is defined through the capability of function fulfilment which provides an estimates of how much every function is performed in a given forest plot compared to the average performance of the same forest category. This feature introduces the novel concept of the relative performance in a 0 to 10 range.
- iii) identification of which forest functions we have to take into consideration is carried out through a participatory process involving local stakeholders and experts.

Furthermore we aimed to test the method proposed by Paletto et al. (2012) in a different forest



**Figure 1 -** The study area and its municipalities.

**Table 1 -** Forest categories distribution in the study area.

Forest categories	Area (ha)	%
Beech forests	4785	29.7
Turkey oak forests	6644	41.2
Downy oak forests	290	1.8
Hop-hornbeam forests	1556	9.7
Chestnut forests	320	2.0
Riparian forests	842	5.2
Holm oak forests	18	0.1
Other broadleaved forests	1020	6.3
Shrublands	406	2.5
Coniferous plantations	212	1.3
<b>TOTAL</b>	<b>16094</b>	<b>100</b>

environment. Indeed, the application of the method in a different social and ecological context is a further element useful to improve the method and it can provide important suggestions from a practical point of view.

## Materials and methods

### Study area

The study area is included by the “Comunità Montana” of Matese, located in the Molise Region in Central Italy (Fig. 1). It has a total area of 36,500 ha and includes 11 municipalities.

The altitude ranges from 422 m a.s.l. of Spinete lowland to the 2,050 m a.s.l. of Monte Miletto.

The study area has 15,687 ha of forest lands and 407 ha of other wooded lands (Chirici et al. 2011). Forest area covers 43% of Matese district; the percentage of forest area varies from a maximum of 75% in Guardiaregia municipality to a minimum of 19% in Cercepicolica municipality.

The most forested area is represented by the South-western part of study area; in the North-eastern part forests are more fragmented and juxtaposed with urban and agricultural lands.

In terms of surface (Fig. 1), Turkey oak (*Quercus cerris* L.) forests are the most extended forest category (41.2% of forest area), they are often pure and fertile stands with well-shaped trees. Turkey oak forests are divided into the following forest types: i) mesophilous Turkey oak forests, closed and mainly pure stands growing in very fertile sites; ii) meso-xerophilous Turkey oak forests, with the significant presence of meso-xerophilous species or more rarely mesophilous species such as common hornbeam (*Carpinus betulus* L.), sycamore maples (*Acer pseudoplatanus* L.) and downy oak (*Quercus pubescens* Willd.).

The second forest category is represented by European beech (*Fagus sylvatica* L.) forests which occupy an area of 4,785 ha (29.7% of forest area) and are localized at the highest elevations and northern expositions. European beech forests are divided into the following three forest types (Chirici et al. 2011): i) high-mountainous beech forests, localized

just below the timberline, in high slopes or in peak summits often characterized by rocky soils, strong winds, soil aridity and low fertility; ii) mountainous beech forests, which are the beech main forest type characterized by pure and fertile stands, where the understory vegetation is very sparse or absent; iii) sub-mountainous beech forests, localized in the transition zone between beech and Turkey oak forests or more rarely hop-hornbeam forests.

Other significant forest categories are represented by hop-hornbeam forests (9.7% of forest area) and by other broadleaved forests (6.3% of forest area). Finally riparian forests occupy the 5.2% of forest area and are localized along main creeks and rivers at the lowest altitudes.

Considering the economic importance of European beech and Turkey oak forests which occupy the 70.9% of forest area, for the multifunctionality analysis we focused only on these two forest categories which represent our reference population.

### Method

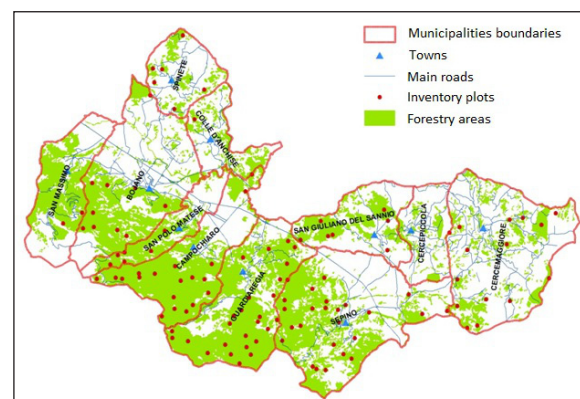
We characterized the selected forest categories surveying 117 inventory plots and collecting qualitative and quantitative data.

We carried out an unaligned systematic sample design consistent to the Italian National Forest and Carbon sinks Inventory (INFC, 2004).

We generated a geo-referenced squared grid with 1 km step and random origin. A point with random coordinates was positioned in every square. Finally all points (more than 10,000) were overlapped to Molise forest types map (Chirici et al. 2011) in order to select the reference sample plots (117) in European beech or Turkey oaks forests (Fig. 2).

We described a 0.5 ha area around the sample plot by filling a form including the following information: site condition, tree species composition, stand origin and structure, silvicultural system, health condition, microhabitats presence.

In every sample plots we carried out the multifunctionality assessment and the effect estimation



**Figure 2 -** Distribution of sample plots over the map of forest land use in the study area.



**Table 2 -** Stakeholders interviewed during the first phase of the participatory process.

Stakeholder	Num.
Majors	10
Forest enterprises	8
Associations	7
Agri-touristic farms	3
Freelance foresters	4
Local Action Groups	3
Forest nurseries	1
Sawmills	1
Mushrooms/truffles canning industry	1

of alternative management options on ecosystem goods and services by the method described below.

From 117 plots, 63 plots (53.8%) were classified as Turkey oak forests and 54 plots (46.2%) as European beech forests. In terms of silvicultural system, instead, 65 plots (55.6%) fell into coppice system and 52 (44.4%) into high forest system. In high forests, the most represented structure were the one-layered (32.5%), this suggesting shelterwood as the most common system. Nonetheless, also more complex high forest structures were found: two-layered (10.3%) and multi-layered (8.5%).

#### **Multifunctionality: silvicultural system and forest category**

At the purpose of this study, we considered the ability of forest ecosystem to supply goods and services. As a consequence, multifunctionality was assessed by a forest experts' team in each plot by assigning a value for two parameters: i) function priority level and ii) capability of function fulfilment.

The function priority level is a score aiming to relatively rank all functions considered essential for each plot in the specific context where the forest is located. The score consisted in an integer positive value ranging from 1 to  $n$ , where  $n$  is the number of all functions considered essential for that specific plot. The most important function takes the value 1 and the less important function takes the value  $n$ . An even score is possible if two functions are considered equally important.

The capability of function fulfilment is an estimation of how much that forest can perform every considered function compared to the average performance of the same forest type. The score ranges from 0 (no performance) to 10 (best performance for that forest type).

Forest functions considered in the study area were selected taking into account four aspects at once: i) ecological, social and economic context of the study area, ii) internationally recognized forest functions resulting from a literary review, iii) a participatory process involving local stakeholders, and iv) existing and up to date forest planning at unit level in the study area.

Concerning the participatory process, 39 stake-

holders were contacted and interviewed to highlight the most relevant forest functions in the study area (Table 2).

The seven forest functions identified are described below.

- **Landscape conservation.** Considering the landscape as the result of interaction between human and natural environment (Brady 2003), landscape management is based on multiple values including ecological, economic, cultural and perception aspects (Sepp et al. 1999). Evaluation criteria were: the relative importance of the landscape in the local cultural context and the visibility from road and trail networks.
- **Firewood/biomass production.** All products (primary and secondary) provided by the forest for domestic heating.
- **Timber production:** all wood assortments not used for heating.
- **Non-wood forest production.** The total of non-wood forest products such as truffles, mushrooms, berries, etc.
- **Soil and water protection.** Direct and indirect protection against natural hazards such as floods, landslides, rock falls, soil erosion, etc. (Führer 2000).
- **Touristic/recreational function.** Forests provide many recreational opportunities such as trekking, bird-watching, biking, orienteering, plant and animal observing etc. (Krieger 2001).
- **Environment conservation.** It considers the positive effect that forests have on biodiversity and microhabitat conservation. We evaluated the possibility/ opportunity of increasing the number of microhabitats and diversifying forest structure (horizontal and vertical) to promote wildlife biodiversity (FAO 2006).

In a first step, we stratified plots by silvicultural system (coppice or high forest) and by forest category. During a second step, we compared the strata by multifunctionality level indicators using two indicators described below.

Mean priority level and mean fulfilment capability were calculated for each function as:

Where:

$$\bar{v}_{f\ ji} = \frac{\sum_{i=1}^n v_{f\ i}}{n}$$

$n$  = total number of plots per stratum;  
 $v_{f\ i}$  = priority level or fulfilment capability for the  $f$  function in the  $i$ -th plot.

This indicator assesses the priority level or the fulfilment capability for every forest category (or silvicultural system) and for each function. Thus it

**Table 3 -** Silvicultural options.

<b>coppices</b>	1) traditional coppicing: total harvesting of trees except the release of a variable number of standards with a main dissemination function (Perrin, 1954); 2) conversion into high forest: set of techniques aiming at the preparation for the conversion into high forest. The application of these treatments lead to a transitory stand alike to a high forest structure (Bernetti, 2005). 3) natural evolution of the stand.
<b>high forests</b>	1) even-aged high forest regeneration practices: shelterwood, large-medium strips or large-medium groups felling (Kimmins, 2004); 2) coppice/high forest integration; 3) high forest in continuous regeneration: to get an uneven-aged structure per single tree by selection felling or per small groups by small strips or group shelterwood (Helms, 1998); 4) natural evolution of the stand

gives useful indications for operational purposes at a stratum level.

Total mean priority level and fulfilment capability as:

Where:

$$\bar{V}_{FFT} = \frac{\sum_{j=1}^m \bar{v}_{f, ft, j}}{m}$$

$m$  = total number of selected functions;  
 $\bar{v}_{f, ft, j}$  = mean priority level or mean fulfilment capability of the stratum for the  $j$ -th function.

This indicator assesses the total multifunctionality value of the stratum giving a synthetic value. It is useful to compare different forest categories and silvicultural systems.

The joint analysis of these indicators provide a synthetic evaluation of the current multifunctionality of the stratum (forest category or silvicultural system) which is the base to analyse future silvicultural options (Paletto et al. 2012)

#### **Performance capability of silvicultural options**

In this study we evaluated the capability of each silvicultural option to perform the requested function, that means how much each treatment application can affect the function fulfilment both in the short- and mid-term (Agnoloni et al. 2009).

We considered for each plot the silvicultural options described in Table 3.

In each plot, a team composed by two forest experts evaluated each silvicultural option by giving a synthetic score for the capability of the treatment to perform each function.

In Table 4 we reported the correspondence between the evaluation and the score in 7 classes.

N.P. represents a null fulfilment capability, it is used when a specific silvicultural option is not able to allow the stand to perform a specific function

(e.g. natural evolution is evaluated N.P. for firewood production function).

N.A. is used when a specific silvicultural option is technically or legally not applicable in that particular forest context (e.g. coppicing option is evaluated N.A. in the case of a coppice abandoned for more than the legally allowed period to be coppiced, specifically two times the rotation period).

The evaluations were carried out considering the effects of each treatment both in short-term (validity of a management plan, equal to 10 years), and in mid-term (20-30 years).

A degree of function fulfilment of each silvicultural option was calculated for every forest category by the Capability of Function Fulfilment Index. It was calculated as the mean of the product between the index of importance of function and the capability of the silvicultural option to fulfil the function of all sampling points related to the forest category:

Where:

$$C_{s, ft, f} = \frac{\sum_{i=1}^n I_{f, i} \cdot c_{s, i}}{n}$$

$n$  = total number of plots per stratum;  
 $I_{f, i}$  = priority level of  $f$  function for the  $i$ -th plot;  
 $c_{s, i}$  = capability of  $s$  silvicultural option to fulfil the  $f$  function in the  $i$ -th plot.

Expert evaluation acquires a relevant importance for forest planning, because experts assess directly in field the possible effects of a silvicultural option which can affect positively or negatively each forest function (Paletto et al. 2012).

Our dataset do not respect all assumptions for parametric analysis and almost all the variables are ordinal and non-normally distributed. Thus, we carried out a non parametric analysis. Specifically the Mann-Whitney (U) test (Mann and Whitney 1947) was utilized to investigate the differences between forest categories (European beech and Turkey oak forests) and between silvicultural systems (coppices and high forests); we set a p-level = 0.01 to separate significant from non-significant differences.

**Table 4 -** Score to evaluate the fulfilment of each silvicultural option.

Evaluation	Score
Good	5
Average good	4
Average	3
Average poor	2
N.P. = Not performing	1
N.A. = Not applicable	0

**Table 5** - Mean values of functions' priority level and fulfilment capability by silvicultural systems.

Function/Silvicultural system	Priority level		Fulfilment capability	
	<i>Coppices</i>	<i>High forests</i>	<i>Coppices</i>	<i>High forests</i>
Landscape conservation	4.98	4.52	7.19	7.13
Firewood/biomass production	6.03	4.31	6.86	6.28
Timber production	2.70	4.31	4.29	6.06
Non-wood forest production	4.00	3.61	6.00	5.85
Soil and water regulation	4.24	4.50	6.90	6.98
Touristic/recreational function	3.52	4.07	5.94	6.44
Nature conservation.	3.81	4.07	6.37	6.57
<b>Mean value</b>	<b>4.18</b>	<b>4.20</b>	<b>6.22</b>	<b>6.47</b>
<b>Standard deviation (<math>\sigma</math>)</b>	<b>1.07</b>	<b>0.32</b>	<b>0.97</b>	<b>0.46</b>

## Results

### Priority level

Regarding the silvicultural system and considering the full set of functions, we obtained the following results of multifunctionality ( $V$ ): for coppices the mean priority level was 4.18 ( $\sigma = 1.10$ ), and the mean fulfilment capability was 6.18 ( $\sigma = 0.82$ ); for high forests the priority level resulted 4.22 ( $\sigma = 0.82$ ) and the mean fulfilment capability resulted 6.54 ( $\sigma = 0.63$ ) (Table 5).

Considering the value of priority level for single functions ( $v$ ), we can note that firewood production is the main function for coppices and the third for high forests. The difference between coppices and high forests is statistically significant ( $U = 2,466.5$ , Expected value = 1,701, p-value = 0.0001).

Both landscape conservation and soil and water protection have high priority for both silvicultural systems.

Concerning the fulfilment capability of single functions, high forests fulfil more non-productive functions such as (in order of importance) landscape conservation, soil and water protection, environment conservation and touristic/recreational function.

Another result is the high mean priority level of coppices for (in order of importance) the landscape conservation and the soil and water protection.

Moreover, timber production resulted as one of the less important function for both silvicultural systems. This is probably due to the main use of wood coming from Matese forests i.e. firewood, also when it could be useful for alternative uses.

Nonetheless, timber production resulted more important in high forests than in coppices and this difference is statistically significant ( $U = 1,037.5$ , Expected value = 1,701, p-value = 0.0001). Also the fulfilment capability of this function resulted significantly higher for high forests than for coppices ( $U = 839$ , Expected value = 1,701, p-value = 0.0001).

Regarding the forest category and considering the full set of functions, we obtained the following

results of multifunctionality ( $V$ ): for Turkey oak the mean priority level was 4.18 ( $\sigma = 1.07$ ), and the mean fulfilment capability was 6.22 ( $\sigma = 0.97$ ); for European beech forests priority level was 4.20 ( $\sigma = 0.32$ ) and the mean fulfilment capability was 6.47 ( $\sigma = 0.46$ ) (Table 5).

Considering the value of priority level for single functions ( $v$ ) we can note that in Turkey oak forests firewood production is the most important function and significantly more important than in European beech forests ( $U = 2,447.5$ , Expected value = 1,690, p-value = 0.0001). Furthermore, Turkey oak forests have a priority level of the landscape conservation function higher than European beech forests ( $U = 2,311$ , Expected value = 1,690, p-value = 0.001).

On the other hand, European beech forests showed two prior functions: the most important was the soil and water protection ( $U = 1,098$ , Expected value = 1,690, p-value = 0.001), the second was the environmental conservation.

These results reflect very clearly the different geo-morphological position of the two forest categories. Indeed, Turkey oak forests are mainly located at a lower altitude and in sites with lower slopes than European beech forests.

Concerning the productive aspects, European beech forests have a significantly higher priority level for the timber production function ( $U = 1,203$ , Expected value = 1,690, p-value = 0.006). Instead, for Turkey oak forests the timber production show the lowest priority level among functions considered.

On the other hand, European beech forests show to fulfil better non-productive functions: soil and water protection, landscape conservation and environmental conservation.

Particularly, European beech forests show a significantly higher fulfilment capability than Turkey oak forests for soil and water protection ( $U = 910.5$ , Expected value = 1,690, p-value = 0.0001), and for environmental conservation ( $U = 1,113$ , Expected value = 1,664, p-value = 0.002).

Fulfilment capability of timber production is for both silvicultural systems at the last rank. None-

**Table 6** - Mean values of functions' priority level and fulfilment capability by forest categories.

Function/Silvicultural system	Priority level		Fulfilment capability	
	<i>Turkey oak forests</i>	<i>Beech forests</i>	<i>Turkey oak forests</i>	<i>Beech forests</i>
Landscape conservation	5.37	4.02	7.20	7.12
Firewood/biomass production	5.98	4.31	6.74	6.40
Timber production	2.89	4.13	4.60	5.73
Non-wood forest production	4.05	3.54	5.97	5.88
Soil and water regulation	3.82	5.04	6.54	7.44
Touristic/recreational function	3.54	4.08	6.03	6.35
Nature conservation.	3.58	4.42	6.16	6.87
<b>Mean value</b>	<b>4.18</b>	<b>4.22</b>	<b>6.18</b>	<b>6.54</b>
<b>Standard deviation (<math>\sigma</math>)</b>	<b>1.10</b>	<b>0.46</b>	<b>0.82</b>	<b>0.63</b>

**Table 7 -** Results of objectives-options matrix for Turkey oak forests.

Option	Coppicing (only coppice)		Conversion into high forest (only coppice)		Even-aged high forest (only high forest)		Coppice/high forest integration (only high forest)		Uneven-aged high forest (only high forest)		Natural evolution (both coppices/ high forest)	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Landscape conservation	23.5	23.9	24.6	25.7	22.3	22.4	9.7	10.0	18.9	19.0	26.7/26.7	25.3/25.6
Firewood/biomass production	29.8	30.5	19.9	23.5	20.3	21.2	6.2	6.8	10.4	10.9	0/0	0/0
Timber production	4.5	5.2	4.8	8.3	13.0	16.1	2.9	3.6	8.7	11.1	0/0	0/0
Non-wood forest production	13.3	14.7	14.2	15.8	14.3	15.0	5.7	5.0	11.4	11.8	13.3/13.5	13.6/13.8
Soil and water regulation	15.5	15.8	16.9	17.6	15.7	16.2	7.1	7.2	14.5	14.7	17.5/17.6	17.4/18.0
Touristic/recreational function	10.6	10.9	12.8	15.0	12.8	13.8	4.0	4.8	10.5	11.4	11.3/11.6	12.8/12.9
Environmental conservation	12.5	12.6	14.0	15.3	13.4	13.2	6.2	6.4	12.9	13.1	15.9/16.0	17.4/17.6
<b>Mean value</b>	<b>15.7</b>	<b>16.2</b>	<b>15.3</b>	<b>17.3</b>	<b>16.0</b>	<b>16.9</b>	<b>5.8</b>	<b>6.3</b>	<b>12.5</b>	<b>13.2</b>	<b>12.1/12.2</b>	<b>12.4/12.6</b>
<b>Standard deviation (<math>\sigma</math>)</b>	<b>8.4</b>	<b>8.4</b>	<b>6.2</b>	<b>5.8</b>	<b>3.8</b>	<b>3.6</b>	<b>2.2</b>	<b>2.1</b>	<b>3.4</b>	<b>2.9</b>	<b>9.6/9.6</b>	<b>9.4/9.5</b>

theless, the non-parametric test of Mann-Whitney shows statistical significantly differences for this function in the European beech forests ( $U = 1,153.5$ , Expected value = 1,690,  $p$ -value = 0.003)

From a productive viewpoint, we can confirm that firewood/biomass production is the only product requested by the market for both forest categories. This is particularly relevant for Turkey oak forests.

#### **Silvicultural options and multifunctionality**

Concerning Turkey oak fulfilment capability calculated for every silvicultural option (Table 7), results show very high values for firewood/biomass production function by coppicing. This capability increase from short-term (29.8) to long-term (30.5). Coppice system allows to maintain good capability to fulfil soil and water protection (15.5-15.8) and landscape conservation (23.5-23.9).

These results highlight that coppicing and even-aged high forest options are more able to fulfil every function than the integration of both options.

Concerning timber production, results show that longer is the term of application of every option, higher is the capability to fulfil a specific function. This aspect is especially evident for even-aged high forest option which has a capability to fulfil timber production of 13.0 in the short-term and 16.1 in the long-term.

Besides, the experts' team evaluated natural evolution as the optimal option to foster together environmental conservation, soil and water protection, and landscape conservation.

Concerning European beech forests (Table 8), firewood/biomass production by coppicing has a fulfilment capability halved compared to Turkey oak forests. This aspect is due to the position of European beech coppices mainly located at high

elevation on sloping and medium-low site-index terrains often going to be naturally converted to high forests.

Coppicing, conversion into high forests and even-aged high forest options are fulfilling firewood production with similar performance.

As already reported for Turkey oak, timber production by even-aged high forests options is fulfilled better in the long-term (20.7) than in the short-term (17.7).

Furthermore, this option allows to maintain good fulfilment capability for non-monetary forest functions such as: soil and water protection, touristic/recreational function, environment conservation and landscape conservation.

Also for European beech forests, natural evolution fulfils forest services such as: landscape conservation, soil protection and water regulation, environmental conservation. The same option fulfils better than others non-wood forest production, too.

#### **Discussion and conclusions**

Forest planning in Molise has been and still is very active. Economic planning of regional forests started to be active since the 20<sup>th</sup> century and also contributed - thanks to its methodological consistency - to create a still lasting standardization of forest planning methods (Cantiani et al. 2010).

This consideration is valid also for the Matese area, where economic targets conditioned forest planners and managers choices, influencing both structure and developmental stages of forest stands.

Concerning Turkey oak high forests, their old customary management has been linked to the railway sleepers production. This context produced the spreading of even-aged stands, initially generated from shelterwood. Nonetheless, because of the



**Table 8 -** Results of objectives-options matrix for beech forests.

Option	Coppicing (only coppice)		Conversion into high forest (only coppice)		Even-aged high forest (only high forest)		Coppice/high forest integration (only high forest)		Uneven-aged high forest (only high forest)		Natural evolution (both coppices/ high forest)	
	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term
Landscape conservation	11.6	12.4	14.8	15.8	15.0	15.4	8.9	9.3	13.1	13.5	18.7/19.7	16.8/17.2
Firewood/biomass production	16.3	16.1	16.2	16.6	15.9	16.2	10.8	12.8	12.7	13.8	0/0	0/0
Timber production	4.3	4.3	6.3	9.8	17.7	20.7	5.1	6.2	14.2	16.8	0/0	0/0
Non-wood forest production	10.5	10.5	12.8	13.8	12.8	12.8	10.2	10.1	11.5	11.4	13.9/14.5	13.4/14.1
Soil and water regulation	14.7	15.9	22.7	22.9	19.2	20.3	13.3	13.7	19.1	19.2	24.0/22.9	22.6/21.7
Touristic/recreational function	7.6	7.6	9.3	11.8	17.2	18.4	7.1	7.9	15.2	15.4	11.1/11.9	18.7/17.9
Environmental conservation	9.2	9.4	16.5	20.1	16.9	17.6	10.9	11.7	16.5	17.0	20.8/22.4	19.9/20.1
<b>Mean value</b>	<b>10.6</b>	<b>10.9</b>	<b>14.1</b>	<b>15.8</b>	<b>16.4</b>	<b>17.3</b>	<b>9.4</b>	<b>10.2</b>	<b>14.6</b>	<b>15.3</b>	<b>12.7/13.1</b>	<b>13.0/13.0</b>
<b>Standard deviation (<math>\sigma</math>)</b>	<b>4.1</b>	<b>4.3</b>	<b>5.3</b>	<b>4.6</b>	<b>2.1</b>	<b>2.8</b>	<b>2.7</b>	<b>2.7</b>	<b>2.6</b>	<b>2.6</b>	<b>9.6/9.8</b>	<b>9.4/9.2</b>

unsuitable application of thinning and regeneration felling, these stands have been acquiring an irregular structure favouring the invasion of secondary species, these contributing to threaten Turkey oak regeneration (Cantiani et al. 2010).

Only at 36% of Turkey oak high forests plots the presence of Turkey oak regeneration was reported. Turkey oak's natural regeneration can be considered absent at the remaining 64%.

Based on the traditional presence of Turkey oak, the experts considered landscape conservation one of the most important functions performed by this forest type. The more appropriate options to fulfil this function were assumed to be natural evolution and shelterwood system (uniform or by groups); this last option, indeed, allows both natural regeneration, and environmental conservation as well as soil protection and water regulation.

From the perspective of production, Turkey oak high forests are linked exclusively to the increase of local firewood demand. Nonetheless, the fulfilment of timber production was considered to increase from short to long-term management under an even-aged regime. This aspect highlights that an appropriate silvicultural treatment (e.g. selective thinning) and in-depth studies on technological features of Turkey oak wood fibre, can improve its market value.

Quite similar considerations can be performed about European beech high forests. Also this type underwent the shelterwood system for many decades as confirmed by all economic plans in the area. Even though many stands reached their technical maturity, the regeneration process has not been activated yet by consistent silvicultural practices.

Multifunctionality analysis of these forest categories highlighted that non-productive functions in Matese are more important for European beech

forests than for Turkey oak ones. Especially, natural evolution has been selected by experts as the most appropriate options to fulfil functions such as: soil and water protection, touristic/recreational function, environmental conservation and landscape conservation.

Nonetheless, wood production function of beech forests must be considered, especially their high capability to fulfil timber and firewood production functions.

Shelterwood has been considered the silvicultural options maximising productivity and maintaining optimal values of fulfilment capability also for non-monetary forest functions.

Concerning coppice system, few are similarities between the two forest categories. In the study area, Turkey oak coppices are more actively managed than European beech coppices. This is confirmed by the low percentage overcoming the maximum legal age to be coppiced (20%) as compared with European beech (40%). This trend is due to the localization of coppices of the two forest categories and to the economic importance of firewood for the area.

These considerations are confirmed also by the multifunctionality indices: firewood production is the most important function for Turkey oak coppices but not for beech coppices. Furthermore, coppicing ensures high values of fulfilment capability also for landscape conservation. This result classifies coppiced Turkey oak patches as very important elements of the Matese landscape.

Firewood production shows on the contrary very low values for European beech coppices: about half of the deciduous oak type. Beech is mainly located at high elevation, in sites with medium-low site-index and their management has been not very active over the last decades leading them towards a natural conversion into high forests. That is why,



both the active conversion into high forest and the natural evolution showed to be the most performing option for European beech coppices to fulfil several functions both in the short and in the long-term.

As after Paletto et al. (2012) the synthetic indicators of multifunctionality:

1. provided adequate outputs: the value of overall multifunctionality increased with the altimetric gradient, from Turkey oak forests at low altitudes to European beech forests at higher elevations;
2. the analysis proved the low economic value of the Matese forests and limited to firewood production;
3. the high forest system provided the fulfilment of the highest number of functions;
4. conversion from coppice to high forest may increase the overall value of the Matese forests because of the parallel increase of protective, touristic and productive functions.

The introduction of the fulfilment capability and the modification of the priority level concept - by which we evaluated how much a function is important compared to the others at each time and for the same plot - represented an improvement to the method proposed by Paletto et al. (2012). This enhanced approach allowed to detect the current state of each plot and its potentiality in the framework of the whole forest. The evaluation of forests functional features using the proposed approach reduces the inherent subjectivity.

The proposed method allows to elaborate useful information on forest multifunctionality and to support forest planners in defining management guidelines consistent with current state and the evolutionary potentiality of forest stands.

## Acknowledgements

This work is part of the researches implemented within the Agreement Consiglio per la Ricerca e la sperimentazione in Agricoltura (CRA) and Regione Molise (Accordo di programma quadro pluriennale per attività di ricerca e sviluppo nel settore forestale). The “ProgettoBosco” informative system and methodology, elaborated by CRA-MPF and CRA-SEL with the MIPAF “Ri.Selv.Italia” - Subproject 4.2 “Geographic informative system for forest management” was also used. Ri.Selv.Italia was a national, multi-year, “problem solving oriented” project in the forest-wood-environment sector promoted by the Ministry of Agriculture and Forests in concert with Regions.

The authors want to thank the anonymous reviewers for the helpful revision of the paper.

All the authors contributed equally to this work.

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