FOREST FUNCTIONS EVALUATION TO SUPPORT FOREST LANDSCAPE MANAGEMENT PLANNING

Paolo Cantiani[1], Isabella De Meo[2], Fabrizio Ferretti[3], and Alessandro Paletto[2]

[1]Agricultural Research Council – Research Centre for Forest Ecology and Silviculture (CRA-SEL), Via S. Margherita 80, 52100 Arezzo, Italy. E-mail: paolo.cantiani@entecra.it

[2]Agricultural Research Council – Forest Monitoring and Planning Research Unit (CRA-MPF), P.za Nicolini 6, 38124 Villazzano, Trento, Italy. E-mail: isabella.demeo@entecra.it, alessandro.paletto@entecra.it

[3]Agricultural Research Council – Apennines silviculture and management Research Unit (CRA-SFA), Via Bellini 8, 86170 Isernia, Italy. E-mail: fabrizio.ferretti@entecra.it

UDC 630.6

Received: 02 August 2010
Accepted: 07 February 2011

Abstract

A preliminary evaluation of forest functions is fundamental in the forest landscape management planning. The evaluation 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 case study based in the Basilicata region, Southern Italy, was conducted. A total of 92 study areas comprising the main forest types – i) Turkey Oak, Hungarian Oak, and Sessile Oak Forests, ii) Downy Oak Forests, and iii) Mediterranean Evergreen Oak Forests, were considered. According to each forest type, an Index of Importance of Function (I) and three different indicators of multifunctionality were calculated.

Key words: forest functions, land classification, Forest Landscape Management Plan (FLMP), Basilicata region (Italy).

Introduction

Ecosystem functions refer to either habitat, biological or system properties, or ecosystem processes that provide, either directly or indirectly, benefits for human populations (Costanza et al. 1997). 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 made by society. A conceptual-theoretical definition of multifunctional forestry dates back to the explanation of the "theory of forest functions" by Dieterich (1953) expounded in the text *Forstwirtschaftspolitik* (Hytönen 1995). In this theory, three main groups of functions were descibed (utility, protection and recreation), and these functions were then integrated, refined and perfected 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 a result of the spread of the concept of multifunctional forestry and the changed environmental awareness after the Rio de Janeiro Conference (1992), forest planning in Europe has shifted from a model based mainly on wood and timber production (Farcy 2004) to multipurpose planning.

Within this frame, the Forest Landscape Management Plan (FLMP) is a useful and integrated instrument to address long-term forest management issues, with special attention to those forest features that cannot be systematically considered when working on a forest management unit level (i.e. single forest ownership). Using a hierarchical approach between the different levels of planning (operational, tactical and strategic), the FLMP -tactical level- (Baskent and Keles 2005) provides forest management guidelines on a broad scale, only providing details when considered either useful or necessary (Bettinger et al. 2005). Based on these premises, the authors provide a technical-managerial evaluation methodology of forest multifunctionality. The research was carried out within a forest management plan in a Comunità Montana[1] of Southern Italy.

[1] The Comunità Montana is the Italian administrative body that coordinates the municipalities located in the mountainous areas and is responsible for administration and economic development.

Materials and Methods

The Comunità Montana Collina Materana (the Materana Hills), 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 hectares, which are divided into seven municipalities (Accettura, Aliano, Cirigliano, Craco, Gorgoglione, San Mauro Forte and Stigliano).

The forests areas cover a surface area of 12,304 hectares, comprising 19.8% of the territory. The large diversity of forest formations are attributable to the great variability in morphology, altimetry and lithology of the area. In the eastern part of the territory, the forests are more sparse, providing space for agricultural lands, shrub lands and bad lands.

The agricultural landscape of the Mountain Community is mainly characterized by wheat fields alternating with pasture lands, with a predominant presence of either bush or degraded Mediterranean high shrub formations.

An original methodology, aimed at drawing up the FLMP, was conducted in the Comunità Montana territory. In this approach, the preliminary evaluation of forest multifunctionality is of key importance in organizing future management scenarios (Agnoloni et al. 2009).

The FLMP was assembled using the existing regional forest map, which is based on forest type and silvicultural management. The informative content of the map was reclassified following a specific and original classification, which was based on the use of a homogeneous cultivation

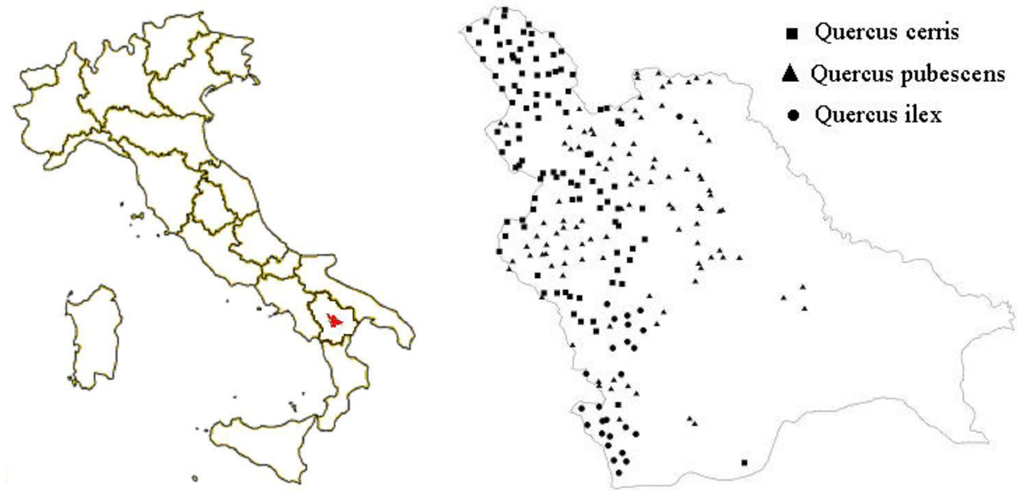

Fig. 1. Basilicata Region (left) and the Comunità Montana Collina Materana with the forest inventory sampling points divided by forest types (right).

subcategory. This feature was ranked as an intermediate between the forest category and the forest type, and took into account both the silvicultural system and possible treatments of the wood. This classification was obtained according to the existing regional forest types and was coherent with superior reference systems (INFC, EUNIS, CORINE).

The qualitative and quantitative description of forests and shrub lands were obtained through stratified descriptive sampling, based on the homogeneous cultivation subcategory, while pasture lands and uncultivated lands were described with extensive surveys.

A circular sampling area of 0.5 hectares was chosen for forests and shrub lands. The features sampled were harmonized, where possible, to both the National Forest Inventory Standards and the Sustainable Forest Management (SFM) Indicators.

A total of 349 descriptive areas were classified, 122 assigned to shrub formations, and 227 to forest formations. The information, retrieved from the forest inventory sampling, was then entered in a Geographical Information System (GIS) built on the regional forest map. In fig.1, the sampling point locations of the main forest types 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 geopedological conditions.

The most widespread forest types in the Collina Materana territory were considered in order to carry out the multifunctionality analysis (EEA 2006):

– Turkey Oak, Hungarian Oak, and Sessile Oak Forests (*Quercus cerris* dominant);

– Downy Oak Forests (*Quercus pubescens* dominant);

– Mediterranean Evergreen Oak Forests (*Quercus ilex* dominant).

The multifunctionality of each sampling point was evaluated by estimating, in the context of an Index of Importance of Function (I), the capacity of each forest to fulfill different functions. This index was calculated by providing a score for each function. 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. This method of evaluation of multifunctionality needs operators with high experience, able to objectively assess the various forest functions in each specific inventory point.

The functions, reported in the literature, had to be adapted to the Collina Materana context because of the characteristics specific to that territory. A number of 8 functions was eventually considered.

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 following functions were taken into account:

– Fuelwood production: wood and wood products, possibly including coppices, scrubs, branches, that were bought or gathered, and then burnt primarily for heating or cooking.

– Timber production: production of timber attributable to environmental factors, condition of the stand, and labour and capital.

– Biomass energy production: forest biomass including, trees that are of harvestable age (but not suitable for lumber), pulp, thinning, residual material from harvesting and trees killed by either fire, diseases or insects.

– Hydro-geological protection: the wood cover plays an important role in flood avalanche proofing, due to the action of water and snow retention, and soil erosion by water and wind, as well as contamination of ground and spring water, desertification, etc. (Führer 2000).

– Tourism and recreation: "forests hold a wide range of recreational opportunities. Forests are the backdrop for non-consumptive recreational activities such as hiking, birdwatching, wildlife, viewing and other such pursuits. Moreover, wilderness areas attract substantial recreational activities (game, fishing)" (Krieger 2001).

– Habitat conservation: the role of the forest in preserving flora and fauna and ecological processes as a result of the protection of the space that they occupy (Hierl et al. 2008).

– Landscape conservation: given that the landscape is the result of the interactions of human activity and natural environment (Brady 2003).

– Environmental protection: this function includes the positive effects of forests on air and water quality, and the key-role of forests in the global carbon cycle.

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

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

$$\overline{\mathrm{N}}_{\mathrm{fft}} = \frac{\sum_{i=1}^{i=n} f_i}{n}$$, where:

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 $\bar{v}_{\mathrm{fft}}$.

$$\bar{v}_{\mathrm{fft}} = \frac{\sum_{i=1}^{i=n} I_i}{n}$$, where:

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 $\overline{\mathrm{V}}_{\mathrm{FFT}}$ referred to each forest type.

$$\overline{\mathrm{V}}_{\mathrm{FFT}} = \frac{\sum_{j=1}^{j=m} \bar{v}_{\mathrm{fft}\,j}}{m}$$,where:

m = total of functions;

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

Results and Discussion

The evaluation of multifunctionality in the three forest types showed the highest value of $\overline{\mathrm{N}}_{\mathrm{fft}}$ (3.52) and $\overline{\mathrm{V}}_{\mathrm{FFT}}$ (4.00) in the Turkey Oak Forests (Table 1). The Mediterranean Evergreen Oak Forests scored a $\overline{\mathrm{N}}_{\mathrm{fft}}$ equal to 3.40 and a $\overline{\mathrm{V}}_{\mathrm{FFT}}$ equal to 3.88, whilst the Downy Oak Forests yielded the lowest scores of $\overline{\mathrm{N}}_{\mathrm{fft}}$ and $\overline{\mathrm{V}}_{\mathrm{FFT}}$, with values of 2.66 and 3.08, respectively. These results were verified with the non-parametric test of Kruskal-Wallis, where the null hypothesis (H0) is that samples are derived from identical populations. This test was chosen since the different number of observations among forest types and the low number of observations that made difficult to assess the reliability of the distribution. The test was applied to the total number of observations subdivided in forest types (264 in Turkey Oak Forests, 40 in Mediterranean Evergreen Oak Forests and 232 in Downy Oak Forets). Trasformation of data was not necessary in reason of the fact that Kruskal-Wallis test is appropriate for non-normal distribution of data. The test did not highlight any significant difference between the three forest types (K observed = 5.22, K critical = 5.99, $\alpha = 0.05$), consequently the H0 was rejected.

Taking into account the $\bar{v}_{\mathrm{fft}}$, Turkey Oak Forests are important for landscape conservation, and, secondarily, for firewood production and hydro-geological protection. Downy Oak Forests had the highest average value for firstly hydrogeological protection and then for firewood production. High values for hydrogeological protection and landscape conservation were also found for the Mediterranean Evergreen Oak Forests.

The data of $\bar{v}_{\mathrm{fft}}$ were successively grouped into three macro-groups of functions (social, economic and environmental) according to Ritter and Dauksta (2006), in order to analyse the multifunctionality on a less detailed scale and, as a consequence, to retrieve useful information for wide-scale management guidelines. The biomass energy, fuelwood and roundwood functions were included in the economic group, whereas tourism and landscape conservation, intended as landscape contemplation, were included in the social group. Habitat conservation, environmental and hydrogeological protection were all included in the environmental function category. Table 2 shows that, the data aggregation into macro groups produced the highest values for the environmental functions, followed by the social functions. The reason is attributable to the fact that the Collina Materana forests are without timber production and as a result, have a low economic importance. The non-parametric test of Kruskal-Wallis shows significant differences between the three

Table 1. Average value of each function associated to a forest type ($\overline{v}_{\mathrm{fft}}$).

Functions/Forest type	Turkey Oak Forests	Mediterranean Evergreen Oak Forests	Downy Oak Forests
Biomass energy	0.85	0.00	0.34
Habitat conservation	1.52	0.00	0.34
Fuelwood	7.94	4.00	7.45
Roundwood	0.00	1.40	0.00
Tourism	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	**4.00**	**3.88**	**3.08**
St. dev.	**4.60**	**4.61**	**4.41**

Table 2. Average values of macro-group of functions per forest type ($\overline{v}_{\mathrm{fft}}$).

Macro-group of functions/Forest type	Turkey Oak Forests	Mediterranean Evergreen Oak Forests	Downy oak forests	Mean	St. dev.
Environmental	4.83	5.53	3.64	**4.37**	**4.66**
Economic	2.93	1.80	2.60	**2.70**	**4.22**
Social	4.36	4.50	2.97	**3.77**	**4.58**

macro-groups of functions (K observed = 23.76, K critical = 5.99, $\alpha = 0.05$, p-value < 0.0001). The non-parametric test of Mann-Whitney was applied to compare mean values of pairs of macro-groups. The test did not highlights any significant differences only between social and environmental functions, while the differences are significant between economic and environmental function (U = 66950.0, Expected value = 80802.0, $\alpha = 0.05$, p-value < 0.0001) and between economic and social function (U = 48106.0, Expected value = 53868.0, $\alpha = 0.05$, p-value = 0.005).

Conclusion

This method provides an evaluation of the multifunctionality of an area. In absolute terms, the method indicates the number of functions and provides a global value, whereas, in comparative terms, a rank among functions or group of functions is provided.

Hence, the preliminary evaluation is a valuable instrument in supporting the design of a FLMP, addressed to long-term forest management issues, and which is also required to consider the environmental, social and economic aspects of a forest. The knowledge of the relative importance of any single function in a certain area permits the selection of a particular silvicultural option, best able to optimize multiple functions and, concomitantly, to achieve both mid and long-term planning goals. The advantages of the method reside in its speediness and easy applicability. This is of relevance when planning large territories, which require a strategy providing a good compromise between limited financial resources and the reliability and quality of the data obtained. On the contrary, the main constraint regards the operative application of the method, since experienced operators are needed to assess, within each context, both the productive and recreational aspects of the forest. Additionally, the operators who perform the evaluation must be both objective and precise and must also avoid simply embracing any specific management paradigm.

Acknowledgements

This research was supported by MIPAAF (Italian Ministry of Agriculture and Forestry) National Research Project Ri. Selv. Italia (Subproject 4.2 – Forest Planning) and by the National Institute of Agricultural Economics Research (INEA), Basilicata Headquarter.

The authors have contributed to this study and paper in equal parts.

References

Agnoloni S., Bianchi M., Bianchetto E., Cantiani P., De Meo I., Dibari C., Ferretti F. 2009. I piani forestali territoriali di indirizzo: una proposta metodologica. Forest@ 6 (1): 140–147.

Baskent E. Z., Keles S. 2005. Spatial forest planning: a review. Ecological modelling 188: 145–173.

Bettinger P., Lennette M., Johnson K. N., Spies T. A. 2005. A hierarchical spatial framework for forest landscape planning. Ecological Modelling. 182: 25–48.

Brady E. 2003. Aesthetics of the natural environment. Edinburgh: Edinburgh University Press Ltd., 263 p.

Costanza R., d'Arge R., De Groot R., Farber S., Grasso M., Hannon B., Limburg K., Maeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., van der Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253–260.

Dieterich V. 1953. Forst-Wirtschaftspolitik – Eine Einführung, in Verlag Paul Parey. Hamburg und Berlin, 398 p.

EEA 2006. European forest types. EEA Technical Report 9, Luxembourg, 111 p.

Farcy C. 2004. Forest Planning in Europe: state of the art, international debates, emergent tools. In : Andersson, F., Birot, Y., Päivinen, R. (Eds.). EFI Proceedings 49: 11–20.

Fernand J. 1995. Multiple-use forestry – a concept of communication. In: Hytönen M. (editors) "Multiple-use forestry in the Nordic countries" METLA, The Finnish Forest Research Institute.

Führer E. 2000. Forest functions, ecosystem stability and management. Forest Ecology and Management 132 (1): 29–38.

Hierl L. A., Franklin J., Deutschman D. H., Regan H. M., Johnson B. S. 2008. Assessing and Prioritizing Ecological Communities for Monitoring in a Regional Habitat Conservation Plan. Environmental Management 42: 165–179.

Hytönen M. 1995. History, evolution and significance of the multiple-use concept. In: Hytönen M. (editors) "Multiple-use forestry in the Nordic countries" METLA, The Finnish Forest Research Institute.

Krieger D. J. 2001. Economic Value of Forest Ecosystem Services: A Review. Washington: The Wilderness Society, 30 p.

Ritter E., Dauksta D. 2006. Ancient Values and Contemporary Interpretations of European Forest Culture – reconsidering our understanding of sustainability in forestry. "Small-scale forestry and rural development: the intersection of ecosystems, economics and society", Proceedings of IUFRO 3.08 Conference, hosted by Galway-Mayo Institute of Technology, Galway, Ireland, 18–23 June 2006.

Vos W. 1996. Changing Forest Functions in New Europe: from Alienation to Involvement. In: Glück P., Weiss G. (eds.) "Forestry in the Context of Rural Development: Future Research Needs", EFI Proceedings 15: 127–139.