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Sustainable Forest Management indicators to evaluate silvicultural practices at the stand and landscape management levels

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RIASSUNTO

La Gestione Forestale Sostenibile (GFS), così come definita nel 1993 ad Helsinki durante la prima Conferenza Ministeriale per la Protezione delle Foreste in Europa, ha lo scopo di equilibrare le esigenze socio-economiche, ecologiche e culturali delle generazioni presenti e future e di mantenere le risorse attraverso un uso multiplo delle foreste. Si tratta di un concetto in continua evoluzione sia nel tempo sia nello spazio, la cui base operativa è la gestione multifunzionale delle foreste.

La gestione forestale è lo strumento principale attraverso cui è possibile perseguire finalità di tutela e conservazione compatibili con il ruolo economico e sociale delle foreste. Infatti si riconosce alla GFS la funzione di conservazione delle risorse boschive, creazione di impatti sociali positivi e mantenimento dell'efficienza economica nell'organizzazione dei prodotti e dei servizi forestali.

Una gestione sostenibile della foresta non può, quindi, prescindere dagli aspetti ecologici ma nemmeno dalle esigenze della società, pena l'identificarsi con ideologie astratte, avulse dal contesto socio economico di cui le foreste fanno invece parte. Le conoscenze ecologiche da sole non bastano a sviluppare modelli gestionali nuovi che concilino le esigenze di conservazione e quelle tradizionali della selvicoltura. A livello europeo l'adozione dei criteri e degli indicatori di gestione forestale sostenibile (MCPFE, 2002), ha portato ad una migliore considerazione e consapevolezza dell'importanza della gestione forestale per mantenere e valorizzare la salute e la vitalità degli ecosistemi forestali, la biodiversità, la capacità di sequestro di carbonio, la funzione protettiva e lo sviluppo di funzioni produttive e socio-economiche (aspetto multifunzionale delle foreste). Prendendo in considerazione questi aspetti il presente lavoro è strutturato in tre parti: i) lo studio di indicatori di gestione forestale sostenibile per la valutazione della percezione dei portatori di interesse e dei livelli di multifunzionalità della foresta; ii) l'analisi di indicatori di gestione forestale sostenibile per la valutazione di buone pratiche selvicolturali innovative; iii) la messa a punto di nuovi indicatori di gestione forestale sostenibile per la valutazione delle pratiche selvicolturali. Lo scopo ultimo è quello di integrare ed adattare degli indicatori, nati per valutare le performance a livello europeo e nazionale, al fine di renderli utili per la valutazione della gestione forestale a livello locale (territoriale ed aziendale).

ABSTRACT

The Sustainable Forest Management (SFM), defined in 1993 at Helsinki - first Ministerial Conference for the Protection of Forests in Europe - is aimed at balancing the social and economical requirements, the ecological and cultural expectations of present and next generations and to preserve the resources by a multiple use of forests. The concept evolves in continuum both spatially and with time and is operationally based on the multifunctional management of forests. Forestry management is the main tool to pursue the maintenance of the long-lasting forest attributes whilst developing their economic-social role. The driving factor balancing the different, even contrasting, issues by means of a careful and effective organization is committed to SFM and monitored by the relative Criteria and Indicators. The Sustainable Forest Management cannot therefore leave out of consideration the ecological side as well as the societal requirements, otherwise we'll talk about forest systems in the abstract and not as main components of the social and economical context as they are. The advancements in ecology alone are not enough to develop new management models able to reconcile the conservation strategies with the customary practices of silviculture. The adoption of SFM Indicators (MCPFE 2002) at the European level, allowed a better consideration and consciousness of forest management role to maintain and improve both health and vitality of forest ecosystems, biodiversity, their inherent carbon sequestration ability, their protective as well as their social and economical functions. Taking into account these sides, the work has been divided into three main parts: (i) studying SFM Indicators and their perception as well as the one of the associated different functional levels, from the stakeholders' side; (ii) analysing SFM Indicators to evaluate innovative 'good' forest practices in beech forests; (iii) defining new SFM Indicators to assess the quality of management. The main goal here is to put together and adapt SFM Indicators already established to evaluate the performances at the country or EU level and use them for an effective quality assessment at the local land and ownership scale.

MAIN CONTENTS

PREFACE

Since the early seventies of 1900, the management of public-owned, and in part of private forests, shifted from the customary wood production-oriented goals (timber and firewood) towards less intensive practices. This shift originated both from economic reasons and from the established environmental and ecological role of the forest domain. Silvicultural systems with reduced environmental impact or the abandonment of any practice of forestry, especially into the areas submitted to some level of protection, became a ruling principle. The passive conservation, rather than the dynamic and pro-active management was, as a matter of fact, promoted by new-established marginal conditions as well as by the conservative regulations enforced in between (Farrell et al. 2000, Fabbio et al., 2003, Bertini et al. 2011). A large share of forest compartments experienced this way lack of periodical thinnings or passed the customary rotation age. A 'post-cultivation phase' is being therefore in progress across many forests (Piussi and Farrell 2000, Scarascia et al. 2000, Fabbio et al. 2016). A reversal of trend took place over the last period: the newly-established economical attention to forests and especially to energy biomass following the increased costs of fossil fuels, the new green- economy issues and the related promotion measures, determined the renewal of forest planning and forestry practice. The reports on the State of European Forests (MCPFE 2007 e 2011) underline the improvement of many quantitative-qualitative parameters following the recovery of cultivation practices in those countries where it has been undertaken more intensively. Different studies reported how the productivity of managed forests has been increasing over the last years, both at the European (Spiecker et al. 1996) and at the global level (Boisvenue, Running 2006).

Under the perspective of forest practice renewal, the concepts of Sustainable Forest Management and multifunctional forest become more and more important (Corona 2014, Marchetti et al. 2014, Wagner et al. 2014).

In the political context, the concept of SFM was first set out at the United Nations Conference on Environment and Development (UNCED), often referred to as the Earth Summit, in Rio de Janeiro (*Forest Priciples*), in 1992. Subsequently international processes and initiatives (e.g., ITTO, FAO, UNFF) have been launched upon the need to define what constitutes SFM and how to monitor and assess its progress. Similarly, a number of regional initiatives have been established in Africa, Central America, the Amazon basin, Asia and Europe, e.g., Helsinki Process for Europe (1993), Montréal

Process for North America (1993), Tarapoto Process for the Amazon (1995), and the African Timber Organization’s Criteria and Indicators (1996). In the pan-European context, the term was defined conceptually in a political context at the Second Ministerial Conference of Protection of Forests in Europe (MCPFE) in Helsinki in 1993:

“Sustainable management means the stewardship and use of forests and forest lands in such a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems.” (Helsinki 1 Resolution, MCPFE, 1993)

The Sustainable Forest Management is aimed at balancing the social and economical requirements, the ecological and cultural expectations of present and next generations (Wyder 2001, Tabbush 2004) and to preserve the resources by a multiple use of forests (Garcia-Fernandez et al. 2008). The concept evolves in continuum both spatially and with time (Angelstam et al. 2005, Straka 2009) and is operationally based on the multifunctional management of forests (Kangas e Store 2002).

Being based on multiple use, sustainable forest management plays an important role for a whole range of aspects related to ecosystem services: vitality and health of forests, biodiversity conservation, protection against erosion, carbon cycle, adaptative capacity to climate change, environmental and social-cultural issues, wood and biomass production (Kangas and Store 2002, Kant 2004, Lindner et al. 2010, Marchetti et al. 2014).

The Sustainable Forest Management cannot therefore leave out of consideration the ecological side as well as the societal requirements, otherwise we’ll talk about forest systems in the abstract and not as main components of the social and economical context as they are. The advancements in ecology alone are not enough to develop new management models able to reconcile the conservation strategies with the customary practices of silviculture. All these elements, and the recovery of heritage knowledge, may increase the overall forests value significantly (Piussi e Farrell 2000).

At the Third MCPFE, in Lisbon 1998, the first set of “Pan-European Indicators for Sustainable Forest Management” were politically agreed and adopted. An Advisory Group, representing relevant organisations in Europe, was established to ensure the best use of the existing knowledge on indicators and data collection aspects, and to assist the MCPFE during the improvement process (EFI 2013). The improved pan-European set consists of six criteria that include 1) the maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles, 2) the maintenance of forest ecosystems health and vitality, 3) the maintenance and encouragement of productive functions of forests (wood and nonwood), 4) the maintenance, conservation and appropriate enhancement of biological diversity in forest ecosystems, 5) the maintenance, conservation and appropriate enhancement of protective functions in forest management (notably soil and water) and 6) the maintenance of other socio-economic functions and conditions. The fulfilment of the six criteria can be evaluated through 35 quantitative indicators which show changes over time for each criterion and demonstrate the progress made towards its objectives (MCPFE, 2000).

The indicators (35 quantitative and 17 qualitative) were further improved and endorsed by the following MCPFE: 4th MCPFE, 2003 Vienna *European Forests-Common Benefits, Shared Responsibilities*, 5th MCPFE, 2007 Warsaw *Forests for Quality of Life*, 6th MCPFE, 2011 Oslo *European 2020 Targets for Forests and Launching Negotiations for a Legally-Binding Agreement*, 7th MCPFE, 2015 Madrid *Extraordinary Ministerial Conference*.

In this summits, the improved pan-European set has been used as a basis for information collection, analysis and reporting in the State of Europe's Forests (MCPFE 2003, MCPFE 2007, FOREST EUROPE 2011, FOREST EUROPE 2015). On January 2015, the Expert Level Meeting (ELM) decided to update the existing set of Pan-European Indicators for SFM, based on the continuous improvement of knowledge and data collection systems.

The adoption of SFM Indicators (MCPFE 2002) at the European level, allowed a better consideration and consciousness of forest management role to maintain and improve both health and vitality of forest ecosystems, biodiversity, their inherent carbon sequestration ability, their protective as well as their social and economical functions. They are not only a mechanism for systematically implementing sustainable forest management procedures, but also an effective means of assessing and reporting progress (Wijewardana, 2008).

Criteria and Indicators are a key part of the implementation of forest management. They are tool wich enables societies and stakeholdres to reach a consensu – partly on a scientific basis, and partly through political negotiation – on the crucial question: how and why to manage or to conserve our forests? (Alain et al., 2001). At this purpose criteria and indicators for SFM are applied on three different levels (Table 1): (i) international and national, (ii) sub-national/local, (iii) forest management unit. Implementation on all three levels is deemed important (Wijewardana, 2008).

Table 1

Role of criteria and indicators	
International and/or regional scale	• Support international forest policy deliberations and negotiations on issues related to sustainable forest management • Provide a common understanding within and across countries of what is constituted by sustainable forest management • Provide a basis for collecting, categorizing, analyzing, reporting, and representing information the state of forests and their management • Provide an international reference for policy makers in the formulation of national policies and programmes •Serve as a basis for international cooperation and collaboration on SFM activities
National and sub-national level	• Describe, monitor, and report on the national forest trends and changes • Assess progress towards sustainable forest management and identify emerging threats and weaknesses • Assist in the development and evaluation of national and/or sub-national forest policies, strategies, plans and programmes • Serve as a basis for cross-sectoral forest related data collection • Focus research efforts where knowledge is still inadequate
Forest management unit level	• Evaluate management practices, control forest concessions and clarify issues related to certification. • A basis for developing forest certification systems (e.g. PEFC)

Source: FAO/ITTO, 1995; ISCI, 1996; IFF, 1977; FAO, 2001 and 2003; EFI, 2013.

As Boncina (2001) suggest, the third level (forestry planning) has been a traditional tool for ensuring forest sustainability and the maintenance of the long-lasting forest attributes whilst developing their economic-social role. At the same time, the sustainable forest management evaluation in forestry plan is still not completely defined, and sometimes even underestimated (Boncina, 2001).

The main goal here is to put together and adapt SFM Indicators already established to evaluate the performances at the country or EU level and use them for an effective quality assessment at the local land and ownership scale.

Taking into account these aspects, the present work is a collection of scientific papers divided into the following three sections:

- Section 1 - Sustainable Forest Management: assessing stakeholders' perceptions and multiple use of forests: studying SFM Indicators and their perception as well as the one of the associated different functional levels, from the stakeholders' side;
- Section 2 - Sustainable forest management indicators to evaluate innovative silvicultural practices in beech forests: analysing SFM Indicators to evaluate innovative 'good' forest practices in beech forests;
- Section 3 - Traditional and new indicators of sustainable forest management. The ManFor C.BD. Life project experience: defining new SFM Indicators to assess the quality of silvicultural practices at Forest Management Unit Level.

Section 1. Sustainable Forest Management: assessing stakeholders' perceptions and multiple use of forests

Introduction

Sustainable Forest Mangement (SFM) contributes to maintain the role of forests as sources of timber and other forest products, while simultaneously helping to maintain biodiversity and to protect watershed and other ecosystem functions (Putz 1994). Taking into account these aspects, the first part presents two papers that investigate two key factors of SFM: public participation and multifunctionality (Glück and Humphreys 2002). SFM should involve a wide range of actors (e.g. government, local stakeholders, NGOs, private sector, citizens, etc.) in order to improve social acceptance and to reduce conflicts among forest users (Kishor and Belle 2004). The active involvement of individual and collective stakeholders (organizations and associations) is indispensable to develop the sustainable management of forests (Kozak et al. 2008). Furthermore SFM should promote public participation in the decision-making process.

For this purpose the first work was aimed at supporting landscape scale multifunctional planning in order to evaluate stakeholders' perception of forest management and sustainability and therefore to help managing institutions to develop forest management plans capitalizing on local knowledge. The main objective of the paper was to describe a survey methodology capable of assessing community's perception of SFM criteria using questionnaires and cognitive maps.

Multifunctionality presupposes that sustained timber production is no longer the primary goal, and emphasises the importance of the different forest goods and services such as non-wood forest products (NWFP), biodiversity and nature conservation, soil and water protection, tourism and recreation, carbon storage and climate change mitigation, etc. (Wilson and Guéneau 2004).

Multiple use forest management 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). The incorporation of multiple forest values in forest management decisions is one of the important dimensions of SFM (Kant 2007).

The main objective of the research was to improve a method (Paletto et al., 2012) devoted to define the forest multifunctionality to support the forest practitioners. Furthermore we aimed to test the method in a different forest environment. The application of the method in a different social and ecological context was indeed very useful to improve the method and provided important suggestions from a practical point of view.
For both papers the research was conducted in the Matese district, a mountainous area in southern Italy (Molise Region), within the context of an ongoing Forest Landscape Management Plan (FLMP). The main forest types are Turkey oak (Quercus cerris L.) (42.3%), European beech (Fagus sylvatica L.) (30.5%), and European Hop hornbeam (Ostrya carpinifolia Scop.) (10.9%) forests. The main management systems are high forests (51% of the stands) and coppices (49%), which is prevalent for Turkey oak stands.

1.1 Perceptions of Sustainable Forest Management practices: an application from the forestry sector in southern Italy

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ABSTRACT

Community perception of Sustainable Forest Management (SFM) provides decision makers information useful to define forest policies and strategies. This paper aims to contribute to the SFM discourse and focuses on perception of SFM in a case study (Comunità Montana Matese, Italy). Perceptions and perspectives of forestry sector stakeholders are assessed using a survey methodology based on questionnaires and cognitive maps. "Cognitive mapping" is an approach to strategic thinking in order to explore the values, perspectives and objectives of the stakeholders.

A collective cognitive map is used to identify stakeholder groups' perceptions of forest management practices effects on SFM criteria. The knowledge of the stakeholders' perceptions and the cognitive network of forest management practices and SFM criteria were used to compare agreements and disagreements among the categories of stakeholders. Findings of the research can support managers in the development of the forest management strategies.

INTRODUCTION

In the late 1980s and early 1990s the traditional forest management approach – based on stand-level process and sustained-yield – fell into crisis due to the decreased economi c value of timber and other wood products and the low social acceptance (Glück 1987, Peng 2000). As a result of these changes a new approach began to emerge in forest management, based on sustainability principles. Sustainable Forest Management (SFM) is a dynamic concept focused on the maintenance of the economic, social and environmental value of forests for the benefit of present and future generations (Luckert and Williamson 2005). In other words, SFM helps to maintain the role of forests as sources of timber and other forest products, while simultaneously helping to maintain biodiversity and to protect watershed and other ecosystem functions (Putz 1994).

This approach to forest management introduced three key aspects: sustainability, multifunctionality and public participation (Glück and Humphreys 2002). The first of these is based on the concept of sustainable development defined by the Brundtland Commission's report (1987) as: "development which meets the needs of current generations without compromising the ability of future generations to meet their own needs". The concept of sustainability was modified into strong sustainability and weak sustainability (Neumayer 2003). Strong sustainability is based on the fact that all human life occurs within the limitations of natural capital. Strong sustainability assumes that man-made capital cannot take the place of the natural capital or, in other words, that natural capital is irreplaceable. Conversely weak sustainability can be interpreted as an extension to neoclassical welfare economics developed by Solow (1974) and Hartwick (1977). Weak sustainability assumes that natural capital can be replaced with other forms of capital resulting from progress (manufactured goods and services). Sustainability in forest management identifies as a priority to ensure that goods and services supplied by forests meet modern social needs, while at the same time securing their continued accessibility and contribution to long-term development (Wilkie *et al.* 2003). Moreover, SFM should involve a wide range of actors (government, local stakeholders, NGOs, private sector, citizens, etc.) in order to improve social acceptance and to reduce conflicts among forest users (Kishor and Belle 2004). The second aspect presupposes that sustained timber production is no longer the primary goal, and emphasises the importance of the different forest goods and services such as non-wood forest products (NWFP), biodiversity and nature conservation, soil and water protection, tourism and recreation, carbon storage and climate change mitigation, etc. (Wilson and Guéneau 2004). The last key feature of SFM is to promote public participation in the decision-making process. The active involvement of individual and collective stakeholders (organizations and associations) is indispensable to develop the sustainable management of forests (Kozak *et al.* 2008). According to Kant and Lee (2004) SFM can be considered "management by inclusion" as opposed to "management by exclusion" which characterizes traditional forest management.

From the political point of view, the SFM concept was widely accepted at the international level, starting from the United Nations Conference on Environment and Development held in Rio de Janeiro (1992), the Montreal Process (1995) and its associated set of Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, the Intergovernmental Panel on Forests (IPF) in 1995 and the Intergovernmental Forum on Forests (IFF) in 1997 (Holvoet and Muys 2004, Wang and Wilson 2007). In Europe, during the second

Ministerial Conference on the Protection of Forests in Europe (MCPFE) in Helsinki (1993) SFM was defined in the following way: “sustainable forest, management means the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems”.

Subsequently, during the third MCPFE in Lisbon (1998), six criteria and a set of associated indicators was agreed by the main European countries. The criteria elaborated during the third MCPFE took into account the main forest functions (as shown in Table 1 Q6 below).

These criteria and indicators served as a basis for the definition and implementation of the Programme for Endorsement of Forest Certification Schemes (PEFC), first in Europe and then worldwide (Auld *et al.* 2008). SFM has become a relevant topic for the scientific community and a priority for policy makers and forest managers world-wide.

On the other hand, few studies have investigated the community’s perception of sustainable forest management and related aspects (Bass *et al.* 2001, Beesley and Sanderson 2003, Molnar 2004). The knowledge of people’s perception of the forest and of related issues provides useful elements required to define land policies and strategies. This kind of information, together with technical competencies, could increase managers’ capacity to manage forests more effectively for all the stakeholders involved (Trakolis 2001). Finally, supplementing a community’s knowledge with scientific knowledge can make SFM more inclusive.

Starting from these preliminary considerations, the paper aims to contribute to the SFM discourse in investigating new points of view on forest management methods. This work was aimed at supporting landscape scale multifunctional planning in order to evaluate stakeholders’ perception of forest management and sustainability and therefore to help managing institutions to develop forest management plans capitalizing on local knowledge. The main objective of the paper is to describe a survey methodology capable of assessing community’s perception of SFM criteria. In the framework of Forest Landscape Management Planning (De Meo *et al.* 2011, Ferretti *et al*. 2011, Paletto *et al.* 2012), perceptions and perspectives on SFM are assessed using questionnaires and cognitive maps. According to Eden (1988, 1989) cognitive mapping is an approach to strategic thinking, particularly in exploring values, issues, goals, concerns, or “worldviews”.

The cognitive map is a model amenable to formal analysis that is designed to mimic the way a person perceives an issue (Axelrod 1976). It is organized as a set of ideas or concepts framed as a network of nodes, arrows, or links to represent the relationships of the concepts or ideas (Mendoza and Prabhu 2005). In other words, it is a causal-based mapping technique in which the elements of a complex problem – in this case the study of the relationships between management practices and the criteria of sustainable forest management – are represented with arrow diagrams (Mendoza and Prabhu 2003). According to Hjortsø et al. (2005: 153) “the cognitive map developed during an interview is a representation of the network of concepts used to form chains of argumentation”, useful to limit conflicts between forest users and to reduce dysfunctions such as the “groupthink” phenomenon. The research was conducted in the Matese, a mountainous area of southern Italy (Molise Region), within the context of an ongoing Forest Landscape Management Plan (FLMP).

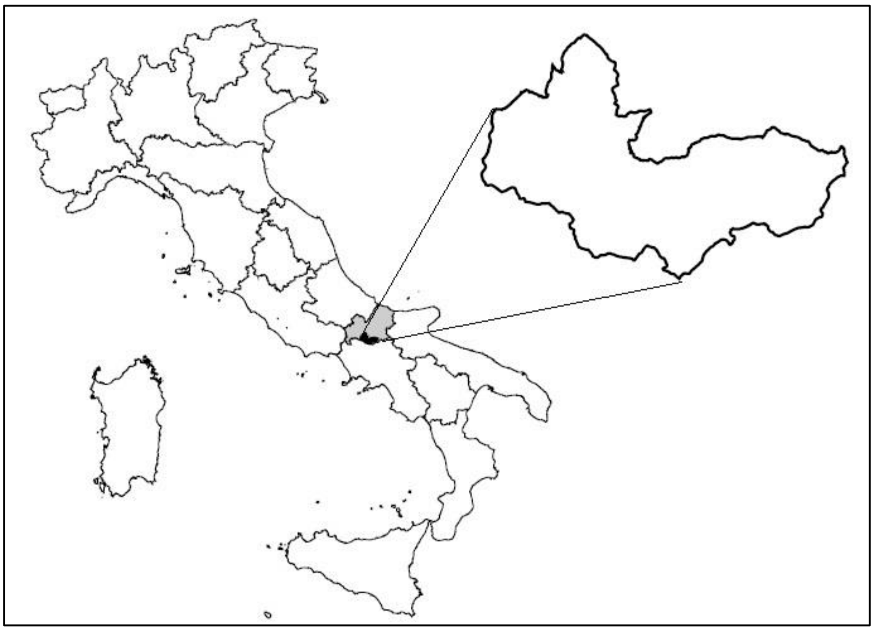

FIGURE 1 **THE COMUNITÀ MONTANA MATESE IN THE MOLISE REGION (ITALY).**

MATERIALS AND METHODS

Study area

The Comunità Montana Matese, located in the Campobasso province (41°29’12’’ N; 14°28’26’’ E) was chosen as the study area. A sub-regional scale was chosen because the Comunità Montana is the Italian administrative body that coordinates the municipalities located in mountainous areas, and is responsible for administration and economic development. In particular, forest management and planning are under the supervision of the Comunità Montana staff. Molise region was selected because a FLMP had been initiated in the Comunità Montana Matese and secondly because the research team was located within or near this region.

The Comunità Montana Matese occupies about 36,500 hectares and includes eleven municipalities (Figure 1). With a population of 21,022 inhabitants, the actual density is 58 people/km2, well below the national average of 200.1 people/km^2. This is the result of a slow population decline (1951–2009 trend: –35.5%), which began in the 1950s and has continued until now. The main land uses in the district are: forests covering 15,712 ha (44.1%), agricultural crops covering 10,649 ha (29.2%) and grasslands covering 5,811 ha (15.9%). As to ownership, privately-owned forests account for approximately 66%, whereas the remaining 34% is owned by public bodies, i.e. various municipalities and the Molise Region. The average area of the private forests is less than one hectare, sometimes split into more than one parcel, and most private forest land is owned by individuals. The main forest types are Turkey oak (Quercus cerris L.) (42.3%), European beech (Fagus sylvatica L.) (30.5%), and European Hop hornbeam (Ostrya carpinifolia Scop.) (10.9%) forests. The main management systems are high forests (51% of the stands) and coppice (48%), which is prevalent for Turkey oak stands.

The agricultural sector plays an essential role in the economic structure of the district, involving 27% of the active population. Conversely, the industrial sector is extremely weak and has not shown a significant development so far, as demonstrated by the very few factories operating in the district. Tourism is also undeveloped.

Survey methodology

The cognitive approach for the evaluation of public perceptions has been used in this paper. Research on public perceptions can be divided into three main categories: psychophysical, cognitive, and phenomenological approaches.

The first two approaches can be regarded as preference studies. The cognitive approach emphasizes how individuals organize, process and interpret the informational content of the environment (Daniel and Vining 1983, Ruddel et al. 1989). Cognitive research is interested in human reactions, and cognitive studies can help us understand the reasons for individual preferences (Karjalainen 2006). In this field, survey methodology can encompass the interviews, questionnaires, drawings or cognitive maps. From the theoretical point of view, cognitive maps are tools for group thinking and problem solving, useful to support the facilitator during the participatory process (Maani and Maharaj 2004). In this process, the proposed survey methodology has therefore the advantage of highlighting, and consequently avoiding, the “groupthink” phenomenon, and of predicting potential conflicts among stakeholders.

The survey methodology was developed in two stages: i) stakeholder analysis and ii) investigation of stakeholders’ perceptions and construction of the cognitive map. The stakeholder analysis was done to identify the key stakeholders, their roles and their relationships. The actors operating in the forestry sector of Matese district, who are directly involved in forest management, were considered as stakeholders, according to the definition of Grimble and Wellard (1997: 175): “a stakeholder is any group of people, organized or unorganized, who share a common interest or stake in a particular issue or system".

A comprehensive list of stakeholders and their roles was drawn up, based on the official statistics and the lists of enterprises recorded by the Chamber of Commerce, Industry, Crafts and Agriculture of Campobasso province. This list was successively built up by "snowball sampling" (Hair et al. 2000), starting from the first actors. Other previously unknown representative actors were then identified. In total, 39 stakeholders were identified.

The stakeholder analysis examined their roles in the forestry sector and their relationships; finally stakeholders were subdivided into four categories as follows: 14 public administrations and public forest owners, 10 forest enterprises, 5 environmental associations and 10 farmers and private forest owners.

Stage two involved a survey with the 39 stakeholders, where questionnaires were used to investigate individual preferences attributed to forest management and SFM. It also considered many other aspects of the social perception of forest which could be usefully employed to support forest management decision making.

The questionnaire contained 47 closed-form questions divided into six sections: "Sustainability of forest management"; "Forest certification"; "Forest functions"; "Forestwood- energy chain"; "Social capital"; "Relationship between people and landscape". In the present paper results of the section "Sustainability of forest management" are presented, which is composed of 7 questions (Table 1). The first three questions are centred on stakeholders' perceptions of forest management and changes in recent decades in the Matese district. The subsequent four questions aim to elicit stakeholders' perception of the importance of forest functions appropriate to the Apennine context and to the SFM criteria elaborated during the third Ministerial Conference on the Protection of Forests in Europe (MCPFE, Lisbon 1998). In particular, the question on the importance of the different ecosystem goods and services (Q5) is relevant to understanding the "system of values" of the respondents. The values are social facts that guide human actions and are related to the norms of a culture, the satisfaction of human requirements (biological and biosocial human needs) and individual or cohort behaviour (Boudon 2001). In forestry it is important to consider three macro value groups (Paletto et al. 2013): economic values, social values and environmental values. The answers to question 5 are important to read and interpret the answers to the following two questions (Q6 and Q7). In particular, the respondents that prefer the social and economic values of forests should assign higher scores to Criteria 3 and 6. Conversely, those who prefer the environmental values of forests should assign higher scores to Criteria 2 and 4 and the corresponding management practices. If these assumptions are not verified, the responses are due to irrational motivations that need to be investigated in depth.

The last question is the primary data source to construct the cognitive map which represents the relationship between management practices and SFM criteria, considering the positive, neutral or negative impacts of practices, as stated by stakeholders.

Statistical analysis

The data collected with the questionnaires were analysed statistically with respect to stakeholders' category. The differences between categories of stakeholders concerning the importance of the criteria and indicators of SFM (Q6) and the perception of the management practices' capacity to increase the SFM (Q7) were tested. Since normal distribution in the various groups could not be guaranteed and the number of observations was limited, the non-parametric test of Kruskal- Wallis was used for statistical analysis, assessed at the $\alpha=0.001$ level. All statistical analyses were carried out using XLStat 2012.

Responses to the seventh question (Q7) were used to construct the cognitive map using the software yEd Graph Editor. A collective map for all the key stakeholders was constructed, in which the forest management practices are represented as nodes, while the lines are the relationship between the activities and the SFM criteria. The average values of the effect of each forest management practice on a criterion are considered. When the average value is ≤ –0.2 the influence of a practice on a criterion is considered negative; when > 0.2, positive and between –0.2 and 0.2 the practice does not influence the criterion.

TABLE 1. **QUESTIONS RELATED TO SUSTAINANLE FOREST MANAGEMENT (SFM)**

Question	Closed-form answer
Q1. Do you perceive these changes in the management practices of the local forests in the last thirty years?(YES or NOT) (multiple answers are allowed)	1. Increasing importance of productive functions of forests (timber and biomass) 2. Decreasing importance of productive functions of forests (timber and biomass) 3. Increasing importance of social and environmental functions of forests 4. No significant changes
Q.2 What has changed in the last thirty years in the management of Apennine forests?	1. Reduction of forest harvesting 2. Growth of forests tourism and recreation 3. Increasing of environmental regulatory constraints 4. I don't know
Q3. Do you think that Matese forests are properly managed? If "NOT", what are the reasons? (multiple answers are allowed)	1. Excessive forest exploitation 2. Abandonment of forest management practices 3. Unregulated grazing in forests 4. Forest damage by wildlife 5. Low protection of flora and fauna

	6. Poor forestry programming 7. I don't know
Q4. Have you ever heard of Sustainable Forest Management (SFM)? If "YES", what do you think are the main issues characterizing the SFM? (multiple answers are allowed)	1. Taking into account all forest functions 2. Preserving forests and enhancing their conditions 3. Producing wood and non-wood forest products 4. Respecting local traditions and customs 5. Other______________________________
Q5. In your opinion, what is the importance of the following goods and services supplied by Matese forests? (5-point Likert scale, 0=not important/not suitable, 4=very important)	1. Carbon stocking 2. Fuelwood production 3. Timber production 4. Grazing 5. NWFP 6. Hunting 7. Biodiversity conservation 8. Hydrogeological protection 9. Tourism and recreation 10. Heritage and cultural values
Q6. Have you ever heard of Criteria and Indicators of SFM? If "YES", in your opinion what is the importance of the following criteria for the Matese forests management? (5-point Likert scale, 0=not important/not suitable, 4=very important)	1. Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles 2. Maintenance of forest ecosystems' health and vitality 3. Maintenance and encouragement of productive functions of forests (wood and non-wood) 4. Maintenance, conservation and appropriate enhance-ment of biological diversity in forest ecosystems 5. Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water) 6. Maintenance of other socio-economic functions and conditions
Q7. Which is the relationship between the following management practices and the SFM criteria? + 1=positive influence, o=neutral influence, - 1 =negative influence	1. Increasing forest cutting and timber and wood biomass extraction 2. Utilization of wood residues (top and branches) for wood chips production 3. Leaving in the forest the coarse woody debris and the standing dead trees (minimum size of diameter 30 cm) 4. Apply silvicultural treatments to favour mixed forests with a diversified structure (horizontal and vertical structure) 5. Develop tourist facilities (paths, benches and tables, etc..) 6. Develop the forest road and the log dumps to stock timber in the forest 7. Support the transition from coppice to high forest 8. Sanitary cuttings to remove sick and dead trees 9. Restriction of harvesting in forest areas with a high slope

RESULTS AND DISCUSSION

The first group of questions (Q1, Q2 and Q3) show interesting differences in stakeholders' perception of forest management. Concerning the perceived changes in the local management practices (Figure 2), a significant change in the last thirty years is widely recognized (only 3 respondents declared that there had been no changes in Matese forest management). The increasing importance of the social and environmental functions of forests is perceived as the most important change (59.0% of total respondents). This is confirmed by the high proportion of positive answers from three categories of stakeholders (64.3% of public administrations, 80.0% of environmental associations, and 70.0% of private forest owners). Conversely, forest entrepreneurs perceive as the most important change the decrease in the productive function of forests (60.0%). These results are confirmed by the answers to the second question, concerning management changes in Apennine mountain forests. About 63% of the respondents consider the increase in environmental regulatory constraints as the main management change, aimed at protecting the ecological and environmental functions of forest ecosystem, followed by the growth of forest tourism and recreation
(26.3%). It is interesting to note that 100% of the representatives of environmental associations perceive the growth of forest tourism and recreation as the only important change that has occurred in Apennine forest management in the last three decades. The other groups of stakeholders gave similar responses (Figure 3).

Only 38.5% of the respondents think that Matese forests are properly managed (Q3), and that the current forest management is sustainable in the long-term. The remaining 61.5% perceive as the main problem of forest management the poverty of forestry programming (79.2%), the abandonment of forest management practices (37.5%) and the low protection of flora and fauna (29.2%). Results of Q4 reveal that the level of knowledge about sustainable forest management is relatively low and only 48.7% of the stakeholders know about the SFM concept. The results show, however, that some important differences between the groups seem to exist. Sixty percent of representatives of environmental associations and private forest owners have heard of SFM, but only 20% of the forest entrepreneurs. The respondents who have heard about SFM consider the capacity to take into account the multifunctionality of forests (84.2%) as the main issue characterizing SFM and secondly the capacity to preserve forests and improve their conditions (52.6%) and the respect of local traditions and customs (47.4%). For the majority of respondents SFM is not a means to increase the economic returns from forests (i.e. timber and other wood products).

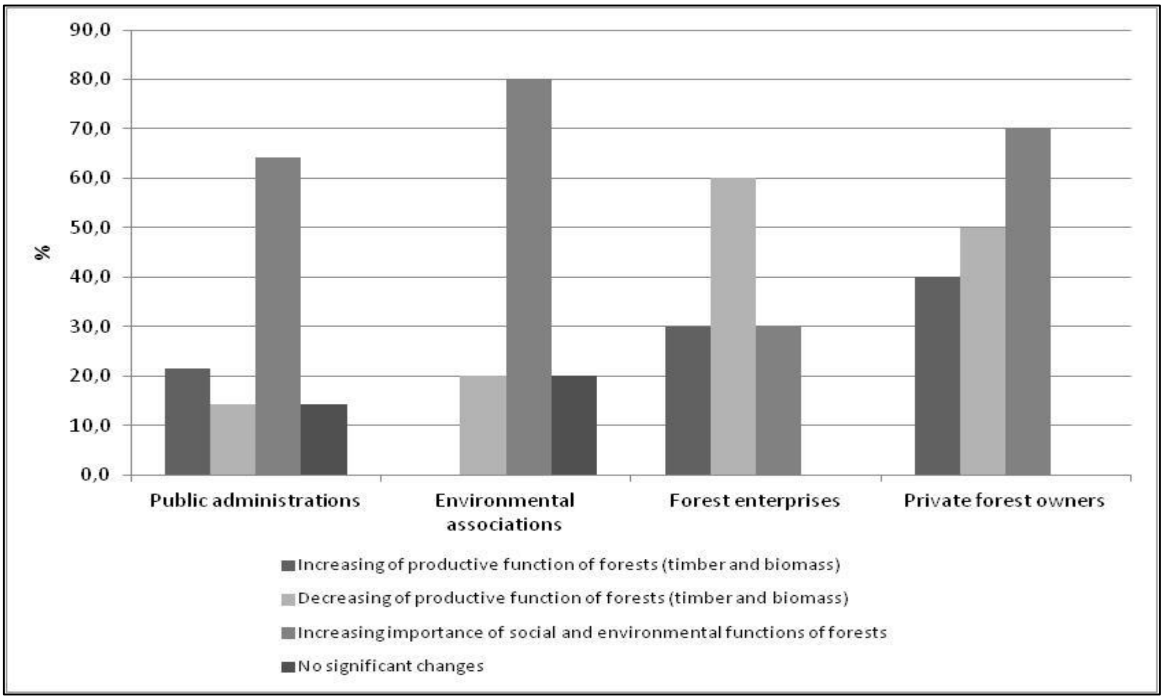

FIGURE 2. **PERCEPTION OF THE MATESE FORESTS MANAGEMENT CHANGES FOR GROUPS OF STAKEHOLDERS (% OF POSITIVE ANSWER).**

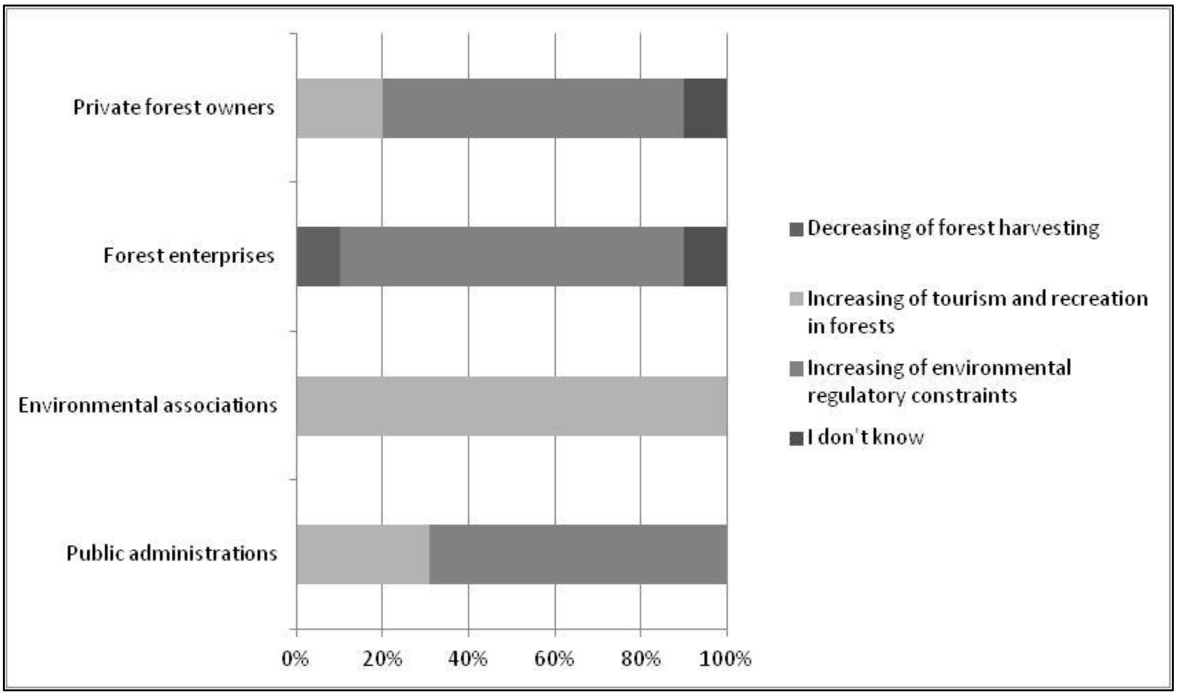

FIGURE 3. **PERCEPTION OF THE APENNINE MOUNTAIN FORESTS MANAGEMENT CHANGES FOR GROUPS OF STAKEHOLDERS**

In Table 2 answers to Q5 are presented for SFM criteria and pertinent forest functions. The forest functions/SFM criteria perceived as the most important – based on the means for all groups of stakeholders – are carbon storage (meanCriterion1=3.60, standard deviationCriterion1=0.32) and biodiversity conservation (meanCriterion4=3.60, standard deviationCriterion4=0.31). Productive functions of forests (SFM Criterion 3) are not relevant for environmental associations (meanCriterion3=2.48, standard deviationCriterion3=0.54). Conversely, firewood production is the most important function for forest entrepreneurs, private owners and public administrations,

while the other productive functions are less valuable. It is interesting to observe that timber production is the least important function for all categories of stakeholders.

In Table 3 are presented the stakeholders' preferences for the single SFM criteria, considering the answers to Q6. The results show an overall preference for Criteria 5 and 2. Comparison of the preferences expressed for the forest functions and for the SFM criteria reveals some important inconsistencies: the forest functions perceived as most important are firewood production, carbon storage and biodiversity conservation, which are related to Criteria 3, 1 and 4. Table 3 shows that these criteria scored lower than hydrogeological protection (Criteria 5) and ecosystem vitality (Criteria 2). The non-parametric test of Kruskal-Wallis showed no statistical differences for all criteria of SFM.

The collective cognitive map (Figure 4) based on the answers to Q7 shows that most respondents (22 of 39 stakeholders) consider six management practices to have a positive influence on SFM criteria.

The forest management practices which positively affect all the criteria are silvicultural treatments favouring mixed forests with a diversified structure (Practice 4). Sanitary treatments to remove sick and dead trees from the forest (Practice 8) is considered to have a positive influence on all the criteria, but with lower scores. Practice 9 and Practice 7 have a positive influence, but on Criteria 3 and 4 respectively, and with lower scores. The map shows a positive influence of developing a forest network (Practice 6) on the increase in timber production and the enhancement of other socioeconomic functions of forests.

Leaving dead wood in the forest (Practice 3) is considered to have a negative effect on all the criteria.

Answers to Q7 divided into groups of stakeholders show that representatives of environmental associations have a different perspective from that of other groups. In particular, environmentalists give a positive score to Practice 3 (leaving coarse woody debris and standing dead trees in the forest), classified as harmful by all groups of stakeholders. On the other hand, Practices 8 and 2 (sanitary treatments and use of residues for wood chips production) are considered to have a positive effect on SFM criteria by all the respondents except environmental associations. The non-parametric test of Kruskal-Wallis showed statistical differences among categories of stakeholders for five management practices: Practice 1 (K observed value=19.965, K critical value=11.345, p-value<0.001), Practice 2 (K observed value=14.458, K critical value=11.345, p-value=0.002), Practice 3 (K observed value=19.056, K critical value=11.345, p-value<0.001), Practice 6 (K observed value=14.822, K critical value=11.345, p-value=0.002), and Practice 8 (K observed value=16.500, K critical value=11.345, p-value=0.001). The differences for all the above-mentioned practices are between the environmental associations and the other categories. In particular, the environmental associations consider Practice 1, 2, 6 and 8 negative for the SFM, and Practice 3 positive for the SFM. The other three categories of stakeholders have the opposite opinion.

TABLE 2. **AVERAGE VALUES ASSIGNED TO THE FOREST FUNCTIONS BY GROUPS OF STAKEHOLDERS (5-POINTS LIKERT SCALE).**

SFM criteria/Forest function	Public administrations	Forest entrepreneurs	Environmental associations	Private forest owners	Total
Criteria 1					
Carbon stocking	3.69	3.44	4.00	3.27	3.60
Criteria 2					
Criteria 3					2,73
Fuelwood production	3.77	4.00	2.80	3.64	3.55
Timber production	1.38	1.44	1.60	2.00	1.61
Grazing	2.38	2.56	2.40	2.91	2.56
NWFP	3.38	3.22	3.00	3.18	3.20
Hunting	2.77	2.89	2.60	2.73	2.75
Criteria 4					
Biodiversity conservation	3.69	3.33	4.00	3.36	3.60
Criteria 5					
Hydrogeological protection	3.27	3.33	3.80	3.50	3.47
Criteria 6					2,90
Tourism and recreation	3.38	2.56	3.20	2.73	2.97
Cultural values	3.00	2.22	3.40	2.73	2.84

TABLE 3 **AVERAGE VALUES ASSIGNED TO THE SFM CRITERIA BY GROUPS OF STAKEHOLDERS (5-POINTS LIKERT SCALE).**

Stakeholders		C1	C2	C3	C4	C5	C6
Public administrat.	Mean	2.79	2.93	2.07	2.57	2.93	2.57
	SD	0.43	0.27	1.00	0.65	0.27	0.51
Forest entrepreneur	Mean	2.33	3.00	2.75	2.33	2.63	2.43
	SD	1.12	0.00	0.46	0.52	0.52	0.53
Environmental associations	Mean	2.20	2.00	1.40	3.00	3.00	2.00
	SD	0.45	1.22	0.89	0.00	0.00	0.71
Private forest owners	Mean	2.50	2.60	2.00	2.50	2.80	2.10
	SD	0.97	0.52	0.67	0.71	0.42	0.57
Total	Mean	2.53	2.73	2.11	2.57	2.84	2.33
	SD	0.80	0.61	0.88	0.61	0.37	0.59

Table 4 summarizes the results of the questions investigated by groups of stakeholders. The data highlight some interesting agreements and disagreements between groups.

As far as perceptions of changes and problems in local and Apennine forest management are concerned, the stakeholders are broadly in agreement: poverty in forestry programming is perceived as the main problem of the current policy management framework. Increasing importance of environmental and social functions of the forest is perceived as the main issue in local management.

Considering the main SFM criterion to be the “Maintenance and appropriate enhancement of protective functions in forest management (notably soil and water)” environmentalists, forest owners and public administrations give a greater emphasis to the protective functions of forests. On the other hand, forest owners and public administrations identified wood production as the primary forest function. Forest entrepreneurs agreed.

Taking into account the forest management practices useful to improve sustainability, results show that each group of stakeholders has different priorities. According to the institutional mission of the public administrations, the most important practices of SFM are linked to the improvement of health and stability of the forest ecosystem (mixed forests with a diversified structure and a low presence of sick and dead trees). The representatives of environmental associations focus on the improvement of the non-productive functions of forests such as biodiversity conservation and soil and water protection through the restriction of harvesting in forests with a high natural hazard risk, while the forest entrepreneurs focussed on practices favouring timber production (increasing forest cutting and developing forest roads and tracks).

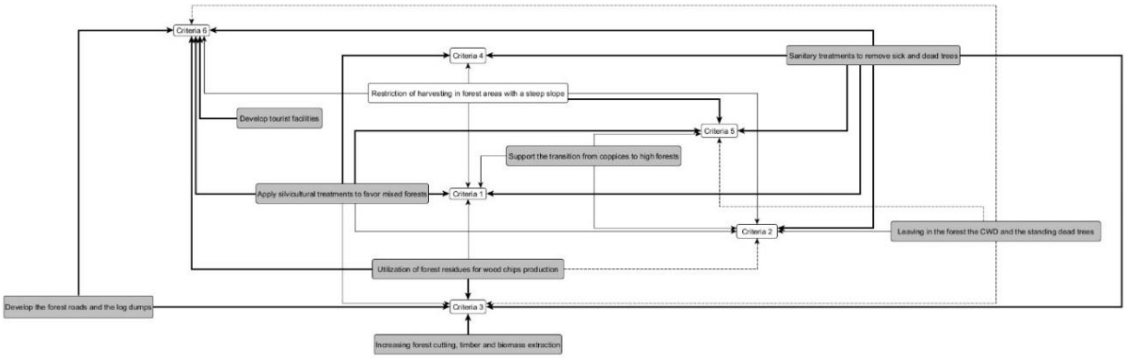

FIGURE 4. **COGNITIVE MAP OF RELATIONSHIP BETWEEN FOREST MANAGEMENT PRACTICES AND SFM CRITERIA BY ALL STAKEHOLDERS. ONLY CONNECTIONS > + 0.2 AND ≤ -0.2 ARE DRAWN. DASHED LINES REPRESENT NEGATIVE CONNECTIONS SOLID LINES POSITIVE CONNECTIONS.THE THICKNESS OF THE LINE INDICATES THE STRENGHT OF THE CONNECTIONS: BOLD LINES CORRESPOND TO A CONNECTION WITH STRENGHT > + 0,5.**

CONCLUSIONS

This research revealed that investigation into local stakeholders' perceptions of forest management and sustainability can produce useful information and support for governance.

The findings indicate that the increased importance of environmental functions of the forest is perceived as the most important forest management issue, both at the local level and more widely. Many of the respondents also believe that forests are not properly managed at present, and poverty in forestry programming is perceived as the main problem.

About half the stakeholders (51.3%) had not heard of the concept of Sustainable Forest Management. It seems that although local changes and problems in forest management are well-known to stakeholders, more theoretical and conceptual topics, such as that of sustainable forest management, were quite unfamiliar to most respondents.

Some agreement appeared among groups as to the priority accorded to the sustainability criteria chosen to enhance the protective functions of forest. At the same time firewood production is perceived as the most important function of the local forests by three groups of actors. These findings highlight contradictions between perceptions of local forest problems and priorities and general opinions about SFM criteria.

The cognitive map shows that respondents perceive as positive in terms of sustainability the influence of silvicultural treatments which protect from hydrogeological risk and improve biodiversity. These indications could support the managing institutions in setting guidelines and priorities as they are relevant to the forest management plans to be developed in the district.

So far as the method of survey is concerned, quantitative surveys are very good vehicles for assessing preferences and perceptions in a community (Babbie 2010). In the present case the questionnaire-based survey was useful since the preferences expressed by stakeholders were explicit and therefore measurable. Furthermore, the cognitive map was useful to create a concise and schematic representation of the network of concepts that relate management practices to their influence on SFM criteria. The research shows cognitive mapping to be an effective technique for investigating the meaning of a conceptual theme like sustainable management. Hence, the approach followed in the present research revealed itself well-suited to the reality surveyed. This kind of survey offers support in identifying on-going trends that need to be monitored over the course of time and could prove to be extremely effective if the questionnaires and maps were to be employed at regular intervals.

Based on our research, forest management policies need to recognize the relevance of these newer perceptions. According to Sheppard *et al.* (2001) they reflect emerging world views and local knowledge sources of other forest cultures and the growing diversity of forest users. Decision makers must be ready to listen to people's opinions, capitalize on local knowledge and perceptions, and adapt their interventions and plans accordingly. The opinions of the interested actors play an important role in creation and preparation of management plans and forest programming.

As Bell (2000) suggests, planners, forest managers and decision makers should fix their attention more on the cognitive factors which affect public reactions to forest management practices, rather than just on the design of practices themselves. Knowing the perceptions of the local actors will provide information and suggestions on what should be carried out, changed and improved in the field of forest management. It is especially true when, as shown in this case study, stakeholders' perceptions display lack of knowledge and contradictions between perceptions of local forest problems and priorities and general opinions concerning SFM criteria. This reveals once more the importance of having tools able to investigate stakeholders' perceptions in order to develop forest management in accordance with a bottom-up approach.

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

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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 “fulfi lment 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 defi ne 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 “fulfi lment capability” and the modifi cation 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 defi ning management guidelines consistent with current status and potential evolutive pattern.

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 (Garcıa-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 defi nition, 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 fl oods 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 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, Cubbage 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 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 Cercepiccola 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.

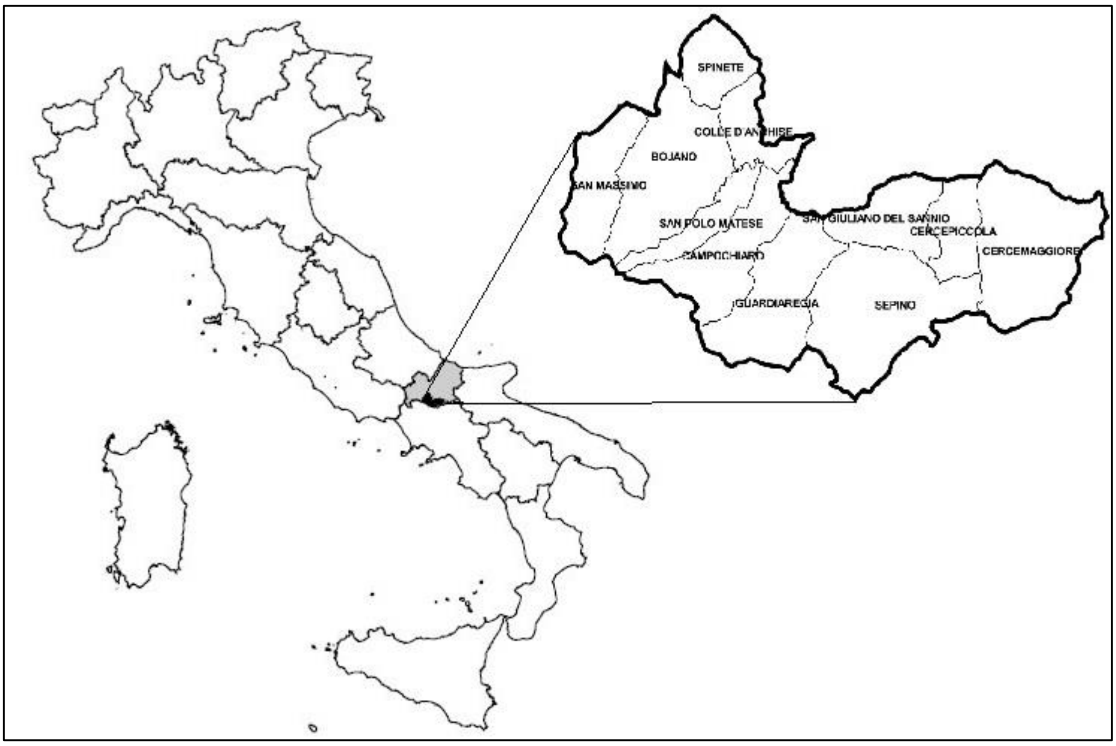

FIGURE 1**. THE STUDY AREA AND ITS MUNICIPALITIES.**

In terms of surface (Table 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.).

TABLE 1. **FOREST CATEGORIES DISTRIBUTION IN THE STUDY AREA.**

Forest categories	Area (ha)	%
Beech forests	4,785	29.7
Turkey oak forests	6,644	41.2
Downy oak forests	290	1.8
Hop-hornbeam forests	1,556	9.7
Chestnut forests	320	2.0
Riparian forests	842	5.2
Holm oak forests	18	0.1
Other broadleaved forests	1,020	6.3
Shrublands	406	2.5
Coniferous plantations	212	1.3
TOTAL	**16,094**	**100**

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, localizedjust 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).

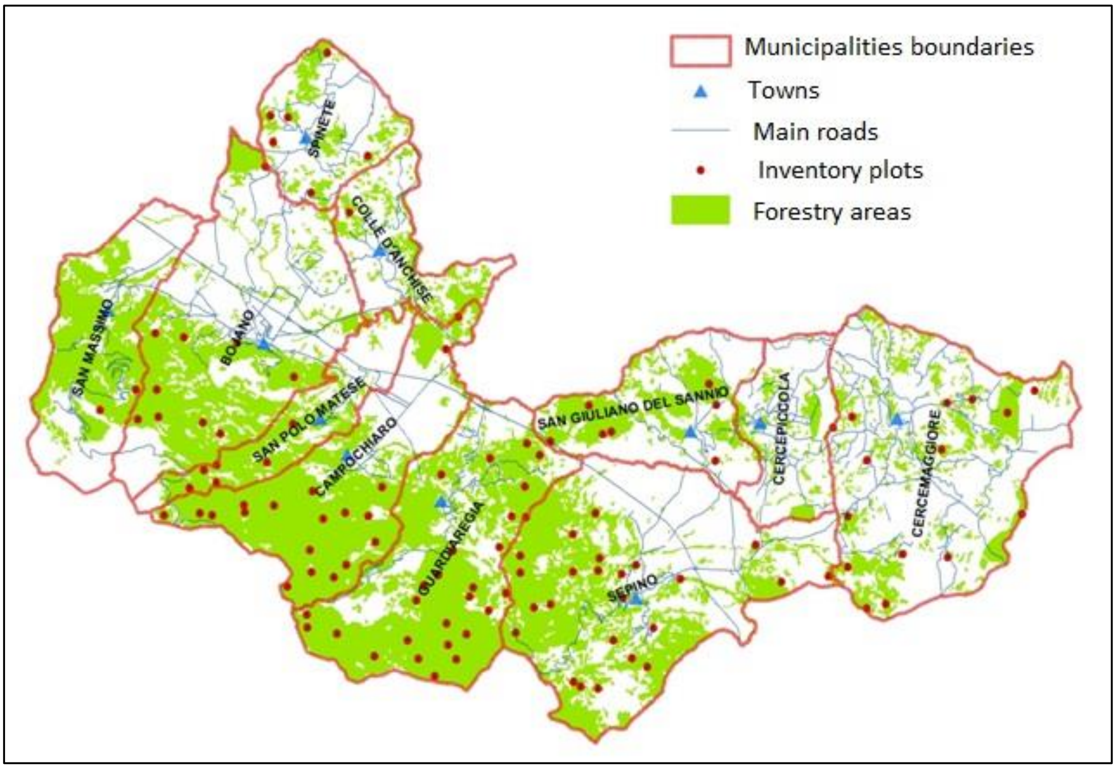

FIGURE 2. **DISTRIBUTION SAMPLE PLOTS OVER THE MAP OF FOREST LAND USE IN THE STUDY AREA.**

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 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).

TABLE 2. **STAKEHOLDERS INTERVIEWED DURING THE FIRST PHASE OF THE PARTICIPATORY PROCESS.**

Stakeholder	**Num.**
Majors	10
Forest enterprises	8
Associations	7
Agritouristic farms	3
Freelance foresters	4
Local Action Groups	3
Forest nurserys	1
Sawmills	1
Forest food products plant	1

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:

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

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 gives useful indications for operational purposes at a stratum level.

Total mean priority level and fulfilment capability as:

Where:

$$\overline{V}_{F\,FT} = \frac{\sum_{j=1}^{m} \overline{v}_{f\,ft\,j}}{m}$$

m = total number of selected functions;

$\overline{v}_{f\,ft\,j}$= 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.

TABLE 3. **SILVICULTURAL OPTIONS.**

coppices	1) traditional coppicing: total harvesting of trees except the retention of a variable number of standards with a main dissemination function (Perrin, 1954); 2) conversion to high forest: set of techniques aiming at the preparation for the conversion to high forest. The application of these treatment lead to a transitory stand with an high forest-like structure (Bernetti, 2005). 3) natural evolution of the stand.
high forests	1) even-aged high forest regeneration treatments: shelterwood, large-medium strips or large-medium groups felling (Kimmins, 2004); 2) coppice/high forest integration; 3) high forest in continuous regeneration: to obtain 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

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).

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

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;

If i = priority level of *f* function for the *i*-th plot;

cs 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.

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 (σ = 1.10), and the mean fulfilment capability was 6.18 (σ = 0.82); for high forests the priority level resulted 4.22 (σ = 0.82) and the mean fulfilment capability resulted 6.54 (σ = 0.63) (Table 5).

TABLE 5. **MEAN VALUES OF FUNCTIONS' PRIORITY LEVEL AND FULFILMENT CAPABILITY BY SILVICULTURAL SYSTEMS.**

Function/Silvicultural system	Priority level		Fulfilment capability	
	Coppices	*High forests*	*Coppices*	*High forests*
Landscape conservation	4.98	4.52	7.19	7.13
Firewood/biomass production	6.03	4.31	6.86	6.28
Lumber 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
Mean value	**4.18**	**4.20**	**6.22**	**6.47**
Standard deviation (σ)	**1.07**	**0.32**	**0.97**	**0.46**

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, 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, 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 (σ = 1.07), and the mean fulfilment capability was 6.22 (σ = 0.97); for European beech forests priority level was 4.20 (σ = 0.32) and the mean fulfilment capability was 6.47 (σ = 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, 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 (Tabel 6).

TABLE 6. **MEAN VALUES OF FUNCTIONS' PRIORITY LEVEL AND FULFILMENT CAPABILITY BY FOREST CATEGORIES.**

Function/Forest categories	Priority level		Fulfilment capability	
	Turkey oak forests	*Beech forests*	*Turkey oak forests*	*Beech forests*
Landscape conservation	5.37	4.02	7.20	7.12
Firewood/biomass production	5.98	4.31	6.74	6.40
Lumber 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
Mean value	**4.18**	**4.22**	**6.18**	**6.54**
Standard deviation (σ)	**1.10**	**0.46**	**0.82**	**0.63**

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 theless, the non-parametric test of Mann-Whitney shows statistical significantly differences for this function in the European beech forests (U = 1,153, 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 evenaged 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.

TABLE 7. **RESULTS OF OBJECTIVES-OPTIONS MATRIX FOR TURKEY OAK FORESTS.**

Option	Coppicing (only coppie)		Conversion to high forest (only coppie)		Even-aged high forest (only high forests)		Coppice/high forest integration (only high forests)		Uneven-eged high forest (only high forests)		Natural evolution (both coppices /high forests)	
Function	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
Lumber 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
Environment 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
Mean value	**15.7**	**16.2**	**15.3**	**17.3**	**16.0**	**16.9**	**5.8**	**6.3**	**12.5**	**13.2**	**12.1/12.2**	**12.4/12.6**
Standard deviation	**8.4**	**8.4**	**6.2**	**5.8**	**3.8**	**3.6**	**2.2**	**2.1**	**3.4**	**2.9**	**9.6/9.6**	**9.4/9.5**

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).

TABLE 8. **RESULTS OF OBJECTIVES-OPTIONS MATRIX FOR BEECH FORESTS.**

Option	Coppicing (only coppie)		Conversion to high forest (only coppie)		Even-aged high forest (only high forests)		Coppice/high forest integration (only high forests)		Uneven-eged high forest (only high forests)		Natural evolution (both coppices /high forests)	
Function	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
Lumber 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
Environment 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
Mean value	**10.6**	**10.9**	**14.1**	**15.8**	**16.4**	**17.3**	**9.4**	**10.2**	**14.6**	**15.3**	**12.7/13.1**	**13.0/13.0**
Standard deviation	**4.1**	**4.3**	**5.3**	**4.6**	**2.1**	**2.8**	**2.7**	**2.7**	**2.6**	**2.6**	**9.6/9.8**	**9.4/9.2**

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 20th 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 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.

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Conclusions

Stakeholders' perception and multiple use of forests are two key factors of Sustainable Forest Management, and their assessment turn out to be crucial.

In a public participation process there is a risk that decisions made on the basis of stakeholder consensus may not adequately consider the requirements for maintaining some values (e.g. cultural heritage values, viability of species populations, sustainable wood supply) (McDonald and Lane 2004). In order to decrease this risk a preliminary investigation into local stakeholders' perceptions of forest management and sustainability can produce useful information and support for governance.

Knowing the perceptions of the local actors will provide information and suggestions on what should be carried out, changed and improved in the field of forest management. It is especially true when, as shown in this case study, stakeholders' perceptions display lack of knowledge and contradictions between perceptions of local forest problems and priorities and general opinions concerning SFM criteria. At this purpose the cognitive map method could be useful to create a concise and schematic representation of the network of concepts that relate management practices to their influence on SFM criteria to limit conflicts between forest users and to reduce dysfunctions such as the "groupthink" phenomenon.

At the same time the method proposed for the assessment of forests' multifunctionality levels allows to elaborate useful information on forest multiple use and to support forest planners in defining management guidelines consistent with current state and the evolutionary potentiality of forest stands. This approach allowed to detect the current state of each stand and its potentiality in the framework of the whole forest and reduces the techinicians' subjectivity.

Section 2. Sustainable forest management indicators to evaluate innovative silvicultural practices in beech forests

Introduction

Forest ecosystems provide not only wood but many other ecosystem service as well, ranging from biodiversity conservation and carbon storage to various social functions and any form of management needs to consider all these different factors (Food and Agriculture Organization, 2006). In developed countries, most semi-natural forests have been cultivated since centuries, standardizing their structural features and have been heavily modified by long-lasting silvicultural practices. Recent changes in forest management perspectives have resulted both in the decrease in wood exploitation and in the elongation of rotation periods. Harvesting time has become a somehow flexible concept and forests are, as a matter of fact, experiencing a lengthening of stand life-span. As a consequence, large forest areas are currently managed over the traditional rotation or are in a post-cultivation stage.

Forests continue to keep a sustained growth even far beyond the former economic rotation (Spiecker et al., 1996; Kahle et al., 2008; Bertini et al., 2011) but they are reasonably unable to change their arrangement proactively, apart from natural, abrupt occurrences, unforeseeable to a great extent in their outcomes. The traditionally applied silviculture, when tailored to former main purpose of wood production, seems to be not suited to handle the current, new-targeted follow-up.

At the same time the conservation of basic structural and functional attributes of forests is a crucial task for sustainable land management.

Furthermore, the type and intensity of management influence stand structure dynamics and ecological processes such as nutrient cycling, decomposition rate and regeneration patterns (Blanco, Zavala, Imbert, & Castillo, 2005; Heneghan, Salmore, & Crossley, 2004; Toboada, Kottze, Tarrega, & Salgado, 2006; Uotila&Kouki, 2005; Zenner, Lähde, & Laiho, 2011).

Based on these premises, the papers presented in this section are intended to assess: i) the effectiveness of different forest management options in meeting multiple economic and environmental objectives, providing indications for a sustainable forestry; ii) forest structural attributes and their dynamics before and after traditional and innovative silvicultural practices.

The studies were carried out in four even-aged beech forest stands selected as being representative of the more diffuse types in Italy. Each site illustrates a specific management system, a unique history of management practices, and a stand structure within a range of ages. Site 1 (Cansiglio) is a mature (according to planned rotation) high forest in the pre-Alps (northern Italy). Site 2 (Vallombrosa) is a mature high forest located in the northern Apennines (central Italy). Site 3 (Chiarano-Sparvera) is an overgrown coppice forest undergoing conversion to a high forest incentral Apennines and Site 4 (Mongiana) is a young high forest in southern Italy.

2.1 Adaptive silvicultural practices to face the new challenges: the ManForCBD experience.

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ABSTRACT

Goals of the ongoing LIFE+'Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing' are the design and implementation of adaptive silvicultural practices aimed at: (i) maintaining growth pattern, i.e. carbon sequestration and forest health and vitality over longer life-spans, (ii) reducing outstanding structural homogeneity and symmetrical competition, (iii) promoting as well the development of levels and types of biodiversity at the operational scale of silvicultural practice, i.e. at the stand level. Basic requirement of the applied practices is their economic feasibility. All of this seems to be the basic tool to face future unpredictability and provide wider adaptive ability to uncertain scenarios. Ten experimental trials, 7 in Italy and 3 in Slovenia, were established at the purpose. Four of them, all beech forests positioned along a latitudinal gradient, are considered in this paper. Cansiglio (Veneto) aged 120- 140, Vallombrosa (Toscana) 110-160, Chiarano (Abruzzo) 70, Marchesale (Calabria) 75. The replicated experimental design compared (i) the customary practice of low to mixed thinnings over the full standing crop; (ii) the crown thinning at the older sites and the selective thinning releasing best phenotypes and removing direct crown competitors on a pre-fixed number (40-80 trees per unit area), at the younger sites. First results highlight the heavier harvesting of innovative vs. customary practice, this being allowed by the relatively high growing stocks due to full stand density. Stand structure is being moved and canopy arrangement changes as for crown texture, gaps'fraction size and distribution. Continuous monitoring as in the adaptive management protocol will provide further elements of analysis and suggest possible adjustments in the follow-up.

INTRODUCTION

Forest ecosystems provide multiple goods and benefits through own woody and non-woody productions, protective and recreational functions and inherent biological diversity. Most of semi-natural forests in Europe have experienced however a long history of cultivation mainly focused on timber production. The long-lasting practices heavily modified the original stand structures, often originating stands with simplified structures far beyond the bio-ecological specific requirements.

Recent changes in forest management perspectives have resulted both in the decrease in wood exploitation and in the elongation of rotation periods. Harvesting time has become a somehow flexible concept and forests are experiencing as a matter of fact a lengthening of stand life-span. As a consequence, large forest areas are currently managed over the traditional rotation or are in a post-cultivation stage. Where applied, the former criteria of wood production-oriented silviculture are anyway, often less intensively, practiced. An early, exploratory phase between technical and biological permanence-time is therefore in progress. In these stands, trees are getting thicker and older, growing stocks are becoming higher and symmetrical competition acts as a lasting attribute. The diffuse protection regime in terms of cover, the onset of additional binding forces to pro-active management implementation, the less profitable wood harvesting, the other than productive functions prevailing, contribute the current condition (MCPFE, 2011; FAO, 2014).

Forests continue to keep a sustained growth even far beyond the former economic rotation (Spiecker *et al*., 1996; Kahle *et al*., 2008; Bertini *et al*., 2011) but they are reasonably unable to change their arrangement proactively, apart from natural, abrupt occurrences, unforeseeable to a great extent in their outcomes. The traditionally applied silviculture, when tailored to former main purpose of wood production, seems to be not suited to handle the current, new-targeted follow-up.

An additional, emerging benchmark to forest management is the progress of environmental conditions'shift. This involves directly both physics and chemistry of growth medium - atmosphere and soil - with concurrent and counteracting factors (increase of air temperature and CO2 content, abrupt changes in rainfall regime, extreme events, airborne acidifying pollution, N fertilization, ozone level) (Ferretti *et al.*, 2014; Nabuurs *et al.*, 2013; Seidl *et al.*, 2014).

Because of the full involvement of growth medium attributes, tree growth level and pattern (i) provide the evidence of this occurrence and (ii) synthesize the balance between positive and negative inputs in the short, as well as in the long run (Solberg *et al.*, 2009).

The analysis of complex relationships between factors highlights the role of drivers, the onset of limiting factors and feedbacks (Magnani *et al.*, 2007; de Vries *et al.*, 2008; Hetzold *et al.*, 2014; Stephenson *et al.*, 2014). Time elapsing since the biological community is being affected is relatively short because of the rate of change in progress and of its cumulative effect, e.g. the rapid turning point of N in the soil from 'tree growth stimulating factor to nutritional unbalancing and acidifying factor'. That is why monitoring of 'tree growth level and pattern' may contribute significantly the understanding of condition in progress and the adjustment of management (Dobbertin *et al.*, 2008; Lindner *et al.*, 2010).

Mitigation to climate change, major global driver, is contributed by forests through the maintenance or enhancement of inherent carbon sequestration and stock ability in standing crop and soil. This adds a new goal to the already manifold forests' functions and involves directly the design of management criteria.

Further to these assumptions, is the awareness of the increasing 'uncertainty' about the progress of environmental conditions'shift. The question is: are we living a path of change - this underlying a start and an end point - or are we going to live a perennial transition well-known in its beginning, but quite completely unknown in its further course? How fast it will proceed and which will be the prevailing direction of change and predictable feedbacks on complex organisms as forest ecosystems is quite unknown. That is why 'risk management' comes to be a customary companion to forest ecologists, managers and planners.

The ongoing LIFE+ project ManForCBD (Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing) is aimed at developing and testing novel adaptive silvicultural practices for the maintenance/enhancement of carbon storage and sequestration, i.e. forest mitigation ability, forest health and vitality, productive functions, types and levels of biodiversity. Reference is made to Criteria 1 to 4 of SFM -MCPFE.

Focus is made on the design and implementation of practices aimed at: (i) reducing the outstanding structural homogeneity and implicit symmetrical competition, (ii) maintaining tree growth over prolonged life-spans, (iii) enhancing the diversity of stand structures. Experimental trials have been established to implement, test and monitor the effectiveness of the developed management options for the achievement of these multiple objectives and provide data and guidance of best practice.

MATERIALS

Four out of the ten sites of the project, i.e. beech forests distributed along a latitudinal gradient, were considered here: Cansiglio (Veneto) aged 120-140, Vallombrosa (Toscana) 110-160, Chiarano (Abruzzo) 70, Marchesale (Calabria) 75.

Standing crop attributes at each site are the heritage of techniques ruling past silvicultural management. In Cansiglio, forestry is documented consistently since 1200-1300 under the Republic of Venice. First management plan dates 1638; the establishment of 'National forest' is dated 1871 and the first 'modern' plan (Morelli) was implemented in 1930 (Bessega, 2008).

Stand regeneration is being successfully established following the group shelterwood system and the uniform physiognomy is carefully shaped here by the long-lasting standard techniques aimed at timber production throughout the forest compartments. Only few patches, irregular for position, reduced site-index and/or specific composition, are being excluded, as a rule, from management. This background and the site quality, optimal to beech vegetation, make this forest the prototypical pre-alpine beech forest regularly managed for purpose of wood-production.

The management history of Vallombrosa is closely linked to centuries of forestry activity implemented by the friars of local Benedictine Abbey and subsequently by the National Forest Service. Current standing crops at the test-site originated partly from the reafforestation of pastures beyond the pristine forest edge and partly from the conversion of former coppice into high forest (Galipò, 2012, personal communication). Current physiognomies varied between the more regular, grown dense even-aged crops, and the less homogeneous former coppice characterized by the scattered, grownup standards and the stems selected on the original stools, now indiscernible from trees originated from seed. This composite history is still recognizable in the current physiognomy of the beech high forest.

Chiarano is the typical beech transitory crop becoming established since the suspension of former coppice harvesting since mid 1900 and undergoing periodical thinning aimed at reducing progressively shoots' number on each stool and maintaining a full crown cover all over the conversion cycle. Number of standards is quite reduced resulting in a fairly homogeneous stand structure. The age-related tree density is high and crowns are smallsized and upper-inserted. An outstanding symmetrical competition is frequently observed in these crops (Del Rio *et al.*, 2014), it being temporarily settled by periodical thinning in the still young forest. Marchesale, geographically opposite to Cansiglio, summarizes the distinctiveness of southern beech forests as for the management history and the higher diversity of Mediterraneanmountain environments. Last, unfinished regeneration cutting: an arrangement between the group shelterwood, the clear-cut and the clear cut with reserves systems, released around the first half of 1900 grouped or single stems of former cycle, at now standing out among the dominant crop. The patchy presence of silver fir mother trees and of close regeneration cohorts scattered in the beech forest, provides further spots of specific and structural diversity. The resulting physiognomy is therefore less regularly distributed throughout the full cover. Bedrock and climate (Table 1) are optimal to beech vegetation at all sites from the pre-alpine environment up to the very southern Apennines outcrops. Main mensurational parameters at the sites are reported in Table 2.

TABLE 1. **SITE CHARACTERISTICS.**

	Cansiglio	Vallombrosa
Area (ha)	30 - 35	30
Geographical coordinates (UTM-WGS84)	46° 03'N, 12°23' E	43°44'N, 11°34'E
Altitudinal range (m a.s.l.)	1100 – 1200	470-1440
Landscape morphology	Gently sloping mountainsides and plains	Gently sloping mountainsides
Bedrock	limestone, marlstone (Cretaceous)	sandstone (Chianti formation)
Mean Temp °C	5.6	9.7
Max Temp °C (average warmest month)	14.8, August	33.5, July
Min Temp °C (average coldest month)	-4, January	-0.8, January
Total Rainfall (mm)	2004	1337
	Chiarano Sparvera	**Marchesale**
Area (ha)	30	30
Geographical coordinates (UTM-WGS84)	41°51' N, 13°57' E	38° 30'N, 16°14'E
Altitudinal range (m a.s.l.)	1700 - 1800	1100
Landscape morphology	Upper mountain slope range 22°÷28,5°	Uneven mountain terrain (slope up to 40%)
Bedrock	Cretaceous limestone	Granite (Serra and Sila formation)
Mean Temp °C	8.5	10.1
Max Temp °C (average warmest month)	17, July	18.4, July
Min Temp °C (average coldest month)	-0.2, January	2.2, February
Total Rainfall (mm)	1000	1808

TABLE 2. **MAIN MENSURATIONAL PARAMETERS AT THE SITES.**

Parameter	Cansiglio	Vallombrosa	Chiarano	Marchesale
Tree density	323±65.9	532±117	1367±353	510±130
Basal area (m^2)	40.9±5.2	54.9±3.5	38.8±4.4	41.2±7.3
Mean height (m)	26.6±0.5	28.2±1.6	14.3±0.8	23.3±1.5
Mean dbh (cm)	40.6±3	37.3±5.6	19.4±2.4	32.9±6.1
Dominant dbh (cm)	49±3.6	50.5±6.0	30.3±4.6	46.2±6.8
Dominant height (m)	27±0.6	31.9±1.2	17.0±0.9	26.2±1.2
Standing volume (m^3)	543±72	795±80.3	183±24.4	497±110.8

METHODS

Rationale of silvicultural practices

Customary technique, common to all case-studies, is the mass tending of standing crop according to main, but not exclusive, wood production purpose. Low (first stage) to mixed (following stages up to harvesting) thinnings rule the applied criteria following the mass regeneration pattern under the shelterwood system.
Such technique is canonical to beech requirements and aimed at getting quality timber as well as at matching the specific bio-ecological attributes, i.e. beech shade tolerance and its natural trend to build up evenaged, one-storied stands. This was the context of management under the quite steady environmental conditions and before the shift in progress.

The working hypothesis moved from the following rationale: face up to the emerging changes by a proactive silviculture, to meeting mitigation demand whilst maintaining tree 'health and vitality' and promoting biological diversity. The economic sustainability of techniques employed is a basic requirement to make them easily enforceable in the practice of management. Carbon sequestration implies the maintenance of a consistent growth efficiency for the expected prolongation of stand life-time, this being too the basic awaited attribute for growing out 'healthy and vital' higher stocks. In the meantime, role of the applied practices is to reduce current evenness while implementing cost-effective interventions.
The proposed adaptive silvicultural practices focused on tree canopy, i.e. the physical layer where tree growth takes place, where individual potential is being naturally developed or may be promoted through crown differentiation, where an active interface works between inner, outer and the full range of intermediate conditions. The assumption was the design of manipulative practices usefully addressed to the main crown layer to make available further growing space, promote a more effective crown-stem-root ratio, ensure further growth, differentiate current evenness, get patches inside housing more diverse living communities. Basically, move from a mass tending aimed at growing trees sized and shaped likewise as in the customary practice, to a targeted crop tending supporting and promoting both growth and the more balanced development of best phenotypes or a selected set of trees within the dominant layer, as in the 'crown' and in the 'selective' thinning practice. The progress of shifting conditions calls for its enforcement even at different, intermediate ages of stand lifespan as in the case-studies, in spite of the canonical application ruling each thinning type since earlier stages of stand development. Both method and context of practices' enforcement inform the typical attributes of an adaptive approach.

Experimental design

LIFE rules foresee, among others, the 'demonstration' character of implementation practices, this allowing to work on a wide area in the case - 30 hectares at each site - i.e. an operational scale as for silviculture and forest management.The replicated design compared (i) the customary practice i.e. the low to mixed thinning over the full standing crop; (ii) the innovative criterion, i.e. (a) the crown thinning at the older sites, Cansiglio and Vallombrosa; (b) the selective thinning releasing a prefixed number of trees (40-80 per unit area) and removing direct crown competitors at the younger sites, Chiarano and Marchesale. The thesis of no intervention has been added at the three high forest sites both as 'control' and as possible, current management choice in progress.

FIRST RESULTS

Main mensurational parameters at the sites (Table 2) provide values and range at the time of survey as a function of site-index, dominant stand age and origin (seed or agamic), cultivation history, namely applied regeneration cutting type and thinning regime over the life-span. Standard deviation summarizes variability within the standing crop. Tree density drops as a function of stand age and thinning intensity, being also influenced by the distributive pattern. Its value at Cansiglio and Vallombrosa, two stands aged about likewise, suggests the more conservative management at the latter site, whilst Marchesale averages out the inner tree density variability due to the patchy release of former cycle trees. Chiarano exhibits vice versa the customary density of coppice forests undergoing the intermediate phase of conversion into high forest.

Basal area is age-dependent but much less sensitive to tree density variation where, as in the case-studies, crown cover is quite complete and the growing space almost saturated. The higher value at Vallombrosa, slightly older than Cansiglio, is due to tree density as well as to growth space efficiency due to the complementary dendrotypes. The gap mean to dominant tree height at Vallombrosa compared to Cansiglio strengthens this assumption. Trees of the older cycle raise dominant height at Marchesale, in spite of the young stand age. Standing volume summarizes the other variables and highlights its maximum at Vallombrosa, approaching 800 m3ha-1. The relatively higher tree density and the quite similar dominant tree height raise standing volume at Marchesale close to value found at Cansiglio, partly reflecting the higher productivity of southern beech forests (Fabbio *et al.*, 2006).

Results (Table 3 and 4) highlight the heavier harvesting of innovative vs. customary practice. According to the innovative criterion, removal in basal area and volume is quite similar in Cansiglio and Vallombrosa and more intensive (up to 40%) at Chiarano, i.e. the densest stand. The removal drops at Marchesale at about one half, but tree density is here about one-third than at Chiarano, due to the high forest system. Customary removal is less heavy than innovative but not so widely diverging, with the exception of Vallombrosa, where it is close to zero.

TABLE 3. **MAIN MENSURATIONAL PARAMETERS BEFORE AND AFTER THINNING OPERATION. (I) INNOVATIVE THINNING, (C) CUSTOMARY THINNING.**

Parameters	Cansiglio				Vallombrosa			
	Before thinning		After thinning		Before thinning		After thinning	
	I	C	I	C	I	C	I	C
Tree density	320	326	187	235	511	598	316	567
Basal area (m^2)	41.8	40.7	26.3	30.3	56.9	54.3	36.4	52.6
Mean height (m)	26.8	26.5	27.0	26.5	28.5	27.7	26.4	25.3
Mean dbh (cm)	40.3	40.1	43.7	40.5	38.5	34.5	30.0	27.0
Dominant dbh (cm)	49.6	47.8	48.1	46.9	61.0	50.1	58.9	50.1
Dominant height (m)	27.8	27.6	27.0	26.6	33.6	31.4	33.2	31.4
Standing volume (m^3)	561.0	529.0	358	402	838.0	768.0	542.0	741.0

Parameters	Chiarano Sparvera						Marchesale			
	Before thinning			After thinning			Before thinning		After thinning	
	I-80	I-40	C	I-80	I-40	C	I	C	I	C
Tree density	1293	1515	1293	684	655	613	528	479	409	408
Basal area (m^2)	40.3	39.9	36.1	23.1	24.2	23.5	43.5	38.7	33.7	31.6
Mean height (m)	14.1	14.6	14.3	15.0	15.1	15.3	23.4	23.5	24.2	23.5
Mean dbh (cm)	20.3	18.6	19.3	22.8	21.7	21.7	32.3	32.5	33.0	33.4
Dominant dbh (cm)	31.9	30.3	30.7	32.0	30.0	31.0	47.0	47.0	47.0	47.0
Dominant height (m)	17.4	17.1	17.1	17.4	17.1	17.1	26.2	26.2	23.3	26.0
Standing volume (m^3)	304	292	272	180	192	177	528	468	401	377

This owing to the advice of local staff responsible for tree marking of customary practice (as at all the other sites) to follow strictly the planned thinning time ruled by the management plan. The apparent pre-post change in mean/dominant dbhs and tree heights is viceversa the output of the different target layer(s) manipulated by each thinning type. All of this, as for the quantitative side of removal.

TABLE 4. **THINNINGS' REMOVAL.**

	PERCENTAGE REMOVAL		
	N	G	V
CANSIGLIO			
Innovative	41	37	36
Customary	28	26	24
VALLOMBROSA			
Innovative	38	36	35
Customary	3.6	3.1	3.0
CHIARANO			
Customary	53	36	34
I-80	47	40	37
I-40	57	41	40
MARCHESALE			
Innovative	22	21	24
Customary	15	19	20

Values of crown cover and overlapping, crown layer texture, i.e. gaps'size and shape, their spatial distribution, fragmentation/connection - before and after thinning operation - give the evidence of crown layer manipulation operated by each practice. A first dataset is provided for the forest of Cansiglio (Fig. 1 and 2).

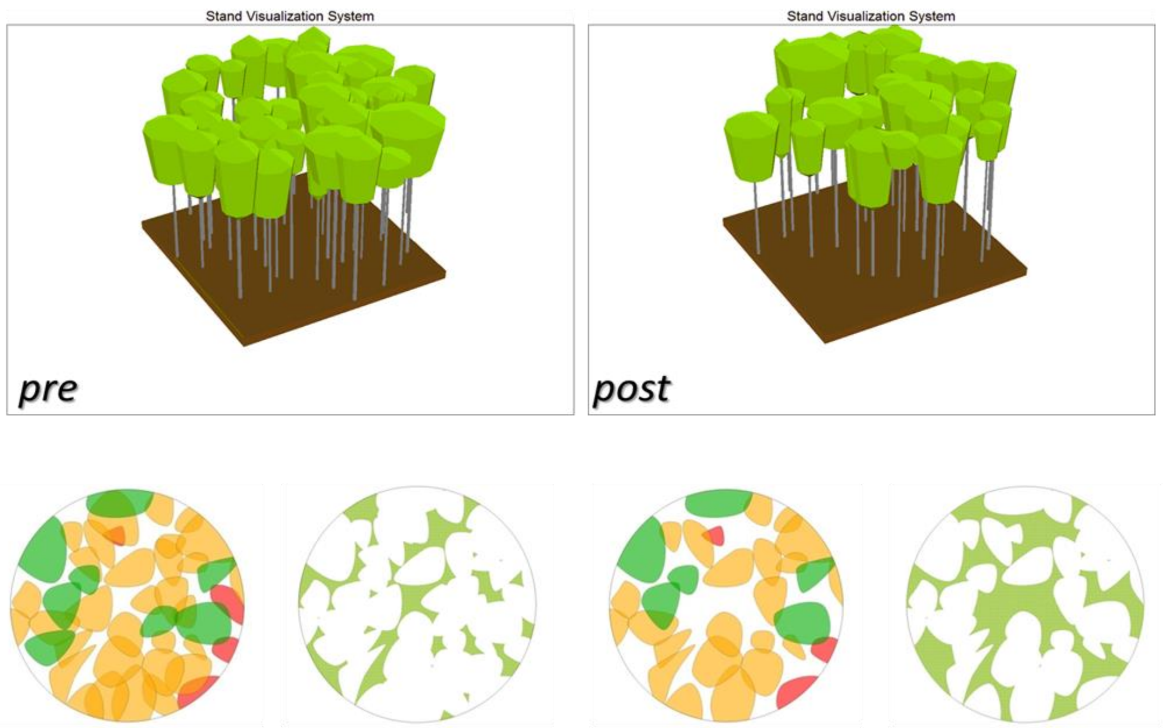

FIGURE 1. **SAMPLE PLOT BEFORE AND AFTER** CUSTOMARY **THINNING IMPLEMENTATION AT CANSIGLIO**

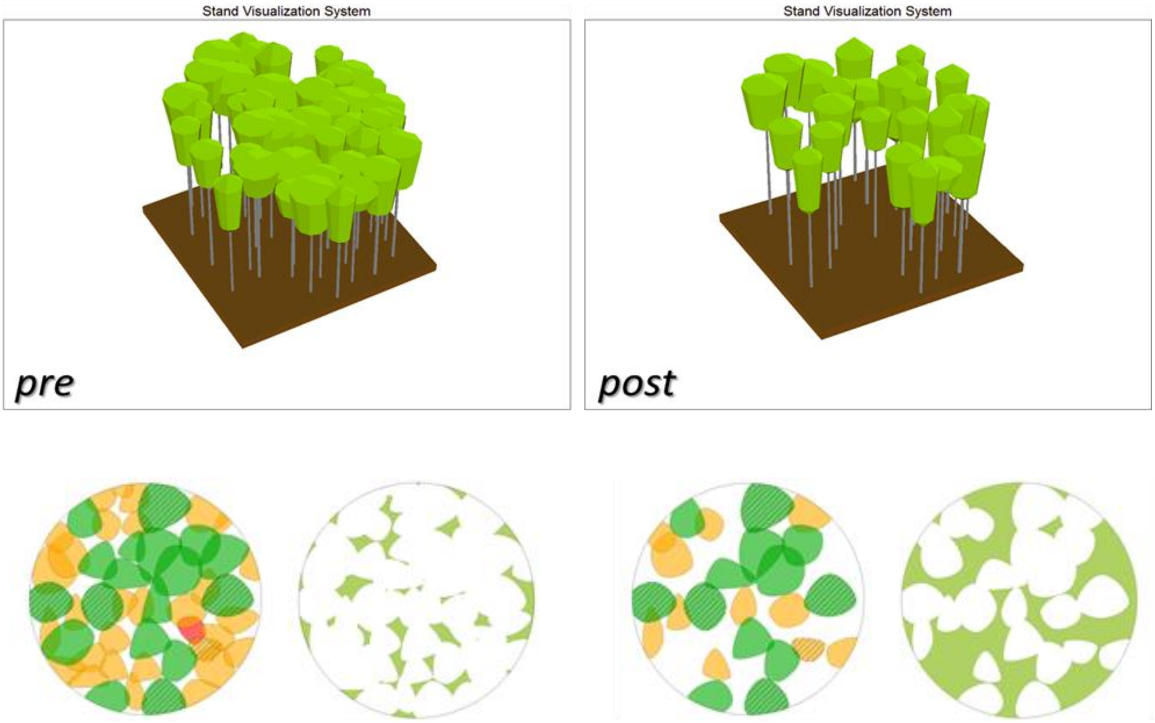

FIGURE 2. **SAMPLE PLOT BEFORE AND AFTER** INNOVATIVE **THINNING IMPLEMENTATION AT CANSIGLIO.**

Total number of gaps was similar between the theses after the intervention.

The innovative thinning produced a gap fraction 10% higher than the customary intervention and almost a double mean gap size. As a consequence, mean gap perimeter/area ratio dropped significantly under the innovative thinning, while it remained steady under the customary removal. Finally, edge density increased at both theses. The increase was slightly higher (10%) under the innovative one.

DISCUSSION

The outcome of thinning is the less homogeneous physiognomy of stand structure; this reducing too the progress of symmetrical competition detrimental to individual growth course and stand growth pattern. Canopy arrangement has been changed as for crown texture, gaps' fraction size, shape and distribution, according to each applied criterion. Specifically, the innovative thinning released wider and less fragmented gaps. They are expected to produce more lasting openings at the main crown level, whilst customary intervention gives rise to more temporary gaps. The higher radiation and throughfall amount to the soil are expected to trigger bio-geo-chemical processes able to establish further habitats and ecological niches for the enrichment of types of biodiversity inside. The more differentiated tree crown sizes will contribute resistance to disturbances and enhance growth pattern within tree population. Thinning operations provided a positive outcome, i.e. a revenue, at all sites and for both the applied theses, in proportion to the harvested volumes and independently of the position of harvested trees, both of thinning types foreseeing - within own different distribution (mass or spotty) - removals over the full area. The high removal of the innovative criterion has been allowed by the relatively high growing stocks due to the quite full stand densities.

Data immediately after thinning implementation provide the baseline condition and the reference to the content and design of surveys to be carried out in the following monitoring phase, this being an integral part of the procedure to test the effectiveness of any adaptive approach. A previous study (Becagli *et al.*, 2013) documented the impact of silvicultural practices on forest structure by a set of structural diversity and tree competition metrics at the sites of Cansiglio and Marchesale. Results highlighted the effectiveness of tree spatial competition indexes to promptly assess response to thinning and the great capability of crown-based indexes to differentiate thinning criteria compared with mensurational parameters. Conversely, most of spatial and nonspatial tree diversity indexes tested showed slight or null sensitivity to the applied practices. Their use will become more relevant at later steps after thinning occurrence.

The careful monitoring of standing crop parameters following manipulation, will provide the elements to verify both consistency of the applied theses and the progress towards the awaited goals, possible failures or need of adjustment. At the same time, which components, directions, extents have to be better addressedtuned. Stand attributes are only a part of the system to be surveyed, this including the other relevant communities and the soil system. As for standing crop, a special focus will be devoted to the rearrangement of canopy interface, it holding a leading role to achieving most of expected benefits as for structural attributes of forest stand (Pretzsch, 2014), but also for herbs, shrubs, tree regeneration layers, soil organic content and microbial activity, all of them contributory to the ecosystem functioning and balance.

In this respect, any manipulation of upper canopy interface drives radiation regime and throughfall inside with direct relapses on inner microclimate, heat and water availability, evapo-transpiration, litterfall amount, decomposition rate, respiratory losses, all of them contributing to handle the overall carbon allocation and release, i.e., the carbon budget. Beech bio-ecological attributes as the own reaction ability to late thinnings and the inherent crown plasticity to recover the space made available, provide foreseeable elements of positive reaction to the implemented practices (Fichtner *et al.*, 2013).

CONCLUSIONS

The paper provides a first insight into the ongoing experience. Continuous monitoring as in the adaptive management rationale will test out the implementations and provide further elements of analysis and adjustement in the follow-up. Current scenario and future uncertainty call for an adaptive management approach taking into account drivers, feedbacks and limiting factors, comparing heritage and new criteria but moving from the former 'steady' condition to a more dynamic approach as in the AFM protocol. The design and implementation of innovative practices consistent with growth environments and specific bioecological requirements, the comparison with customary silviculture and with the post-cultivation phase where this option is in progress in the management practice, seems to be the main, technically feasible, reliable and operational tool to tackle the challenge.

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2.2 Monitoring managed forest structure at the compartment-level under different silvicultural heritages: An exploratory data analysis in Italy.

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ABSTRACT

The more and more diffused multifunctional role addressed nowadays to public forests, calls for targeted analysis aimed at highlighting the overall outcome of different practices implemented on the same forest compartment, according to the locally prevailing function. This study was carried out in four Italian beech forests across a latitudinal gradient representative of multiple management history, stand structure, and dominant stand age. We analyze forest structure at the compartment scale before and after silvicultural practices. We aim to explore relationships and similarities between 10 stand attributes (mensurational and structural variables) to identify relevant indicators for the monitoring and management of forest ecosystems. Results indicate changing patterns of correlation and similarity among mensurational variables following practice implementation. A sensitivity gradient to silvicultural practice was finally identified within the four sites investigated as a result of the diverging stand structure. Our approach suggests a way and provides an insight for the design of adaptive forestry management practices required to meet environmental targets, in addition to the already acknowledged supply of primary goods and services.

INTRODUCTION

According to Forest Europe (2014), conservation of basic structural and functional attributes of forests is a crucial task for sustainable land management. Forest structure, understood as the distribution of standing biomass and the vertical/horizontal arrangement of tree individuals and sizes, age distribution, and canopy’s layering, is related to functionality and resilience of natural ecosystems (Kint, Mohren, Geudens, De Wulf, & Lust, 2004; Zenner & Hibbs, 2000). Stand structure variables are considered proxies of forest management quality since (a) stand structure is the most manipulated element to achieve management goals; (b) stand structure is a proxy for hardly measurable ecological functions and processes; and (c) stand structure has an inherent value for wood production, providing aesthetic values and ecological niches at the same time (Franklin et al., 2002; McElhinny, Gibbons, Brack, & Bauhus, 2005). Stand structure is also considered a basic element of diversity under central Europe growth conditions and/or where tree species richness is low, such as in mountain forests (Brunialti et al., 2010; Jung, Kaiser, Bohm, Nieschulze, & Kalko, 2012; Winter & Moller, 2008).

Stand structure arrangement is a proxy of ecosystem complexity and community diversity, being considered a basic attribute when forecasting stand dynamics and growth (Staudhammer & LeMay, 2001). Interpreting forest complexity (i.e., the multidimensional character of forest stands, see Beckschafer et al., 2013; Kimmins, 2005; Sabatini, Burrascano, Lombardi, Chirici, & Blasi, 2015) requires dedicated approaches suited for such assessment—e.g., the manifold sides of stand structure. A number of indicators have been proposed to assess forest structural attributes (Corona, D'Orazio, Lamonaca, & Portoghesi, 2005; Del Rio, Montes, Canellas, & Montero, 2003; Neumann & Starlinger, 2001; Pommerening, 2006). Indicators have been also proposed to classify forest stands on the basis of management intensity (Schall & Ammer, 2013), developmental phases (Whitman and Hagan, 2007), or "naturalness" (McRoberts, Winter, Chirici, & Lapiont, 2012).

According to Pretzsch (2009), the horizontal distributive pattern of trees, tree density, tree size differentiation, and tree species intermingling are the main components of stand structure. Structural variables at the macro-, meso-, and micro-scales are reliable indicators of ecological diversity, ecosystem resilience, and management outcomes (Winter, 2012). The relationship between structure and functioning is a fundamental issue for ecosystems where patterns at higher levels emerge from localized interactions and selected processes acting at lower levels (Arthur et al., 1997; Levin, 1998). Investigating the extent to which system features are the result of self-organization and the importance of environmental conditions and management history in the development of natural ecosystems, is relevant in forest management (Levin, 1998).

The distribution, structure, and species composition of European forests are the result of long-lasting management practices and more recent land-use changes. Forest management influences soil properties, the amount and quality of deadwood, litter accumulation, and understory vegetation (Cutini & Hajny, 2006; Siitonen, Martikainen, Punttila, & Rauh, 2000; Strandberg, Kristiansen, & Tybirk, 2005). Furthermore, the type and intensity of management influence stand structure dynamics and ecological processes such as nutrient cycling, decomposition rate, regeneration patterns (Blanco, Zavala, Imbert, & Castillo, 2005; Heneghan, Salmore, & Crossley, 2004; Toboada, Kottze, Tarrega, & Salgado, 2006; Uotila&Kouki, 2005; Zenner, Lähde, & Laiho, 2011).

The physiognomical impacts of management are detected in forest structure. Standard silvicultural practices, such as thinning and regeneration cuttings, heavily manipulate stand structure and its arrangement over the stand's entire life span (Nagai & Yoshida, 2006). Cultivated forests maintain the attributes of complex but simplified systems, as their structural dynamics are being periodically altered by practices impacting tree spatial pattern and regeneration age. Silviculture basically acts repeatedly on the aggregation and hierarchical organization of trees at its operational patch or management unit scale (McElhinny et al., 2005). At higher spatial scales—i.e. at the compartment level—forests constitute a shifting mosaic of unevenly distributed patches following the temporal and spatial arrangement of silvicultural operations. Forest "compartment" is intended here as "a portion of a forest defined for [the] purposes of locational reference and as a basis for forest management" (Helms, 1998, p. 34).

Traditional approaches preferentially investigate one or a few target variables—usually wood production or a specific type (or level) of biological diversity (Fabbio & Bertini, 2009a; Parviainen & Frank, 2003). By contrast, complex forest systems can be better interpreted vis à vis the impact of silvicultural practices using multicriteria methodologies assessing forest structure and the latent relationship and similarity patterns among related metrics (Becagli et al., 2013). As a matter of fact, the multifunctional role involving today many public forests makes that different silvicultural approaches are being implemented together at the small scale—i.e., within the same compartment. Multivariate statistical approaches investigating latent spatial patterns and similarities among forest descriptors are thus particularly useful when exploring forest structural complexity and the overall impact of harvesting on stand characteristics.

This study goes beyond the customary comparisons of silvicultural practices in order to identify relevant indicators for both forest monitoring and management. We focused on the forest compartment scale—i.e., a defined forest area made of patches (units) managed at different times according to a series of planned interventions. This arrangement was simulated at one time on thinned and unthinned patches as a forest compartment's partition at each site. This approach tests the impact of silvicultural practices on mensurational and structural variables across a gradient of forests differing in structure and dominant age. Based on these premises, we applied an exploratory data analysis to shed light on forest structural dynamics before and after silvicultural practice occurrence. As such, this study contributes to the development of a possible approach for designing and monitoring adaptive forest management practices.

MATERIALS AND METHODS

Study area

Beech forests extend about 5,553 km^2 across Italy. Beech grows in high quality stands (due to the ensemble of wood yield, environmental functions, and aesthetical value) from the pre-Alps up to southern Apennines and Sicily—i.e., the southernmost beech populations in Europe. High forests and coppice forests account for 40 and 60% of the total beech cover in Italy, respectively. This study was carried out at four even-aged beech forest stands selected as being representative of the more diffuse types. Each site illustrates a specific management system, a unique history of management practices, and a stand structure within a range of ages. Site 1 is a mature (according to planned rotation) high forest in the pre-Alps (northern Italy). Site 2 is a mature high forest located in the northern Apennines (central Italy). Site 3 is an overgrown coppice forest undergoing conversion to a high forest incentral Apennines. Site 4 is a young high forest insouthern Italy (Table 1).

Heritage management criteria and related stand structure attributes

Site 1 forest is managed according to certified management plans because of its economic value and geographical position. Basic cultivation rules consist of moderate thinning from below or mixed, repeated thinning every 20–25 yr on the same patch. Stand regeneration becomes easily established by the group shelterwood system at the stand age of 130–140 yr. Regeneration cuttings are planned on the regular occurrence of full mastyears.Stand structure is quite uniform due to the longstanding canonical practices in the forest. The age ranges from 120 to 140 yr.

TABLE 1. **LOCATION OF THE FOUR STUDY AREAS AND SITE CHARACTERISTICS.**

	Site 1	Site 2	Site 3	Site 4
	Cansiglio	Vallombrosa	Chiarano	Marchesale
Area (ha)	30 - 35	30	30	30
UTM-WGS84	46° 03'N, 12°23'E	43°44'N, 11°34'E	41°51' N, 13°57' E	38° 30'N, 16°14'E
Altitudinal range (m a.s.l.)	1100 – 1200	470-1440	1700 - 1800	1100
Landscape morphology	Gently sloping mountainsides and plains	Gently sloping mountainsides	Upper mountain slope range 22°÷28,5°	Uneven mountain terrain (slope up to 40%)
Bedrock	limestone, marlston (Cretaceous)	sandstone (Chianti formation)	Cretaceous limestone	Granite (Serra and Sila formation)
Mean Temp °C	5.6	9.7	8.5	10.1
Max Temp °C (average warmest month)	14.8, August	33.5, July	17, July	18.4, July
Min Temp °C (average coldest month)	-4, January	-0.8, January	-0.2, January	2.2, February
Total Rainfall (mm)	2004	1337	1000	1808

At Site 2, the standing crop originates from the natural beech cover as well as from coppice conversion into a high forest during the mid-1800s and from the reafforestation of pastures beyond the pristine forest edge. Cultivation rules were similar to Site 1, being more conservative today: management practices are reduced according to the ruling management plan. Physiognomy varies between the more regular structure of the evenaged crops, grown dense and one-layered with small, upper-inserted crowns; and the less homogeneous structure of the former coppice crop, which is made of the scattered, grown-up standards and the stems selected on the original stools, now indiscernible from trees that originated via seed. This composite heritage is still apparent in the current physiognomy of beech forest, aged between 110 to 160 yr. At Sites 1 and 2, similar to other public-owned forests, the age of final cutting is being shifted. This adjustment matches the emerging recreational, scenic, and mitigation functions of the forests effectively. Site parameters (elevation, position, soil, rainfall amount, and rainfall pattern) are optimal to beech vegetation, and such conditions well support the prolongation of stand permanence.

Site 3, located in the upper tree vegetation layer of the central Apennines, was managed under the coppice system up to the early 1950s and then submitted to conversion into a high forest following the suspension of fuelwood harvesting. The practice consisted of stools thinning and release of best shoots, which was repeated every 20–30 yr and usually performed a few years after former rotation (overgrown phase) up to the age of regeneration from seed. This step ends the conversion stage and establishes the high forest cycle.

The applied progressive thinning results in simplified structures because of the mass selection operating over the conversion cycle. Stands are usually one-storied and made up of similar phenotypes. The stand age of the test area is 70 yr.

Site 4, originated from natural regeneration following the final cutting via combined shelterwood and clear-cut with reserves systems performed around the mid twentieth century. Its location in the upper part of the mountain system is typical of beech vegetation in the southern Apennines. Fog from the Tyrrhenian sea makes the physical environment wet enough for beech vegetation throughout the year. Older trees, scattered or grouped along the streams, are the remnants of previous growth cycles; tree density is variable and small patches of silver fir, consisting of seed trees and their own regeneration cohorts, are present. Thinning practices are similar to Site 1 both in the applied method(s) and the repetition schedule. The customary system, made up of low to mixed thinning, only occasionally produces lasting openings in the main canopy layer. The resulting stand structure is less homogeneous because of the combined final cutting system, resulting in an uneven structure and a shorter elapsed time since the previous regeneration. The age of the designated area is 75 yr.

Research design and rationale

Research was designed in accordance with the ongoing LIFE+ ManForCBD guidelines comparing customary and innovative silvicultural practices with the aim of proposing a more sustainable and adaptive forest management to accomplish manifold ecological functions. A protocol consisting of two forest patches undergoing two different thinning criteria and one untouched patch, replicated three times and randomly distributed over 30 ha, was established at each site.

The first option (customary) consisted of low to mixed thinning. The second option, innovative in terms of common silvicultural practices in the Italian beech forests, was based on (a) crown thinning at Sites 1 and 2, (b) selective thinning releasing a prefixed number of good phenotypes and removing direct competitors without any mass intervention on the remaining standing crop at Site 4, and (c) the same design plus a mass low thinning of the interposed patches at Site 3.

Taken together, the selected design generated a number of nine plots per treatment (customary, innovative, no thinning) for a total of 27 circular plots (20 m radius) on the same compartment at each site. Along with stand life span, management units forming each compartment undergo silvicultural practices within fixed time intervals. At each year, a few units are being thinned or harvested with some others being left untouched, producing a fragmented and heterogeneous forest landscape.

The overall impact of the mixture of silvicultural practices on forest structure was assessed comparing premensurational, postmensurational, and stand structure variables (Del Rio et al., 2003).The proposed framework is consistent with the small-scale segregation theory (Paletto, 2001) assigning different functions to each forest patch. Our rationale provides an insight into spatial relationships and similarity patterns among variables before and after practices occurrence. Monitoring the diverging impact of silviculture on forest structure may contribute to the design of sustainable and adaptive management strategies.

Forest variables

Ten variables concerning forest growth (i.e., main response variable of tree “health and vitality” and carbon sequestration ability) and stand structure diversity (see Table 2) were selected according to Fischer and Pommerening (2003); Bertini, Fabbio, and Pichi (2006); and Fabbio, Manetti, and

Bertini (2006) with the aim of analyzing the pretreatment condition and the manipulative effect of treatment at each site, indipendently of the respective criterion of design.

Statistical analysis

Changes in forest structure after practice implementation were assessed from three different viewpoints: (a) descriptive statistics (median, average, and standard deviation of the selected indicators, see Table 3), (b) pairwise nonparametric correlations illustrating latent relationships among forest variables, and (c) hierarchical clustering identifying similarity patterns among forest variables. These approaches provide complementary information on forest heterogeneity in response to practice implementation, based on different criteria and computational analysis.

The proposed rationale is a simplified exploratory approach that evaluates relationships among mensurational and stand structure attributes before and after practice implementation. It allows for the assessment of changes over time in the similarity pattern among variables at each site. Pairwise correlations among forest variables at each site were checked using Spearman pairwise nonparametric statistics testing for significance at $p < .05$ after Bonferroni corrections for multiple comparisons. The number of significant correlations within each of the eight matrices (four sites and two steps: pretreatment and posttreatment) was considered as a measure of connectedness and partial redundancy between mensurational and (or) stand structure variablesat each site. Similarity patterns among variables were studied within each of the eight matrices using hierarchical clustering based on Euclidean distances and Ward's agglomeration rule by computation on the standardized values of each variable.

Cluster membership was defined fixing a 60% standardized linkage distance as the threshold value. Statistical analyses were performed using the STATISTICA 7.0 (StatSoft, Tulsa, OK, USA) software.

TABLE 2. **MENSURATIONAL (M) AND STAND STRUCTURE (S) VARIABLES.**

Acronym	Name	Short description	Unit/Algorithm	Variables
Den	Tree density (M)	Number of trees per ha	N ha^{-1}	
Bas	Tree basal area (M)	Trees' area at breast height per ha	m² ha^{-1}	
Hei	Mean tree height (M)	Height of mean diameter tree	m	
Dia	Mean tree diameter (M)	Quadratic mean diameter	cm	
Bio	Tree biomass (M)	Phytomass (dry weight) per ha	Mg ha^{-1}	
CE	Clark Evans index[1](S)	Horizontal structure - index of aggregation	r_A / r_E $r_A = \frac{\sum_{i=1}^{n} HDist_{ij}}{n}$ $r_E = \frac{1}{2}\sqrt{\frac{A}{N}}$	$HDist_{ij}$ = Euclidean distance between i-th tree and its nearest neighbour A = plot area N = plot tree number
W	Contagion index[2] (S)	Horizontal structure - index of neighbourhood pattern	$\frac{1}{n} * \sum_{j}^{n} v_{ij}$	v_{ij} = 1 $\alpha_j < \alpha_0$, v_{ij} = 0 otherwise
A	Species profile index[3] (S)	Vertical structure - index of specific abundance in the profile	$-\sum_{i}^{S}\sum_{j}^{B} \pi_{ij} * \ln \pi_{ij}$	S = number of different tree species B = number of height bands =3
T	Diameter differentiation index[4] (S)	Dimensional structure - spatial distribution of tree sizes	$\frac{1}{n} * \sum_{i}^{n}\left(1 - r_i\right)$	r_i= (thinner dbh)/(thicker dbh) of tree pair i n= number of measured tree pairs
CVdbh	Dbh coefficient of variation (S)	Dimensional structure - relative variability of tree size distribution	%	

TABLE 3. **DESCRIPTIVE STATISTICS (MENSURATIONAL VARIABLES: MEDIAN ± SD; STAND STRUCTURE VARIABLES: MEAN ± SD) MEASURED AT THE FOUR SITES BEFORE AND AFTER THINNING IMPLEMENTATION.**

Indicator	Pre treatment				Post treatment			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
Den	334±69	594±116	1300±353	493±130	231±79	552±164	640±195	414±140
Bas	40.6±5.5	55.6±5.2	39.5±4.4	38.2±7.3	31.7±6.9	49.1±11	23.8±3.3	35.4±7.1
Hei	26.6±0.5	27.9±1.7	14.6±0.8	25.1±1.1	26.7±0.6	27.5±1.7	15.0±0.9	24.3±1.7
Dia	40.1±3.6	35.3±6.2	20.2±2.4	31.8±6.1	41.1±4.1	35.6±6.6	21.4±3.3	31.5±6.1
Bio	350±45.9	497±164.4	183±24.3	291±70.8	253±61.7	453±169.2	115±18.6	258±64
CE	1.23±0.1	1.28±0.1	1.16±0.1	1.17±0.19	1.29±0.1	1.31±0.1	1.20±0.1	1.24±0.2
W	0.62±0.02	0.63±0.1	0.63±0.03	0.63±0.03	0.63±0.04	0.64±0.03	0.64±0.03	0.68±0.7
A	0.44±0.2	0.81±0.2	0.91±0.07	0.93±0.23	0.42±0.2	0.80±0.2	0.79±0.3	0.92±0.2
T	0.20±0.1	0.24±0.04	0.26±0.03	0.24±0.03	0.20±0.1	0.26±0.05	0.25±0.04	0.24±0.06
CVdbh	24.4±10	26.9±6.1	29.7±5.1	31.7±6.1	23.7±11	27.6±6.8	28.1±6.3	31.2±6.8

RESULTS

Descriptive analysis

Thinning reduced tree density and basal area by 31 and 22% at Site 1; by 7 and 12% at Site 2; by 51 and 40% at Site 3; by 16 and 7% at Site 4, respectively (Table 3). Mean diameter and mean height values discriminate Site 3 from the other three sites. Average tree size remained quite unchanged after practice implementation at all sites. Tree biomass ranged from a minimum of 183 Mg ha^{-1} to a maximum of 497 Mg ha^{-1} (pretreatment), and from 115 to 453 Mg ha^{-1} (posttreatment) at Sites 3 and 1, respectively. Clark-Evans aggregation index classified tree positions as regularly distributed (CE > 1) at all sites, this pattern being consolidated after thinning. The average Contagion index (W), a single-tree-based index alternative to CE, classified the point pattern into the "clumped" category (W > 0.60). The vertical profile index (A) had a lower value (0.4) at Site 1, the more homogeneous single-storied stand, increasing at the less uniform sites: 2 (0.8), 3 (0.9) and 4 (0.9). This index decreased after treatment at all sites, most rapidly at Site 3. The average diameter differentiation (0.20 to 0.26) denotes the small size difference among trees within each forest compartment with null or minimum changes after treatment. Tree size variability (CVdbh) changed consistently with the vertical profile index, from a minimum value at Site 1 (21%) to a maximum value at Site 3 (31%).

Assessing correlations between the selected forest variables

Pairwise Spearman Rank coefficients among forest variables (Table 4) identified a different number of significant correlations at each site as a proxy for connectedness and redundancy among stand attributes. The original (i.e., prethinning) stand structure was characterized by a total of nine significant pairwise correlations respectively at Sites 1, 2 and 4, and 12 at Site 3. After thinning, the number of significant correlations maintained stable at Site 1, increasing at Site 3 and decreasing at Sites 2 and 4. Mensurational variables are more redundant and connected than stand structure attributes (Table 5).

TABLE 4. **PAIRWISE SPEARMAN RANK CORRELATION COEFFICIENTS AMONG FOREST VARIABLES BY TREATMENT (SIGNIFICANT CORRELATIONS AT P < .05 AFTER BONFERRONI'S CORRECTION FOR MULTIPLE COMPARISONS WERE INDICATED IN BOLD).**

	Cansiglio									Vallombrosa								
	Bas	**Dia**	**Hei**	**Bio**	**CE**	**W**	**A**	**T**	**CV dbh**	**Bas**	**Dia**	**Hei**	**Bio**	**CE**	**W**	**A**	**T**	**CV dbh**
Pre-treatment										*Pre-treatment*								
Den	**0.65**	**-0.76**	**-0.76**	**0.56**	0.27	-0.14	-0.21	-0.18	-0.15	-0.11	**-0.65**	**-0.66**	-0.03	-0.22	-0.17	0.39	0.37	0.27
Bas		-0.03	-0.03	**0.97**	0.34	0.00	-0.28	-0.35	-0.36		**0.57**	**0.58**	**0.69**	0.48	0.07	-0.18	-0.11	-0.04
Dia			**1.00**	0.05	-0.12	0.11	-0.01	-0.07	-0.09			**0.97**	**0.54**	0.24	0.07	-0.45	-0.11	0.03
Hei				0.05	-0.12	0.11	-0.01	-0.07	-0.09				0.49	0.24	0.10	-0.48	-0.07	0.08
Bio					0.34	0.07	-0.27	-0.36	-0.37					0.40	0.06	-0.38	-0.15	-0.22
CE						0.12	-0.33	-0.28	-0.37						0.06	-0.44	-0.50	**-0.56**
W							-0.19	-0.44	-0.44							-0.16	0.13	0.11
A								**0.69**	**0.68**								0.24	0.29
T									**0.90**									**0.89**
Post-treatment										*Post-treatment*								
Den	**0.78**	**-0.75**	**-0.75**	**0.79**	-0.10	-0.30	0.03	0.07	0.22	**0.59**	-0.42	-0.42	**0.54**	**-0.71**	-0.46	0.33	0.05	0.12
Bas		-0.22	-0.22	**0.88**	-0.26	-0.47	0.01	0.15	0.31		0.27	0.27	**0.84**	-0.25	-0.31	-0.12	-0.25	-0.16
Dia			**1.00**	-0.30	-0.25	0.04	-0.06	0.05	0.02			**1.00**	0.34	0.44	0.13	-0.44	0.00	0.03
Hei				-0.30	-0.25	0.04	-0.06	0.05	0.02				0.34	0.44	0.13	-0.44	0.00	0.03
Bio					-0.36	-0.29	0.08	0.07	0.30					-0.09	-0.28	-0.17	-0.17	-0.10
CE						0.20	-0.25	-0.28	-0.40						0.33	-0.43	-0.26	-0.34
W							-0.08	-0.36	-0.42							-0.27	0.31	0.27
A								**0.68**	**0.63**								0.22	0.31
T									**0.88**									**0.88**

TABLE 4. **PAIRWISE SPEARMAN RANK CORRELATION COEFFICIENTS AMONG FOREST VARIABLES BY TREATMENT (SIGNIFICANT CORRELATIONS AT $p < .05$ AFTER BONFERRONI'S CORRECTION FOR MULTIPLE COMPARISONS WERE INDICATED IN BOLD).**

Site		Bas	Dia	Hei	Bio	CE	W	A	T	CV dbh
Chiarano	*Pre-treatment*									
	Den	0.15	**-0.91**	**-0.91**	-0.21	0.16	**-0.63**	0.17	-0.39	-0.39
	Bas		0.21	0.21	**0.86**	-0.36	-0.09	-0.27	0.22	0.18
	Dia			**1.00**	**0.54**	-0.27	**0.64**	-0.19	0.51	**0.52**
	Hei				**0.54**	-0.27	**0.64**	-0.19	0.51	**0.52**
	Bio					-0.44	0.24	-0.33	0.38	0.40
	CE						-0.28	0.15	-0.22	-0.14
	W							-0.21	0.26	0.32
	A								0.20	0.19
	T									**0.86**
	Post-treatment									
	Den	**0.71**	**-0.70**	**-0.70**	**0.58**	0.11	-0.30	0.40	0.30	0.23
	Bas		-0.09	-0.09	**0.96**	-0.15	-0.10	0.46	**0.52**	**0.52**
	Dia			**1.00**	0.08	-0.39	0.44	-0.13	0.13	0.17
	Hei				0.08	-0.39	0.44	-0.13	0.13	0.17
	Bio					-0.20	-0.01	0.40	**0.59**	**0.59**
	CE						-0.22	-0.18	**-0.58**	-0.46
	W							-0.27	0.03	0.03
	A								0.44	**0.52**
	T									**0.91**
Marchesale	*Pre-treatment*									
	Den	-0.17	**-0.82**	**-0.82**	-0.44	0.18	-0.39	-0.03	-0.17	-0.02
	Bas		**0.66**	**0.66**	**0.94**	-0.35	0.22	-0.11	-0.01	-0.09
	Dia			**1.00**	**0.85**	-0.31	0.35	-0.01	0.15	0.00
	Hei				**0.85**	-0.31	0.35	-0.01	0.15	0.00
	Bio					-0.36	0.27	-0.07	0.06	-0.05
	CE						0.07	-0.44	-0.32	-0.28
	W							0.08	-0.27	-0.05
	A								0.27	0.36
	T									**0.65**
	Post-treatment									
	Den	0.13	**-0.80**	-0.45	-0.08	-0.18	-0.48	0.12	0.00	0.15
	Bas		0.43	**0.68**	**0.92**	-0.35	-0.16	-0.02	-0.10	-0.23
	Dia			**0.81**	**0.59**	-0.02	0.34	-0.11	-0.08	-0.31
	Hei				**0.80**	-0.31	-0.04	0.09	-0.08	-0.19
	Bio					-0.37	-0.02	-0.10	-0.11	-0.17
	CE						0.44	-0.29	-0.08	-0.10
	W							-0.15	-0.16	-0.02
	A								0.36	0.42
	T									**0.65**

The percentage of significant correlations among mensurational variables ranged between 60% (Sites 1 and 3) and 80% (Site 4), decreasing slightly after treatment (between 40% at Site 2 and 60% at the remaining three sites). By contrast, the percentage of significant correlations among stand structure attributes before treatment was relatively low, ranging between 10% at Sites 3 and 4 and 30% at Site 1, with moderate changes after treatment (ranging between 10% at Sites 1 and 2 and 30% at Site 3). Taken together, Sites 3 and 2 exhibited, respectively, the highest and the lowest connectedness and redundancy among variables after practice implementation. Site 1 showed the most stable connectedness among variables; this indicates a forest structure with a lower sensitivity to treatment compared with the other three sites. Site 3 experienced a slight increase in connectedness, with the reverse pattern observed for Sites 2 and 4. These evidences outline how practice implementation impacted stand structure in a variable manner among sites, possibly according to pretreatment structural complexity.

TABLE 5. **PERCENTAGE OF SIGNIFICANT SPEARMAN RANK CORRELATIONS BY FOREST SITE, TREATMENT, AND GROUP OF VARIABLES (M: MENSURATIONAL, M & S: MIXED, S: STRUCTURAL).**

	Pre-treatment			Post-treatment		
	M	M&S	S	M	M&S	S
Site 1	60	0	30	60	0	10
Site 2	70	0	20	40	4	10
Site 3	60	20	10	60	16	30
Site 4	80	0	10	60	0	10

Assessing similarity in the spatial pattern of the selected variables

Hierarchical clustering was used to evaluate similarity in the statistical distribution of the 10 stand descriptors before and after treatment (Figure 1). Dendrograms provide similar results to what was described in the previous section. Hierarchical clustering underline a diverging pattern in the distribution of stand attributes at the four sites, highlighting the different impact of treatment on forest structure. At Site 1, two indicators (Tree biomass and Tree density) were found to be similarly distributed and divergent from the other variables before treatment. After treatment, similarity patterns were characterized by four groups of variables (i.e., Tree density and Tree biomass, Species profile index and dbh coefficient of variation, Mean tree dbh and Mean tree height, Clark-Evans and Contagion indices).

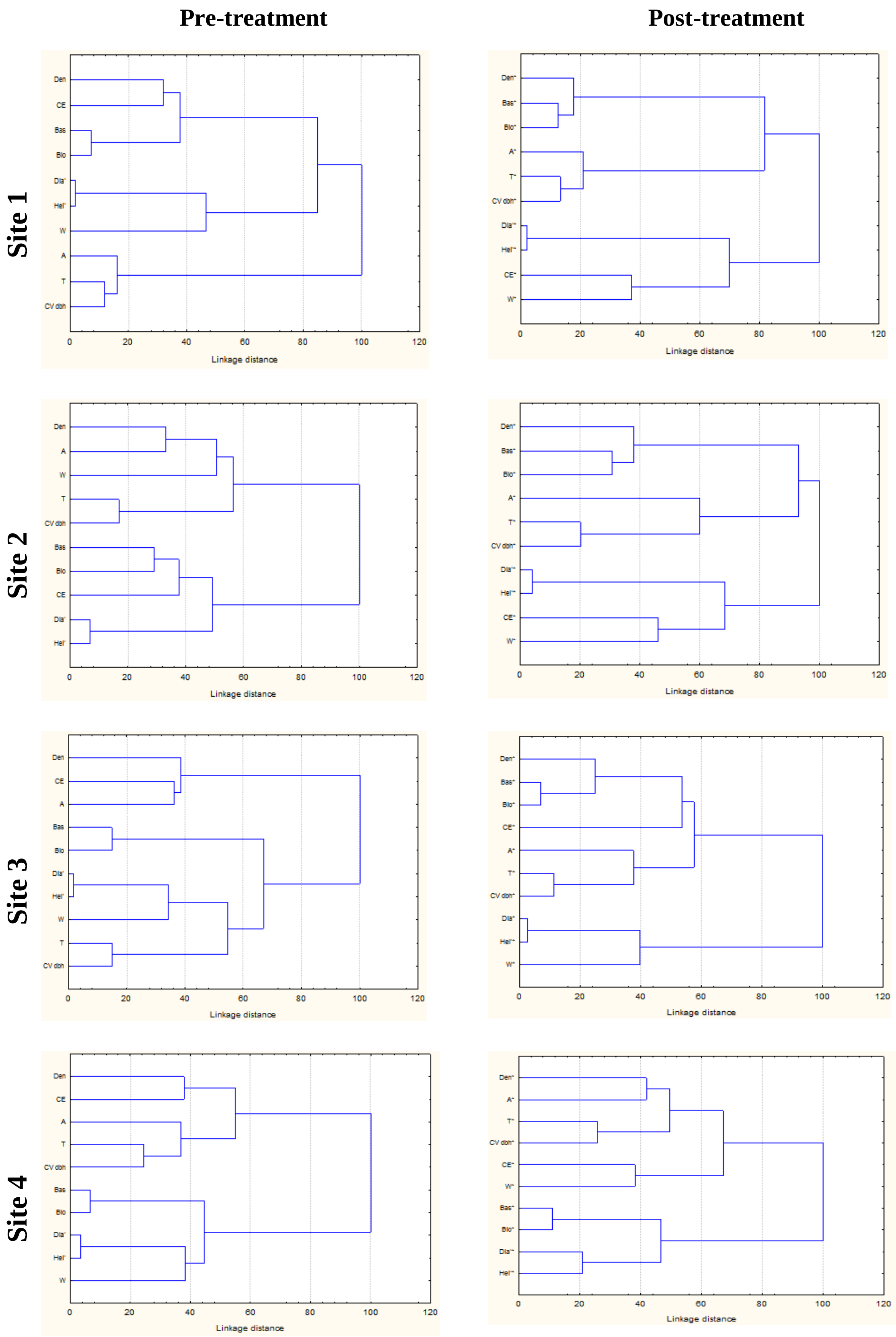

FIGURE 1. **HIERARCHICAL CLUSTERING ON STAND VARIABLES BY FOREST SITE AND TREATMENT.**

Two groups of variables (Tree density and dbh coefficient of variation; and Tree basal area and Contagion index) were representative of the pretreatment structure at Site 4. This pattern consolidated after treatment, with the Contagion index shifting from the first to the second cluster. At Site 3, three main groups of variables (Tree density and Species profile index; Tree basal area and Tree biomass; and Tree dbh and dbh coefficient of variation) were identified, possibly indicating a more heterogeneous pretreatment structure here than at the other sites. After treatment, the cluster structure was relatively stable with only a few indicators moving between the identified groups (Tree density and Clark- Evans index; Tree dbh and Contagion index; and Species profile index and dbh coefficient of variation). Similarity patterns diverged largely before and after treatment in Site 2, suggesting a major impact of practices on forest structure compared to the other three sites.

DISCUSSION

The present study proposes an original exploratory framework to assess mensurational and stand structure attributes and to quantify the impact of applied practices at the forest compartment scale. The four structures herein analyzed—shaped by cultivation practices throughout the stand life cycle and since former cycles—are representative of managed beech forests over the Italian peninsula. The analysis goes beyond the traditional comparison of silvicultural practices using one or a few performance criteria at small test areas, while considering a wider set of variables at an adequate spatial scale to simulate the compartment level. Our approach is intended to contribute to adaptive silviculture, identifying latent patterns and similarity among forest variables with the final objective of assessing stand sensitivity to practice implementation (Franklin et al., 2002). Mensurational and stand structure variables at the four sites provided values at the time of survey as a function of the main attributes—i.e., site-index, dominant stand age and origin (seed or agamic), cultivation heritage, and applied regeneration cutting and thinning regimes over the full life span of the stand. Understanding prethinning and postthinning dynamics of selected stand variables is particularly interesting when designing sustainable forestry practices (Schall & Ammer, 2013; Toboada et al., 2006; Zenner & Hibbs, 2000).

Concerning prethinning conditions, tree density among sites dropped as a function of stand age and of previous thinning regime (Cutini & Hajny, 2006; Franklin et al., 2002;
Nagai & Yoshida, 2006). Tree density at Sites 1 and 2, two stands of equal age (135 yr on average), outlines the impact of a quite “conservative” management at Site 2, where practices are being currently reduced to a minimum. Site 4 has the highest variability in tree density due to the patchy release of trees belonging to the former cycle. By contrast,

Site 3 exhibits the highest density typical of coppice forests undergoing the intermediate phase of conversion into high forest. These results corroborate evidence illustrated in previous studies (Becagli et al., 2013). Basal area is age-dependent but less sensitive to tree density variation while crown cover is quite complete and the growing space is nearly fully occupied. The higher value at Site 2, slightly older than Site 1, is mostly due to the higher efficiency in the occupancy of growing space at the canopy level because of the complementary dendrotypes (old standards, shoots, trees from seed) living together on the same ground. The gap mean to dominant tree height at Site 2 compared with Site 1 corroborates this assumption. Trees of the older cycle raised dominant height at Site 4, in spite of the younger stand age.

Standing volume (data not shown) summarized the other variables reaching the maximum value at Site 2 (around 800 m^3 ha^{-1}). The relatively higher tree density and the comparable dominant tree height raise standing volume at Site 4 (497 m^3 ha^{-1}) close to the value of Site 1 (543 m^3 ha^{-1}). This evidence supports the higher observed productivity of southern beech forests in Italy (Fabbio & Bertini, 2009a, 2009b). As for the horizontal tree distribution, the different point pattern detected by CE and Contagion W indices outlines a distinction between regular, random, and clumped point patterns, in partial contrast with the average Contagion index as reported by Albert and Gadow (1998). The vertical profile is well depicted by the A index, discriminating sites according to the stand structural arrangement (Bailey & Tappeiner, 1998; Del Rio et al., 2003; McElhinny et al., 2005). The reduced size differentiation (T) applies to even-aged stands, and the variation of CVdbh is in accordance with the development of vertical profile (A). Concerning postthinning conditions, results highlighted the different amount of harvesting at each site in terms of tree density and basal area, accounting for removal intensity. The heavier harvestings were performed at Sites 1 and 3. The shift from a coppice forest to a high forest at Site 3 reflected the complete rearrangement of the standing crop from shoots clustering to a random distribution, which implies heavy removals in between. Postthinning configuration at Site 4 can be considered intermediate in terms of tree density and basal area. The resulting gradient of removal intensity may reflect a different impact on forest biodiversity, as preliminary hypothesized by Fabbio et al. (2006) in beech forests of Italy. Further investigation is required in this field possibly according to empirical approaches proposed by Franklin et al. (2002), Jung et al. (2012), McRoberts et al. (2012) and Winter (2012), among others. Thinning impacted the full range of tree positions across horizontal and vertical profiles and accounts for a moderate discrimination among sites in terms of mean tree height and dbh. The results of nonparametric correlation analysis outline latent relationships between mensurational variables and stand structure variables (Pommerening, 2006). The highest number of significant pairwise correlations was observed within mensurational variables. Correlation analysis allows a comparative assessment of transformations in different stand structures following thinning by exploring the intimate relationship between a large set of descriptors (Sabatini et al., 2015). Changes in the number of significant relationships between forest descriptors before and after silvicultural treatment are considered indicative of the sensitivity to thinning of each forest site, irrespective of the former structure (Kint et al., 2004). Patterns of change in the significant relationships among variables are summarized in Table 6.

TABLE 6. **SIGNIFICANT CORRELATIONS OBSERVED BEFORE AND AFTER THINNING AT THE FOUR STUDY SITES.**

Forest	**Pre-treatment**	**Steadiness or direction of change**	**Post-treatment**	**Change among indicators**
Site 1	No. significant correlations **(9)**	↔	**(9)**	no
	Mensurational var. **(6)**	↔	**(6)**	no
	Stand structure var. **(3)**	↔	**(3)**	no
	Mixed var. **(0)**	↔	**(0)**	no
Site 2	No. significant correlations **(9)**	↓	**(6)**	
	Mensurational var. **(7)**	↓	**(4)**	
	Stand structure var. **(2)**	↓	**(1)**	
	Mixed var. **(0)**	↑	**(1)**	
Site 3	No. significant correlations **(12)**	↑	**(13)**	
	Mensurational var. **(6)**	↔	**(6)**	yes
	Stand structure var. **(1)**	↑	**(3)**	
	Mixed var. **(5)**	↓	**(4)**	
Site 4e	No. of significant correlations **(9)**	↓	**(7)**	
	Mensurational var. **(8)**	↓	**(6)**	
	Stand structure var. **(1)**	↔	**(1)**	no
	Mixed var. **(0)**	↔	**(0)**	no

The correlation between stand structure variables are of special concern for management issues because they involve both quantitative and qualitative dimensions of forest complexity (Becagli et al., 2013). The relationship between tree size differentiation and the overall tree size variability was

observed as being significantly correlated at all sites. The vertical profile index (A) was also correlated with CVdbh at
Site 1 and 3 (posttreatment only), whereas a significant correlation between A and the spatial-size index (T) was also observed at Site 1. Finally, the aggregation index (CE) was correlated to tree size variability at Site 2 (pretreatment) and to T at Site 3 (posttreatment). Hierarchical clustering evaluates the different impact of applied practices on forest structure based on the similarity profile among stand descriptors before and after treatment.

Silvicultural impacts are more evident in forest structures where similarities among variables change more rapidly following practice implementation. Based on these premises, Site 1 was considered less sensitive to harvesting than Sites 2, 3, and 4. Results at Site 1 also indicate that a homogeneous forest may be less sensitive to silvicultural practices when compared to younger and (or) less homogeneous sites (Kint et al., 2004).

A changing similarity pattern between stand variables at Site 1 may finally indicate spatial heterogeneity and increased stand structural complexity. At Site 3, clustering patterns following treatment is an indirect evidence of the still-standing pattern of the former coppice management system. Treatments have a smaller impact at Site 4, with the similarity analysis illustrating the supposedly higher plasticity of forest structure
(Neumann & Starlinger, 2001).

Mensurational variables appear to be the most responsive to treatment and require a specific monitoring approach when designing and implementing sustainable and adaptive silvicultural practices. This result is in line with views expressed by Pommerening (2006) and corroborate previous results provided by Del Rio et al. (2003) and Corona et al. (2005). Based on these findings, Site 1, taken as the most homogeneous structure, was clearly distinguished from the other three sites in terms of low sensitivity to thinning. Sites 2 and 4, which were more heterogeneous as for heritage management and structural composition, showed a less sensitive structure according to the reduction of the overall number and types of significant correlations. By contrast, the coppice forest (Site 3) demonstrated the opposite pattern, with an overall increase in the total number of correlations and a marked change in correlation patterns. The on-going transition from coppice to high forest supports these findings (Zenner & Hibbs, 2000).

CONCLUSIONS

The empirical evidence presented in this study contributes to the design of sustainable forestry identifying significant relationships and similarity patterns among stand descriptors which assess the outcome of different silvicultural practices in terms of harvesting intensity and the resulting changes in stand structure. The proposed methodology allows producing a more comprehensive assessment of structural forest complexity following practice implementation. Comparative approaches investigating the response of adaptive systems (such as cultivated forests) are required to understand state and structure of forests and how human intervention may affect them, as clearly pointed out by Franklin et al. (2002). An in-depth knowledge of the outcomes of silvicultural practices with different aims and harvesting intensity may help designing a truly adaptive forestry strategy.

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Conclusions

Conservation of basic structural and functional attributes of forests is a crucial task for sustainable land management. Forest structure, defined as the distribution of standing biomass and the vertical/horizontal arrangement of tree individuals and sizes, age distribution, and canopy's layering, is related to functionality and resilience of natural ecosystems (Kint, Mohren, Geudens, De Wulf, & Lust, 2004; Zenner & Hibbs, 2000). Stand structure variables are considered proxies of forest management quality

The present studies suggest an original exploratory framework to assess mensurational and stand structure attributes to quantify the impact of applied practices at the forest compartment scale.

The outcome of thinning is the less homogeneous physiognomy of stand structure, reducing too the progress of symmetrical competition detrimental to both individual and stand growth pattern. Specifically, the innovative thinning produced wider and less fragmented gaps. They are expected to produce more lasting openings at the main crown level, whilst customary intervention gives rise to more temporary gaps. The higher radiation and throughfall amount to the soil are expected to trigger bio-geo-chemical processes able to establish further habitats and ecological niches for the enrichment of biodiversity. The more differentiated tree crown sizes will contribute resistance to disturbances and enhance growth pattern within tree population.

Mensurational parameters, recorded immediately after thinning implementation, provide the baseline condition and the reference to the content and design of surveys to be carried out in the following monitoring phase, this being an integral part of the procedure to test the effectiveness of any adaptive approach.

Results highlighted the effectiveness of tree spatial competition indexes to promptly assess response to thinning and the great capability of crown-based indexes to differentiate thinning criteria compared with mensurational parameters. Conversely, most of spatial and nonspatial tree diversity indexes tested showed slight or null sensitivity to the applied practices. Their use will become more relevant at later steps after thinning execution.

Silvicultural impacts are more evident in forest structures where similarities among variables change more rapidly following practice implementation.

The proposed methodology allows producing a more comprehensive assessment of structural forest complexity following practice implementation. Comparative approaches investigating the response of adaptive systems (such as cultivated forests) are required to understand state and structure of forests and how human intervention may affect them, as clearly pointed out by Franklin et al. (2002). An in-depth knowledge of the outcomes of silvicultural practices with different aims and harvesting intensity may help designing a truly adaptive forestry strategy.

Section 3. Traditional and new indicators of sustainable forest management. The ManFor C.BD. Life project experience

Introduction

The Sustainable Forests Management concept was widely accepted at the international level, starting from the United Nations Conference on Environment and Development held in Rio de Janeiro (1992), the Montreal Process (1995) and its associated set of Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, the Intergovernmental Panel on Forests (IPF) in 1995 and the Intergovernmental Forum on Forests (IFF) in 1997 (Holvoet and Muys 2004, Wang and Wilson 2007).

The quantitative indicators of sustainable forest managements are subdivided in the following criteria (FOREST EUROPE 2015):

1. Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles
2. Maintenance of Forest Ecosystem Health and Vitality
3. Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood)
4. Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems
5. Maintenance and Appropriate Enhancement of Protective Functions in Forest Management (notably soil and water)
6. Maintenance of other socioeconomic functions and condition

In order to directly account criteria, each criterion is defined by a set of quantitative or qualitative indicators, which have to be measured and monitored regularly to determine the effects of forest management interventions, or non-intervention, over time (Castañeda 2000, FAO 2003).

According to Prabhu et al. (1999) a **criterion** defines the essential elements against which sustainability is assessed, with due consideration paid to the productive, protective and social roles of forests and forest ecosystems. Each criterion relates to a key element of sustainability, and may be described by one or more indicators. **Indicators** are parameters which can be measured and correspond to a particular criterion. They measure and help monitor the status and changes of forests in quantitative, qualitative and descriptive terms that reflect forest values as seen by those who defined each criterion.

Criteria and indicators of sustainable forest management: i) help to define, understand and promote the concept of sustainable forest management; ii) reflect a holistic approach to forests as ecosystems, highlighting the full range of forest values; iii) facilitate policy dialogue and the development of policies or strategies ; iv) help to implement forest related policies, plans and programmes; v) contribute to cross-sectoral sustainability assessments, as well as assessments for other sectors (e.g. environment, energy, climate change, agriculture, sustainable land management); vi) guide forest management practice; vii) help to identify the changes in forest management; viii) help to develop forest certification principles, standards and indicators. (FOREST EUROPE 2015, FAO 2003).

The principle behind the indicator concept is that the characteristics of an easily measured feature convey information about more than itself, summarizing and communicating complex information in a way that can be quickly understood (UNESCOSCOPE 2006, Biodiversity Indicators Partnership 2011). Thus indicators are of crucial importance because they can be used for a variety of purposes, such as: describe and diagnose a situation; check the effectiveness of management practices, discriminating among alternative policies, forecast future trends (Linser 2001, Failing and Gregory 2003). In this way they support sound decision making and connect policy to science (Biodiversity Indicators Partnership 2011).

Data collecting, reporting and verification are needed to monitor and analyze global forests trends, and are of crucial importance to improve SFM worldwide, which requires empirical evidence that forests are actually well managed and protected (Siry et al., 2005). The demand to measure and monitor the sustainability of forest management has lead countries to throughout the world to develop a regional and international set of criteria and indicators, which are commonly recognized as appropriate tools for defining, assessing and monitoring progress toward SFM (Van Bueren and Blom 1997, Mendoza and Phraubu 2003, Siry et al., 2005, Wolfslehner et al. 2005).

With these purposes in this section the results of ManFor C.BD. Life project are illustrated. Manfor C.BD. project carried out its activities in 7 Italian and 3 Slovenian forests where different management options were applied. In the selected areas the project evalueted the traditional management practices and designed, implemented, evalueted and compared new management practices at the same forests.

The main project objective was to test the effectiveness of multifunctional forest management practices in field providing data and further guidelines for the optimal forest management (De Cinti and Kutnar, 2016). To this end, the project tried to assess the sustainability of management options implemented through the following actions (Matteucci, 2016):

- collect and compare data related to Pan European indicators for Sustainable Forest Management;
- define, test and evaluate additional quantitative indicators related to forest management in order to fulfil the need of International Conventions and European Action Plans.

Of all the indicators developed under the ManFor C.BD. project this section is focused on the use of traditional indicators and the development of new indicators connected with criteria 1, 3 and 4 (Figure 1).

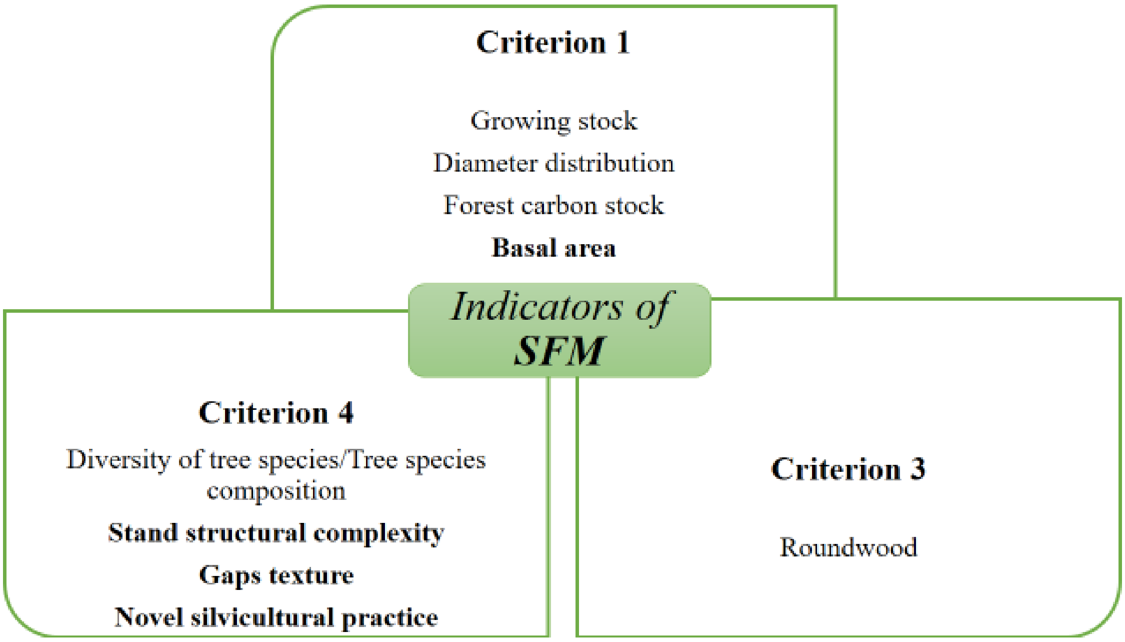

FIGURE 1. **THE TRADITIONAL AND NEW INDICATORS (BOLD ITALICS) ASSESSED FOR EACH CRITERION (D’ANDREA ET AL., 2016 – modified).**

The survey methodology was carried out in two phases: 1) pre management and 2) post management practice. The objective of phase 1 was to collect information on and analyze the heterogeneity of forest stand structure and collect forest attributes according to an inventory-like sample design. The objective of phase 2 was to monitor the change in attributes after management practice.

An area of 30 hectares, divided into nine compartments, was devoted to the management trials at each site. Two or three theses were identified and randomly assigned in three replicates to each compartment (1 to 9). A cluster of three circular sampling plots - with a different radius length considering the different stand structure - was established within each compartment according to a systematic design to survey measuring parameters (species, dbh, height, tree position, social rank, crown projections, etc.). At Lorenzago site only six plots were established (Di Salvatore et al., 2016).

Volume data is obtained by applying INFC (National Forest Inventory and Carbon Sinks) yield tables (Tabacchi et al., 2011). Structural diversity indices (Chiavetta et al., 2016): BALMOD, Hg, Hg mod, CE, TD, TH, STVIdbh, STVIhtot, were calculated according to Clark et al. (1954), Hegyi (1974), Pommerening (2002), Pretzsch (2010), Schroder and von Gadow (1999), Staudhammer and LeMay (2011).

The information regarding each indicator was gathered in a summary sheet, containing the following points (D'Andrea et al., 2016):

- the indicator name, with a reference, if applicable, to the MCPFE indicator according to FOREST EUROPE (2015);
- full text: brief description of the indicator;
- rationale: description and justification of the indicator;
- method: how the indicator may be measured;
- measurement units;
- measurement time: special timing issues related to indicator and/or if it should be measured before and/or after silvicultural treatments
- the feasibility of application of each indicator (scale of application, specific knowledge required, costs).

Each indicator have a great significance at Regional and National level. However, their ability to describe phenomena that influence the forest ecosystem at the forest management forest management scale should be tested. In this context, the Life project ManFor C.BD. offered to stakeholders and practitioners a practical account of the effect of management on carbon cycle, biodiversity and landscape. Forest management cannot be evaluated using a single indicator because sustainability is connected to several factors related to production, carbon cycle, biodiversity and landscape. Hence all the different criteria and scales should be taken into account, as a network of processes, to assess the sustainability of different management options (D'Andrea et al., 2016).

3.1 Implementing forest management options for the Life project ManFor C.BD. Description of the test areas

Di Salvatore U.[1], Becagli C.[1], Bertini G.[1], Cantiani P.[1], Chiavetta U.[1], Fabbio G.[1], Ferretti F.[1], Kobal M.[2], Kobler A.[3], Kovač M.[3], Kutnar L.[2], Sansone D.[1], Skudnik M.[3], Simončič P.[2]

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Test areas

Manfor C.BD. project carried out its activities in 7 Italian and 3 Slovenian forests (Fig. 1) where different management options were applied. Public forests managed by public bodies were selected to ensure a monitoring of the results in the future.

Site 1 – Cansiglio (It)

Site description

The area is located in the Veneto Region, in Province of Belluno (at the border with the Province of Treviso).

The management is directly carried out by the National Forest Service of Italy. It is included in the Natural Biogenetic Reserve Pian Parrocchia-Campo di Mezzo (established in 1977).

The total area is 667 ha and the dominant species is beech (*Fagus sylvatica*). The main management type is high forest treated with shelterwood cuttings.

Generally 700 to 1000 m^3 of wood are extracted per intervention, over 10 to 15 ha.

The forest is listed as Special Protection Zone (ZPS, 79/409/CEE) and as Sites of Community Importance (SIC, 92/43/CEE). Since 1996, the forest is also included in the Italian network of the forest ecosystem monitoring (CONECOFOR), part of the of the UN/ECE International Cooperative Programme of Forests (ICP Forests, http://www.icpforest.org) that, in 2009-2010, was monitored under LIFE+ FutMon (http://www.futmon.org).

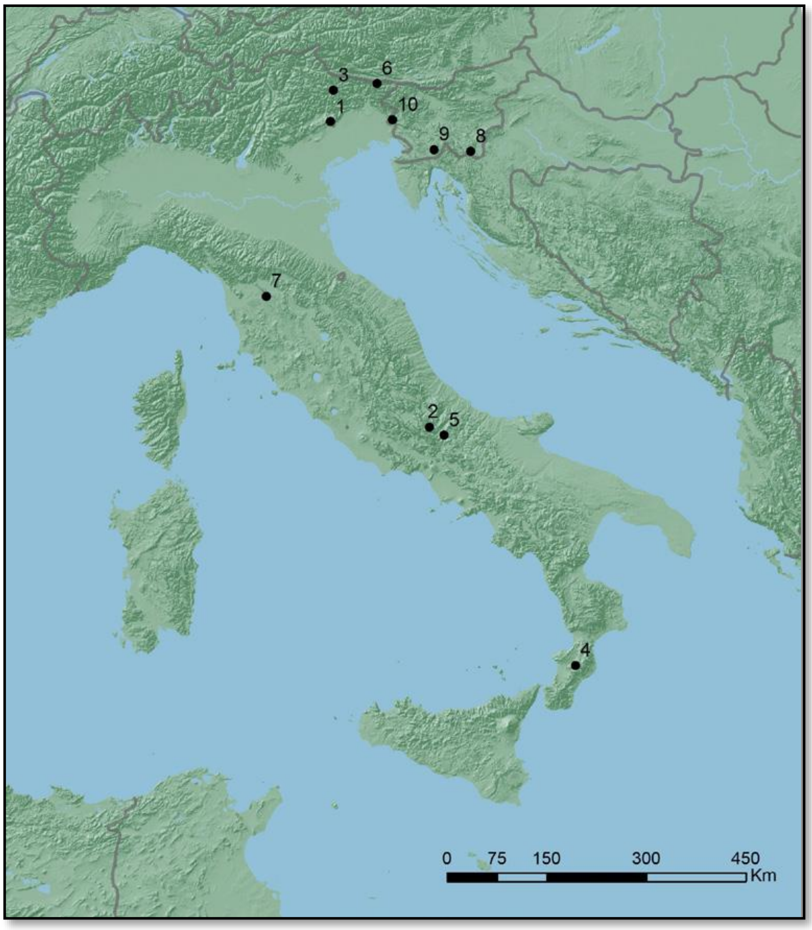

FIGURA 1. **LOCATION OF THE STUDY SITES: 1. CANSIGLIO, 2. CHIARANO SPARVERA, 3. LORENZAGO DI CADORE, 4. MONGIANA, 5. MONTEDIMEZZO-PENNATARO, 6. TARVISIO, 7. VALLOMBROSA, 8. KOČEVSKI ROG, 9. SNEŽNIK, 10. TRNOVO.**

UN/ECE International Cooperative Programme of Forests (ICP Forests, http://www.icpforest.org) that, in 2009-2010, was monitored under LIFE+ FutMon (http://www.futmon.org).

Total area of Foret Management Unit (FMU) is 35 ha. Altitude within FMU ranges from 1100 m to 1200 m a.s.l..

The designated site lies in a beech high forest compartment aged 120 to 145 years. The forest has a long tradition of forest management: basic rules applied are moderate thinnings from below or mixed, repeated every 20 years, while stand regeneration is by group shelterwood system. Currently, the age of final cutting is being shifted to a not-definite (at now) stand age, matching the emerging recreational, landscape and mitigation functions. Site parameters (elevation, position, soil, rainfall amount and pattern) are optimal for beech growth and such conditions allow the prolongation of standing crop permanence time (rotation length).

Description of the traditional silvicultural system

The traditional system has been optimal when framed into the classical rotation up to the age of 120-140 years (Muzzi 1953, Hoffman 1967, Bessega 2007). Current shift well-addresses the emerging functions but no updating of silvicultural techniques has been proposed to face up to longer rotations.

The achievement of older stand ages implies to maintain as long as possible the current sequestration ability and higher growing stocks, as well.

Furthermore, the present homogeneous structure of cultivated beech forests clashes with structural diversity connected to the landscape and functional values of mature forest stands.

The innovative criteria applied

The demonstrative/innovative criterion consisted of the identification of a not-fixed number of scattered, well-shaped trees (usually in the predominant- dominant social classes) and crown thinning of neighbouring competitors in order to promote the future growth ability of selected trees at crown, stem and root level. These will be the main key-specimen able to reach the final, overmature stages and to regenerate the forest. The resulting harvested wood amount is not far from that extracted by traditional thinning, but its spatial arrangement is quite diverse on the ground and at crown level. Shape, size and distribution of canopy gaps is also different between the traditional and new practice. The remaining standing crop is fully maintained and will produce differentiation in crown layer, stem distribution and size. Mortality of dominated or defective trees will promote the establishment of snags and lying deadwood, at present understocked. A higher complexity of stand structure and habitats may be reached through consistent practices, and support the diverse, concurrent demands currently addressed to forest management. The trial compares traditional and innovative technique, plus the no-intervention or delayed-intervention thesis that, in the context of beech high forests, has sound reasons to be tested because of its wide application in similar conditions.

In this forest, an additional “ageing patch” has also been planned.

In addition, a further area has been planned where implement an “ageing patch” literally from french “îlot de sénescence”. It consists of an area of a few hectares where trees are left to an indefinite ageing, up to their death and decay. Part of living stems were girdled to create standing dead trees or felled and left on the ground to establish microhabitats, niches and corridors for saproxylic insects and micro-fauna.

Site 2 – Chiarano Sparvera (It)

Site description

The area is located in the Abruzzi Region, province of L'Aquila in a Regional Forest, included in the external protection zone of the National Park of Abruzzo-Lazio-Molise and partially in Natura 2000 sites.

The total area is 766 ha and the main forest species is beech (95%).

The main historical management type is coppice with standards. The forest area is now under conversion to high forest. In the last 20 years, the treatments were aimed at converting coppice to high forest and at thinnings to increase structural diversity (also under LIFE NAT/IT/006244 and LIFE04 NAT/IT/00190). The selected stand is not listed as Site of Community Importance (SIC) nor as Special Protection Zone (ZPS) of Natura 2000 network.

Total area of Forest Management Unit is roughly 30 ha, the area consist of 2 parts separated by a stripe of meadow and rocks. Altitude within FMU ranges from 1700 m to 1800 m a.s.l. The site lies in a beech forest located at the upper tree vegetation layer in the Central Apennines and managed under the coppice system up to mid

19th century. Following the suspension of fuelwood harvesting, the conversion into high forest has been undertaken on two-thirds of the original coppice cover, whilst the remaining forest is made up of aged coppice structures. The designated area, aged 70, is included into a wide compartment under conversion. The practice of coppice conversion into high forest consists of low to mixed thinnings of the transitory crop, repeated every 20-30 years, usually performed the first time a few years after the end of former rotation and up to the age of regeneration from seed. This step closes the conversion stage and opens the high forest cycle. The above-mentioned silvicultural system is applied throughout the Apennines and pre-Alpine area.

Description of the traditional silvicultural system

The traditional system works well if site-index is high enough (as in the case), but the resulting structures are very simplified because of mass selection operated by thinning system applied all over the conversion cycle (La Marca 1980). Stands are usually one-storied, show a limited dbh range and an homogeneous distribution of trees and crown volumes.

The innovative criteria applied

The demonstrative/innovative criteria applied consisted of the preliminary choice of a number of 40-80 well-shaped phenotypes per hectare (stem form and crown development are the relevant attributes) and cutting of all surrounding competitors.

Intercropping trees are being fully released or removed only along hauling courses. In this way, the overall stand structure is being moved both at stem and crown level. The high tree density of intercropped stand will promote regular mortality and deadwood enrichment; the establishments of further habitats and related niches will be favoured.
The trial compares the traditional technique and two innovative theses different as for the selected tree number (40-80) per unit area.

Site 3 – Lorenzago di Cadore (It)

Site description

The area is located in the territory of the town of Lorenzago di Cadore, province of Belluno and the forest is owned by the village of Lorenzago di Cadore
The total area is 1100 ha. It is bordering Friuli Venezia Giulia Region. The climate is of Mesalpic type and the altitudinal range is 800 – 1800 m a.s.l.
According to altitude, the forest types are different: fir (*Abies alba*) forests of carbonatic and siliceous soils (800 – 1300 m); secondary montane (*Picea abies*) spruce forests (1000 – 1350 m); spruce forests on carbonatic and siliceous soils (1300 – 1800 m)
The main management type applied is selection cuttings (from single-tree to small groups) and natural regeneration is present in all treatment variants.
Annual cuttings: 1660 m^3 (26% of annual increment). The Lorenzago di Cadore area is included in one of the largest Special Protection Zone of the Alps (ZPS
IT3230089 “Dolomiti of Cadore and Comelico”) and contains two Sites of Community.
Total area of Foret Management Unit is 25 ha. Altitude within FMU ranges from 925 m to 1220 m a.s.l..
The site lies in a mixed, uneven-aged coniferous forest (silver fir 51%, Norway spruce 46%, European larch 2%, beech 1%) traditionally managed according to the selection system. Every n years the practice includes the contemporary: (i) harvesting of mature trees; (ii) thinning in the intermediate storey; (iii) progressive side cuttings around the alreadyestablished regeneration patches to promote their successful growth; (iv) felling of defective stems and withering trees throughout. The less-intensive harvesting over the last period has promoted the increase of growing stock over the threshold usual to the uneven-aged type. This results in a less-balanced distribution of mature and intermediate age classes (i.e. large and medium sized trees), currently prevailing on young classes and the regeneration layer.

Description of the traditional silvicultural system

Mature trees and groups of dense intermediatesized trees, determine growing stock exceeding regular stocking. Such condition raises shading, affecting survival and growth of the established regeneration and preventing the establishment of new regeneration patches. The hauling system with horses used in the past allowed the frequent harvesting of scattered mature trees; the use of tractors nowadays makes harvest feasible, but needs to concentrate fellings on the ground somehow (Bortoluzzi 2002).

The innovative criteria applied

The contemporary harvesting of a few mature trees and thinning of intermediate-sized trees all of them being arranged into small groups, make possible a minimum degree of mechanized harvesting. Such demonstrative/innovative practice has been implemented by the opening of strip clear-cuttings 60 m long (1½ top height) and 20 m wide (½ topheight). This practice contributes to a more balanced equilibrium of the storied structure, triggering regeneration establishment (canopy opening) and allowing to concentrate log harvesting along each strip. These “light thinnings” are NW-SE oriented along the direction of maximum slope. Broadleaved trees and young regeneration on the strips are being released. Cutting as usual gets strips connected. Beech regeneration (eradicated in the past because not valuable as compared with fir and spruce timber), is always favoured to enhance tree specific diversity.

Site 4 – Mongiana (It)

Site description

The area is located in the Calabria Region, Province of Vibo Valentia. The management is directly carried on by the National Forest Service of Italy (CFS).

The selected forest area is included in the Marchesale Biogenetic Reserve, Natura 2000 sites

The total area is 1257 ha and the altitudinal range is 750 ÷ 1170 m (a.s.l.)

The forest types are beech managed as high forest and chestnut (*Castanea sativa*) stands managed as coppice (a number of stands are aged coppices.

There is a small fraction of mixed beech-fir high forest (5%). From 2000 to 2009, silvicultural intervention were implemented over 108 ha.

Total area of Forest Management Unit is roughly 30 ha. Altitude within FMU ranges from 1000 m to 1100 m a.s.l.

The site lies in a beech high forest originated from regeneration following the final cutting by the shelterwood system or clear-cut or clear-cut with reserves, performed at mid 19th century close the end of 2nd World War. The designated compartment is aged about 70. Its location in the upper part of the mountain system is typical of beech forests in Southern Apennines. The interception of fogs, wet winds and rain originated on the sea makes the physical environment wet enough all over the year. As for stand structure, older trees, scattered or grouped along streams, are remnants of previous cycle; tree density is variable and small patches of silver fir consisting of mother trees and their regeneration cohorts, are present in a few sectors of the compartment.

Description of the traditional silvicultural system

The traditional system made up of periodical low thinnings is rather conservative and only occasionally opens the canopy. It makes, as already stated for other beech forests, the stand structure homogeneous, besides its former, natural discrepancy (CFS – UTB Mongiana 2011, Mercurio e Spampinato 2006).

The innovative criteria applied

The demonstrative/innovative criterion consisted of the identification of 45-50 trees per hectare i.e. “the candidate trees” and removal of direct competitors.

Also couples of neighbouring trees have been selected at the purpose. No thinning has been applied in the space between candidates or where groups of older trees have naturally spaced the structure.

Silver fir patches have been set free all around from beech crown cover. The applied criterion and the aim of practice is similar to that applied at the Cansiglio forest. The stand age is about one-half here and that is why a predetermined number of trees has been fixed. The thesis of delaying any intervention is also addressed here because of the young age of standing crop and of the variable stand texture made of different tree densities. Traditional and innovative technique, plus the delayed-intervention are being compared in Marchesale forest.

Site 5 – Montedimezzo-Pennataro (It)

Site description

The area is located in the Molise Region, Province of Isernia, and it is included in the Montedimezzo Natural State Reserve, established 1971; MAB-UNESCO Biosphere Reserve; Natura 2000 SIC and ZPS sites.

The total area is ~400 ha and its altitudinal range is 900 - 1300 m (a.s.l.)

The forest type is: Turkey oak (*Quercus cerris*) pure or mixed stands (lower elevation) and beech forest, generally mono-layered (higher elevation).

The main management type is high forest. The future management plan includes measures especially designed for experimental and educational purposes, in four separate units: i) coppice: thinning and small cuttings; ii) high forest above coppice: natural evolution; iii) monoplane high forest: interventions only on battered old or sick trees, control of the regeneration, experimental plantation of yew (*Taxus baccata*); iv) biplane-multiplane high forest: small cuttings inside 5 ha management units with the formation of gaps not exceeding 200-300 m^2 experimental plant of yew. Total area of Forest Management Unit is roughly 30 ha. Altitude within FMU ranges from 900 m to 1000 m a.s.l.

The experimental area has been settled in a Turkey oak forest. Other complementary broadleaves (maples, hornbeam, beech, other minor spp.) are scattered or grouped within the main oak layer.

The terrain is not homogeneous as for slope and presence of large rocky outcrops which make the forest less dense. Remnants of grazed areas under forest cover are still perceptible with light canopies and large-sized, open-grown trees. Stand structure, generally dense, is anyway irregular per patches depending on tree size and arrangement of standing structure. Standing and lying dead trees are present.

Two are the main stand ages: young and overgrown forest, originated from the coppice system applied in the past and from the management under the high forest system, as well.

The prevalent age is 60-70 years, but there are also several individuals of turkey oak estimated age between 130-140 years originated as a result of a clear cut with reserves made at the end of 1800.

Description of the traditional silvicultural system

The traditional system made up of extensive low thinnings performed over the last 40 years and a few seed cuttings in the more aged forest patches – not followed by the removal of seed trees - has as a matter of fact suspended any active forest management at these forest types. This condition, favoured the vegetation of the others than oak sp., the natural evolutive pattern moving towards a mixed forest.

The main management type is high forest and aged coppice, partly in conversion to high forest (Garfì and Marchetti 2011, Marchetti 2008).

The innovative criteria applied

Two pro-active theses are being tested within the experimental area. One aimed at maintaining the structure and composition typical of the “cerreta”, i.e. the oak- dominated forest and the historical model of management in these inner areas of Central

Apennines. The other thesis is aimed at better addressing natural evolution towards a mixed forest as in the criterion at now prevailing under the extensive management applied. The option one is aimed at maintaining the structure and composition typical of the “cerreta”, i.e. the oak- dominated forest and the historical model of management in these inner areas of Central Apennines. The treatment consists of the identification of 60 trees per hectare, i.e. "tree candidate", of Turkey oak among the best individuals.

Around the candidate make a selective thinning in order to facilitate the expansion of the crown and thus growth; while individuals of Turkey oak which do not create competition to the candidates are not affected by the cut. Low to crown thinning has been applied in the space between candidates or where groups of older trees have naturally spaced the structure. In the low strata stumps are treated by releasing the dominated shoot, while monocormic individuals will not be affected by the cut to avoid a new growth from the stump. The option two is aimed at better addressing natural evolution towards a mixed forest as in the criterion at now prevailing under the extensive management applied. The treatment consists of the identification of tree candidates of different species from the turkey oak and making a selective thinning to improve the expansion of the canopy and the full development of the tree. In the low strata stumps are treated by releasing better and dominant shoot, while monocormic individuals will not be affected by the cut to avoid a new growth from the stump. In order to improve the biodiversity, in both options are not affected by the cutting live or dead trees that provide ecological niches (microhabitats) such as cavities, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot.

Site 6 – Tarvisio (It)

Site description

The area is located in the Friuli-Venezia Giulia Region, Province of Udine. It is owned by “Fondo Edifici del Culto” of Ministry of Internal Affairs, under direct management by National Forest Service of Italy, Local Office for Biodiversity (UTB) of Tarvisio

The total area is 23’362 ha, 15’152 ha with forests. The altitudinal range is 750÷2750 m (a.s.l.).

There are two main forest types: mixed forests of spruce, beech, pine (8946 ha), subalpine spruce (1263 ha). Main management type is high forest with close-to-nature silviculture. Forests are treated with border-shelterwood or group-shelterwood (Femmelschlag) cuttings. Long history of forest management plans (1888) is present in the area. It is a mixed forest of spruce (*Picea abies*) (54%), beech (*Fagus sylvatica*) (29%), silver fir (*Abies alba*) (7%), larch (*Larix decidua*) (5.5%), black pine (*Pinus nigra*) and Scot's pine (*P. sylvestris*) (4.5%). The average growing stock is 280 m^3 ha-1, the increment 4.58 m^3 ha-1 yr-1. Annual cuttings are about 30’000 m^3.

The forest is partly included in Special Protection Zones (ZPS, 79/409/CEE) and in Sites of Community Importance (SIC, 92/43/CEE).

Total area of Foret Management Unit is ~30 ha. Altitude within FMU ranges from 1000 m to 1100 m a.s.l..

The designated forest compartment is a Norway spruce and silver fir pole stage originated from regeneration following harvesting of the previous crop. A few other species are scattered within the standing crop, mainly larch and beech. Specific composition in terms of growing stock is as follows: 91% Norway spruce, 2% silver fir, 1% larch, 6% beech and other broadleaves (source: management plan).

Stand structure is naturally dense with many standing and lying dead trees under the main storey; living crowns inserted in the upper part only; Scattered broadleaves (mainly beech) reach the main crop layer (co-dominant and dominant trees).

Description of the traditional silvicultural system

This stage of the life cycle was traditionally submitted to pre-commercial thinnings to reduce intertree competition and manage the release of main crop population. At now, no practices are feasible at this stage because of the high cost of manpower as compared with a quite null revenue (Hoffmann 1971). The only way to implement a sustainable silviculture is the mechanization of thinnings. This practice has been already addressed in neighbouring countries as in Austria, where specific machineries for Alpine forests have been developed and tested successfully.

The innovative criteria applied

Local forest responsibles already experienced a positive result with equipment suited to work into pole stage stands and flexible enough to vary the harvesting pattern on the ground. The resulting tree spacing is not systematic because the release of designated trees may be accounted by a skilled operator. Following the inspection to the test area, the decision was taken to base the demonstrative/ innovative trials on the use of above machinery (innovative for our country). The design will compare the thesis of mechanization with two different densities of tree release: (i) a prevailing pre-commercial thinning criterion resulting in a lower density release and with an estimated time of repetition of 40 years;(ii) a more ecologically-based thinning criterion resulting in a higher density release and a shorter time of repetition. Instructions to the operator will include in both cases the full release of canopy trees whenever a dendrological diversity occurs (e.g. broadleaved trees). A supplementary thesis will compare: (a) a manually-implemented thinning in one of patches of compositional diversity randomly occurring throughout the predominant coniferous texture and: (b) a mechanically-implemented (but always oriented to preserve tree diversity) thinning, into an adjacent patch. Both patches will be analytically described ex ante to allow the comparison of ex post results. Adjacent forest areas characterized by different, both earlier and more adult stages and specific habitats (e.g. wet areas or natural clearings in the tree texture), will be reserved untouched to make possible further comparisons with neighbouring forest environments.

Site 7 – Vallombrosa (It)

Site description

The area is located in the Toscana Region, Province of Firenze. The management is carried out directly by the National Forest Service of Italy – Local Office for Biodiversity (UTB) of Vallombrosa. The area is included in a Biogenetic reserve of Vallombrosa (Natura 2000), established in 1977
The total area is 1279 ha (forest cover: 99%). The altitudinal range is 450 ÷ 1.450 m (a.s.l.) and the forest types are: i) pure fir forests (50%); ii) beech in higher zones; iii) calabrian pine (*Pinus laricio*) in lower areas; iv) deciduous forests dominated by chestnut (*Castanea sativa*).
The main management type is high forest. Forest management is carried out following the Management Plan 2006 – 2025 with the main objective of re-naturalise the today simplified forest stands. An area of 100 ha of pure fir is included in the "Silvomuseo" (silvicultural museum), where the traditional management of clear-cut and artificial regeneration is carried on. Average annual cuttings performed directly by UTB - Vallombrosa are 1500 m^3, mainly of conifers.
The Vallombrosa forest is widely-known because of the age-old management history closely linked to forestry practiced by the local Benedictine Abbey.
Current standing crops originate from the natural beech cover, from coppice conversion into high forest at mid eighteenth century as well as from the reafforestation of pastures beyond the pristine forest edge. Physiognomies vary between the more regular structure of the evenaged crops, grown dense and one-layered with reduced, upper-inserted crowns, and the less homogeneous structure of the former coppice crop. This is made of the scattered, grownup standards and the stems selected on the original stools, now indiscernible from trees originated from seed. This composite heritage is still readable in the current physiognomy of beech forest, aged 110 to 160 at the test area. At Vallombrosa, similarly to other public-owned forests, the age of final cutting is being shifted, it matching the emerging recreational, scenic and mitigation functions. Site parameters (elevation, position, soil, rainfall amount and pattern) are optimal to beech vegetation and such conditions well support the prolongation of stand permanence time.

Total area of Forest Management Unit is roughly 30 ha. Altitude within FMU ranges from 900 m to 1000 m a.s.l. The study area is positioned within a grown up beech high forest compartment aged 100 to 170 years. The forest of Vallombrosa has a long tradition of forest management up to the early sixties of 1900, in accordance with silvicultural criteria ruling the productive beech forests, i.e. periodical moderate thinnings from below or mixed up to the rotation time, usually occurring at 90-100 years as a function of site-class and according to the “maximum yield rotation”. Stand regeneration was performed by the group shelterwood system. As in other public forests managed by the National Forest Service, the age of final cutting is being shifted since the second half of 1900 to a not-definite (at now) stand age, this match ing at best the emerging recreational, landscape and mitigation functions. Site parameters (elevation, position, soil, rainfall amount and pattern) are optimal for beech growth and these conditions allow the prolongation of standing crop permanence time.

Description of the traditional silvicultural system

The traditional silvicultural system has been optimal when framed into the classical rotation up to the age of 100 years. Even if current shift welladdresses the emerging functions, no updating of silvicultural techniques has been proposed to match longer rotations at now. The achievement of older stand ages implies to maintain as far as possible the status of “health and vitality” both at individual and at stand level, to ensure current sequestration ability and higher growing stocks, as well. It clashes with the present, homogeneous structure, heritage of beech forests previously cultivated for production purposes. The achievement of an individual structural diversity by spotty interventions, seems to be the first, basic step to meet the awaited functional goal (Ciancio 2009).

The innovative criteria applied

The demonstrative/innovative criterion consisted of the identification of a not-fixed number of scattered, well-shaped trees (usually in the predominant-dominant social classes) and of crown thinning of neighbouring competitors in order to promote the future development of selected trees at crown, stem and root level. These will be the main key-points able to reach the final, overmature stages and to regenerate the forest. The resulting harvested wood amount is not far from that extracted by traditional thinning, but its spatial arrangement is quite diverse on the ground and at crown level.

Shape, size and distribution of canopy gaps is also different between the traditional and new practice.

The remaining standing crop is fully maintained and will produce differentiation in crown layer, stem distribution and size. Mortality of dominated or defective trees will promote the establishment of snags and lying deadwood, at present understocked.

A higher complexity of stand structure and habitats may be reached through consistent practices, and support the diverse, concurrent demands currently addressed to forest management. The trial compares traditional and innovative technique, plus the no-intervention or delayed-intervention thesis that, in the context of beech high forests, has sound reasons to be tested because of its wide application in similar conditions.

Site 8 - Kočevski Rog (SI)

Site description

The area is located in the southeastern part of Slovenian Dinaric region. The majority of forest area is owned by Slovenian state. Research plots are located within forest management unit FMU *Č*rmošnjice within forest compartments N° 3, 6 and 12.

Total area of FMU is 6580.08 ha (5910.39 ha of forest – 89.8 %). Altitude ranges from 230 m to 1077 m (Kopa). Average yearly precipitation is 1590 mm. Parent material is limestone and dolomite, where leptosols, cambisols and luvisols are present.

Predominant forest type is *Omphalodo-Fagetum* with European beech, silver fir and Norway spruce as main tree species. Elm and Sycamore are also present. The average growing stock is 351.6 m^3 ha^{-1} and the increment is 9.4 m^3 ha^{-1} yr^{-1}. The forests are

partly included in NATURA 2000 network (Slovenian Forest Service, Forest management plan FMU *Č*rmošnjice 2007-2016).

Description of the traditional silvicultural system

The area around this test site has been intensively managed for several centuries. After long-lasting practice of clear-cutting and some other irregular forms of harvesting, in 1892 Hufnagel introduced the selection system, which became the main management system in the region (Hufnagel 1982). That system was practiced until the late 1950s. The loss of vitality of silver fir between the 1960s and late 1980s, omnipresent ungulate browsing as well as the gradual shift from selection silviculture system to improved irregular shelterwood system resulted in the decline of fir and its insufficient ingrowth (Šubic et al. 2007, Šubic 2007).

Site 9 - Snežnik (SI)

Site description

The area is located in the Southern part of Slovenian Dinaric region. The majority of forest areais owned by Slovenian state. Research plots are located within forest management unit FMU Snežnik within forest compartments N° 1 and 2.

Total area of FMU is 1983.02 ha (1894.22 ha of forest – 95.5 %). Altitude ranges from 600 m to 1095 m. Average yearly precipitation is from 2000 to 3000 mm. Parent material is limestone and dolomite, where leptosols, cambisols and luvisols is present.

Predominant forest type is *Omphalodo-Fagetum* with European beech, silver fir and Norway spruce as main tree species. Elm and Sycamore is also present. The average growing stock is 442 m3 ha-1 and the increment is 8.3 m^3 ha^{-1} yr^{-1}. The forests are mainly included in NATURA 2000 network (Slovenian Forest Service, Forest management plan FMU Snežnik 2005-2014).

Description of the traditional silvicultural system

The main management type is high forest with close-to nature silviculture. Forests are treated with group-shelterwood (Femmelschlag) cuttings. Long history of forest management plans (since 1906) is present in the area (Schollmayer 1906).

Site 10 - Trnovo (SI)

Site description

The area is located in the Southwestern part of Slovenian Dinaric region. The majority of forest area is owned by Slovenian state. Research plots are located within forest management unit FMU Trnovo within forest compartment N° 30.

Total area of FMU is 4614.18 ha (4325.04 ha of forest – 93.7 %). Altitude ranges from 550 m to 1445 m. Average yearly precipitation is from 2000 to 3000 mm. Parent material is limestone and dolomite, where leptosols, cambisols and luvisols are present.

Predominant forest type is *Omphalodo-Fagetum* with European beech, silver fir and Norway spruceas main tree species. Elm and Sycamore are also present. The average growing stock is 292.0 m3 ha-1 and the increment is 6.2 m^3 ha^{-1} yr^{-1}. The forests are mainly included in NATURA 2000 network (Slovenian Forest Service, Forest management plan FMU Trnovo 2003-2012).

Description of the traditional silvicultural system

The main management type is high forest with close-to nature silviculture. Forests are treated with group-shelterwood (Femmelschlag) cuttings. Long history of forest management plans (since 1769 / 1771) is present in the area (Flamek 1771).

Innovative criteria (all Slovenian sites - 8, 9, 10)

The innovative criteria are being referred to the intensity of the regeneration cuts. In terms of natural disturbances the experiment mimics three types of disturbances resulting in small regeneration gaps (control = solely diffuse light), medium-sized (half cut = diffuse and direct light) and large-sized regeneration areas (full cut = direct light). It is assumed that the sizes will make possible to determine the best way of regeneration for the dominant species as well as to make trade-offs between different ecosystem services such as wood production, carbon storage, biodiversity and many others.

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3.2 Assessing the maintenance of forest resources and their contribution to carbon cycles

Becagli C. [1], Bertini G. [1], Cammarano M.[2], Cantiani P. [1], Cater M.[3], Chiavetta U. [1], Coletta V.[4], Conforti M. [4], D'Andrea E. [2], **Di Salvatore U.** [1], Fabbio G. [1], Ferlan M. [3], Ferreira A.[5], Ferretti F. [1], Giovannozzi Sermanni A. [2], Kobler A. [5], Kovač M. [5], Marinsek A. [3], Micali M. [2], Pellicone G. [5], Planinšek Š. [5], Rezaei N. [2], Sicuriello F. [2], Skudnik M. [5], Tonti D.[6]

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GROWING STOCK

The Criterion 1 (Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles) includes the “Growing stock on forest and other wooded land, classified by forest type and by availability for wood supply” (FOREST EUROPE 2015).

Full text

Growing stock on forest and other wooded land, classified by forest type and by availability for wood supply.

Rationale

This indicator is one of the basic figures of any forest inventory and useful for various purposes. The standing volume of growing stock is closely related to the above ground woody biomass and provides data for calculating carbon budgets (link to indicator 1.4 (carbon stock). Further on this indicator is mainly linked to indicator 1.3, 2.3 and 2.4. There is also a cross-reference to Criterion 4 (Biodiversity).

Methods

Permanent plots to measure and compare the Growing stock change in progress. Measurements have to be repeated every five years and before and after any silvicultural operations to determine their impact on the parameter. We measured dbh, total height and estimate the standing timber volume by volume tables.

Measurement units

- Status: m^3
- Changes: m^3 per yr.
- Status: m^3 ha-1
- Changes: m^3 ha-1 per yr.

Measurement time

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Basal Area, Diameter distribution

Results and conclusion from ManFor C.BD.:

Indicator name	Site	Before	After
Stem volume (m^3 ha^{-1})	Cansiglio - Innovative	561.2	360.1
Stem volume (m^3 ha^{-1})	Cansiglio - Traditional	524	397.1
Stem volume (m^3 ha^{-1})	Chiarano - Traditional	267.3	177.2
Stem volume (m^3 ha^{-1})	Chiarano - Innovative 80	303.9	192.1
Stem volume (m^3 ha^{-1})	Chiarano - Innovative 40	296.6	177.1
Stem volume (m^3 ha^{-1})	Lorenzago di Cadore Area 1 - Innovative	748.1	596.5
Stem volume (m^3 ha^{-1})	Lorenzago di Cadore Area 1 - Traditional	937	719.6
Stem volume (m^3 ha^{-1})	Lorenzago di Cadore Area 2 - Innovative	828.2	424.1
Stem volume (m^3 ha^{-1})	Lorenzago di Cadore Area 2 - Traditional	904.2	693.1
Stem volume (m^3 ha^{-1})	Mongiana - Innovative	484.3	380.2
Stem volume (m^3 ha^{-1})	Mongiana - Traditional	471.7	381.3
Stem volume (m^3 ha^{-1})	Pennataro - Mixed forest	402.6	275.1
Stem volume (m^3 ha^{-1})	Pennataro - Turkey oak forest	457.1	274.1
Stem volume (m^3 ha^{-1})	Tarvisio – Innovative 1	424.7	246.7
Stem volume (m^3 ha^{-1})	Tarvisio – Innovative 2	326.6	219.6

Stem volume (m^3 ha^{-1})	Tarvisio – Traditional	320.4	259.5
Stem volume (m^3 ha^{-1})	Vallombrosa - Innovative	826.9	538.2
Stem volume (m^3 ha^{-1})	Vallombrosa - Traditional	751.9	737.4
Stem volume (m^3 ha^{-1})	Kočevski Rog - 100	403.23	0
Stem volume (m^3 ha^{-1})	Kočevski Rog – 50	389.71	221.88
Stem volume (m^3 ha^{-1})	Snežnik – 100	605.76	0
Stem volume (m^3 ha^{-1})	Snežnik – 50	628.51	364.37
Stem volume (m^3 ha^{-1})	Trnovo - 100	599.13	0
Stem volume (m^3 ha^{-1})	Trnovo – 50	622.3	278.49

DIAMETER DISTRIBUTION

The Criterion 1 (Maintenance and Appropriate Enhancement of Forest Resources and their Contribution to Global Carbon Cycles) includes the “Age structure and/or diameter distribution of forest and other wooded land, classified by availability for wood supply” (FOREST EUROPE 2015).

Full text

Diameter distribution of forest and other wooded land, classified by forest type and by availability for wood supply.

Rationale

Diameter distributions provide an insight in the future development of forests and are a prerequisite for SFM. The diameter distribution is appropriate to describe the stand level structure. It is the most traditional forest indicators and it is easy to measure in the field. This indicator is mainly linked to other indicators describing forest resources, health and vitality, productive and protective functions as well as biodiversity.

Diameter distribution supports especially the interpretation of indicator 1.2 (growing stock) and also indicates the stability of forests (e.g. overmature forests might collapse). In combination with figures on current state and changes of growing stock, the indicator enables the evaluation of future potential growth and sustainable timber supply.

The results are also linked with the number of thick trees, which may be important as habitat trees. There is also a cross-reference to Criterion 4 (Biodiversity).

Methods

Permanent plots to measure and compare the change in progress in the diameter distribution. Measurements have to be repeated every five years and before and after any silvicultural operations to determine their impact on the parameters.

Measurement units

- Diameter distribution

- Status: Diameter class n ha-1
- Changes: Diameter class n ha-1 per yr.

Measurement time

Before [Y]

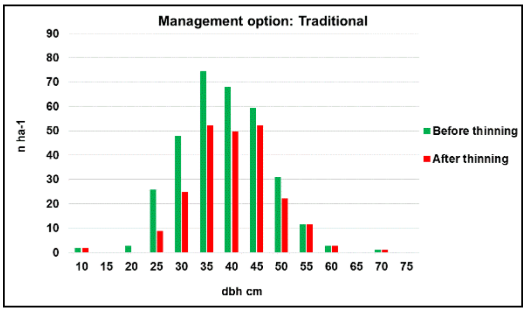
After [Y]

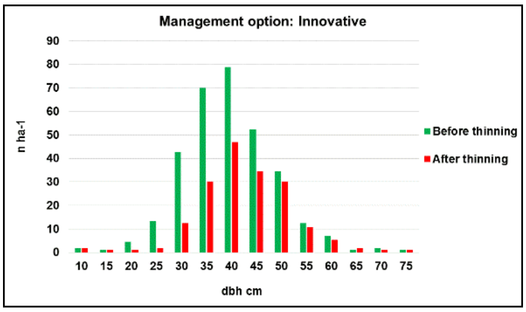
Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Basal Area, Diameter distribution

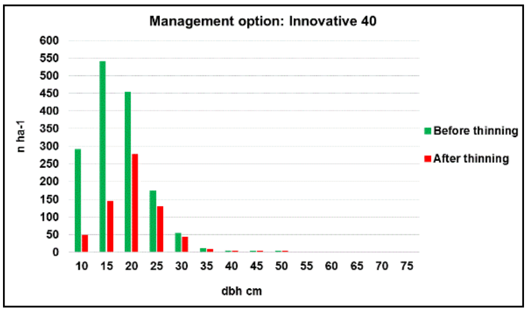
Results and conclusion from ManFor C.BD.:

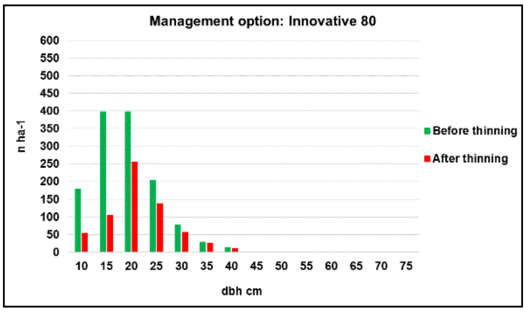
Cansiglio

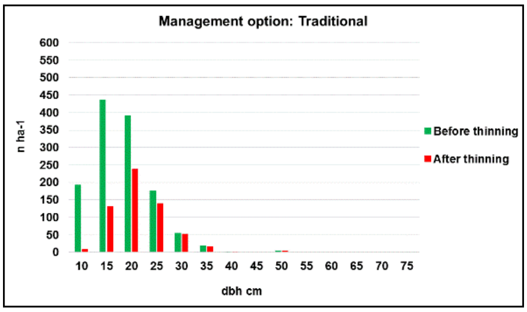




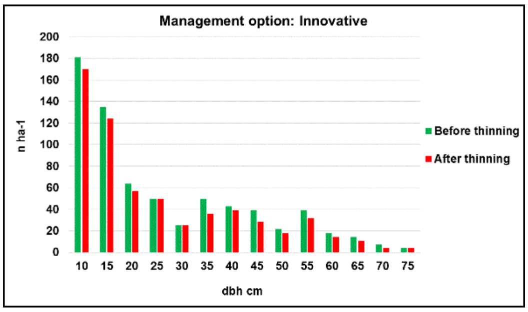
Chiarano

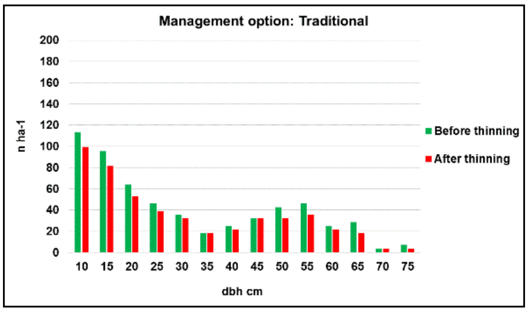




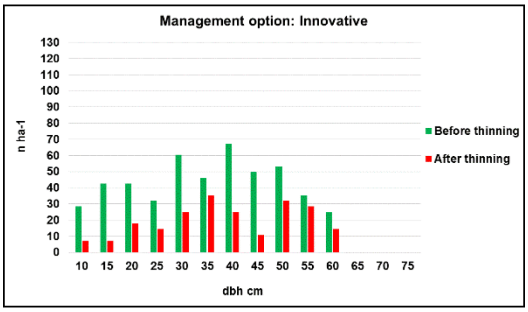


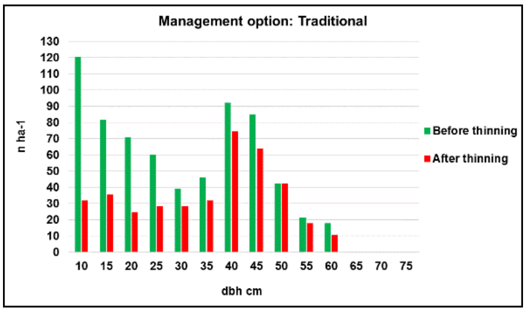
Lorenzago1



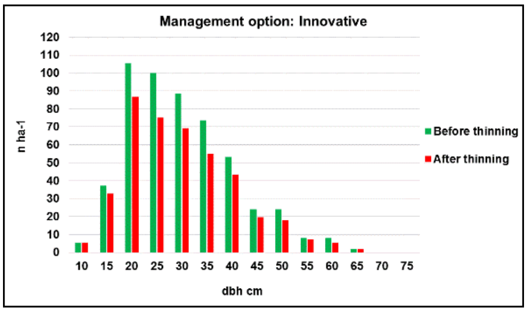


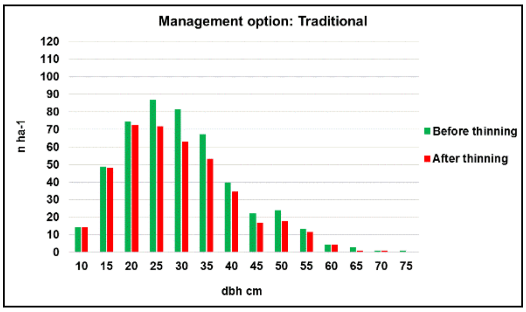
Lorenzago 2



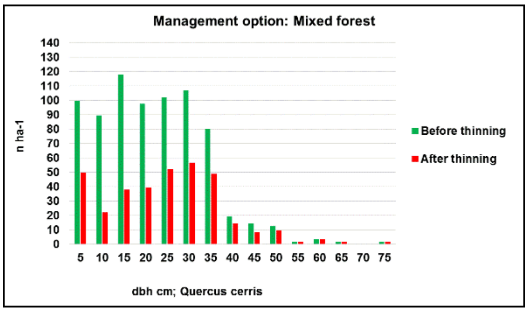


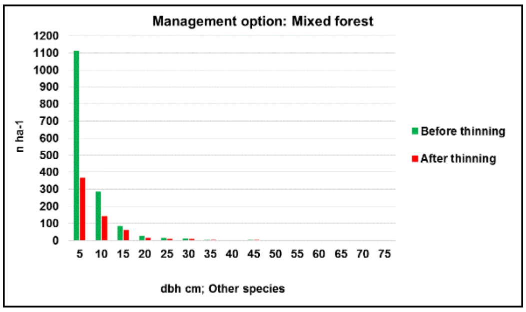
Mongiana

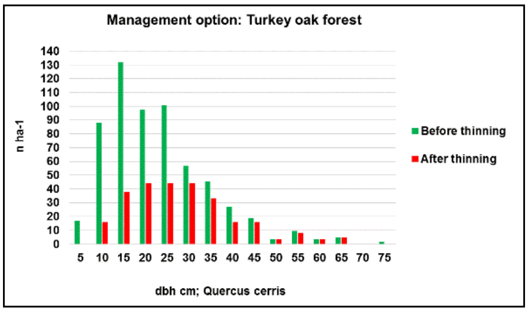


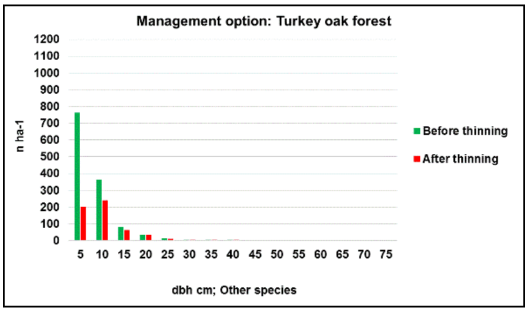


Pennataro

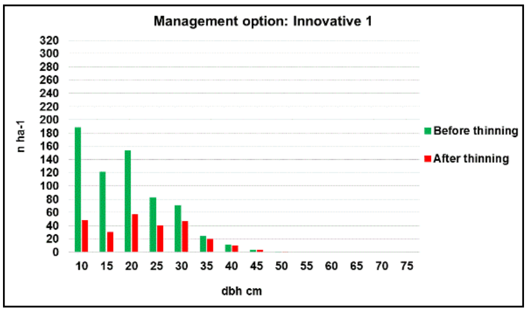


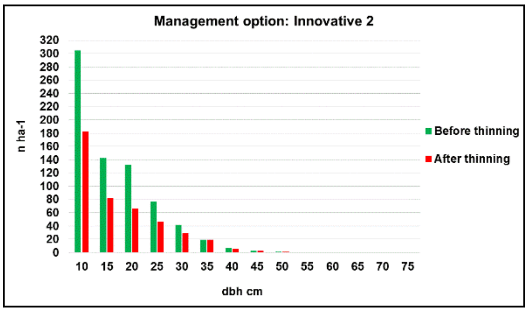


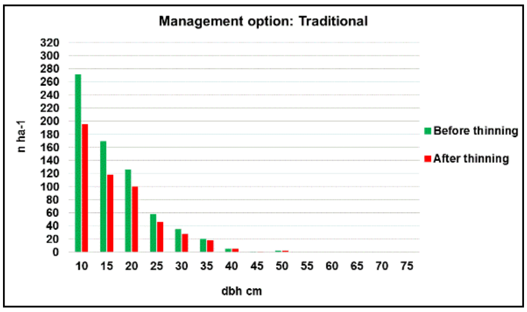




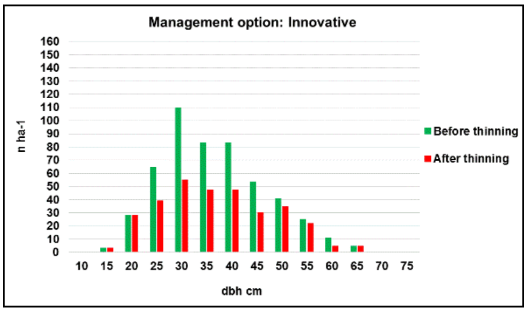
Tarvisio

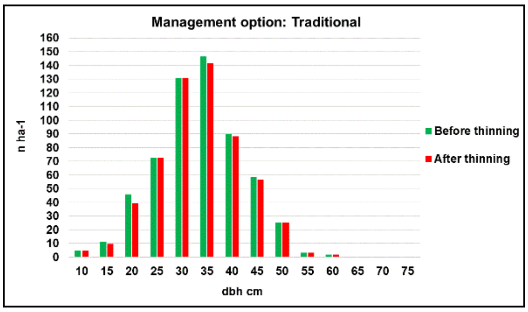






Vallombrosa





FOREST CARBON STOCK

The Criterion 1 includes the "Carbon stock and carbon stock changes in forest biomass, forest soils and in harvested wood products" (FOREST EUROPE 2015).

Full text

Carbon stock of biomass, deadwood, litter and soil on forest.

Rationale

Carbon sequestration in forest ecosystems contributes to a reduction in the concentration of greenhouse gases in the atmosphere. Carbon accumulates in forest ecosystems through absorption of atmospheric CO2 and its assimilation into biomass (above and below ground). Then carbon migrates from biomass in litter (leaves) or in deadwood, and from these components to soil. Carbon is retained for different periods in the forest biomass (above-below ground biomass), litter, deadwood and soils (MCPFE, 2007). European forests are a large reserve of carbon with 53 gigatonnes of carbon sequestered in forest biomass and deadwood.

They continue to be a significant carbon sink, as evidenced by their increase in carbon stocks of 2 billion tonnes since 1990. Knowledge on the status and trends of carbon stocks in forest litter and soil remains limited (MCPFE,2007). This indicator can be useful to evaluate effects of different silviculture treatments on the five carbon pools.

Methods

Branches, stems and roots biomass can be assessed using allometric equations or other models, then measuring carbon concentration (or using the 0.5 coefficient) biomass carbon pool is estimated. Litter carbon pool is estimated collecting samples from forest using a frame and measuring carbon concentration. Soil carbon pool is estimated using specific field sampling then in laboratory bulk density and carbon concentration is measured. Deadwood is assessed in plots, assigning each debris to a decay class (that differ for density and carbon content).

Measurement units

Status: MgC ha-1

Changes: MgC ha-1per yr.

Measurement time

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Basal Area, Soil respiration, C/N

Results from ManFor C.BD.

Indicator name	Site	Below ground biomass ANTE	Above ground biomass ANTE	Woody Debris ANTE	Litter ANTE	Soil ANTE	Total ANTE	Below ground biomass POST	Above ground biomass POST	Woody Debris POST	Litter POST	Soil POST	Total POST
Carbon Stock	Cansiglio Innovative	50.44	149.94	2.80	7.85	58.91	269.94	50.44	90.72	8.83	7.85	47.17	205.02
Carbon Stock	Cansiglio Traditional	46.30	141.18	5.08	7.99	52.75	253.29	46.30	100.97	8.92	7.99	45.77	209.95
Carbon Stock	Chiarano Traditional	27.78	118.91	3.39	4.60	100.06	254.74	27.78	79.39	4.85	4.60	108.61	225.23
Carbon Stock	Chiarano I80	27.60	131.84	3.03	5.06	106.42	273.95	27.60	88.68	7.24	5.06	116.32	244.90
Carbon Stock	Chiarano I40	27.13	130.26	4.23	5.28	97.32	264.22	27.13	74.95	7.21	5.28	113.36	227.93
Carbon Stock	Mongiana Innovative	48.16	149.37	1.68	4.61	172.22	376.04	48.16	119.49	8.13	4.61	161.05	341.43
Carbon Stock	Mongiana Traditional	42.31	135.48	1.53	5.21	188.81	373.34	42.31	111.38	8.64	5.21	180.74	348.29
Carbon Stock	Kočevski Rog 100	24.09	118.63	2.31	4.39	140.56	289.99	24.09	0.00	44.20	4.18	130.15	202.62
Carbon Stock	Kočevski Rog 50	21.51	106.59	7.35	4.15	173.17	312.77	21.51	53.30	26.09	4.10	168.95	273.95
Carbon Stock	Snežnik 100	36.69	179.77	8.44	6.92	123.29	355.11	36.69	0.00	72.10	6.59	114.15	229.53

Carbon Stock	Snežnik 50	35.42	173.24	3.35	3.47	121.74	337.22	35.42	86.62	34.05	3.43	118.77	278.30
Carbon Stock	Trnovo 100	33.77	165.74	3.47	8.21	197.63	408.82	33.77	0.00	62.10	7.82	182.99	286.69
Carbon Stock	Trnovo 50	33.94	167.35	2.75	5.17	224.00	433.20	33.94	83.67	32.27	5.10	218.53	373.52

* In Italian Sites soil carbon pool was assessed 30 cm depth, In Slovenian sites 1 m (or bedrock) depth.

BASAL AREA

Full text

Basal area is the area of a given section of land that is occupied by the cross-section of tree trunks and stems at the base.

Rationale

The indicator is easy to measure and to calculate. The results depend only on the measured dbh of the tree. The indicator is already included into most of the forest management plans. With basal area it is possible to monitor the development of the stand. Through raw data it is possible to calculate the number of thick trees (potential habitat trees).

Methods

Permanent plots to measure and compare the nBasal area change in progress. Measurements have to be repeated every five years and before and after any silvicultural operations to determine their impact on the parameter. All living trees with dbh at least 7.5 cm were included.

Measurement units

Status: m2

Changes: m2 per yr.

Status: m2 ha-1

Changes: m2 ha-1 per yr.

Measurement time

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Growing stock

Results from ManFor C.BD.

Indicator name	Site	Before	After
Basal area (m^2 ha^{-1})	Cansiglio Innovative	41.9	26.6
Basal area (m^2 ha^{-1})	Cansiglio Traditional	39.6	29.8
Basal area (m^2 ha^{-1})	Chiarano Traditional	36.7	23.1
Basal area (m^2 ha^{-1})	Chiarano I80	40.4	24.8
Basal area (m^2 ha^{-1})	Chiarano I40	40.2	23
Basal area (m^2 ha^{-1})	Lorenzago Area 1 Innovative	53.3	43.1
Basal area (m^2 ha^{-1})	Lorenzago Area 1 Traditional	58.8	46.4
Basal area (m^2 ha^{-1})	Lorenzago Area 2 Innovative	54.6	28.1
Basal area (m^2 ha^{-1})	Lorenzago Area 2 Traditional	58	43.2
Basal area (m^2 ha^{-1})	Mongiana Innovative	41.6	32.6
Basal area (m^2 ha^{-1})	Mongiana Traditional	38.7	31.4
Basal area (m^2 ha^{-1})	Pennataro Mixed forest	38.6	24.9
Basal area (m^2 ha^{-1})	Pennataro Turkey oak forest	43.7	25.3
Basal area (m^2 ha^{-1})	Tarvisio – Innovative 1	47.7	25.8
Basal area (m^2 ha^{-1})	Tarvisio – Innovative 2	37.9	24.7
Basal area (m^2 ha^{-1})	Tarvisio – Traditional	35.7	28.5
Basal area (m^2 ha^{-1})	Vallombrosa Innovative	56.9	36.7
Basal area (m^2 ha^{-1})	Vallombrosa Traditional	54.3	53.2
Basal area (m^2 ha^{-1})	Kočevski Rog 100	30.89	0
Basal area (m^2 ha^{-1})	Kočevski Rog 50	31.1	17.94
Basal area (m^2 ha^{-1})	Snežnik 100	40.99	0
Basal area (m^2 ha^{-1})	Snežnik 50	45.53	25.71
Basal area (m^2 ha^{-1})	Trnovo 100	43.78	0
Basal area (m^2 ha^{-1})	Trnovo 50	45.51	19.48

PROMPT RESPONSE OF STEM GROWTH

Full text

Response of tree diameter increment to forest management.

Rationale

Tree growth can be useful indicator of processes that occur in the natural environment (Fritts 1976, Harley and Grissino-Mayer 2012). Since the growth rate of a tree is sensitive to both natural and human-induced events, conditions during a given year will be either favourable or unfavourable for tree growth, resulting in a variation in tree ring widths (TRW) from year to year throughout the life of a tree. This pattern of wide and narrow growth rings can serve as an indicator for monitoring environmental processes. Tree diameter increment is connected with gross primary production, which could be influenced by stand structure, competition, etc. This indicator can be useful to evaluate effects of different silvicultural treatments on the carbon cycling.

Methods

Comparing the radial growth Before and After silvicultural treatments allow us to evaluate the effect of applied forest management measures.

Using woody cores enable us to compare the mean standardized growth of the trees 5 years before the silvicultural treatments and the years after the cutting, when the growth area is released. An easy way to standardize the growth is to divide each annual tree ring width by the mean of the tree ring width of the considered period.

Instruments: Incremental hammer; Core borers; Tree ring widths measurers (TSAP, Software for Image Analysis)

Measurement units

Ratio between before and after treatment growth

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Tree level, Stand	2	2-4 (depending to TRW mesures)	Carbon stock, Growing stock

Results and conclusion from ManFor C.BD.:

Indicator name	Site	Befor e	After
Differences in growing stock	Trnovo, Kočevski Rog, Snežnik	YES	YES
Differences in growing stock	Cansiglio - Innovative	0.95	1.59
Differences in growing stock	Cansiglio - Control	0.91	0.59
Differences in growing stock	Cansiglio - Traditional	1.07	0.94
Differences in growing stock	Chiarano - Traditional	0.98	1.18
Differences in growing stock	Chiarano - I80	0.83	1.67
Differences in growing stock	Chiarano - I40	0.94	1.47
Differences in growing stock	Mongiana - Innovative	0.80	1.39
Differences in growing stock	Mongiana - Control	1.05	0.95
Differences in growing stock	Mongiana - Traditional	0.89	0.96

SOIL EFFLUX

Full text

CO2 efflux from forests soils.

Rationale

CO2 efflux out of the soil is the primary function of soil respiration; it is a significant component of the total atmospheric carbon cycle. Significant disturbances related with aboveground biomass could increase the soil CO2 efflux. This indicator can be useful to evaluate effects of different silviculture treatments on the carbon cycling (Eler et al. 2013).

Methods

Different chambers techniques Soil temperature and soil water profiles

Measurement units

Status: tones of C /ha

Flux: tones of C /ha/yr.

Measurement time Diurnal [day]. Growing

season [months/period]

Before [Y]

After [Y]

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	5	5	Difference in growing stock

Results and conclusion from ManFor C.BD.:

Indicator name	Site	Before	Growing season (Jun-Oct 2014)
Soil respiration (µmolCO_2m^2/sec)	Trnovo (100)		2.1
Soil respiration (µmolCO_2m^2/sec)	Trnovo (control beech stand)		2.3
Soil respiration (µmolCO_2m^2/sec)	Chiarano - Innovative 80		3.44
Soil respiration (µmolCO_2m^2/sec)	Chiarano - Innovative 40		2.82
Soil respiration (µmolCO_2m^2/sec)	Chiarano - Control		4.34
Soil respiration (µmolCO_2m^2/sec)	Mongiana - Innovative		2.69
Soil respiration (µmolCO_2m^2/sec)	Mongiana - Traditional		2.39
Soil respiration (µmolCO_2m^2/sec)	Mongiana - Control		2.24

*Slovenian data include also night measures; in all the sites there was a control plot to avoid to measurements before treatments.

LAND USE

Full text

Main land uses classes in the land.

Rationale

Land use is the type of activity being carried out on a unit of land. In GPG-LULUCF this term is used for the broad land-use categories, important for greenhouse gas (GHG) inventory reporting: Forest, Grassland, Cropland, Wetlands, Settlements and Other Land. It is recognized that these land categories are a mixture of land cover (e.g. Forest, Grassland, Wetlands) and land use (e.g., Cropland Settlements) classes (IPCC 2003).Information about land area is needed to estimate carbon stocks and emissions and removals of greenhouse gases associated with Land Use, Land- Use Change and Forestry (LULUCF) activities.The categories are broad enough to classify all land areas in most countries and to accommodate differences in national classification system (IPCC 2003).

Methods

In practice, countries use methods including annual census, periodic surveys and remote sensing to obtain area data (IPCC 2003). For Slovenian sites of the ManForCBD project, were used vector layers of the Agricultural land use map (scale 1:5,000) (Ministry of Agriculture, Forestry and Food) from 2012, reclassified in 25 national land use classes to 6 main LULUCF categories. For Italian sites the Corine Land Cover maps (scale 1:100,000) from 2006 were used.

Measurement units

Status: Percentage (area of land use category/ total area*100)

Measurement time

Before [Y]

After [N] (longer time period is necessary)

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Landscape/Regional	5	2	All biodiversity indicators, Carbon stock

Results and conclusion from ManFor C.BD.:

Indicator name	Site	Ante	Post
Land use	Kočevski Rog	Forest: 95 %, Settlements: 1 %,Otherland: 4%	
Land use	Snežnik	Forest: 80 %, Settlements: 2 %,Otherland: 18 %	
Land use	Trnovo	Forest: 83 %, Settlements: 2 %,Otherland: 15 %	
Land use	Cansiglio	Forest: 76 %, Settlements: 1 %,Otherland: 60 %	
Land use	Chiarano	Forest: 35 %, Settlements: 20 %,Otherland: 60 %	

ROTATION LENGTH

Full text

Increased rotation lengths

Rationale

Rotation length is together with site index a major determinant of Carbon stock both in the standing crop and in the forest soil. Carbon sequestration, i.e. annual NPP, is vice versa depending on silvicultural management and the permanence time of the forest stand. It allows avoiding overstocking in the juvenile phase, creating and maintaining the condition for the full expression of individual growth rate and pattern (i.e. a sufficient available growing space) both at stemwood and branchwood level, the latter including the well-balanced crown expansion and the related rooting system growth.

Where both an increased lifespan (as compared to traditional rotations) and consistent silvicultural practices are foreseen and applied in forest management, the goal of a high carbon stock and of a sustained sequestration ability may be reached. The issue may be well-addressed to all forests where different, complementary purposes to wood production, are being pursued as in most of cases today. The rationale may be summarized as "working with high growing stocks". Furthermore to increase rotation length promotes a more differentiated and complex structure and creates new microhabitats and related ecological niches.

Methods

We measure the rise in rotation length at stand level, the level to which we apply silvicultural treatments.

Measurement units

Status: year

Changes: year

Measurement time

Before [Y]

After [Y]

Feasibility

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand, Compartment	2(inventory technician)	2	Carbon stock, Basal area, Diameter distribution, Novel practices

Results and conclusion from ManFor C.BD.:

Indicator name	Site	Ante	Post
Rotation length	Cansiglio	90-100 years	140 years
Rotation lenght	Vallombrosa	120 years	160 years

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3.3 Assessing indicators of forest productive functions

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<u>ROUNDWOOD</u>

The Criterion 3 (Maintenance and Encouragement of Productive Functions of Forests (Wood and Non-Wood) includes the "Quantity and market value of roundwood" (FOREST EUROPE 2015).

Full text

Value and quantity of marketed roundwood.

Rationale

Marketed roundwood includes all wood removed from the forest with or without bark, including wood removed in its round form, or split, roughly squared or in other form and sold by the forest owner. Value added processing steps is not included. This indicator assesses the role that forest products play in the sequestration, cycling, or emission of carbon. Long term storage of carbon in products and landfills delays or reduces emissions.

Use of wood products can also reduce emissions if they substitute products with higher carbon emission processes. As forest biomass is harvested, carbon is shifted from forest ecosystems to forest products held in products and landfills. The rate of accumulation of carbon in products can be influenced by the mix of products and uses. In addition, marketed roundwood is a direct contribution to the income of the forest owner. This indicator is mainly linked to indicator 3.3 and 3.4.

Methods

We calculated separately potential and real roundwood, because they give different information. The first can be used to evaluate the potential value of each silvicultural treatment. The second one is the real result considering the wood market and operators ability. Roundwood volume can be estimated using a simple assortment table, which returns the different woody assortment in function of diameter. Real assortment can be assessed after treatments trough direct observation.

Measurement units

Status: percentage of the different assortments.

Measurement time

Before [N]

After [Y]

Feasibility

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	1	1	Carbon stock, Basal area, Prompt response of stem growth

Results and conclusion from ManFor C.BD.:

Potential roundwood

Indicator name	Site	Saw Log (high value)	Log (middle value)	Fuel wood (low value)
Roundwood (%)	Cansiglio Innovative	42.19%	27.61%	30.20%
Roundwood (%)	Cansiglio Traditional	39.61%	29.78%	30.61%
Roundwood (%)	Chiarano Traditional	0.15%	38.96%	60.88%
Roundwood (%)	Chiarano I80	3.02%	40.55%	56.43%
Roundwood (%)	Chiarano I40	3.81%	44.38%	51.81%
Roundwood (%)	Lorenzago Area 1 Innovative	79.66%	0.42%	19.92%
Roundwood (%)	Lorenzago Area 1 Traditional	80.00%	0.00%	20.00%
Roundwood (%)	Lorenzago Area 2 Innovative	74.26%	7.18%	26.39%
Roundwood (%)	Lorenzago Area 2 Traditional	57.97%	27.53%	55.70%
Roundwood (%)	Mongiana Innovative	44.39%	25.83%	29.79%
Roundwood (%)	Mongiana Traditional	19.77%	45.28%	34.95%

Real roundwood

Site	Roundwood %					
	structural timber	**sawlog**	**log**	**pallet parquet**	**wood biomass**	**fuelwood**
Cansiglio						
Total	-	-	-	11.7	-	88.3
Vallombrosa	not available					
Chiarano						
Innovative 40	-	-	-	-	-	100
Innovative 80	-	-	-	-	-	100
Traditional	-	-	-	-	-	100
Mongiana						
Innovative	-	56.1	24.6	-	-	19.3
Traditional	-	47.0	27.7	-	-	25.3
Bosco Pennataro						
Turkey oak forest	-	-	-	-	-	100
Mixed forest	-	-	-	-	-	100
Lorenzago Area 1						
Innovative	88.4	-	-	11.6	-	-
Traditional	85.1	-	-	14.9	-	-
Lorenzago Area 2						
Innovative	99.8	-	-	0.2	-	-
Tarvisio						
Total	-	79.6	-	-	18.6	1.8

3.4 Assessing indicators of forest vegetation, diversity, stand structure and tree canopy arrangement

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DIVERSITY OF TREE SPECIES – (SLOVENIA)

The Criterion 4 (Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems) includes the "Area of forest and other wooded land, classified by number of tree species occurring" among its indicators (FOREST EUROPE 2015).

Full text

Area of forest and other wooded land, classified by number of tree species occurring and by forest type.

Rationale

The tree species composition is the indicator used in the context of the Ministerial Conference for the Protection of Forests in Europe (Forest Europe) and is, therefore, comparable throughout Europe. However, the comparisons of tree species composition only make sense, if the corresponding ecological, economic and social conditions are also taken into consideration. These precondition change from region to region and also over time.

Method:

- The assessment of tree species in permanent sampling area (comparable between statuses in different periods).
- The cover of tree species can be evaluated by different scales (e.g. Braun-Blanquet, Barkman, Londo) transferable to %.

- The cover of tree species can be estimated in separate vertical layers (e.g. upper-tree layer, lower-tree layer)

Measurement units:

- Status: Number per hectare (or surface in m^2)/ Cover (in %) per hectare (or surface in m^2).
- Changes: Number per hectare (or surface in m^2) / Cover (in %) per hectare (or surface in m2)

Measurement time:

Before [Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Plot or stand level	3	2	Other indicators of plant/biodiversity indicators and SFM indicator 4.3 Naturalness

Results and conclusion from ManFor C.BD (Slovenia):

Indicator name	Site	Before	After
Diversity of tree species mean number of tree layer species	in 27 plots in 3 Slovenian sites	5.8 species per 400m^2 plot (min: 3 species; max: 10 species)	6.2 species per 400m^2 plot (min: 4 species; max: 10 species)
Tree species composition mean cover of main tree species	in 27 plots in 3 Slovenian sites	Upper tree layer: Fagus sylvatica: 38.9% Abies alba: 14.5% Picea abies: 10.1%	Upper tree layer: Fagus sylvatica: 18.1% Abies alba: 5.3% Picea abies: 5.2%
Tree species composition mean cover of main tree species	in 27 plots in 3 Slovenian sites	Lower tree layer: Fagus sylvatica: 29.2% Abies alba: 3.5% Picea abies: 1.6%	Lower tree layer: Fagus sylvatica: 14.0% Abies alba: 1.0% Picea abies: 0.8%

The mean cover of the main tree species was measured in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo) for three silvicultural measures (control without logging, logging 50 % and 100 % of growing stock on 0.4 ha) before and two years after the logging.

Mean cover for the 3 Slovenian sites (n=9)	CONTROL		LOGGING 50% GS		LOGGING 100% GS	
	Before	After	Before	After	Before	After
UPPER TREE LAYER						
Fagus sylvatica (%)	39.9	33.9	30.4	20.4	46.4	0.0
Abies alba (%)	9.0	8.5	21.2	7.4	13.3	0.0
Picea abies %)	13.4	10.6	13.2	5.1	3.6	0.0
LOWER TREE LAYER						
Fagus sylvatica (%)	25.6	26.7	33.1	8.6	29.0	6.8
Abies alba (%)	2.8	1.7	3.0	1.4	4.6	0.0
Picea abies (%)	1.9	1.9	2.4	0.4	0.5	0.0

TREE SPECIES COMPOSITION - (ITALY)

Full text

Stand classified by number of tree species occurring.

Rationale

Forest biodiversity and dynamics depend considerably on the composition of tree species. Multispecies forest and other wooded land are usually richer in biodiversity than monospecific forest and other wooded land. However, it has to be considered that some natural forest ecosystems have only one or two tree species, e.g. natural subalpine spruce stands.

Method

Permanent plots to quantify the numerousness of different tree species. Measurements have to be repeated before and after any silvicultural operations to determine their impact on the parameter.

Measurement units:

- Status: Number of trees.
- Changes: The same as status.

Measurement time:

Before [Y]

After [Y]

Feasibility:

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Plot or stand level	3	2	Other indicators of plant/biodiversity indicators and SFM indicator 4.3 Naturalness

Results and conclusion from ManForC.BD.:

Indicator name	Site	Before	After
Number of tree species	Cansiglio Innovative	1	1
Number of tree species	Cansiglio Traditional	1	1
Number of tree species	Chiarano Traditional	1	1
Number of tree species	Chiarano Innovative 80	1	1
Number of tree species	Chiarano Innovative 40	1	1
Number of tree species	Lorenzago Area 1 Innovative	3	3
Number of tree species	Lorenzago Area 1 Traditional	4	3
Number of tree species	Lorenzago Area 2 Innovative	4	3
Number of tree species	Lorenzago Area 2 Traditional	4	4
Number of tree species	Mongiana Innovative	1	1
Number of tree species	Mongiana Traditional	1	1
Number of tree species	Pennataro Mixed forest	14	13
Number of tree species	Pennataro Turkey oak forest	13	12
Number of tree species	Tarvisio Innovative 1	6	5
Number of tree species	Tarvisio Innovative 2	4	4
Number of tree species	Tarvisio Traditional	5	4
Number of tree species	Vallombrosa Innovative	1	1
Number of tree species	Vallombrosa Traditional	1	1

NATURALNESS – (SLOVENIA)

The Criterion 4 (Maintenance, Conservation and Appropriate Enhancement of Biological Diversity in Forest Ecosystems) includes the "Area of forest and other wooded land by class of naturalness" among its indicators (FOREST EUROPE 2015).

Full text

Describe the Area of forest and other wooded land, classified by "undisturbed by man", by "semi-natural" or by "plantations"

Rationale

Indicator Naturalness is associated with the tree species composition (also with understory species).The concept of naturalness has been proposed and used for describing the ecological value of forest ecosystems, evaluating management efforts to conserve biodiversity, and identifying natural, old-growth forests for purposes of establishing protection areas. The necessity for harmonized reporting motivated an investigation of variables that can be used to quantify and assess forest naturalness. National forest inventories (NFIs) could be sources of the most comprehensive and extensive data available (e.g. as reference values) for assessing naturalness in particular study sites.

Method:

- The assessment of tree species composition in the permanent sampling area(comparable between statuses in different periods).
- The comparison of tree species composition to reference values in certain stratum (e.g. forest type, habitat type, forest community).
- Mathematical calculation of the deviation from the model (natural) state.

Measurement units:

- Status: % of undisturbed area comparing to the reference values
- Changes: % of undisturbed area comparing to the reference values

Measurement time:

Before[Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Plot or Stand or Landscape level	4	2	Other indicators of plant/biodiversity indicators and SFM indicator 4.1 Tree species composition/Diversity of tree species

This indicator has not been tested by the project.

PLANT SPECIES RICHNESS (SLOVENIA)

Full text

Number of vascular plant species - all seed-bearing plants (the gymnosperms and angiosperms) and the pteridophytes (including the ferns, lycophytes, and horsetails) - in forest and other wooded land, classified by number of vascular plant species occurring.

Rationale

The plant species richness is common used indicator for evaluation of biodiversity status of forests, and it is comparable throughout Europe. Plant species richness is simply the number of vascular plant species present in a sample, community, or taxonomic group. Species richness is one component of the concept of species diversity, which also incorporates evenness, that is, the relative abundance of species. Species diversity is one component of the broader concept of biodiversity.

Method:

- Assessment of vascular plant species in permanent sampling area (comparable between statuses in different periods).
- Counting the number of different vascular plant species.
- Number of vascular plant species can be estimated for each separate vertical layer (e.g. herb, shrub layer).

Measurement units:

- Status: Number per hectare (or surface in m^2).
- Changes: Number per hectare (or surface in m2).

Measurement time:

Before[Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Plot or Stand	5	3	Other indicators of plant/biodiversity indicators and SFM indicators 4.1 Tree species composition/Diversity of tree species and indicator 4.3 Naturalness

Results and conclusion from ManForC.BD.:

Indicator name	Site/treatment	Before	After
Plant species richness (total number of vascular plant species)	in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo)	151 species	250 species
Plant species richness (mean min & max number of vascular plant species)	in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo)	48.8 species per 400m^2 plot (min: 29 species; max: 68 species)	70.4 species per 400m^2 plot (min: 41 species; max: 106 species)
plant species richness (mean,min & max number of herbspecies*)	in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo)	37.2 species per 400 m^2 plot (min: 21 species; max: 51 species)	57.0 species per 400 m^2 plot (min: 33 species; max: 87 species)

* HERB SPECIES – including all non-woody (non-ligneous) plants (also without mosses and lichens)

Indicator name	Site	Before (mean species number per plot)	After (mean species number per plot)
Plant species richness	Kočevski Rog	47.4	65.9
Plant species richness	Snežnik	55.8	78.1
Plant species richness	Trnovo	43.1	67.3

Indicator name	Treatment	Before (mean species number per plot)	After (mean species number per plot)
Plant species richness	Control	50.7	50.6
Plant species richness	50% logging	49.2	73.3
Plant species richness	100% logging	46.4	87.4

VERTICAL VEGETATION STRUCTURE (SLOVENIA)

Full text

Number and cover of vertical vegetation layers (tree, shrub, herb and moss layer).

Rationale

The vertical vegetation structure indicators is used for assessment of current status and development of forest stands. This indicator is used for evaluation of biodiversity status of forests. In general, more developed vertical structure with more layers is favourable for biodiversity in broader sense.

Method

The visual estimation of the percentage cover of each vertical vegetation layer (moss, herb, shrub, and tree layer) may be performed according to the ICP-Forests protocol (Canullo et al. 2011). The definitions of vertical vegetation layers are following:

– moss layer (i.e. bryophytes and lichens),
– herb layer (all non-ligneous, and ligneous, including eventual seedling and browsed trees under 0.5 m height)
– shrub layer (only ligneous and all climbers of a height between 0.5 m and 5 m),
– tree layer (only ligneous and all climbers with a height over 5 m).

Besides the cover of vegetation layers, share of bare soil and of surface rock could be estimated.

Measurement units:

- Status: Number of vertical vegetation layer per plot/site; cover of vertical vegetation layer (in %).
- Changes: Number of vertical vegetation layer per plot/site; Cover of vertical vegetation layer (in %).

Measurement time:

Before[Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Plot or stand	3	2	Other indicators of plant/biodiversity indicators and SFM indicators 4.1 Tree species composition/Diversity of tree species and indicator 4.3 Naturalness and Plant species richness indicator.

Results and conclusion from ManForC.BD.:

Indicator name	Site/treatment	Before	After
Vertical vegetation structure	MEAN COVER OF LAYERS in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo)	Tree layer cover: 95.4% Shrub layer cover: 7.1% Herb layer cover: 27.5% Moss layer cover: 24.9%	Tree layer cover: 48.0% Shrub layer cover: 7.3% Herb layer cover: 47.5% Moss layer cover: 22.9%

Indicator name	Site	Before (mean herb-layer cover (in %) per plot)	After (mean herb-layer cover (in %) per plot)
Vertical vegetation structure	Kočevski Rog	23.6	40.6
Vertical vegetation structure	Snežnik	21.7	38.9
Vertical vegetation structure	Trnovo	37.2	63.1

Indicator name	Treatment	Before (mean herb-layer cover (in %) per plot)	After (mean herb-layer cover (in %) per plot)
Vertical vegetation structure	Control	25.0	23.3
Vertical vegetation structure	50% logging	33.3	51.1
Vertical vegetation structure	100% logging	24.1	68.1

PLANT DIVERSITY INDEXES (SLOVENIA)

Full text: A plant diversity index is a quantitative measure for biodiversity.

Rationale: A plant diversity index is a measure that reflects how many different plant species occur in a forest type (or stand or plot), and simultaneously takes into account how evenly plant species are distributed within this forest type (or stand or plot). The value of a plant diversity index increases both when the number of types increases and when evenness increases. For a given number of species, the value of a plant diversity index is maximized when all species are equally abundant.

Method: The Shannon index or Shannon's diversity index is calculated as follows:

$$H' = -\sum_{i=1}^{R} p_i ln p_i$$

The Simpson index is calculated as follows:

$$\lambda = \sum_{i=1}^{R} p_i^2$$

where p_i is a relative cover of species *i* in a record.

Measurement units:

– Status: Values of Shannon/Simpson index.

– Changes: Values of Shannon/Simpson index.

Measurement time:

Before[Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Plot or stand level	4	3	Other indicators of plant/biodiversity indicators and SFM indicators 4.1 Tree species composition/Diversity of tree species and indicator 4.3 Naturalness and Plant species richness indicator/Vertical vegetation structure)

Results and conclusion from ManForC.BD.:

Indicator name	Site/treatment	Before	After
Plant diversity indexes mean values of plant diveristy indexes	in 27 plots in 3 Slovenian sites (8-Kočevski Rog; 9-Snežnik; 10-Trnovo)	Shannon index: 2.413Simpson index: 0.801	Shannon index: 3.074 Simpson index: 0.881
Plant diversity indexes MEAN values of simpson index	in plots of 3 silvicultural measures (control plots without logging, plots with logging 50% of GS, plots with logging 100% of GS)	Control: 0.811 50% logging: 0.812 100% logging: 0.782	Control: 0.822 50% logging: 0.896 100% logging: 0.926

Indicator name	Site	Before (mean value of Shannon index per plot)	After (mean value of Shannon index per plot)
Plant diversity indexes	Kočevski Rog	2.53	3.01
Plant diversity indexes	Snežnik	2.40	3.30
Plant diversity indexes	Trnovo	2.31	2.91

STAND STRUCTURAL COMPLEXITY

Full text

Indexing changes towards the structural, compositional and functional diversity at the stand scale

Rationale

The basic features of a large share of cultivated forests over Europe present a diffuse uniformity of stand structures and of a nearly monospecific composition, either because of the autoecology of component tree species (e.g. beech forests) or due to former choices of removing less valuable (in terms of timber) or less productive species. Current trend of forest management is aimed at improving the overall stand complexity to meet the manifold goals addressed over the same forest or forest patch, i.e. the stand level. Efforts are therefore made to mimic a more "natural" physiognomy through the use of consistent silvicultural practices, designed to maintain the affordable cost of interventions and to improve as well the three components of diversity i.e. the structural, compositional and functional types at the operative or stand level.

Method

Permanent plots to measure and compare the change in progress within a series of suited indexes descriptive of types of diversity along with the development of applied silvicultural practice. Measurements have to be repeated before and after any silvicultural operations to determine their impact on the parameters concerning structural, compositional and functional diversity.

Measurement units:

- Status: Value of descriptive indexes
- Changes: The same as for status
- **Measurement time:**

Before [Y]

After [Y]

Feasibility:

Scale of application	Specific knowledge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Basal Area, Diameter distribution

Results and conclusion from ManForC.BD.:

Aggregation Index [CE] (Clark and Evans, 1954)

Indicator name	Site	Before	After
CE	Cansiglio Innovative	1.22	1.38
CE	Cansiglio Traditional	1.24	1.34
CE	Chiarano Traditional	1.19	1.29
CE	Chiarano I80	1.19	1.29
CE	Chiarano I40	1.11	1.23
CE	Lorenzago Area 1 Innovative	0.90	0.86
CE	Lorenzago Area 1 Traditional	1.00	0.99
CE	Lorenzago Area 2 Innovative	1.03	0.80
CE	Lorenzago Area 2 Traditional	1.03	0.94
CE	Mongiana Innovative	1.14	1.21
CE	Mongiana Traditional	1.16	1.21
CE	Pennataro Mixed forest	0.97	1.13
CE	Pennataro Turkey oak forest	1.05	1.15
CE	Tarvisio Innovative1	0.94	1.07
CE	Tarvisio Innovative2	0.92	1.05
CE	Tarvisio Traditional	0.95	0.95
CE	Vallombrosa Innovative	1.32	1.41
CE	Vallombrosa Traditional	1.31	1.32

DBH - Differentiation [TD] (Pommerening, 2002)

Indicator name	Site	Before	After
TD	Cansiglio Innovative	0.19	0.19
TD	Cansiglio Traditional	0.19	0.18
TD	Chiarano Traditional	0.25	0.18
TD	Chiarano I80	0.27	0.24
TD	Chiarano I40	0.26	0.23
TD	Lorenzago Area 1 Innovative	0.41	0.47
TD	Lorenzago Area 1 Traditional	0.44	0.44
TD	Lorenzago Area 2 Innovative	0.36	0.32
TD	Lorenzago Area 2 Traditional	0.50	0.35
TD	Mongiana Innovative	0.24	0.25
TD	Mongiana Traditional	0.25	0.25
TD	Pennataro Mixed forest	0.40	0.42
TD	Pennataro Turkey oak forest	0.41	0.43
TD	Tarvisio Innovative1	0.32	0.32
TD	Tarvisio Innovative2	0.30	0.32
TD	Tarvisio Traditional	0.30	0.31
TD	Vallombrosa Innovative	0.25	0.28
TD	Vallombrosa Traditional	0.22	0.23

Diameter diversity based on variance [$STVI_{dbh}$] (Staudhammer and LeMay, 2011)

Indicator name	Site	Before	After
$STVI_{dbh}$	Cansiglio Innovative	0.31	0.27
$STVI_{dbh}$	Cansiglio Traditional	0.28	0.26
$STVI_{dbh}$	Chiarano Traditional	0.20	0.17
$STVI_{dbh}$	Chiarano I80	0.22	0.18
$STVI_{dbh}$	Chiarano I40	0.20	0.13
$STVI_{dbh}$	Lorenzago Area 1 Innovative	1.00	1.00
$STVI_{dbh}$	Lorenzago Area 1 Traditional	1.00	1.00
$STVI_{dbh}$	Lorenzago Area 2 Innovative	0.67	0.60
$STVI_{dbh}$	Lorenzago Area 2 Traditional	1.00	0.60
$STVI_{dbh}$	Mongiana Innovative	0.46	0.49
$STVI_{dbh}$	Mongiana Traditional	0.50	0.49
$STVI_{dbh}$	Pennataro Mixed forest	0.88	0.83
$STVI_{dbh}$	Pennataro Turkey oak forest	0.77	0.75
$STVI_{dbh}$	Tarvisio Innovative1	0.37	0.33
$STVI_{dbh}$	Tarvisio Innovative2	0.36	0.36
$STVI_{dbh}$	Tarvisio Traditional	0.42	0.41
$STVI_{dbh}$	Vallombrosa Innovative	0.42	0.46
$STVI_{dbh}$	Vallombrosa Traditional	0.29	0.29

Height - Differentiation [TH] (Pommerening, 2002)

Indicator name	Site	Before	After
TH	Cansiglio Innovative	0.07	0.07
TH	Cansiglio Traditional	0.06	0.06
TH	Chiarano Traditional	0.13	0.08
TH	Chiarano I80	0.14	0.12
TH	Chiarano I40	0.14	0.11
TH	Lorenzago Area 1 Innovative	0.46	0.46
TH	Lorenzago Area 1 Traditional	0.43	0.43
TH	Lorenzago Area 2 Innovative	0.27	0.25
TH	Lorenzago Area 2 Traditional	0.46	0.25
TH	Mongiana Innovative	0.11	0.11
TH	Mongiana Traditional	0.12	0.13
TH	Pennataro Mixed forest	0.29	0.30
TH	Pennataro Turkey oak forest	0.31	0.32
TH	Tarvisio Innovative1	0.24	0.28
TH	Tarvisio Innovative2	0.21	0.20
TH	Tarvisio Traditional	0.22	0.21
TH	Vallombrosa Innovative	0.12	0.14
TH	Vallombrosa Traditional	0.12	0.12

Height diversity based on variance [$STVI_{htot}$] (Staudhammer and LeMay, 2011)

Indicator name	Site	Before	After
$STVI_{htot}$	Cansiglio Innovative	0.05	0.04
$STVI_{htot}$	Cansiglio Traditional	0.06	0.07
$STVI_{htot}$	Chiarano Traditional	0.05	0.02
$STVI_{htot}$	Chiarano I80	0.06	0.04
$STVI_{htot}$	Chiarano I40	0.06	0.04
$STVI_{htot}$	Lorenzago Area 1 Innovative	0.99	0.99
$STVI_{htot}$	Lorenzago Area 1 Traditional	1.00	1.00
$STVI_{htot}$	Lorenzago Area 2 Innovative	0.62	0.55
$STVI_{htot}$	Lorenzago Area 2 Traditional	1.00	0.60
$STVI_{htot}$	Mongiana Innovative	0.10	0.11
$STVI_{htot}$	Mongiana Traditional	0.14	0.15
$STVI_{htot}$	Pennataro Mixed forest	0.63	0.63
$STVI_{htot}$	Pennataro Turkey oak forest	0.56	0.51
$STVI_{htot}$	Tarvisio Innovative1	0.27	0.15
$STVI_{htot}$	Tarvisio Innovative2	0.24	0.20
$STVI_{htot}$	Tarvisio Traditional	0.29	0.23
$STVI_{htot}$	Vallombrosa Innovative	0.12	0.14
$STVI_{htot}$	Vallombrosa Traditional	0.10	0.10

BAL modified [BAL_{MOD}] (Schröder and Gadow, 1999)

Indicator name	Site	Before	After
BAL_{MOD}	Cansiglio Innovative	0.66	0.46
BAL_{MOD}	Cansiglio Traditional	0.67	0.53
BAL_{MOD}	Chiarano Traditional	0.59	0.33
BAL_{MOD}	Chiarano I80	0.63	0.40
BAL_{MOD}	Chiarano I40	0.68	0.39
BAL_{MOD}	Lorenzago Area 1 Innovative	3.46	3.22
BAL_{MOD}	Lorenzago Area 1 Traditional	3.44	3.02
BAL_{MOD}	Lorenzago Area 2 Innovative	2.18	1.32
BAL_{MOD}	Lorenzago Area 2 Traditional	2.97	1.80
BAL_{MOD}	Mongiana Innovative	0.93	0.84
BAL_{MOD}	Mongiana Traditional	0.95	0.86
BAL_{MOD}	Pennataro Mixed forest	1.39	1.00
BAL_{MOD}	Pennataro Turkey oak forest	1.28	0.83
BAL_{MOD}	Tarvisio Innovative1	1.04	0.55
BAL_{MOD}	Tarvisio Innovative2	1.02	0.74
BAL_{MOD}	Tarvisio Traditional	1.07	0.88
BAL_{MOD}	Vallombrosa Innovative	0.77	0.62
BAL_{MOD}	Vallombrosa Traditional	0.77	0.77

Haegyi [Hg] (Haegyi, 1974)

Indicator name	Site	Before	After
Hg	Cansiglio Innovative	0.77	0.34
Hg	Cansiglio Traditional	0.79	0.47
Hg	Chiarano Traditional	1.77	0.66
Hg	Chiarano I80	1.67	0.64
Hg	Chiarano I40	2.27	0.63
Hg	Lorenzago Area 1 Innovative	1.56	1.09
Hg	Lorenzago Area 1 Traditional	1.60	1.39
Hg	Lorenzago Area 2 Innovative	1.82	0.82
Hg	Lorenzago Area 2 Traditional	1.21	1.31
Hg	Mongiana Innovative	1.22	0.84
Hg	Mongiana Traditional	1.19	0.90
Hg	Pennataro Mixed forest	2.12	0.82
Hg	Pennataro Turkey oak forest	1.98	0.72
Hg	Tarvisio Innovative1	3.14	1.05
Hg	Tarvisio Innovative2	3.24	1.68
Hg	Tarvisio Traditional	2.81	2.16
Hg	Vallombrosa Innovative	1.29	0.72
Hg	Vallombrosa Traditional	1.45	1.40

Haegyi modified [Hg mod] (Pretzsch, 2010)

Indicator name	Site	Before	After
Hg mod	Cansiglio Innovative	0.97	0.47
Hg mod	Cansiglio Traditional	0.95	0.59
Hg mod	Chiarano Traditional	1.88	0.79
Hg mod	Chiarano I80	1.91	0.78
Hg mod	Chiarano I40	2.29	0.81
Hg mod	Lorenzago Area 1 Innovative	2.37	1.91
Hg mod	Lorenzago Area 1 Traditional	2.19	1.80
Hg mod	Lorenzago Area 2 Innovative	2.00	0.97
Hg mod	Lorenzago Area 2 Traditional	1.65	1.23
Hg mod	Mongiana Innovative	1.25	0.96
Hg mod	Mongiana Traditional	1.24	0.89
Hg mod	Pennataro Mixed forest	2.11	0.92
Hg mod	Pennataro Turkey oak forest	1.99	0.76
Hg mod	Tarvisio Innovative1	2.84	1.04
Hg mod	Tarvisio Innovative2	2.70	1.40
Hg mod	Tarvisio Traditional	2.57	1.85
Hg mod	Vallombrosa Innovative	1.34	0.70
Hg mod	Vallombrosa Traditional	1.39	1.33

NOVEL SILVICULTURAL AND MANAGEMENT PRACTICES

Full text

Novel silvicultural practices: from mass to selective tending.

Rationale

Forest customarily devoted to timber production are nowadays managed according to manifold goals, i.e. wood production but also other non wood productions, biodiversity, recreation, amenity and scenic value. Traditional rotations are in the meantime becoming longer and canonical silvicultural practices applied in the past, in full accordance with the former management models, may be adapted to the new scenario and to multiple management goals. Into even-aged forests it basically means to move from a mass tending of standing crop to the selective tending of a number of final crop trees, to ensure their “health and vitality” up to the farther regeneration time. This approach is economically more feasible because: aimed at spatially concentrating intermediate fellings all around selected trees; operates also in the co-dominant and dominant layers and this results in the higher exploited woody mass; breaks the uniformity of the stand structure usually one-storied and is the basis to build up a more differentiated and complex structure over the following permanence time; promotes the even residual specific diversity preserving other species at tree level; creates new habitats and related ecological niches. As for uneven-aged forests, the formal shift is basically from the single-tree to the small-group harvesting, promoting more easily enforceable technical operations and preserving as well patchy unevenness at the stand scale.

Method

Permanent sampling plots to measure and compare the changes in terms of harvested wood and of the indexes of tree size range and relative frequencies, biomass allocation per layer, stand structure evenness and specific diversity. Measurements have to be repeated before and after any silvicultural operations to determine their impact on stand texture.

Measurement units:

- Status: Number of trees (tree density), allocation of number of trees per layer; relative tree size distributive patterns: basal area per layer and diameter distribution per layer.
- Changes: The same as for status.

Measurement time:

Before [Y]

After [Y]

Feasibility:

Scale of application	Specific knowlwdge	Costs	Interaction with other indicators
Stand	2 (inventory technician)	2	Carbon stock, Basal Area, Diameter distribution

Results and conclusion from ManForC.BD.:

Indicator name	Site	Layer	Before	After
Tree density per layer (n ha^{-1})	Cansiglio Innovative	Dominant	85	64
		Codominant	210	110
		Overtopped	26	5
Tree density per layer (n ha^{-1})	Cansiglio Traditional	Dominant	139	112
		Codominant	161	105
		Overtopped	25	9
Tree density per layer (n ha^{-1})	Chiarano Traditional	Dominant	241	218
		Codominant	686	341
		Overtopped	350	36
Tree density per layer (n ha^{-1})	Chiarano Innovative 80	Dominant	303	234
		Codominant	603	314
		Overtopped	391	96

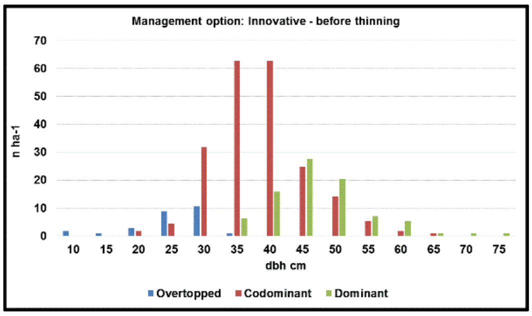
Tree density per layer (n ha^{-1})	Chiarano Innovative 40	Dominant	272	207
		Codominant	866	379
		Overtopped	391	73
Tree density per layer (n ha^{-1})	Lorenzago Area 1 Innovative	Dominant	131	103
		Codominant	110	95
		Overtopped	446	400
Tree density per layer (n ha^{-1})	Lorenzago Area 1 Traditional	Dominant	120	95
		Codominant	88	67
		Overtopped	371	325
Tree density per layer (n ha^{-1})	Lorenzago Area 2 Innovative	Dominant	131	81
		Codominant	180	74
		Overtopped	170	60
Tree density per layer (n ha^{-1})	Lorenzago Area 2 Traditional	Dominant	95	81
		Codominant	255	191
		Overtopped	325	117
Tree density per layer (n ha^{-1})	Mongiana Innovative	Dominant	302	234
		Codominant	150	118
		Overtopped	75	66
Tree density per layer (n ha^{-1})	Mongiana Traditional	Dominant	219	184
		Codominant	157	126
		Overtopped	103	98
Tree density per layer (n ha^{-1})	Pennataro Mixed forest	Dominant	254	184
		Codominant	145	91
		Overtopped	1285	542
Tree density per layer (n ha^{-1})	Pennataro Turkey oak forest	Dominant	310	171
		Codominant	192	96
		Overtopped	1779	676
Tree density per layer (n ha^{-1})	Tarvisio Innovative 1	Dominant	357	226
		Codominant	645	241
		Overtopped	500	124
Tree density per layer (n ha^{-1})	Tarvisio Innovative 2	Dominant	234	170
		Codominant	984	590
		Overtopped	295	144
Tree density per layer (n ha^{-1})	Tarvisio Traditional	Dominant	213	188
		Codominant	841	640
		Overtopped	383	245
Tree density per layer (n ha^{-1})	Vallombrosa Innovative	Dominant	242	157

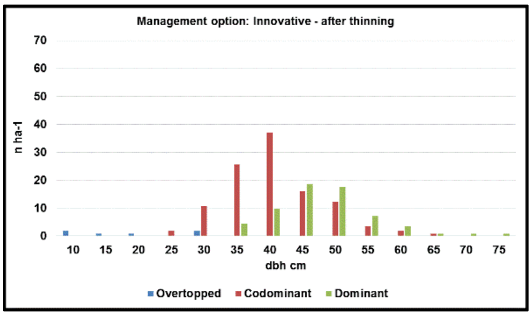
		Codominant	178	88
		Overtopped	88	71
Tree density per layer (n ha^{-1})	Vallombrosa Traditional	Dominant	266	261
		Codominant	215	211
		Overtopped	107	101

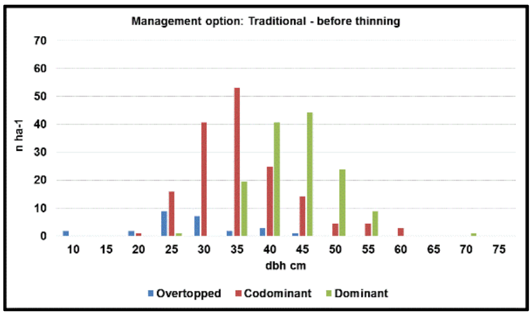
Indicator name	**Site**	**Layer**	**Before**	**After**
Basal area per layer (m^2 ha^{-1})	Cansiglio Innovative	Dominant	15.1	11.7
		Codominant	25.3	14.6
		Overtopped	1.4	0.2
Basal area per layer (m^2 ha^{-1})	Cansiglio Traditional	Dominant	21.0	17.3
		Codominant	17.0	11.9
		Overtopped	1.6	1.7
Basal area per layer (m^2 ha^{-1})	Chiarano Traditional	Dominant	12.5	11.6
		Codominant	19.0	10.9
		Overtopped	5.1	0.6
Basal area per layer (m^2 ha^{-1})	Chiarano Innovative 80	Dominant	17.0	13.5
		Codominant	18.0	9.9
		Overtopped	5.4	1.4
Basal area per layer (m^2 ha^{-1})	Chiarano Innovative 40	Dominant	13.6	10.6
		Codominant	21.8	11.4
		Overtopped	4.8	1.0
Basal area per layer (m^2 ha^{-1})	Lorenzago Area 1 Innovative	Dominant	30.6	23.7
		Codominant	12.6	11.0
		Overtopped	10.0	8.5
Basal area per layer (m^2 ha^{-1})	Lorenzago Area 1 Traditional	Dominant	31.1	24.3
		Codominant	15.7	11.2
		Overtopped	12.0	10.9
Basal area per layer (m^2 ha^{-1})	Lorenzago Area 2 Innovative	Dominant	25.0	16.2
		Codominant	11.9	8.6
		Overtopped	6.7	3.3
Basal area per layer (m^2 ha^{-1})	Lorenzago Area 2 Traditional	Dominant	16.8	14.7
		Codominant	33.2	25.0
		Overtopped	8.0	3.5
Basal area per layer (m^2 ha^{-1})	Mongiana Innovative	Dominant	30.0	23.5
		Codominant	9.0	6.9
		Overtopped	2.6	2.2

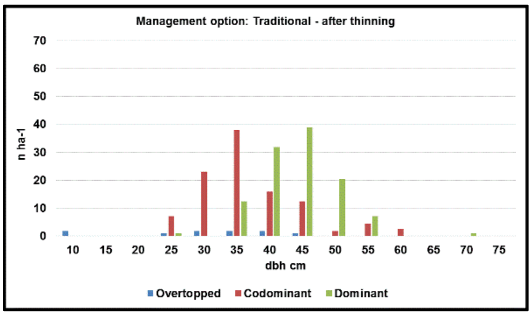
Basal area per layer (m^2 ha^{-1})	Mongiana Traditional	Dominant	25.5	21.1
		Codominant	10.3	7.6
		Overtopped	3.0	2.8
Basal area per layer (m^2 ha^{-1})	Pennataro Mixed forest	Dominant	23.8	16.8
		Codominant	5.9	3.8
		Overtopped	8.9	4.4
Basal area per layer (m^2 ha^{-1})	Pennataro Turkey oak forest	Dominant	24.6	15.9
		Codominant	9.1	4.8
		Overtopped	9.9	4.5
Basal area per layer (m^2 ha^{-1})	Tarvisio Innovative 1	Dominant	21.2	16.5
		Codominant	19.3	7.6
		Overtopped	7.3	1.8
Basal area per layer (m^2 ha^{-1})	Tarvisio Innovative 2	Dominant	13.5	11.5
		Codominant	21.8	12.2
		Overtopped	2.7	1.1
Basal area per layer (m^2 ha^{-1})	Tarvisio Traditional	Dominant	14.0	12.6
		Codominant	18.0	13.6
		Overtopped	3.7	2.3
Basal area per layer (m^2 ha^{-1})	Vallombrosa Innovative	Dominant	34.9	23.9
		Codominant	17.5	9.3
		Overtopped	4.6	3.4
Basal area per layer (m^2 ha^{-1})	Vallombrosa Traditional	Dominant	30.9	30.3
		Codominant	18.8	18.4
		Overtopped	4.6	4.4

Cansiglio









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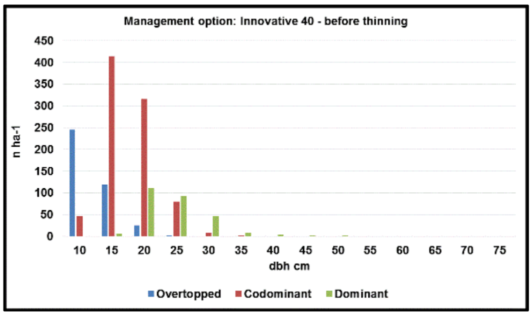

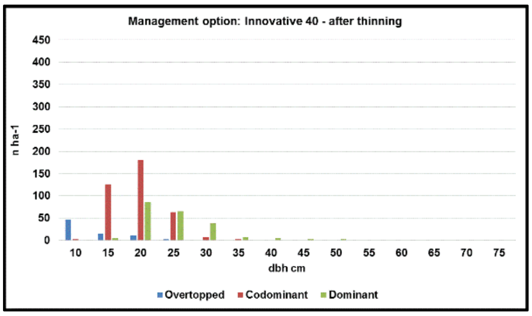

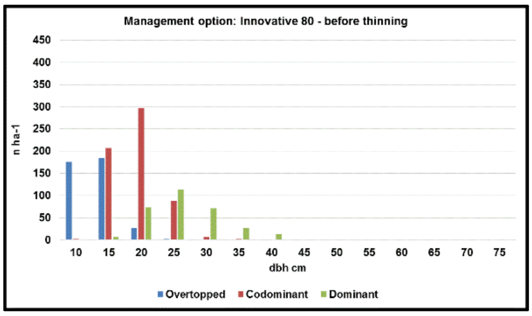

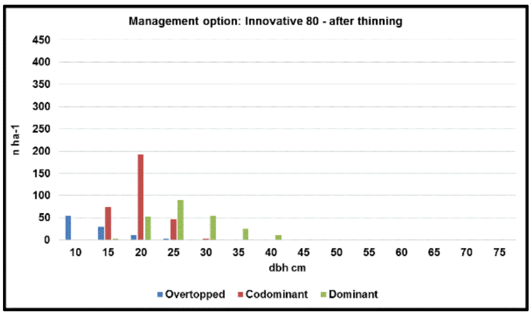

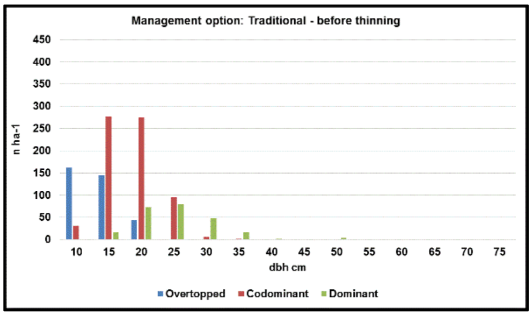

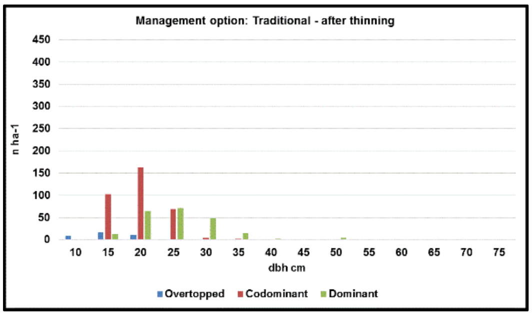

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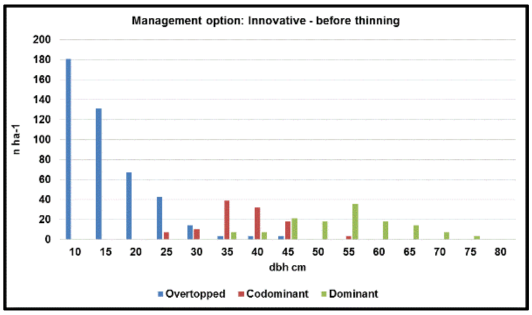

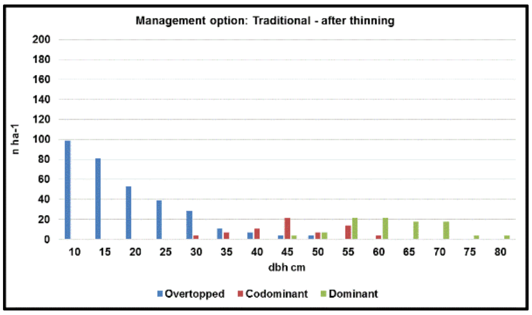

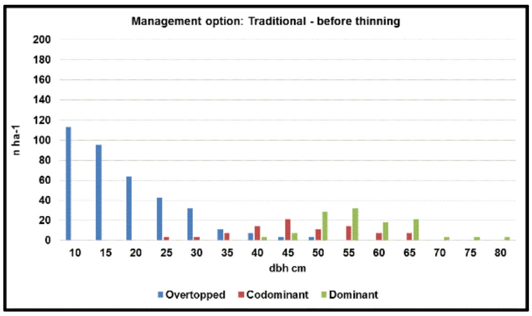

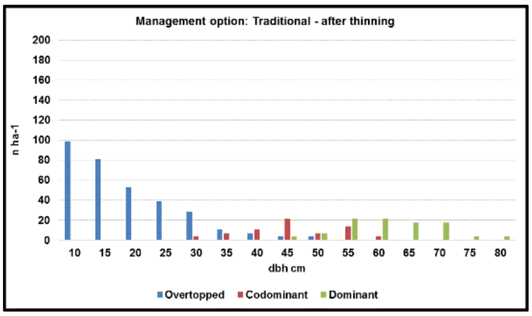

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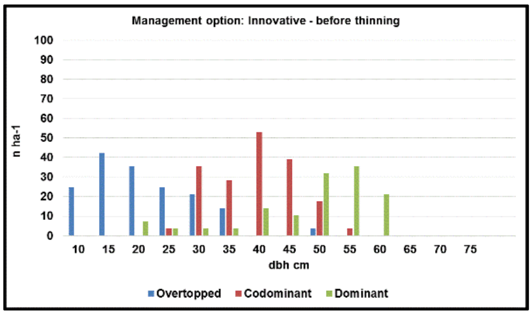

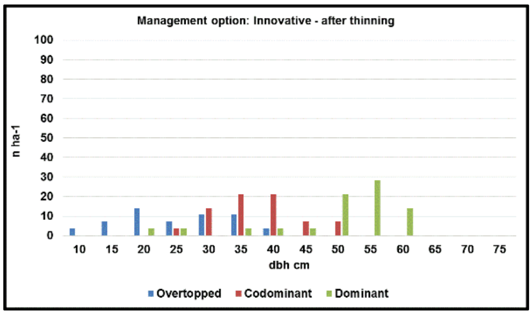

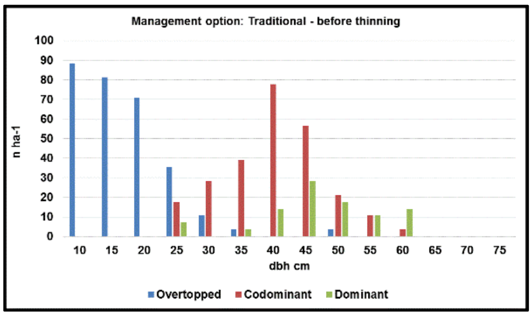

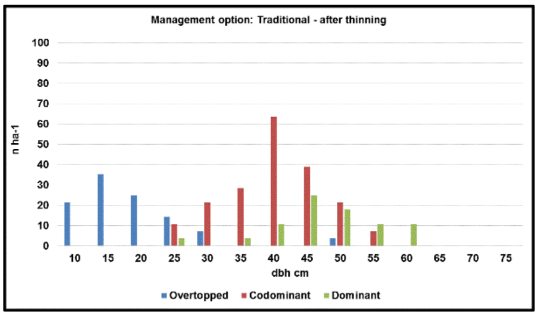

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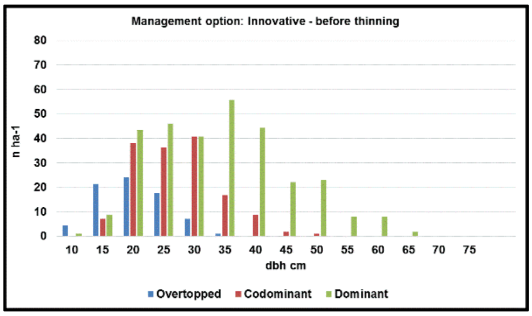

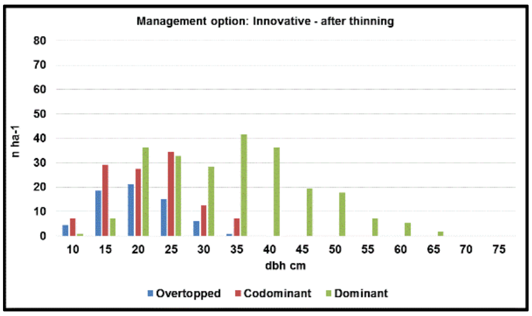

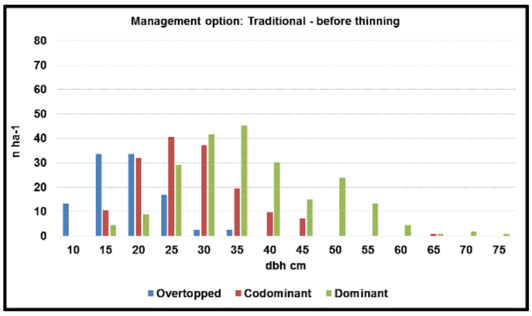

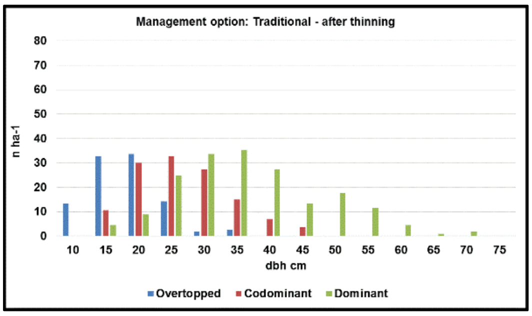

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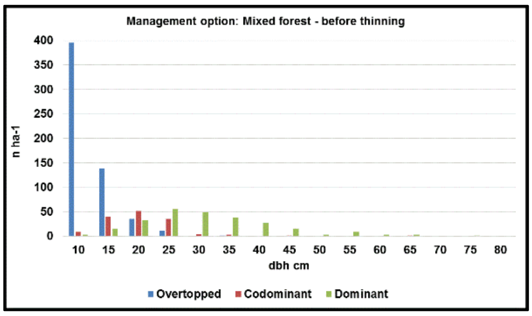
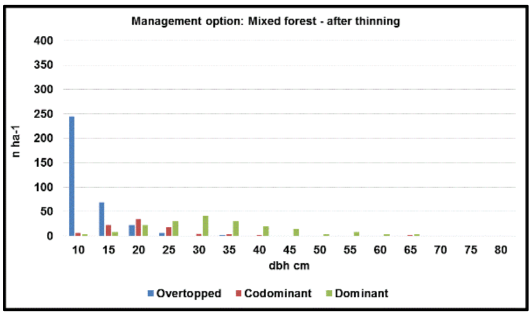
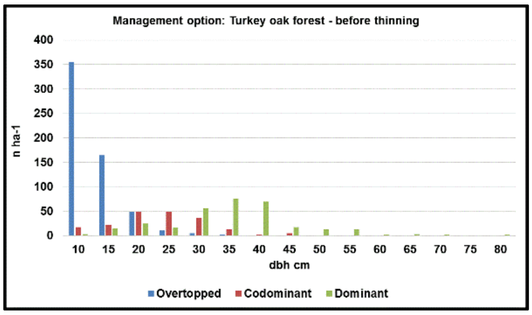
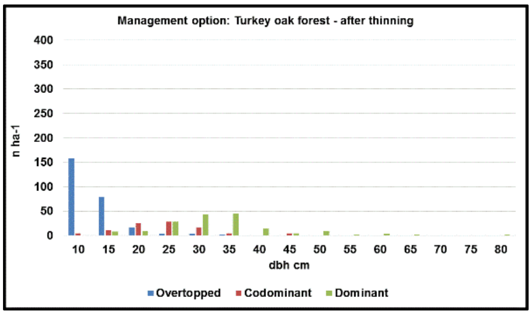
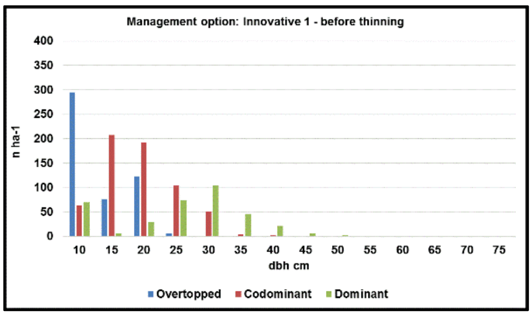


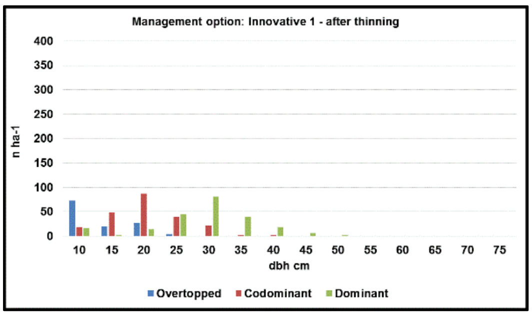


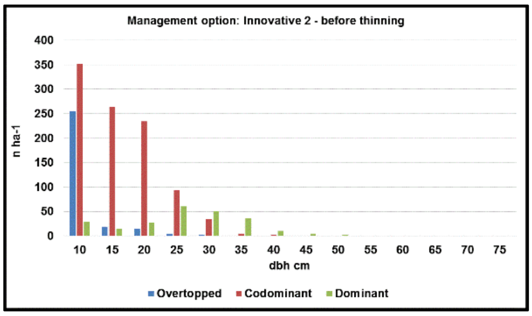


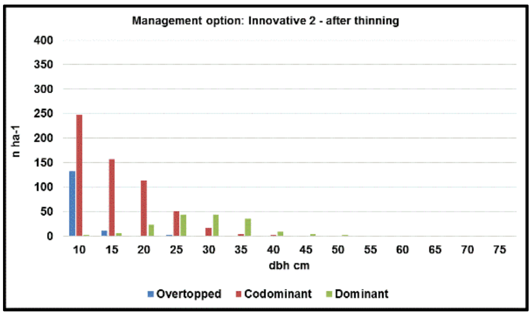


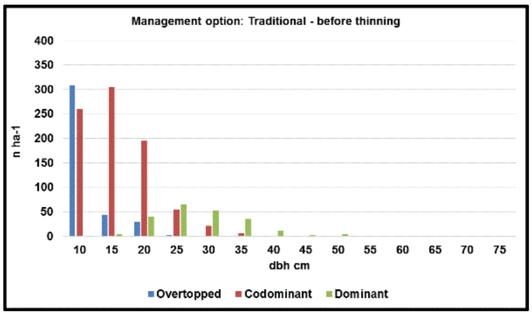
Tarvisio

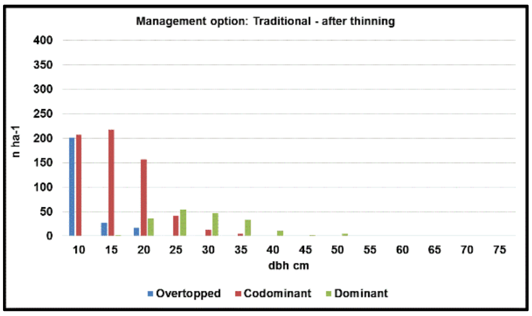




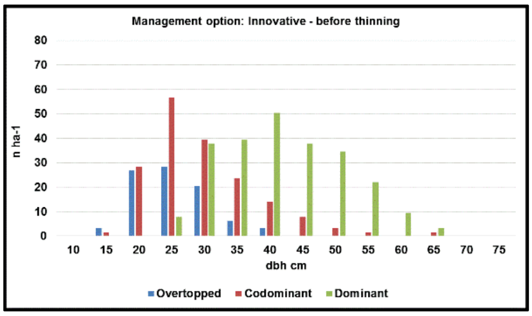


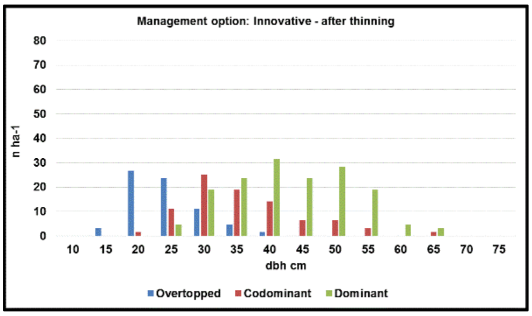


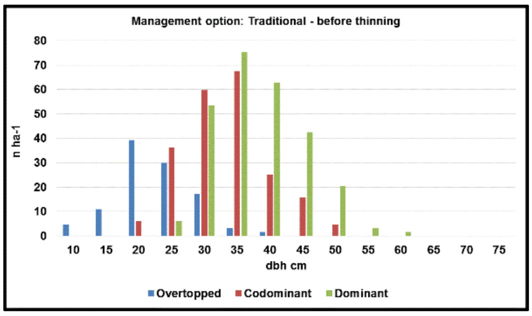


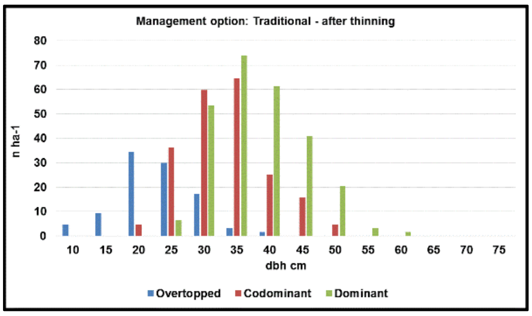


Vallombrosa









OTHER POTENTIAL INDICATORS RELATED TO VEGETATION DIVERSITY

Horizontal structure indicators (share of different forest types within area): number and share of vegetation syntaxa (e.g. association, geographic variance, sub-association, facies); number and share of habitat types (e.g. Natura 2000 habitat types, PHYSIS habitat type, EUNIS habitat type, etc).

Life forms (based on the place of the plant's growth-point (bud) during seasons with adverse conditions): Structure of Raunkiær's life forms (e.g. share of Phanerophyte, Chamaephytes, Hemicryptophyte, Geophytes, Therophyte)(Raunkiær 1934).

Plant functional traits (functional traits of species as indicator of species' persistence and recovery following habitat change or disturbance):Grime's CSR strategies (share of Competitor species (C; adapted to low stress and low levels of disturbance), Stress-tolerator species (S; adapted to high stress and low levels of disturbance), and Ruderal species (R; adapted to low stress and high levels of disturbance) (Grime, 1977);LEDA trait based functional traits (e.g. Mean canopy height, Age of first flowering, Seed mass) (Kleyer et al. 2008); BIOLFLOR trait based functional traits (e.g. Vegetative propagation and dispersal, Leaf persistence, Pollen vector) (Klotz et al. 2002) etc.

Plant species indicators (presence/absence and status of key plant species or group of species):Number, vitality and abundance of characteristic species (e.g. for association, geographic variance habitat type);Number, vitality and abundance of environmental sensitive species (e.g. shade tolerant species, cold site species, dry tolerant species, nutrient indicator species), etc.

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Conclusions

Over the past 25 years, the criteria and indicators for sustainable forest management (SFM) have been powerful tools and have played a key role in the management and monitoring of European forests. As reported in the literature, the main merits of Criteria and Indicators implementation are (Grainger, 2012; Wijewardana, 2008):

- supporting a global understanding of what constitutes SFM;
- a vehicle to foster political processes on SFM;
- find a common symbolic language to overcome historic conflicts (e.g., forestry vs. environmentalists) and hence support consensus-finding;
- find a common terminology in the global environmental governance;
- substantial progress in streamlining and structuring forest reporting;
- support unambiguous communication and learning among stakeholders;
- serving as a means for education and capacity building by fostering participatory decision-making and decentralized policy implementation.

They are not only a mechanism for systematically implementing sustainable forest management procedures, but also an effective means of assessing and reporting progress (Wijewardana, 2008).

As Dale and Beyeler (2001) suggest, ecological indicators need to capture the complexities of the ecosystem yet remain simple enough to be easily and routinely monitored. Those indicators can be used to assess the condition of the environment, to provide an early warning signal of changes in the environment, or to diagnose the cause of an environmental problem. For this purpose indicators should meet the following criteria: (1) be easily measured; (2) be sensitive to stresses on the system; (3) respond to stress in a predictable manner; (4) be anticipatory; (5) predict changes that can be averted by management actions; (6) be integrative; (7) have a known response to disturbances, anthropogenic stresses and changes over time; and (8) have low variability in response (Dale and Beyeler, 2001).

Indicators are not just data, but represent dynamic processes within ecosystems. They need to be analysed meaningfully to determine trends and identify the policy interventions needed to redress any imbalances. This requires common understanding on key concepts and definitions along with skill, training and experience to interpret them (Dale and Beyler, 2001).

While the major focus of the regional and international processes has been the national level implementation of criteria and indicators, at the Forest Management Unit level measurements can be more precise, and the impact of forest management practices on the forest, and on local populations, is more evident. (Wijewardana, 2008).

On a more technical level it was also reported that criteria and indicators have proven strengths for measuring aspects of SFM at regional and forest management unit level (Mendoza and Prabhu, 2000; Raison et al., 2001), facilitating global convergence in the understanding of criteria and indicators (McDonald and Lane, 2004), serving as a reference for regional and local criteria and indicators application (e.g., Adam and Kneeshaw, 2008), allowing for combined top-down and bottom-up approaches in criteria and indicators development (Khadka et al., 2012) and supporting participatory process in forest management pianification (Paletto et al., 2014).

Furthermore, the experience of the studies presented in this work suggests that the use by the silviculturist of the criteria for SFM at forest management unit level could be crucial to help the choice of silvicultural treatment (Figure 1).

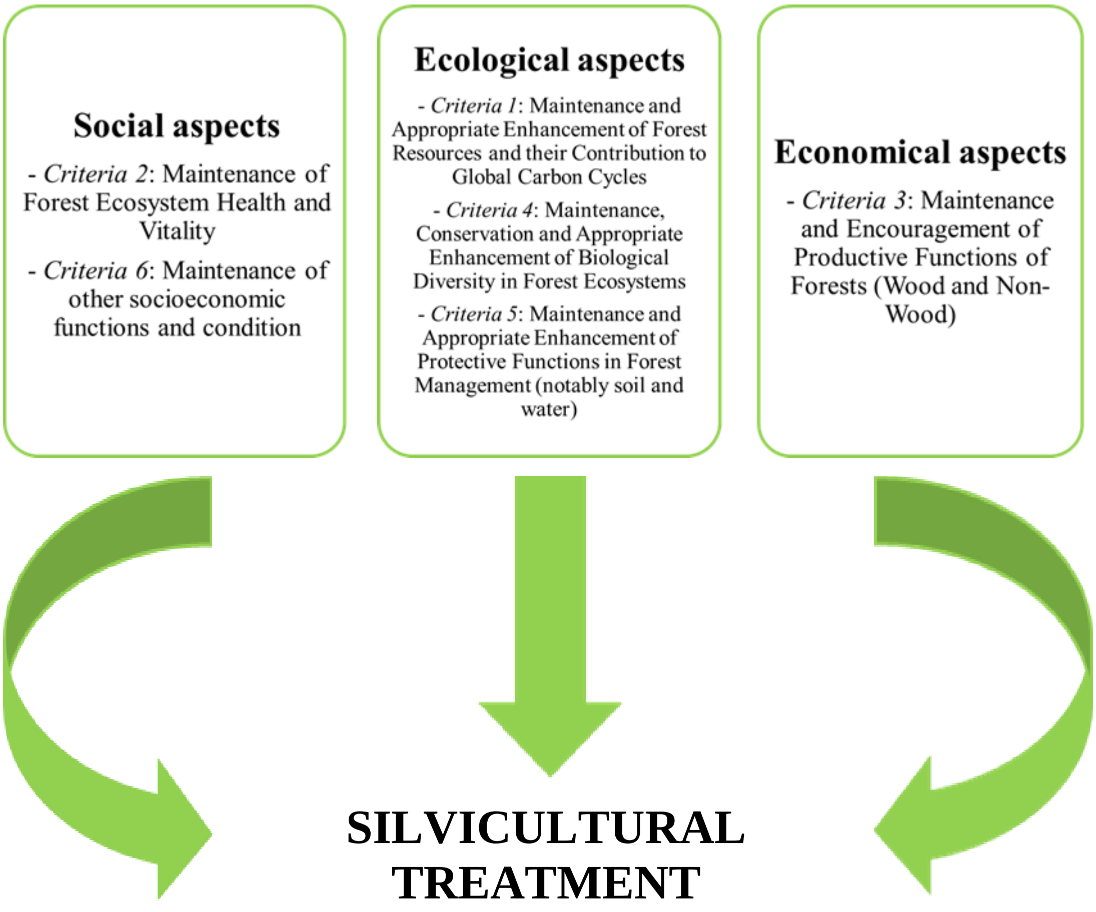

Figure 1. **SUSTAINABLE FOREST MANEGEMENT CRITERIA AND INDICATORS AS A TOOLS TO CHOICE A SILVICULTURAL TREATMENT**

Practically, the traditional approach to choice the silvicultural treatment depends on several factors that can be summarized in three fundamental questions: what the history of the forest is, its current status and how it will evolve in the future. This questions could be answered by using SFM criteria and indicators explicitly tailored for the forest management unit level.

Mainly, when we manage a forest using a traditional approach our first goal or, more precisely, our unique goal is to reach the maximum productivity ensuring forest regeneration and protection against soil erosion and flood. Usually, we do not consider to preserve some habitat trees, to increase deadwood amount, or to increase diversity at stand and landscape scale. Similarly we do not take into account if the carbon fluxes are positive or negative. In other words, normally the traditional approach does not take into account the six criteria of sustainable forest management (FOREST EUROPE, 2015).

A lot of tools useful to evaluate productivity are available, yet it isn't the case of the other criteria. Combining the traditional approach to choice the silvicultural treatment and the SFM criteria and indicators could be helpful to fill this gap

The innovative approach proposed to choice the silvicultural treatment (Figure 1) is intended to demonstrate that it is possible to carry out management options characterized by high levels of multifunctionality and able to promote the achievement of the "Goals for European Forests" (FOREST EUROPE, 2015): to enhance provision of goods and services and to increase the potential of forests to mitigate climate change, through carbon sequestration in trees and soils, carbon storage in forest products and substitution of non-renewable material and energy sources (producing good quality wood for marking durable products for competing materials having a larger atmospheric CO_2 footprint, increasing the economic value of the forest through increased incremental reaction, increasing vertical structural diversity to improve photosynthesis and carbon storage); to reduce the loss of biodiversity (the opening of small gaps in the canopy cover determines the possible coexistence of different species both animal and vegetal; to increase forest healthy and resilience (increasing mechanical stability of the standing trees, increasing the flexibility of future management options: the greater stability of forest stand allows to increase the rotation length and to have a wide range of silvicultural choices in phase of the regeneration of the forest).

Finally, taking into account the Sustainable Forest Management paradigm (defined at the Montreal Process, 1987), 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 (Garcıa-Fernandez et al.. 2008) and on the stakeholders' needs (Paletto et al., 2014) management plans must reflect these aspects of forest life and address the management goals at appropriate scales.

For example, soil and water values need to be protected at the site level by local engineering measures, while others (e.g. home range and population targets of large vertebrates) must be considered at the whole forest scale. Wood production goals will also be set at larger scales, with some patches of forest making no contribution and others making a large contribution. This is effectively a zoning of forest use to meet agreed objectives (Raison et al., 2001).

The use of indicators as a tool for addressing silvicultural choices should take into account that indicators at the forest management unit level will be influenced by factors such as forest type and topography, in addition to social and economic considerations.

Forest management unit level criteria and indicators may thus differ among individual forest areas , as well as over time, depending on the prevailing conditions, priorities and aims of management of a given forest area. Interventions in individual forest areas should complement each other in space and time (Castañeda, 2000).

With these premises will be necessary that the Forest Management Plan gives full details of silviculture treatments on a case-by-case basis, specifying the different best practices in space and in time. It is actually important to plan forest management at a not only stand level but also at a landscape level. In such a way the benefits derived from best practices silvicultural treatments fall on to the entire forest and will be constant over time.

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