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open access journal

Italian Journal of Agronomy

Rivista di Agronomia

A Journal of Agroecosystem Management

ISSN 1125-4718

www.agronomy.it

2016 | volume 11 s1

From the experience of LIFE+ ManFor C.BD. to the Manual of Best Practices in Sustainable Forest Management

Editors

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Italian Journal of Agronomy

Publisher

PAGEPress Publications
via Giuseppe Belli 7
27100 Pavia, Italy
Tel. +39.0382.464340 – Fax. +39.0382.34872.
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Italian Journal of Agronomy

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Italian Journal of Agronomy

Rivista trimestrale registrata al Tribunale di Udine
n. 3/97 del 12-2-1997.

Direttore Responsabile: Michele Perniola.

Proprietà: Società Italiana di Agronomia.

Stampa: Press Up s.r.l.
via La Spezia, 118/C 00055 - Ladispoli (RM)
Tel. e Fax: +39.076.15.27.351.

Italian Journal of Agronomy
volume 11(s1), 2016

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The present volume was printed with the contribution of the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

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Acknowledgements

It was possible to write this volume thanks to many people that contributed in different ways to the project activities. We want to acknowledge in particular: Daraio A., Franzè G., Gallè G., Angilletta C., Costa C., Dilena C., Barsottini P., Favero P., Dorigo E., Bortoluzzi L., Azzalini S., Torrini L., Gallipò G., De Vincenzi D., Terlicher P., Vedovato A., Dilena F., Altea T., Bottacci A., Panella M., La Civita F., Salvidio S., Gobbo G., Nicolao B., De Martini E., Consalvo M., Sammarone L. Many other people were involved in the project and we want to show our thankfulness to all of them.

Cite this volume as:

De Cinti et al., (Eds). From the experience of LIFE+ ManFor C.BD to the Manual of Best Practices in Sustainable Forest Management. Italian Journal of Agronomy 2016; 11(s1).

de Groot et al., 2016. Forest management for invertebrate conservation. In: De Cinti et al. (Eds). From the experience of LIFE+ ManFor C.BD to the Manual of Best Practices in Sustainable Forest Management. Italian Journal of Agronomy 2016; 11(s1).

From the experience of LIFE+ ManFor C.BD to the Manual of Best Practices in Sustainable Forest Management

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This volume should be interpreted as a manual of best practices for sustainable forest management deriving from the experience of the project LIFE09ENV/IT/000078 ManFor C.BD coordinated by the National Research Council through the Institute of Agro-environmental and Forest Biology (CNR-IBAF). The other Project partners are: the Council for Agricultural Research and Economics (CREA), the University of Molise (UNIMOL), the Slovenian Forestry Institute (SFI) and the regions of Veneto and Molise. In addition, the National Centre for Forest Biodiversity of Verona and the Regional Office to biodiversity of Castel di Sangro of the Italian National Forest Service (CFS), as well as the Slovenian Forest Service (SFS) collaborated to the project. This manual consists of several individual articles dealing with specific issues related to the project. These articles are conceptually organized into five categories that from the description of the project and of its activities arrive at providing operative indications for forestry operators (Table 1).

The first category is an introductory section where the project itself is described in general terms and positioned into an international context. In particular, Garfì *et al*. (2016) describe the forest governance at European level, introducing the international forestry context referring in particular to sustainable forest management experiences. This contribution contextualizes into the international scenario the national forestry, focusing on Slovenian and Italian forests in terms of forest governance/management options/harvesting methods, and gives an overview on how the project fitted into the two countries legislations. Finally, De Cinti and Kutnar (2016) clarify the project aims and its *modus operandi*.

The second category of papers dealt with defining the requirements of good practices for different aspects of forest services.

This involves to describe the driver factors of forest services (*i.e.*, structure, landscape, and deadwood) as well as the responses to these drivers considered by the project (*i.e.*, wood production, biodiversity conservation, and carbon stocking). In particular, Frate and colleagues (2016) describe the influence of landscape on forest responses. Chiavetta and colleagues (2016) explain the effect of the forest structure on the considered responses. Lombardi and Mali (2016) highlight the importance of deadwood in modifying forest responses. Kovač and Fabbio (2016) describe the best conditions for optimizing the production of wood in terms of driving forces. de Groot and colleagues (2016) illustrate the best conditions of driving forces for the conservation of invertebrates. Costa and colleagues (2016) show the best conditions for the conservations of amphibians and reptiles. Basile *et al*. (2016) explain the optimal conditions for the conservation of birds. Kutnar *et al*. (2016b) focalize on the best condition for the conservation of forest flora. D'Andrea and colleagues (2016a) explain the optimal situation for the maximum capacity of forests to remove carbon form atmosphere and mitigate climate change. Finally, Di Salvatore *et al.* (2016a) synthesize the optimal conditions for all the responses and propose a silvicultural compromise that takes into multiple purposes of management.

The third group of papers describes the contributions of ManFor C.BD to the improvement of multipurpose silvicultural practices. More specifically, the papers show where and how the project activities were carried out for the specific issues and what they indicated in terms of best practices. In particular, Di Salvatore and colleagues (2016c) describe the sites involved in the project. Fabbio *et al*. (2016) quantify the effectiveness of the demonstration experiences carried out in terms of production of wood. Zapponi and colleagues (2016) measure the efficiency of the forestry options carried out in optimizing the conservation of invertebrate species. Romano *et al*. (2016b) measure the effect of the different forestry interventions on the conservation of amphibians and reptiles. Balestrieri *et al*. (2016) focalize on the effect of forest management on the conservation on birds. Kutnar at *al*. (2016a) focalize on the response of flora to forest management measures. Finally, D'Andrea and colleagues (2016b) quantify the influence of the different options of forest management on the process of carbon removal from atmosphere by forests.

The fourth group of papers describe additional experiences carried out within the framework of ManFor C.BD and that provided further suggestion for the formulation of the best practices. These additional experiences were non-conventional experiments not following the standard protocol of the ManFor experiences (*i.e.* one site - three management options - three different responses - one message for forestry). Rather, they were conceived for integrating the messages of the previous, standard experiences, where some further information was needed. In particular, Bombi *et al*. (2016) focalize on the structure and composition of ground beetle communities at a spatial scale larger than the single stands. Romano *et al*. (2016a) highlight the particular response of a rare species of salamander to forest management. Mason and colleagues (2016) illustrate the creation, by means of ManFor C.BD for the first time in Italy, of an area where forest is artificially made older for improving its potentiality for biodiversity conservation. Tonti and Marchetti (2016) show how the forest interventions carried out by the project modified the forest at the landscape scale. Kobler (2016) explains the effect of forest management on the fragmentation of stands. Cammarano (2016) evidences the possibility of modeling forest

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Key words: Best Practices, Forest Management, Manual, ManFor C.BD

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

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Table 1. Structure of the present volume. The individual papers are organized in five different groups with different specific aims. The first group wants to introduce the project ManFor C.BD and clarify the national and international context. The second group intends to define the best requirements for specific forestry purposes. The third group aims to describe the project activities. The fourth group deals with additional experience related to the project. The fifth group synthesizes the results and provides practical suggestions for forest managers.

Introduction	
Vittorio Garfì, Paolo Cantiani, Marko Kovac, Dalila Sansone, Giovanni Carraro, Nicola Pavone, Marco Marchetti	Italian and Slovenian forest governances within the International context
Bruno De Cinti, Lado Kutnar	ManFor C.BD a LIFE+ Project on forest multi functionality
Definition of the requirements of good forestry practices	
Ludovico Frate, Maria Laura Carranza, Daniela Tonti, Andreja Ferreira, Marco Marchetti	Landscape as a driver of forest functions
Ugo Chiavetta, Mitja Skudnik, Claudia Becagli, Giada Bertini, Fabrizio Ferretti, Paolo Cantiani, Umberto Di Salvatore, Gianfranco Fabbio	Diversity of structure through silviculture
Fabio Lombardi, Boštjan Mali	Deadwood as a driver of forest functions
Marko Kovač, Gianfranco Fabbio	Wood production. Hereditary management systems and practices in wood-production forests
Maarten de Groot, Livia Zapponi, Davide Badano, Serena Corezzola, Franco Mason	Forest management for invertebrate conservation
Andrea Costa, Mario Posillico, Marco Basile, Antonio Romano	Conservation of herpetofauna as a function of forestry
Marco Basile, Rosario Balestrieri, Maarten de Groot, Katarina Flajšman, Mario Posillico	Conservation of birds as a function of forestry
Lado Kutnar, Aleksander Marinšek, Carmen Giancola	Conservation of flora as a function of forestry
Ettore D'Andrea, Marco Micali, Flavia Sicuriello, Mario Cammarano, Mitja Ferlan, Mitja Skudnik, Boštjan Mali, Matjaž Čater, Primož Simončič, Bruno De Cinti, Giorgio Matteucci, Tom Levanic, Aleksander Marinsek, Milan Kobal	Improving carbon sequestration and stocking as a function of forestry
Umberto Di Salvatore, Paolo Cantiani, Fabrizio Ferretti	From sectorial-optimum to multipurpose silviculture. How to compromise
Example of the ManFor C.BD Experiences in the Demonstration sites	
Umberto Di Salvatore, Daniela Tonti, Marco Bascietto, Ugo Chiavetta, Paolo Cantiani, Gianfranco Fabbio, Claudia Becagli, Giada Bertini, Dalila Sansone, Mitja Skudnik, Milan Kobal, Lado Kutnar, Andreja Ferreira, Andrej Kobler, Marko Kovač, Fabrizio Ferretti	ManFor C.BD sites and the drivers of forest functions
Gianfranco Fabbio, Marko Kovač, Špela Planinšek, Mitja Skudnik, Paolo Cantiani, Fabrizio Ferretti, Umberto Di Salvatore, Giada Bertini, Claudia Becagli	Wood production. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services?
Livia Zapponi, Maarten de Groot, Davide Badano, Daniele Birtele, Serena Corezzola, Maja Jurc, Gregor Meterc	Did ManFor C.BD forest treatments influence diversity and composition of invertebrate communities?
Antonio Romano, Mario Posillico, Marco Basile, Andrea Costa	Did ManFor C.BD forest treatments influence species biodiversity of amphibians and reptiles?
Rosario Balestrieri, Marco Basile, Maarten de Groot, Katarina Flajšman, Mario Posillico	Did ManFor C.BD forest treatments influence diversity and composition of the bird community?
Lado Kutnar, Carmen Giancola, Aleksander Marinšek, Klemen Eler	Did ManFor C.BD forest treatments influence diversity and composition of local flora?
Ettore D'Andrea, Marco Micali, Flavia Sicuriello, Mario Cammarano, Alessandro Giovannozzi Sermanni, Mitja Ferlan, Mitja Skudnik, Boštjan Mali, Matjaž Čater, Primož Simončič, Negar Rezaie, Francesco Mazzenga, Ermenegildo Magnani, Pierangelo Bertolotto, Bruno De Cinti, Tom Levanic, Aleksander Marinsek, Milan Kobal, Nicola Ricca, Vittoria Coletta, Massimo Conforti, Gaetano Pellicone, Antonella Veltri, Raffaele Froio, Gabriele Buttafuoco, Giorgio Matteucci	Did ManFor C.BD forest treatments influence carbon stock and sequestration?
Example of the ManFor C.BD Additional experiences	
Pierluigi Bombi, Vittoria Gnetti, Valerio Muzzini, Ettore D'Andrea	Community analysis at medium scales: focus on Carabids
Antonio Romano, Andrea Costa, Mario Posillico, Marco Basile	Forest management and amphibians: focus on the genus Salamandrina
Franco Mason,Umberto Di Salvatore, Livia Zapponi, Paolo Cantiani, Bruno De Cinti, Fabrizio Ferretti	Îlots de senescence in the ManFor C.BD sites
Daniela Tonti, Marco Marchetti	From forest stand to forest landscape: the spatial distribution of forest treatments in the landscape of ManFor Italian sites
Andrej Kobler	Forest fragmentation at forest stand level at three test sites in Slovenia
Mario Cammarano	Comparing silvicultural treatments through a forest simulator
Mitja Ferlan	Innovative system for measuring soil respiration
Rodolfo Picchio, Raffaello Spina, Luca Calienno, Rachele Venanzi, Angela Lo Monaco	Forest operations for implementing silvicultural treatments for multiple purposes
From theory to practice: suggestions for forest management	
Matteo Recanatesi, Bruno De Cinti, Matjaž Čater, Flavia Sicuriello, Pierluigi Bombi, Giorgio Matteucci, Urša Vilhar	Informing people about forest management and field operations
Umberto Di Salvatore, Fabrizio Ferretti, Livia Zapponi, Paolo Cantiani, Pierluigi Bombi, Primož Simončič, Giorgio Matteucci, Bruno De Cinti	How results from test area can be suggested as 'good practice'
Fabrizio Ferretti, Matjaž Čater, Paolo Cantiani, Umberto Di Salvatore, Ugo Chiavetta, Claudia Becagli, Franco Mason, Livia Zapponi, Gianfranco Fabbio	Exportability of options and results to other forests

dynamics after treatments and simulating the mid- and long-term evolution in term of forest structure. Ferlan (2016) describes a new method for carrying out measures of soil respiration developed during the ManFor activities. Finally, Picchio and colleagues (2016) measure the impact on soil of the operations related to tree cut and removal.

The fifth and last category of papers are final contributions aimed to allow other forest managers and operators to take advantage of the ManFor teaching. These papers, and the second one in particular, are supposed to represent a sort of vade mecum for all those involved in forest management and interested in multipurpose sustainable forestry. Ideally, reading these papers, they should know which is the best option to be adopted in a certain context, how this choice should be communicated to people, and how similar choices can be adopted in different contexts. In particular, Recanatesi *et al.* (2016) evidence the importance of disseminating information about forest management to the general public and explain the best way to do this. Di Salvatore *et al*. (2016b) provide a practical list of things to do under different conditions and for different purposes, representing the real core of the present volume. Finally, Ferretti *et al*. (2016) explain how the good forestry practices, proposed by this volume, can be adapted to situations different from those existing in the ManFor sites and applied successfully under variable conditions.

Therefore, the papers published in this volume can generally be read as self-standing studies disentangling specific issues of forest science but, more effectively, they can be seen as individual parts of a unique process of learning that from experience generates knowledge. In this light, the reader will have the possibility of going directly to the paper which he is interested in, he can use uniquely the final list of practical suggestions (Di Salvatore *et al*., 2016b) as a ‘field guide’, or he can go through the entire manual and understanding the source of the best practices for sustainable forestry. For instance, an entomologist can be interested in reading only the paper on the large scale response of carabids (Bombi *et al*., 2016), a forest manager can adopt only the indications provided in the practical list (Di Salvatore *et al*., 2016b), and a student in forest science can follow the entire manual for deepening the best practices genesis.

References

Balestrieri R, Basile M, de Groot M, Flajšman K, Posillico M, 2016. Did ManFor C.BD forest treatments influence diversity and composition of the bird community? Ital. J. Agron. 11(s1):1-175.

Basile M, Balestrieri R, de Groot M, Flajšman K, Posillico M, 2016. Conservation of birds as a function of forestry, Ital. J. Agron. 11(s1):1-175.

Bombi P, Gnetti V, Muzzini V, D'Andrea E, 2016. Community analysis at medium scales, focus on Carabids. Ital. J. Agron. 11(s1):1-175.

Cammarano M, 2016. Comparing silvicultural treatments through a forest simulator. Ital. J. Agron. 11(s1):1-175.

Chiavetta U, Skudnik M, Becagli C, Bertini G, Ferretti F, Cantiani P, Di Salvatore U, Fabbio G, 2016. Diversity of structure through silviculture. Ital. J. Agron. 11(s1):1-175..

Costa A, Posillico M, Basile M, Romano A, 2016. Conservation of herpetofauna as a function of forestry. Ital. J. Agron. 11(s1):1-175.

D'Andrea E, Micali M, Sicuriello F, Cammarano M, Ferlan M, Skudnik M, Mali B, Čater M, Simončič P, De Cinti B, Matteucci G, Levanic T, Marinsek A, Kobal M, 2016a. Improving carbon sequestration and stocking as a function of forestry. Ital. J. Agron. 11(s1):1-175.

D'Andrea E, Micali M, Sicuriello F, Cammarano M, Giovannozzi Sermanni A, Ferlan M, Skudnik M, Mali B, Čater M, Simončič P, Rezaie N, Mazzenga F, Magnani E, Bertolotto P, De Cinti B, Levanic T, Marinsek A, Kobal M, Ricca N, Coletta V, Conforti M, Pellicone G, Veltri A, Froio R, Buttafuoco G, Matteucci G, 2016b. Did ManFor C.BD forest treatments influence Carbon Stock and sequestration. Ital. J. Agron. 11(s1):1-175.

de Groot M, Zapponi L, Badano D, Corezzola S, Mason F, 2016. Forest management for invertebrate conservation. Ital. J. Agron. 11(s1)1-175.Matteucci G, Simončič P, 2016. Accomplishing European strategies for environment through a LIFE + project on forest multifunctional management. Ital. J. Agron. 11(s1):1-175..

De Cinti B, Kutnar L, 2016. ManFor C.BD a LIFE+ Project on forest multi functionality, Ital. J. Agron. 11(s1):1-175.

Di Salvatore U, Cantiani P, Ferretti F, 2016a. From sectorial-optimum to multipurpose silviculture. How to compromise. Ital. J. Agron. 11(s1):1-175.

Di Salvatore U, Ferretti F, Zapponi L, Cantiani P, Bombi P, Simončič P, Matteucci G, De Cinti B, 2016b. How results from test area can be suggested as 'good practice'. Ital. J. Agron. 11(s1):1-175.

Di Salvatore U, Tonti D, Bascietto M, Chiavetta U, Cantiani P, Fabbio G, Becagli C, Bertini G, Sansone D, Skudnik M, Kobal M, Kutnar L, Kobler A, Ferreira A, Kovač M, Simončič P, Ferretti F, 2016c. ManFor C.BD sites and the drivers of forest functions. Ital. J. Agron. 11(s1):1-175.

Fabbio G, Kovač M, Planinšek S, Skudnik M, Cantiani P, Ferretti F, Di Salvatore U, Bertini G, Becagli C, 2016. Wood production. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services? Ital. J. Agron. 11(s1):1-175

Ferlan M, 2016. Innovative system for measuring soil respiration. Ital. J. Agron. 11(s1):1-175.

Ferretti F, Čater M, Cantiani P, Di Salvatore U, Chiavetta U, Becagli C, Mason F, Zapponi L, Fabbio G, 2016. Exportability of options and results to other forests. Ital. J. Agron. 11(s1):1-175.

Frate L, Carranza ML, Tonti D, Ferreira A, Marchetti M, 2016. Landscape as a driver of forest functions. Ital. J. Agron. 11(s1)1-175.

Garfì V, Cantiani P, Kovac M, Sansone D, Carraro G, Pavone N, Marchetti M, 2016. Italian and Slovenian forest governances within the International context. Ital. J. Agron. 11(s1):1-175.

Kobler A, 2016. Forest fragmentation in Slovenia at forest stand level. Ital. J. Agron. 11(s1):1-175.

Kovač M, Fabbio G, 2016. Wood production. Hereditary management systems and practices used in wood-production forests. Ital. J. Agron. 11(s1):1-175.

Kutnar L, Giancola C, Marinšek A, Eler K, 2016a. Did ManFor C.BD forest treatments influence diversity and composition of local flora Ital. J. Agron. 11(s1):1-175.

Kutnar L, Marinšek A, Giancola C, 2016b. Conservation of flora as a function of forestry, Ital. J. Agron. 11(s1):1-175.

Lombardi F, Mali B, 2016. Deadwood as a driver of forest functions. Ital. J. Agron. 11(s1):1-175.

Mason F, Zapponi L, Di Salvatore U, Cantiani P, De Cinti B, Ferretti F, 2016. Senescence Islands (Ilots De Senescence - Ids) in the ManFor C.BD sites. Ital. J. Agron. 11(s1):1-175.

Picchio R, Spina R, Calienno L, Venanzi R, Lo Monaco A, 2016. Forest operations to implement silvicultural treatments for multiple purposes. Ital. J. Agron. 11(s1):1-175.

Recanatesi M, De Cinti B, Čater M, Sicuriello F, Bombi P, Matteucci G, Vilhar U, 2016. Informing people about forest management and field operations. Ital. J. Agron. 11(s1):1-175.

Romano A, Costa A, Posillico M, Basile M, 2016a. Forest management and amphibians: focus on the genus Salamandrina. Ital. J. Agron. 11(s1):1-175.

Romano A, Posillico M, Basile M, Costa A, 2016b. Did ManFor C.BD forest treatments influence species biodiversity of amphibians and reptiles? Ital. J. Agron. 11(s1):1-175.

Tonti D, Marchetti M, 2016. From forest stand to forest landscape: the spatial distribution of forest treatments in the landscape of ManFor Italian sites. Ital. J. Agron. 11(s1):1-175.

Zapponi L, de Groot M, Badano D, Birtele D, Corezzola S, Jurc M, Meterc G, 2016. Did ManFor C.BD forest treatments influence diversity and composition of Invertebrate communities? Ital. J. Agron. 11(s1):1-175.

Italian and Slovenian forest governances within the International context

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Introduction

The European forests are characterized by a wide diversity of forest types, extent of forest cover, ownership structure and socio-economic conditions. EU forests are situated in very different ecological environments, ranging from Boreal to Mediterranean, and from Alpine to lowlands. In the EU-27 the forests and other wooded lands (OWL) occupy, respectively, some 157 million ha (38%) and 20 million ha (5%) of the EU's land area. Over recent decade (2000-2010) the EU forest area has increased by around 0.4% per year due to afforestation and natural succession (UNECE/FAO, 2011). Sweden has the largest forest area in the EU total land area followed by Finland, Spain and Germany (Figure 1). In Italy forests and OWL occupy 11 million ha (37%), whereas in Slovenia they cover 1.3 million ha (63%) (UNECE/FAO, 2011).

Currently in the EU, only 60-70% of the annual increment is being cut, therefore the growing stock of wood is rising. However, according to Member States' projections under Land Use, Land-Use Change and Forestry (LULUCF), harvest rates are expected to increase by around 30% by 2020 as compared to 2010. The 60% of forests are owned by several millions of private owners, with numbers set to rise as restitution of forest ownership in some Member States continues. The remainder belongs to the state and other public owners (European Commission, 2013a).

The EU's land area is composed by different biotopes where, forests habitats have largest number of species on the continent and provide important environmental functions, such as the conservation of biodiversity and the protection of water and soil. Protected areas are about 12% (30 million ha) of the EU total land area. Around 20% of these protected area under rather strict regulation (none or minimum intervention), the remaining is based on active management of the biodiversity with minor restrictions on forest management (UNECE/FAO, 2011).

The Treaty on the EU Functioning makes no reference to specific provisions for an EU forest policy, however the EU has a long history of contributing through its policies to implement sustainable forest management and to coordinate Member States' decisions on forests.

The Council Resolution on a Forestry Strategy for the European Union was adopted in (European Commission, 1998). It established a framework for forest-related actions in support of Sustainable Forest Management (SFM) based on the coordination of the forest policies of the Member States and Community policies as well as initiatives relevant to forests and forestry.

The Strategy emphasizes SFM as defined by FOREST EUROPE (former MCPFE – Ministerial Conference on the Protection of Forest in Europe) with the multifunctional role of forests as overarching principles for action. The Strategy states that forest policy is competence of each Member States (based on the principle of subsidiarity and the concept of shared responsibility), but the EU can contribute to the implementation of SFM through common policies also on forest related fields. It also emphasizes the implementation of international commitments, principles and recommendations through national and/or sub-national forest programs or equivalent instruments, as well as active participation in all forest-related international processes. Moreover, it stressed the need to improve coordination, communication and cooperation in all policy areas that are of relevance for the forest sector.

In response to the Council request, the EU Forest Action Plan (FAP) was put forward and adopted in 2006 by the Commission. The FAP (expired in 2011) formulates a core rationale for European forest policy: "Forest for society: long-term multifunctional forestry fulfilling present and future societal needs and supporting forest related livelihoods" (European Commission, 2006). It is based on the principles and elements identified in the EU Forestry Strategy, and it covers the following four objectives, subdivided in 18 key actions (Figure 2):
- Improve the long-term competitiveness;
- Improve and protect the environment;
- Contribute to the quality of life;
- Foster coordination and communication between Community

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Key words: Italy, Slovenia, forest strategy, forest governante, forest law.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

actions, as well as, between Community actions and the forest policies of the Member States.

Currently, a new EU Forest Strategy is under discussion, with its focus and contents still under negotiation.

Italian national level – Forestry law

The current policy heterogeneity within European level is the consequence of unevenly distributed forest resources and to the mentioned not specific EU competence on forestry sector. The consequence of such situation is a heterogeneity of the national laws leading every Country to define regulation instruments taking into account their priorities. At Italian national level a Framework Program for the Forest Sector (Programma Quadro Settore Forestale, PQSF) was launched in 2009 to coordinate the sector as a local implementation of the EU Forest Action Plan (PQSF, 2009). The PQSF set up a National Coordination board (Tavolo di Coordinamento Forestale, TCF) similar to the EU Standing Forestry Committee and will last ten years.

Forestry and related topics are matters defined *"di competenza residua",* that means Regional authorities have the jurisdiction on them. Italian Regions make specific laws to regulate the sector (Forestry law and linked regulation according to the Italian legal system) but these do not always includes other aspects as well as environmental or biodiversity protection (main focus of other kind of laws, often based on EU directives and touching Central government authority). Considering both the aspects (regional autonomy and different authority on) forest laws differs each from another and show clear differences on the base of the time of approval.

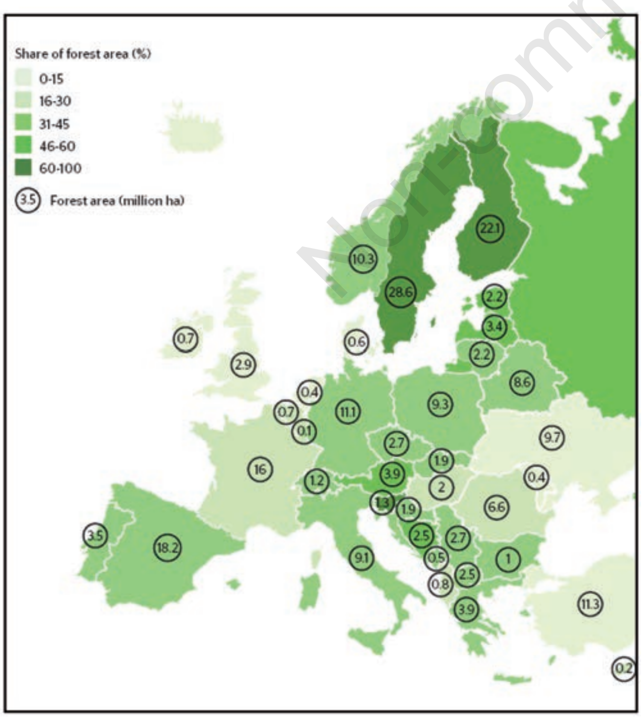

Figure 1. Forest area (million ha) and share (percent) of land area by country in year 2010 (UNECE/FAO, 2011).

Usually more recent ones are more complete and complex than the ancient and reflect an increasing attention to such themes as biodiversity and protection. That is also the consequence of the general international interest for the forests' role and an answer to the new social expectations.

An Italian forest law regulates silvicultural practices, describes the type of admissible interventions, defines timing and procedures, forestry planning rules and banning.

All the forest laws approved by the Italian Regions involved in the ManFor C.BD project (our subject in the following discussion) mention biodiversity, ecosystem and landscape protection among their purposes, and consider sustainable forest management the key tool to pursue them.

Forest planning is an important component of forest law content and whole parts are dedicated at describing methodologies and technical aspects. It is worthy to note that regional forest laws deal with public and private forests and do not include protected areas. Protected areas are under a specific national and regional regulation, while if forest management plans includes them (partially or not), an environmental impact assessment is needed (VAS), according to specific EU directives. Furthermore protected areas have their own authorities which opinion on every kind of intervention or planning activities inside the area is mandatory. For protected areas we mean both those of national or regional interest (L. 394/1991) and those included in the Natura 2000 network (DPR 357/1997).

Another aspect to consider is the role recognized to certification that is often promoted to guarantee sustainability in forestry sector.

Abruzzo (2014), Calabria (2012) and Friuli Venezia Giulia (2007) Regions explicitly mention international agreement and Italian government commitment on biodiversity, sustainable development and climate change.

Despite the introductive part of any of these laws, few of them specifically regulate aspects like carbon sequestration, effects on biodiversity component or deadwood. They just claim as a sustainable and legal activity in woodland leads to the respect of the general principles. Only two Regions Friuli and Toscana have a specific article on biodiversity. Friuli's law (art. 18 LR n. 9 23/04/07 and DP Reg. n. 274 28/12/12) considers close to nature silviculture the instrument to guarantee biodiversity conservation. In particular foresees trees and dead trees retention to increase biodiversity and maintain deadwood species habitat.

(i.e., Described Rules: during harvesting operation releasing of:

- 1 tree per 2 ha with dbh >60 cm (coniferous species) or >50 cm (broadleaved species) assigned to undefined ageing, for harvesting more than 1000 mc or more than 10 ha of interested surfaces.
- All the dead trees with dbh >60 cm (conifers) or >50 cm (broadleaved), for harvesting more than 200 mc or 2.5 ha of surface in coppices
- All the trees with cavity and dbh >30 cm, for harvesting more than 200 mc or 2.5 ha of surface in coppices.)

Tuscany law regulate the harvesting of some protected species (the list is provided by the art. 12 LR 39/2000), that must be released if less than a minimum density (20 per ha), furthermore is foreseen the release of an undefined ageing tree per ha, to be chosen among the biggest ones. In this Region cutting systems different from those described by law can be approved if aimed at particular cultural needs, conservation or animals habitats creation.

Hereafter is given a short description of Italian Regional law contents dealing with the ManFor C.BD project main focus, even if we want to remark again that there is not an uniform regulation on these kind of topics. A chronological criterion is used to put in evidence how policy perception has changed over time.

Veneto L.R. 52/1978 and L.R. 25/97

This is the oldest law among those considered. Despite changes later approved, there are no references to such themes as biodiversity, carbon storage, deadwood and so on. Among the purposes listed, only a generic soil and environmental protection appears.

However the legal body of Veneto Region includes lots of acts with technical rules for different forest activities, in particular for planning.

Toscana L.R. 39/00 and DPR 48/R 2003

This is one of the two forest laws including a specific article focused on biodiversity. It aims at biodiversity conservation, natural habitats protection and multifunctional forest management. Other kind of safeguards are put on monumental trees and spontaneous flora (ex a dedicated law L.R 56/00 "*Norme per la conservazione e la tutela degli habitat naturali e seminaturali della flora e della fauna selvatiche*" – "Rules for natural and seminatural habitats, flora and fauna conservation and protection").

Besides, Tuscany Region promote forest planning and certification processes.

Removal of humus, soil, grass cover and leaves is forbidden except particular condition; the branches management on the top soil after cutting is also regulated, but not with a specific interest for dead wood and its functional role.

Molise L.R. 6/2000

Despite approved years ago, in this regional law no detailed rules on biodiversity and conservation in general are mentioned. Law's finalities include natural habitat conservation; existing biodiversity and ecosystems protection are mentioned among the interventions to pursue them.

Nevertheless, a Regional technical document contains specific rules and excludes from environmental impact evaluation some interventions in protected areas belonging to Natura 2000 network (D.G.R n. 1233/2009). The document lists the interested protected habitats and the kind of precautions to observe, during silvicultural operations, in order to avoid negative impact on biodiversity (flora and fauna).

Friuli Venezia Giulia L.R. 9/2007

This law quotes International agreement on biodiversity and sustainable development and among finalities appear: i) close to nature silviculture recognition as the main instrument to protect and enhance biodiversity of forest ecosystems (Natura 2000 network included); ii) public intervention promotion in mountain areas; and iii) sustainable and integrated management of forest resources with its major costs recognition.

Besides the specific attention to biodiversity mentioned above with a dedicated article (art. 18), there are two other interesting aspects: the role of certification in promoting principles of sustainable management and the introduction of a new planning tool PRFA (Forest and Environmental requalification project) supporting management plans.

Differently from other cases flora and fauna protection are not regulated by other regional laws but has an own section, while for forest ecosystem protection is foreseen the identification of a certain number of forest areas with an high biological and naturalistic

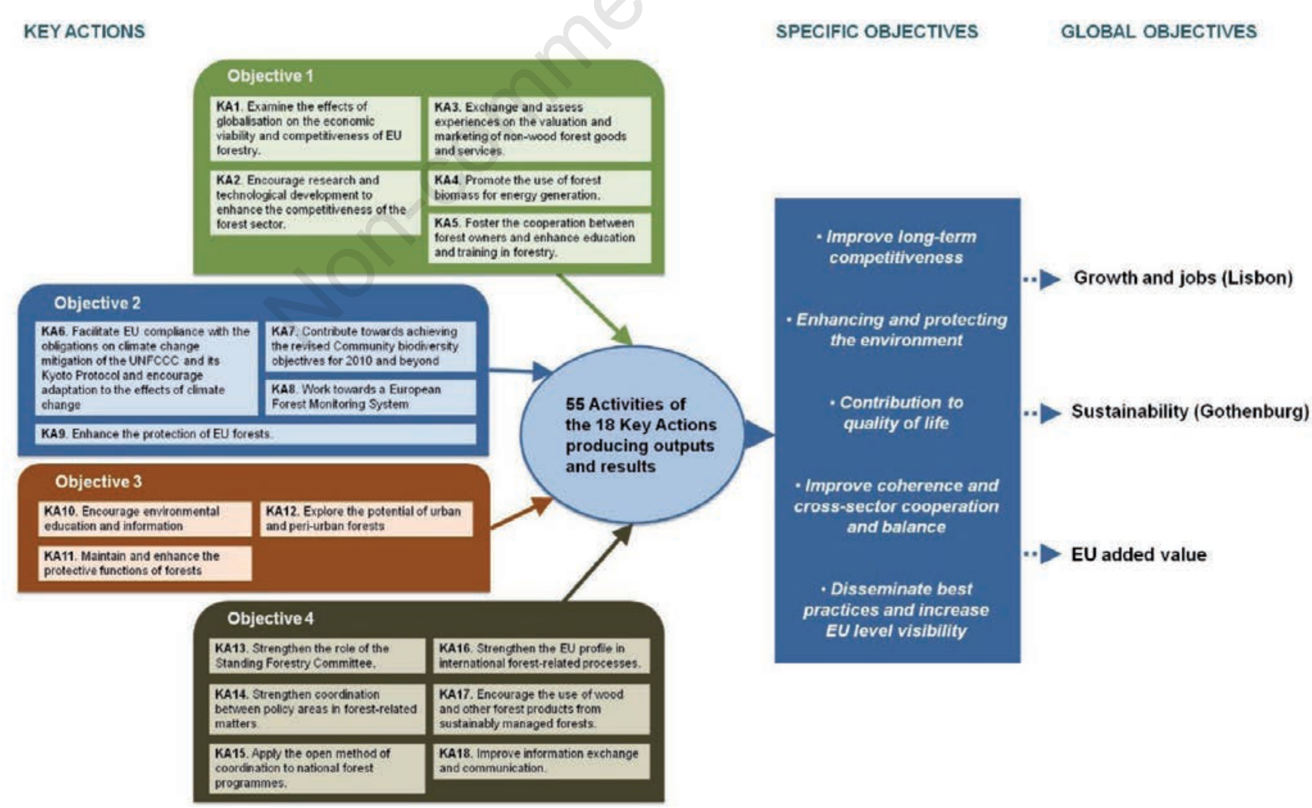

Figure 2. The Forest Action Plan: objectives and key actions (EFI, 2012).

value to design for undisturbed evolution dynamics (art. 67). This areas would have a scientific role and are intended as an useful condition for the elaboration of new management systems. The law describes criteria for their identification and related banning.

Considering the landscape, cultural and touristic forest functions, this law foresees the individuation and conservation of trees and stands of natural, historical, cultural and spiritual interest. An inventory of these elements is prescribed with specific management rules.

Calabria L.R. 45/2012

This region promote the sustainable forest management to favour: i) forest ecosystem functionality; ii) biodiversity conservation and development; iii) forested areas enlargement and enhancement and their contribution to carbon cycle; iv) management plans approval and control; v) certification processes.

Except from monumental trees and ancient forest stands protection there are no specific rules dealing with biodiversity or multifunctionality.

Abruzzo L.R. 3/2014

Among the finalities of this law is interesting the recognition of the forest contribution to climate stabilization. The law considers the Italian government commitment on biodiversity, sustainable management, climate change and greenhouses gases emission. Maintaining and increasing biological diversity and protection of high naturalist value areas are two of the objectives listed.

Forest planning is considered crucial to realize law finalities and to guarantee sustainability; besides the Region promotes interventions aimed at favouring forest biodiversity and certification processes. It is also claimed that public property is managed following active and sustainable management principles to favour,

Box 1 – Description of the Italian and Slovenian forestry sector
(Short introduction and synthetic outline dealing with main forestry sector features: surfaces, management, typology, property, protected areas' extension, Natura 2000 Network)

ITALY
(Source Italian National Forest Inventory, 2005)
Italian forests occupy 8.8 million ha. Coppice is the main silvicultural system (41.8%) followed by high forest (36.1%). Other wooded lands cover about 1.7 million ha (INFC, 2005)
Even high forests are mainly "seminatural" (Italian Inventory sensu) and derive from natural regeneration promoted by silvicultural interventions. Young stage forests are few as the great part of harvesting lasted form the end of the World War II to the 70s. Only 3% of the Italian forest surface is less than 20 years old.
Ownership is mainly private (66% of the total).
Beech high forests is the main category (about 1 million ha). These forests are above all "seminatural" or derived from abandoned or under conversion coppices (transitory stands).

Microhabitats (wide and linear) are present in 40% of the Italian forests.
Wide microhabitats are: clearings, water surfaces, moist areas, screes, abandoned buildings, rocks, while linear or punctiform microhabitats are: dry-walls, sources, monumental trees, trees with cavity, dead or wilted, burrow, caves.
The Italian forest total growing stock: 1.3 billion m^3.
Beech high forest volume: 240 million m^3
Current increment: 36 million m3 (4.1 $m3 \cdot ha^{-1}$)
Prescribed cut: 13.8 million m3 (1.1% of the total growing stock)
The deadwood total volume: 76.5 million m^3 (8 $m3 \cdot ha^{-1}$).
Natural protected areas cover the 27.5% of national surface (share of national surface belonging to Natura 2000 network 19%).

SLOVENIA
Forests cover 1.2 million ha of the Slovenia's total land. 35% of the forests belong to the group of even-aged forests, 57% to uneven-aged, ca. 4% to coppice and the rest to other groups such as multilayer forest, bushy forest, etc. 75% of forests are in private ownership and 25% belong to the state and municipalities (SFI, 2013).
The present forest structure is inconvenient. Its major problem is over-ageing, resulting in 67% of old growth forests, 5% of young growth and in 28% of pole stands. Natural regeneration is the prevalent way of forest regeneration on approximately 97 %. Among tree species, the highest shares belongs to Norway spruce and European beech (both 31%), silver fir (7%) and soak (ca. 5.5%)(SFI, 2013).
Other forest statistics (SFI, 2013):
Mean growing stock volume: 333.9 $m^3 \cdot ha^{-1}$;
Total growing stock volume: 400.7 million m^3;
Mean gross growing stock volume increment: 8.6 $m3 \cdot ha^{-1}$;
Total annual growing stock volume increment: 10.3 million m^3
Planned annual harvest: 6.0 million m^3 (1.5% of the total growing stock volume)
Mean deadwood volume: 19.8 $m3 \cdot ha^{-1}$;
Total deadwood volume: 23.8 million m^3;
Areas under nature protection encompass 39.7% of the national territory (SEA, 2009). This area includes diverse protected areas, such as national, regional and landscape parks and diverse reservations and areas belonging to the Natura 2000 network. Approximately 70% of this territory belongs to forests.

among other things the enlargement of fauna amount and biodiversity. Describing the rules for monumental and old stands protection, occurrence and role of dead wood, as well as those of species linked to microhabitats due to structural features, are considered. In this case the law foresees dedicated management plans.

A further element to consider is the role of the other forest related regulation that strong influence the sector, as well as at EU level. The most relevant example is the National application of the EU CAP policy; both the past and the present Rural National Development plans contain forest measures dealing with increasing of sustainability, enhancement of stability and management of forests.

Slovenian national level – Forestry law

Similarly to the EU and pan-European countries, Slovenia's forest governance follow number of hard and soft laws that come from the national, the EU and global level and regulate all aspects of forests and forestry, ranging from traditional forest harvesting to much more complex climate change.

Matters related to forests, sustainable forest management and forestry in general are regulated by the national Forest Act (UrL RS, 1993-2014) and its statutory instruments, in contrast, the Nature Conservation Law (UrL RS, 1999-2014) reagulates matters related to biological diversity, including forest biodiversity. In addition to these two acts, the forest sector is also influenced by numerous international legal documents, covering air pollution and forest health (UN/ECE, 1979), conservation of biodiversity (European Commission, 1992, 2010; UN, 1992), climate change (UN, 1997; European Commission, 2013b), etc.

Among the soft laws it is noteworthy to mention the Resolution on the national forest program (UrL RS, 2007), promoting sustainable forest development, ecosystem and multipurpose forest management, National Renewable Energy Action Plan 2010-2020, promoting better energy consumption and national Action plan to increase the competitiveness of the forest-wood chain in Slovenia by 2020 entitled "Wood is beautiful", promoting more efficient wood use.

Forest Act (UrL RS, 1993-2014), adopted in 1993 is the most important legislative forestry document. It regulates: i) forest management planning and the hierarchy of plans; ii) silvicultural practices and forest protection, harvesting and road construction to sustain all forest ecosystem services; iii) designated forest areas; iv) forestland transactions; v) public forest service and its competences; vi) forest research and vii) forest owner networking.

The Forest Act regulates the use of all forestlands of the country regardless of ownership and designation status. Additionally it promotes sustainable use of forest resources, forest ecosystem management, based on emulating natural forces and natural regeneration, as well as multipurpose forest management, which only can provide a variety of ecosystem services to the societies. In managing forest services, the current forest management practices promote the combination of integration and segregation approaches (Hanewinkel, 2011; Simoncic *et al.*, 2013). Although forest biodiversity is an inherent part of sustainable forest management, forest biodiversity is regulated by forest biodiversity, regulated by the Nature Conservation Law (UrL RS, 1999-2014). The most far-reaching implication of the split jurisdiction between the two laws the governance of the Nature conservation Law over forest management plans that are considered sectoral plans. Consequently, these plans may not always be directly implemented in the field, but may be subject to strategic environmental impact assessment (European Commission, 2001). As far as biodiversity conservation practices are concerned, they are still under development (Kovač, 2015). Because of a paucity of knowledge on the ecological demands of the Natura 2000 qualification species, some provisions, addressing ecological thresholds invasive species, the amount of deadwood and species monitoring, are provided by the Forest protection rule.

Similar to forest sectors of the other European countries, the Slovene forest sector is also overruled by sectors - such as nature conservation, agriculture, energy industry, spatial planning and so forth (compare Pülzl *et al*., 2013). The situation is hardly manageable because of insufficient collaboration within and between the sectors at the governmental level and at lower operational levels and also because of weakly developed competences for sectorial performances (Kluvánková-Oravská *et al*., 2009).

The complexity of demands thus makes the policy goals as a whole inconsistent and difficult to attain.

References

EFI, 2012. Ex-post Evaluation of the EU Forest Action Plan. http://ec.europa.eu/agriculture/evaluation/market-and-income-reports/2012/forest-action-plan/fulltext_en.pdf

European Commission, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A31992L0043

European Commission, 1998. Council Resolution of 15 December 1998 on a forestry strategy for the European Union. Official Journal C 056, 26/02/1999 P. 0001 - 0004EFI, 2012. Ex-post Evaluation of the EU Forest Action Plan. Available from: http://ec.europa.eu/agriculture/evaluation/market-and-income-reports/forest-action-plan-2012_en.htm

European Commission, 2001. The assessment of the effects of certain plans and programmes on the environment. The European parliament and the council of the European union, Directive 2001/42/EC of 27 June 2001. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32001L0042

European Commission, 2006. European Union Forest Action Plan. Communication from the Commission to the Council and the European Parliament of 15 June 2006 on an EU Forest Action Plan.[COM(2006) 302 final - not published in the Official Journal. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=URISERV%3Al24277

European Commission, 2010. Directive 2009/147/ec of the European parliament and of the council of 30 November 2009 on the conservation of wild birds. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32009L0147

European Commission, 2013a. A new EU Forest Strategy: for forests and the forest-based sector. Available from: http://ec.europa.eu/agriculture/forest/strategy/staff-working-doc_en.pdf

European Commission, 2013b. Decision n. 529/2013/EU of the European parliament and of the council of 21 May 2013 on accounting rules on greenhouse gas emissions and removals resulting from activities relating to land use, land-use change and forestry and on information concerning actions relating to those activities. Available from: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013D0529

Kluvánková-Oravská T, Chobotová V, Banaszak I, Slavikov L, Trifunovova S, 2009. From government to governance for biodiversity: the perspective of central and Eastern European transition countries. Environ. Policy Governance 19:186-196.

Kovač, M., 2015. Ukrepi za zagotavljanje ugodnega ohranitvenega stanja gozdnih habitatnih tipov in habitatov vrst: predlogi dobrih praks. Gozdarski vestnik. 73:32-58.

PQSF, 2009. Programma qaudro settore forestale. Available from: http://www.reterurale.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/2826

Pülzl H, Hogl K, Kleinschmit D, Wydra D, Arts B, Mayer P, Palahi M, Winkel G, Wolfslehner B, 2013. European Forest Governance: Issues at Stake and the Way Forward, European Forest Institute. 122.

Regione ABRUZZO L.R. 3/2014 Legge organica in materia di tutela e valorizzazione delle foreste, dei pascoli e del patrimonio arboreo della regione Abruzzo.

Regione CALABRIA L.R. 45/2012 Gestione, tutela e valorizzazione del patrimonio forestale regionale.

Regione FRIULI VENEZIA GIULIA L.R. 9/2007 Norme in materia di risorse forestali.

Regione MOLISE L.R. 6/2000 Legge forestale della Regione Molise.

Regione TOSCANA L.R. 39/00 and DPR 48/R 2003 Regolamento di attuazione della Legge Forestale Toscana.

Regione VENETO L.R. 52/78 and L.R. 25/97 Legge forestale regionale.

SEA, 2016. Environmental Indicators in Slovenia; NV01 - Nature areas under protection. Slovenian Environment Agency (http://kazalci.arso.gov.si/?data=indicator&ind_id=204&lang_id=94)

SFI, 2013. FFECS - Forest and forest ecosystem condition survey 1985-2013 - field data. Ljubljana, Slovenian Forestry Institute.

Simoncic T, Boncina A, Rosset C, Binder F, De Meo I, Cavlovic J, Gal J, Matijasic D, Schneider J, Singer F, Sitko R. 2013. Importance of priority areas for multi-objective forest planning: a Central European perspective. Int For Rev 15: 509 – 523.

UN, 1992. Convention on biological diversity. Retrieved: November 30, 2014. Accessed: March 2015. Available from: http://www.cbd.int

UN, 1997. United Nations framework convention on climate change. Accessed: March 2015. Available from: http://www.globaldialoguefoundation.org/files/ENV.2009-jun.unframeworkconventionclimate.pdf

UN/ECE, 1979. The convention on long-range transboundary air pollution (CLRTAP).

UNECE/FAO, Forest Europe, 2011. State of Europe's Forests 2011. Status and Trends in Sustainable Forest Management in Europe. Ministerial Conference on the Protection of Forests in Europe, Oslo.

UrL RS, 1993-2014. Zakon o gozdovih. U. l. RS. 30/93, 56/99 - ZON, 67/02, 110/02 - ZGO-1, 115/06 - ORZG40, 110/07, 106/10, 63/13, 101/13 - ZDavNepr in 17/14.

UrL RS, 1999-2014. Zakon o ohranjanju narave (ZON). U. l. RS. št. 96/04 – uradno prečiščeno besedilo, 61/06 – ZDru-1, 8/10 – ZSKZ-B in 46/14)

UrL RS, 2007. Resolucija o nacionalnem gozdnem programu (ReNGP). U. L. RS. Uradni list RS, št. 111/2007 z dne 5. 12. 2007.

ManFor C.BD a LIFE+ Project on forest multi functionality

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The sense of the Project

The purpose of forests is not only the production of timber: they play an important role in many important matters as climate regulation, and biodiversity conservation, providing also opportunities for recreation and study.

Forest management practices are mostly focused on increasing efficiency of growing and harvesting trees to achieve economic goals. However, preserving and enhancing biodiversity have become desirable forest management objectives in light of species preservation and mitigation of climate changes worldwide.

Some 'new functions' of the forests, indeed, are becoming more and more important than timber; sometimes even more important, also from the economic point of view. The project LIFE + ManFor C.BD (Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing) was initiated to evaluate multi-functionality of the forest and was co-funded by the European Commission and coordinated by the National Research Council through the Institute of Agro environmental and Forest Biology (IBAF). The other Project partners are: the Council for Agricultural Research and Economics (CREA), the University of Molise (UNIMOL), the Slovenian Forestry Institute (SFI) and the regions of Veneto and Molise. Italian National Forest Service (CFS) collaborated through the National Center for Biodiversity Forest of Verona for monitoring saproxylic arthropods and through the Regional Office to biodiversity of Castel di Sangro (AQ), for monitoring different vertebrate groups (Figure 1).

Beside the Slovenian Forestry Institute (SFI), also the Slovenian Forest Service (SFS) was involved in the field and dissemination activities; Biotechnical Faculty, Department for Forestry and Renewable Resources of Ljubljana took part in assessment of selected invertebrate groups and some forest management aspects.

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Key words: carbon sequestration; biodiversity; LIFE ManFor C.BD; forest management; silviculture; multi-functional forest management.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Project objectives

The main project objective was to test the effectiveness of multi-functional forest management practice in field (capability to storage carbon from atmospheric CO_2, management supporting biodiversity, wood production, soil/slopes protection, *etc.*), providing data and further guidelines for the optimal forest management.

At every project research site the following goals have been considered:

- Proposition and implementation of forest multifunctional management options,
- Evaluation of their actual applicability,
- Comparison between innovative/new management options and traditional ones in the area,
- Selection of optimal approaches and promotion of their application,
- Project result dissemination on different levels - from scientific to the political-decision-making and general public level.

How does the Project work

Activities within ManFor C.BD project focused on ten sites (test areas); seven in Italy and three in Slovenia. Each Italian test area was about 30 ha in size while, each Slovenian site is composed of a focal area of 0.4 ha, deputed to detailed measurements, located within a wider monitored area of approx.70 ha. Large site size facilitates the adoption of the proposed management operations even after the end of the project. Sites have been selected in public forests, from the Serre Calabresi to the forests of Tarvisio and also over Slovene - Italian border, within Slovenian Dinaric Mountains (Figure 2).

At all sites, with the traditional management practices applied in the area, two additional approaches, proposed by the project were applied, to improve forest multi-functionality without compromising quality timber production.

The above compromise represented a key element of the project philosophy. Indeed, the project highlighted the importance of several ecosystem services (carbon sequestration and biodiversity preservation up to all), maximizing their effect. At the same time, the project maintained the centrality of the forest timber production improving the quality of wood products.

Reconciling production with the other priority issues was an ambitious goal for the project, requiring the cooperation of all the project experts and understanding of priorities from different fields. Before moving to the operational phase, the decision making criteria proposed by the foresters of the project was studied and discussed with other project group experts such as carbon specialists, biodiversity of vertebrate experts, invertebrate fauna, biodiversity of flora, etc. From such comparison, an optimal solution to reach criteria and demands from all groups and stakeholders was created (Di Salvatore 2016). Competence and specialization of the various groups constituted a guarantee of technical quality and a multifunctional approach, while the presence of institutions and managers who paid attention to the economic sustainability of the interventions have guaranteed their overall economic soundness. The meeting and, at times, the clash between various views is the novelty and represents the new quality and the strength of the project.

The comparison of the measurements (made *ante* and *post* harvesting) have been provided and would provide feedback of the achieved objectives in the future.

Preliminary results show, that proposed management options by the project, although different and sometimes more intensive than the traditional ones, have maintained stable forest cover and regarding biodiversity, the optimal structural diversity. Innovative interventions emphasize the best phenotypes and the assortments obtained by the thinning of the proposed management options by the project, sometimes more valuable than traditional ways.

By the proposed treatments several goals were obtained:

- Material devoted to be used for permanent employment (an advantage in term of increased carbon permanence time in the wood),
- Greater revenue in economic terms,
- Vantages in terms of increased diversity (structural, vegetative, wildlife), also at the landscape scale.

Figure 1. Project meeting in Arezzo with most of the project members (Courtesy of: Umberto Di Salvatore).

Figure 2. Locations of ManFor C.BD sites.

Senescence Islands

In the project proposed treatments, the release of an adequate rate of deadwood distributed in all studied forests has been foreseen. Other studies (Mason *et al.,* 2016) emphasized the importance and close relation between the stage of biodiversity and the share of deadwood in the forests. Establishment of permanent 'micro-reserves' known as senescence islands along conventional silvicultural treatments (*îlot de sénescence*, ÎdS) has been applied and adopted in many forest management experiences mostly from France, Switzerland, Canada Slovenia and United States.

The project put in practice proposed techniques in Italy for the first time. The IdS structures are achieved by unconventional thinning interventions aimed to concentrate the forest increment in big trees, potentially (or actually) rich of microhabitats.

The ÎdS, together with "habitat trees" and the dead wood released on the ground, constitute a network covering the harvested areas. This network helps the forest ecosystem to quickly regenerate its biodiversity level after any disturbances (*e.g.* harvesting).

Dissemination

To inform and engage visitors and local communities, the project included many initiatives, activities, web sites, informative manuals (Bino *et al.*, 2015),, newsletters (Kutnar, 2013, 2014a, 2014b; Kutnar and Vilhar, 2015; Recanatesi *et al*., 2014, 2015) and articles published at different levels (De Cinti *et al*., 2014 and publications discussed in the current supplement).

Within such examples "educational paths" were established on every demonstration site (Cater *et al*., 2014a, 2014b, 2014c). The paths are organized by stages, with information panels describing the operations and consequences of performed measures. Studied parameters and measurements were illustrated.

Another example is the fairy tale book 'The Guardians of Nature' published in collaboration with the CFS to promote the message of the project among teachers and children (Favero *et al*., 2014).

References

Bino E, Marchi N, De Cinti B, Bombi P, Dissegna M, Carraro G, Causin L, 2015. ManFor C.BD Esperienze di gestione forestale nelle Alpi venete: fra tradizione e innovazione. Europrint, Treviso. 151 pp.

Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P,

Skudnik M, 2014a. Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi = Multifunctional forest managenet; carbon, biodiversity and socioeconomic benefits: Kočevje. Ljubljana: Slovenian Forestry Institute, 2 panels.
Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P, Skudnik M, 2014b. Večnamensko gospodarjenje z gozdom : ogljik, biotska raznovrstnost in socio-ekonomske koristi = Multifunctional forest managenet; carbon, biodiversity and socioeconomic benefits: Snežnik. Ljubljana: Slovenian Forestry Institute, 2 panels.
Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P, Skudnik M, 2014c Večnamensko gospodarjenje z gozdom : ogljik, biotska raznovrstnost in socio-ekonomske koristi = Multifunctional forest managenet; carbon, biodiversity and socioeconomic benefits: Trnovo. Ljubljana: Slovenian Forestry Institute, 2 panels.
De Cinti B, Fabbio G, Ferretti F, Cantiani P, Di Salvatore U, Bascietto M, Bombi P, D'Andrea E, Lombardi F, Mason F, Zapponi L, Matteucci G, 2014. Progetto LIFE + ManFor C.BD: Un'esperienza per valorizzare tutte le funzioni del bosco. Sherwood 206:29-32.
Di Salvatore U, Cantiani P, Ferretti F. 2016. From sectorial-optimum to multipurpose silviculture. How to compromise. Ital. J. Agron. 11(s1):1-175.
Favero P, Lampo M, De Cinti B, 2014. I custodi della natura. Edizioni Filò, Belluno.
Kutnar L (ed.), 2013. ManFor novice: številka/issue 1, ManFor C.BD LIFE09ENV/IT/000078 projekt - Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing (Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi). Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.
Kutnar L (ed.), 2014a. ManFor novice: številka/issue 2, ManFor C.BD LIFE09ENV/IT/000078 projekt - Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing (Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi). Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.
Kutnar L (ed.), 2014b. ManFor novice: številka/issue 3, ManFor C.BD LIFE09ENV/IT/000078 projekt Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing (Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi). Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.
Kutnar L, Vihar U (eds.), 2015. ManFor novice: številka/issue 4, ManFor C.BD LIFE09ENV/IT/000078 projekt Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing (Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi). Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.
Mason F, Di Salvatore U, Zapponi L, Cantiani P, De Cinti B, Ferretti F, 2016. Îlots de senescence in the ManFor C.BD sites. Ital. J. Agron. 11(s1):1-175.
Recanatesi M, De Cinti B, Matteucci G (eds.), 2014. Manfor Magazine. ManFor C.BD LIFE09ENV/IT/000078 project - Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing.
Recanatesi M, De Cinti B, Matteucci G (eds.), 2015. Manfor Magazine. ManFor C.BD LIFE09ENV/IT/000078 project - Managing Forests for Multiple Purposes: Carbon, Biodiversity and Socio-Economic Wellbeing.

Landscape as a driver of forest functions

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Introduction

A landscape is a heterogeneous land area composed of a set of interacting ecosystems that is repeated in a similar way over wide areas. This landscape pattern is driven by specific climate, geomorphology, soils, vegetation and disturbance regimes (Forman and Godron, 1986). Each landscape is characterized by a specific set and amount of ecosystems (said landscape composition) spatially arranged in a precise manner (said landscape spatial pattern). Such ecosystems or landscape elements can be briefly classified, according with their extension and form, into three types: patches (discrete areas of relatively homogeneous environmental conditions that differ from their surroundings), corridors (strips of specific ecosystem types that differ from the adjacent land on both the sides and that represent the physical linkage between focal patches within a landscape), and the matrix (the background land use type in a mosaic, characterized by extensive cover, high connectivity, and/or control over dynamics that occur within patches and corridors). A landscape mosaic derives from interacting biological, geophysical and anthropogenic driving forces that give rise to different land uses, infrastructures, social organizations, institutional arrangements, and cultural, spiritual, and utility values (Frost *et al*., 2006). Landscapes change constantly but in the last decades, humans have accelerated such changes with little thought to the cumulative impact of such transformations (EEA, 2011). Over the last fifty years, landscape mosaics have been modified more rapidly and extensively than during any comparable period in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in substantial gains in human well-being and economic development, and has caused increasing costs and degradation of many ecosystems (EEA, 2005). Millennium Ecosystem Assessment states that demographic development is an essential driver for ecosystem and land use change (Nelson *et al*., 2006; EEA, 2011, Kroll and Haase, 2010).

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Key words: Forest fragmentation, biodiversity, spatial pattern, harvesting practices.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Forest fragmentation and biodiversity

Forest landscapes have played a major role in human history; forest fragmentation has often been accompanied by the population growth and development throughout the world (FAO, 2012). Forest landscapes are under constant dynamic changes, driven predominantly by changes in management practices that are responding to social, political and economic forces (Chen *et al*., 2008). The current state of forested landscapes in the world is mainly the result of former evolution in land use (Kienast, 1993). For instance, temperate forests in European mountain and hilly landscapes are currently distributed in a mosaic which derives from a long period of extensive forest exploitation and agriculture farming (Axelsson and Östlund, 2001; Rosati *et al*., 2010; Carranza *et al*., 2012), followed by a recent, spontaneous reforestation process which occurred after the World War II rural exodus and abandonment of traditional agricultural practices (MacDonald *et al*., 2000; Rudel *et al*., 2005; Carranza *et al*., 2007). On the contrary, natural forests in developing tropical and subtropical countries are among the most overexploited and threatened forest ecosystems worldwide (Hoekstra *et al*., 2005). Major tropical and subtropical forests are seriously exposed to illegal agricultural clearing, timber exploitation, and forest fires (Carr *et al*., 2009; Honey-Rosés, 2009).

Forest fragmentation is a landscape-level process in which a large, intact area of a single forest type is progressively separated into smaller, geometrically altered and isolated patches (Fahrig, 2003; Forman and Godron, 1986). The extent of forest fragmentation and overexploitation, which has negatively affected and threatened many natural forests worldwide, represents one of the most serious causes of biodiversity loss, which in turn significantly influences both ecosystem structure and function. Many studies have pinpointed the negative effects of forest overexploitation and fragmentation with several and long-lasting environmental and ecological consequences (Trombulak *et al*., 2004; Flaspohler *et al*., 2010). Forest fragmentation also affects ecosystem functions, such as hydrological cycles and soil dynamics (Rudel *et al*., 2005), climate regulation (Nabuurs *et al*., 2003) and biodiversity (see Fahrig, 2003 for a review). Forest fragmentation consists of two interdependent components: forest loss and changes in forest spatial configuration (Long *et al*., 2010). Understanding the effects of these processes on biodiversity is essential for a successful and efficient future forest conservation, but the existing literature does not propose any univocal thesis. In particular, according to the island biogeography theory (MacArthur and Wilson, 1967), forest fragmentation may be expected to cause a reduction in the number or even the extinction of native forest species at local scale (Zuidema *et al*., 1996). On the other hand, Forman (1995) postulates a general principle, according to which larger patches, as environmentally more heterogeneous, host higher species richness than smaller patches. Rosati *et al*. (2010) illustrated this theory with an example on Mediterranean forests, where a positive correlation between patch sizes and diversity values of vascular plants were confirmed. Latest research on European temperate forest established that, some plant species may be more sensitive to fragmentation than others (Chiarucci and Bonini, 2005; Frate *et al*., 2011; Carranza *et al*., 2012). Therefore the analysis of some diagnostic groups may be more suitable than species richness *per se* and could offer a useful information for the future forest conservation and management.

Forest harvesting and forest spatial pattern

Forest harvesting includes logging with different cutting methods. In the forest management goals multiple uses and benefits from forests are defined. With increasing emphasis on the benefits provided by biological diversity, the spatial pattern of managed landscapes has become an important management consideration (Diaz and Apostol, 1992).

Timber extraction can be considered a human induced disturbance that modifies spatial pattern of forests and causes a shift in the ecological succession (Gustafson and Diaz, 2002). Harvesting may be considered as similar to natural disturbances such as fire and wind events (Attiwill, 1994), because it promotes regeneration processes and succession pathways on established gaps (Yamamoto, 2000). For example, the residual forest patches left after different cutting systems, may have a spatial pattern similar to that caused by wind events. The ecological effects of timber harvest and natural disturbance are usually temporary and forests grow back by secondary succession mechanisms. At the same time, harvesting activities differ from natural disturbances in controlled frequency, intensity and applied area (Gustafson and Diaz, 2002).

The extraction of timber in natural and semi natural forests is the primary determinant of landscape pattern in managed forests. In particular, timber extraction has significant consequences on landscape features as forest patch characteristics (size and shape) and connectivity. Forest exploitation promotes the fragmentation processes which in turn greatly affect biodiversity (Foley *et al*., 2005) and many forest ecosystem services (Gamfeldt *et al*., 2013). Indeed, an important effect of harvesting practices is the creation of new patches that differ from other forested areas in terms of dominant vegetation type, successional stage or canopy closure. In addition, after harvesting new edge habitats may be established, characterized by different environmental conditions (*e.g.*, light, moisture) than those of interior forests (Dupuch and Fortin, 2013). The increase of edges in the forest mosaic has consistent effects on biodiversity, promoting the presence of a consistent cohort of edge and clearing species (for a review see Liernet, 2004; Fahrig, 2003; Carranza *et al*., 2012) and the simultaneous decrease in the number of core and true forest species (*sensu* Hermy *et al*., 1999).

The adopted silvicultural system significantly affects the spatial pattern and structure of forests and also the balance between edge and interior areas. For instance, a check-board setting, characterized by several small-dispersed cutting-units, always creates a more fragmented pattern than using large clumped cutting units (Li *et al*., 1993). Yet, the check-board model generates longer edges and reduces the extent of interior habitats (Franklin and Forman, 1987). Conversely, by adopting aggregated cutting units, more forest interior are retained (Figure 1).

The consequences of the edge effect are species-specific since depend on the distance between the forest interior and the forest patch boundary (*e.g.*, Tonti *et al*., 2010). In Figure 1, an example of edge effects expanding into forests for 10 meters is presented. The initial condition is represented in Figure 1A and shows an uncut forest: the portion of interior forest is 3.24 ha and the portion of edge forest is 0.76 ha. The portion of edges and core areas varies consistently with the pattern of timber harvesting. In the reported example we assume an area of timber extraction equal to the 50% of the existing forest area. Adopting the check-board model (Figure 1B) the portion of interior forest is 0.18 ha while that of edge forest is 1.44 ha. Conversely, in the aggregated model (Figure 1C) the portion of interior forest is 1.16 ha while that of edge is

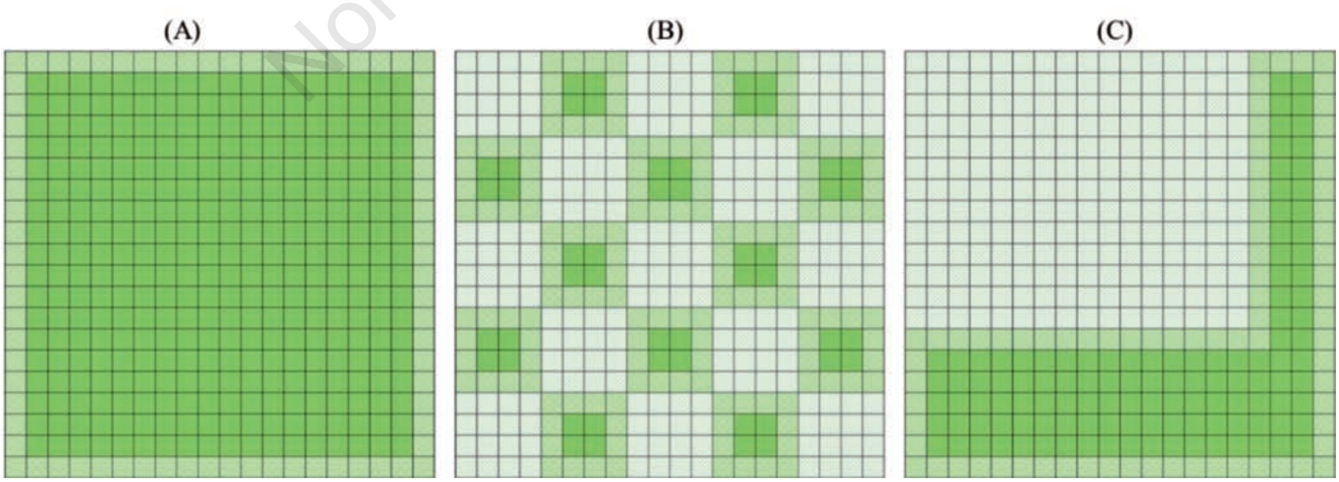

Figure 1. Patterns of timber harvesting of the 50% of existing forests according with two spatial models: (B) check-board model and (C) aggregated model. (A) represents uncut forests. Dark green represents interior conditions whereas light green indicates edge conditions. Aqua green represents the harvested areas. Each cell is 0.01 ha in size of the total 4 ha area. (Modified from Franklin and Forman. Landscape Ecology 1987; 1:5-18).

0.76 ha.

The effects of such simple example on temperate forests may be interpreted according to research performed on European temperate forests (*e.g.*, beech forests, turkey oak forests). For instance Rosati *et al*. (2010) and Carranza *et al*. (2012) described the presence of a rich cohort of edge and clearing vascular plant species in mosaics characterized by long edges (small irregular patches) whereas true forest species (*sensu* Hermy *et al*., 1999) exclusively occur on landscapes where core conditions are dominant.

Since the spatial shape of cuttings may have an important role for biodiversity, the spatial pattern of forest cutting for conservation purposes, should look as natural as possible (Forman, 1995; Saura *et al*., 2008). Unfortunately, increasing in the intensity of human pressure (*e.g.*, mechanized harvesting methods) had led to the oversimplification of landscape shapes (Carranza *et al*., 2007) which could drive to a reduction of the richness of important edge taxonomic groups. For example, Saura *et al*. (2008) showed that the simplification of forest patch shape irregularity is correlated with a decrease of plant diversity and, birds, mammals and total vertebrate species richness in the landscape. For these reasons, much emphasis should be given on the shape irregularity as a key variable to be considered for the management of forest harvesting.

Final remarks

Conservation of forest landscape biodiversity and functioning requires the ability to predict the future responses and extent of changes in biodiversity and function of forests, which would occur as a result of forest disturbance (Chen *et al*., 2008). One should distinguish between forests, fragmented because of agricultural or urban activities and forested landscapes, such as mosaic of mature and regenerating stands. In particular, sustainable management of forest landscapes requires focusing on mosaics of patches and long-term changes in these mosaics to integrate ecological values, such as the maintenance of forest ecosystem integrity, biodiversity conservation, and carbon sequestration, with economic and social purposes, such as timber and recreation. A great challenge would represent the forest management effect to the forest structure and biodiversity and preservation of stability and productivity of forest landscapes.

References

Attiwill PM 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecol. Manag. 63:247-300.

Axelsson AL, Östlund L, 2001. Retrospective gap analysis in a Swedish boreal forest landscape using historical data. Forest Ecol. Manag. 147:109-122.

Carr DL, Lopez AC, Bilsborrow RE, 2009. The population, agriculture, and environment nexus in Latin America: country-level evidence from the latter half of the twentieth century. Popul. Environ. 30:222-246.

Carranza ML, Frate L, Paura B, 2012. Structure, ecology and plant richness patterns in fragmented beech forests. Plant. Ecol. Divers. 5:541-551.

Carranza ML, Acosta A, Ricotta C, 2007. Analyzing landscape diversity in time: the use of Rènyi's generalized entropy function. Ecol. Indic. 7:505-510.

Chen J, Brosofske KD, Lafortezza R, 2008. Ecology and management of forest landscapes. In: R. Lafortezza, J. Chen, G. Sanesi and T.R. Crow (eds.), Patterns and processes in forest landscapes. Springer, The Netherlands, pp. 3-16.

Chiarucci A, Bonini I, 2005. Quantitative floristics as a tool for the assessment of plant diversity in Tuscan forests. Forest Ecol. Manag. 212:160-170.

Diaz N, Apostol D, 1992. Forest landscape analysis and design: a process for developing and implementing land management objectives for landscape patterns. R6 ECO-TO-043-92, USDA Forest Service, Portland, OR, USA.

Dupuch A, Fortin D, 2013. The extent of edge effects increases during post-harvesting forest succession. Biol. Conserv. 162:9-16.

EEA, 2005. Sustainable use and management of natural resources. EEA Report No 9/2005, European Environment Agency, Luxembourg. Available from: http://www.eea.europa.eu/publications/eea_report_2005_9

EEA, 2011. Landscape fragmentation in Europe: joint EEA-FOEN report. EEA Report No 2/2011. European Environment Agency, Luxembourg. Available from: http://www.eea.europa.eu/publications/landscape-fragmentation-in-europe

Fahrig L, 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34:487-515.

FAO, 2012. State of World's Forests 2012. Food and Agriculture Organization of the United Nations, Rome, Italy.

Flaspohler D, Giardina C, Asner G, Hart P, Price J, Cassie Kaapu L, Castaneda X, 2010. Long-term effects of fragmentation and fragment properties on bird species richness in Hawaiian forests. Biol. Conserv. 143:280-288.

Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JK, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice IC, Ramankutty N, Snyder PK, 2005. Global consequences of land use. Science 309:570-574.

Forman RTT, 1995. Land mosaics: the ecology of landscapes and regions. Cambridge University Press, Cambridge, UK.

Forman RTT, Godron M, 1986. Landscape ecology. J. Wiley & Sons, New York, USA.

Franklin JF, Forman RTT, 1987. Creating landscape pattern by forest cutting: ecological conseuqences and principles. Landscape Ecol. 1:5-8.

Frate L, Carranza ML, Paura B, Di Biasi N, 2011.Analisi della diversità floristica dei boschi lungo un gradiente di frammentazione: un caso studio nelle faggete dell'Appennino molisano. Forest@ 8:137-148.

Frost P, Campbell B, Medina G, Usongo L, 2006. Landscape-scale approaches for integrated natural resource management in tropical forest landscapes. Ecol. Soc.11:30.

Gamfeldt L, Snäll T, Bagchi, R, Jonsson M, Gustafsson L, Kjellander P, Ruiz-Jaen MC, Fröberg M, Stendahl J, Philipson CD, Mikusiński G, Andersson E, Westerlund B, Andrén H, Moberg F, Moen J, Bengtsson J, 2013. Higher levels of multiple ecosystem services are found in forests with more tree species. Nat. Commun. 4:1340.

Gustafson EJ, Diaz N, 2002. Landscape pattern, timber extraction and biological conservation. In:, K.J. Gutzwiller (ed.) Applying landscape ecology to biological conservation. Springer, New York, pp. 224-265.

Hermy M, Honnay O, Firbank L, Grashof-Bokdam C, Lawesson JE, 1999. An ecological comparison between ancient and other forest plant species of Europe, and the implications for conser-

vation. Biol. Conserv. 91:9-22.
Hoekstra JM, Boucher TM, Ricketts TH, Roberts C, 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecol. Lett. 8:23-29.
Honey-Rosés J, 2009. Disentangling the proximate factors of deforestation: the case of the Monarch butterfly Biosphere Reserve in Mexico. Land Degrad. Dev. 20:22-32.
Kienast F, 1993. Analysis of historic landscape patterns with a Geographical Information System - a methodological outline. Landscape Ecol. 8:103-118.
Kroll F, Haase D, 2010. Does demographic change affect land use patterns? A case study from Germany. Land Use Policy 27:726-737.
Li H, Franklin JF, Swanson FJ, Spies TA, 1993. Developing alternative forest cutting patterns: A simulation approach. Landscape Ecol. 8:63-75.
Liernet J, 2004. Habitat fragmentation effects on fitness of plant populations: a review. J. Nature Conserv. 12:53-72.
Long JA, Nelson TA, Wulder MA, 2010. Characterizing forest fragmentation: Distinguishing change in composition from configuration. Appl. Geogr. 30:426-435.
MacArthur RH, Wilson EO, 1967. The theory of island biogeography. University Press, Princeton, USA.
MacDonald D, Crabtree JR, Wiesinger G, Dax T, Stamou N, Fleury P, Gutierrez Lazpita J, Gibon A, 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. J. Environ. Manage. 59:47-69.
Nabuurs GJ, Schelhaas MJ, Mohren GMJ, Field CB, 2003. Temporal evolution of the European forest sector carbon sink from 1950 to 1999. Glob. Change Biol. 9:152-160.
Nelson GC, Bennett E, Berhe AA, Cassman K, DeFries R, Dietz T, Dobermann A, Dobson A, Janetos A, Levy M, Marco D, Nakicenovic N, O'Neill B, Norgaard R, Petschel-Held G, Ojima D, Pingali P, Watson R, Zurek M, 2006. Anthropogenic drivers of ecosystem change: an overview. Ecol. Soc. 11:29.
Rosati L, Fipaldini M, Marignani M, Blasi C, 2010. Effects of fragmentation on vascular plant biodiversity in a Mediterranean forest archipelago. Plant Biosyst. 144:38-46.
Rudel TK, Coomes OT, Moran E, Achard F, Angelsen A, Xu J, Lambin E, 2005. Forest transitions: towards a global understanding of land use change. Global Environ. Chang. 15:23-31.
Saura S, Torras O, Gil-Tena A, Pascual-Hortal L, 2008. Shape irregularity as an indicator of forest biodiversity and guidelines for metric selection. In: R. Lafortezza, J. Chen, G. Sanesi and T.R. Crow (eds.), Patterns and processes in forest landscapes. Springer, The Netherlands, pp. 167-189.
Tonti D, Estreguil C, Marchetti M, Oehmichen K, Chirici G, Troeltzsch K, Watts K, 2010. Linking and harmonizing forest spatial pattern analyses at European, National and Regional scales for a better characterization of forest vulnerability and resilience. European Commission, Joint Research Centre and Institute for Environment and Sustainability.
Trombulak SC, Omland KS, Robinson JA, Lusk JJ, Fleischner TL, Brown G, Domroese M. 2004. Principles of conservation biology: recommended guidelines for conservation literacy from the Education Committee of the Society for Conservation Biology. Conserv. Biol. 18:1180-1190.
Yamamoto SI, 2000. Forest gap dynamics and tree regeneration. J. For. Res. 5:223-229.
Zuidema PA, Sayer J, Dijkman W, 1996. Forest fragmentation and biodiversity: the case for intermediate-sized reserves. Environ. Conserv. 2:290-297.

Diversity of structure through silviculture

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Forest structure is a key element in understanding functionality and resilience of forest ecosystems (Kint *et al*., 2004; Zenner and Hibbs, 2000), and is described in general terms as the distribution of biomass, *i.e*. the vertical and horizontal spatial arrangement of plant species, tree sizes, age distribution and tree canopy layering.

Stand structure attributes are increasingly recognized as of theoretical and practical importance in analysing management quality in forest ecosystems, since stand structure i) is the most manipulated element to achieve management goals; ii) it is a readily measurable proxy for functions difficult to be measured directly; and iii) it has an inherent value for wood production as well as in providing externalities *e.g.* aesthetical values or ecological niches (Franklin *et al*., 2002; McElhinny *et al*., 2005). Therefore the preservation of forest structural diversity has been considered as a key issue in the guidelines for the implementation of Sustainable Forest Management (SFM).

Stand structure is also considered as a basic element of diversity (Fischer and Pommerening, 2003; Staudhammer and LeMay, 2011) under central European growth conditions, where it achieves a comparatively higher importance, as tree species number is rather low, especially in mountain forests.

According to Pretzsch (2010), the horizontal distribution pattern of trees, tree density, tree size differentiation and tree species intermingling are the main components of stand structure. Their analysis provides also basic elements for recognition of the inter-tree competitive mechanisms. Main silvicultural practices as thinning and regeneration cuttings, heavily affect the stand structure and its arrangement during the full stand life-span (Bailey and Tappeiner, 1998), with direct impacts on the wildlife populations (Harrington and Tappeiner, 2009), tree regeneration dynamics (Getzin *et al*., 2008) and understory vegetation (Kembel and Dale, 2006). Silviculture basically acts repeatedly on the aggregation and hierarchical organization of trees at its operational patch scale.

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Key words: Forest structure, stand level, structural diversity indexes, inter-tree competition indexes, silvicultural practices.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Different approaches have been developed to study the influence of practices, on the dynamics of forest structure: the spatial individual tree models (Lexer *et al*., 2000), the permanent sample plots (Sullivan *et al*., 2006) and the historic management records (Montes *et al*., 2005).

Type and intensity of management do not only have influence on the ecological processes such as nutrient cycling, decomposition rates, regeneration patterns, but also on stand structure dynamics (Taboada *et al*., 2006); besides, the first physiognomic impact of forest management reflects in forest structure.

For a successful natural regeneration, a minimum level of light reaching the understory is required, which enables seedlings to grow and assure a future trees' generation, especially when the oldest trees are at the end of their life cycle. Optimal light conditions vary for different tree species, shrubs or herbs according to their shade tolerance. The species' shade tolerance may vary in different ecosystems and stage of their development. Intensity, spatial and temporal distribution of light in the understory can be manipulated through silviculture by designing and shaping the harvesting, according to the overstory structure of a forest stand (Angelini *et al*., 2015; Battaglia *et al*., 2002; Beaudet *et al*., 2002; Leibundgut, 1891). As every species, phenological phase and process, such as respiration, photosynthesis, transpiration, etc. depend on the temperature, an optimum range of temperature may be also defined. Out of this range, the efficiency decreases rapidly. During vegetation period, high temperature increase the respiration and transpiration, creating undesirable conditions for the forest regeneration. Most critical are temperature drops below 0°C in the temperate forests, especially during the vegetation phase. Temperature cannot be manipulated directly by human practices, even though harvesting a large area (>5 ha) can provide more continental characteristic on the local micro-climate site and increase extreme temperatures at the ground level (Carlson and Groot, 1997; Chen *et al*., 1993, 1999).

Water, as another key factor determining forest regeneration processes, is influenced by the canopy cover. Large gaps may induce increase in evapotranspiration, which can lead into stress conditions. In high forests, we can shape structure through silvicultural measures in order to create a convenient environment for regeneration and retrieve a profitable wood products, as well (Carlson and Groot, 1997; Chen *et al*., 1993, 1999).

Thinning is a silvicultural practice following the natural process of density reduction due to competition among trees. Both natural and the human-induced thinning tend to alter the stand structure. Differently from regeneration felling, thinning is applied to stimulate radial growth in remaining trees and to achieve desired goal-characteristics. Different criteria can be adopted for thinning. The simplest is the systematic approach, which consist of a simple geometrical rule to harvest a predefined number of trees and could be applied in plantations with recognizable planting patterns. The result of the systematic thinning is a simplified structure, similar to the original in the non-thinned stands. On the other side a selec-

Table 1. List of potential indexes to assess stand structural diversity and inter-tree competition.

Index	Equation	Variables	Range and reference values
Aggregation index [CE] (Clark and Evans, 1954)	$CE=\frac{r_A}{r_E}$	$r_A=\frac{\sum_{i=1}^{n} HDist_{ij}}{n}$; $r_E=\frac{1}{2}\sqrt{\frac{A}{N}}$ $HDist_{ij}$ = Euclidean distance between *i-th* tree and its nearest neighbour A = plot area N = plot tree number	Min value = 0 Max value = 2.1491 CE = 1 → completely spatially random distribution CE < 1 → spatially clustered distribution CE > 1 → spatially regular distribution
DBH-Differentiation [TD] (Pommerening, 2002)	$TD=\frac{1}{n}\sum_{j=1}^{n}\left(1-\frac{min(DBH_i,DBH_j)}{max(DBH_i,DBH_j)}\right)$	n = number of the first 4 nearest neighbours) DBH = diameter at height = 1.3 m	Min value = 0 Max value = 1 TD = 0 → all neighbors have equal DBH TD = 1 → all neighbours have different DBH
Height-Differentiation [TH] (Pommerening, 2002)	$TH=\frac{1}{n}\sum_{j=1}^{n}\left(1-\frac{min(H_i,H_j)}{max(H_i,H_j)}\right)$	n = number of the first 4 nearest neighbours) H = total stem height	Min value = 0 Max value = 1 TD = 0 → all neighbours have equal height TD = 1 → all neighbours have different height
Diameter diversity based on variance [$STVI_{dbh}$] (Staudhammer and LeMay, 2011)	$\begin{cases} 1-\left(\frac{S_U^2-S_k^2}{S_U^2}\right)^{p1,} & if\ S_k^2\le S_U^2 \\ 1-\left(\frac{S_U^2-S_k^2}{m*S_{max}^2-S_U^2}\right)^{p2,} & if\ S_k^2>S_U^2 \end{cases}$	S_k is the empirical variance (dbh or tree height) S_U is the variance of the univariate uniform distribution (dbh or tree height) S_{max} is the maximum possible variance (when the distribution is maximally bimodal)	
Height diversity based on variance [$STVI_{Htot}$] (Staudhammer and LeMay, 2011)			
BAL modified [BAL_{MOD}] (Schröder and Gadow, 1999)	$BALMOD=\frac{1-p_i}{RS}$	p_i is the basal area percentile of the reference tree RS is a relative spacing index (stand level)	
Hegyi [Hg] (Hegyi, 1974)	$Hg_i=\sum_{j=1}^{n} dbh_j/(dbh_i * Hdist_{ij})$	$dbhj$ = diameter at breast height of the competitor trees $dbhi$= diameter at breast height of the	

Continued on next page.

Table 1. Continued from previous page.

Index	Equation	Variables	Range and reference values
		reference tree Hdistij = Euclidean distance between i-th tree and its nearest neighbour n = number of competitors (all trees that fall within a distance of 1/3*Hi)	
Hegyi modified [Hg mod] (Pretzsch, 2010)	$Hg\,(mod)_i = \sum_{j=1}^{n} dbh_j / (dbh_i * Hdist_{ij})$	*dbhj = diameter at breast height of the competitor trees* *dbhi = diameter at breast height of the reference tree* *Hdistij = Euclidean distance between i-th tree and its nearest neighbour* *n = number of competitors = trees identified from an horizontal angle count sample*	
Aggregation (Hui *et al.*, 1998)	$Aggre = \frac{1}{4}\sum_{j=1}^{4} v_j \begin{cases} 1 & \cdots \quad \alpha_j < \alpha_0 \\ 0 & \cdots \quad otherwise \end{cases}$	j = number of the first 4 nearest neighbours *Aggregation is defined as the proportion of angles* α_j *between the four neighbouring trees, which are smaller than the standard angle* α_0 *(90°).*	Min value = 0 Max value = 1 Aggre = 0 → spatially regular distribution of trees Aggre = 1 → spatially clustered distribution of trees
Species mingling (Füldner, 1995)	$Ming = \frac{1}{4}\sum_{j=1}^{4} v_j \begin{cases} 1 & \cdots \quad neighbour\ j\ belongs\ to\ the\ same\ species \\ 0 & \cdots \quad otherwise \end{cases}$	j = number of the first 4 nearest neighbours *Mingling is the proportion of the n nearest neighbours that do not belong to the same species as the reference tree.*	Min value = 0 Max value = 1 Ming = 0 → all neighbors belong to the same tree species. Ming = 1 → all neighbors belong to different tree species
Size differentiation (Hui *et al.*, 1998)	$SizDiff = \frac{1}{4}\sum_{j=1}^{4} v_j \begin{cases} 1 & \cdots \quad neighbour\ j\ is\ smaller\ then\ reference\ tree\ i \\ 0 & \cdots \quad otherwise \end{cases}$	j = number of the first 4 nearest neighbours *Dominance is the proportion of the n nearest neighbours of a given reference tree.*	Min value = 0 Max value = 1 SizDiff = 0 → all neighbors have bigger DBH SizDiff = 1 → all neighbors have smaller DBH
Shannon Index of diversity (SH) (Shannon, 1948)	$SH = \Sigma(\log_2 \pi)\pi$	π - proportion of the BA of trees in the 5 cm DBH class	
Simpson Index of diversity (SI) (Simpson, 1949)	$SH = \Sigma(1 - \pi)\pi$	π - proportion of the BA of trees in the 5 cm DBH class	
Evenness (E) (Lloyd and Ghelardi, 1964; Magurran, 1988)	$E = SH/\log_2 N$	SH - Shannon index N - total number of species	

tive thinning can be used which consist on the selection of the candidate trees and the elimination of direct competitors. Between these two approaches there are intermediate approaches such as thinning from below and thinning from above.

The stand structure induced by silvicultural practices has a strong impact on the growing space availability and distribution. The complexity of the process and factors involved in the forest ecosystems would require a very long dissertation of this issue.

Growing space differentiation determines a larger number of niches to be populated by more species. Avoiding systematic thinning or cutting on large areas (more than 1 ha) may increase species' richness (Torras and Saura, 2008). Additionally, selective thinning should be preferred since it promotes higher structural diversity (Gracia and Retana, 1996).

Secondly, the scale of differentiation depends on the trade-off between economic and ecological efficiency. The approach to determine the proper scale should be based on the minimal economic efficiency. If there is no economic convenience, there is no need to increase the differentiation scale of growing space.

The multidimensional character of forest stands makes it hard to describe their own structure (Beckschäfer *et al*., 2013). An impressive number of indexes have been consequently developed (Pommerening, 2006) as proxies of the forest structure (Corona *et al*., 2005; Neumann and Starlinger, 2001). Traditionally, forest structure may be divided into horizontal and vertical components. Table 1 summarizes a selection of spatially explicit and not spatially explicit indexes. This list is not exhaustive of all possible stand structural information, but represents a comprehensive selection of main structural and competition indexes.

References

Angelini A, Corona P, Chianucci F, Portoghesi L, 2015. Structural attributes of stand overstory and light under the canopy. Ann. Silvic. Res. 39:23-31.

Bailey JD, Tappeiner JC, 1998. Effects of thinning on structural development in 40- to 100-year-old Douglas-fir stands in western Oregon. For. Ecol. Manage. 108:99-113.

Battaglia MA, Mou P, Palik B, Mitchell RJ, 2002. The effect of spatially variable overstory on the understory light environment of an open-canopied longleaf pine forest. Can. J. For. Res. 32:1984-1991.

Beaudet M, Messier C, Canham CD, 2002. Predictions of understory light conditions in northern hardwood forests following parameterization, sensitivity analysis, and tests of the SORTIE light model. For. Ecol. Manage. 165:235-248.

Beckschäfer P, Mundhenk P, Kleinn C, Ji Y, Yu DW, Harrison RD, 2013. Enhanced structural complexity index: an improved index for describing forest structural complexity. Open J. For. 03:23-29.

Carlson D, Groot A, 1997. Microclimate of clear-cut, forest interior, and small openings in trembling aspen forest. Agric. For. Meteorol. 87:313-329.

Chen J, Franklin JF, Spies TA, 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agric. For. Meteorol. 63:219-237.

Chen J, Saunders SC, Crow TR, Naiman RJ, Brosofske KD, Mroz GD, Brookshire BL, Franklin JF, 1999. Microclimate in forest ecosystem and landscape ecology. Bioscience 49:288.

Clark P, Evans F, 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35:445-453.

Corona P, D'Orazio P, Lamonaca A, Portoghesi L, 2005. The Winkelmass index as a forest management tool for inventorying stand structure. Forest@ 2:225-232.

Fischer R, Pommerening A, 2003. Methodology for stand structure assessments in the biodiversity test phase 2003-2005 of EU/ICP Forests 2003. Programme Coordinating Centre of ICP Forests Hamburg, University of Wales Bangor Internal Report.

Franklin JF, Spies TA, Van Pelt R, Carey AB, Thornburgh DA, Berg DR, Lindenmayer DB, Harmon ME, Keeton WS, Shaw DC, Bible K, Chen J, 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications, using Douglas-fir forests as an example. For. Ecol. Manage. 155:399-423.

Füldner K, 1995. Strukturbeschreibung von Buchen-Edellaubholz-Mischwäldern. [Describing forest structures in mixed beech-ash-maple-sycamore stands.]. University of Göttingen.

Getzin S, Wiegand T, Wiegand K, He F, 2008. Heterogeneity influences spatial patterns and demographics in forest stands. J. Ecol. 96:807-820.

Gracia M, Retana J, 1996. Effect of site quality and thinning management on the structure of holm oak forests in northeast Spain. Ann. Sci. For. 53:571-584.

Harrington TB, Tappeiner JC, 2009. Long-term effects of tanoak competition on Douglas-fir stand development. Can. J. For. Res. 39:765-776.

Hegyi F, 1974. A simulation model for managing jack pine stands. In: J. Fries (ed.) Proc. IUFRO Meeting Sr., Royal College of Forestry, Stockholm, pp. 74-90.

Hui GY, Albert M, Von Gadow K,. 1998. Das Umgebungsmaß als Parameter zur Nachbildung von Bestandesstrukturen. [The diameter dominance as a parameter for simulating forest structure]. Forstwissenschaftliches Cent. 117:258-266.

Kembel SW, Dale MRT, 2006. Within-stand spatial structure and relation of boreal canopy and understorey vegetation. J. Veg. Sci. 17:783-790.

Kint V, Mohren GMJ, Geudens G, De Wulf R, Lust N, 2004. Pathways of stand development in ageing Pinus sylvestris forests. J. Veg. Sci. 15 549-560.

Leibundgut H, 1891. Die natürliche Waldverjüngung [The natural regeneration]. Haupt, Germany.

Lexer MJ, Lexer W, Hasenauer H, 2000. The use of forest models for biodiversity assessments at the stand level. Investig. Agrar. Sist. y Recur. For. 9:297-316.

Lloyd M, Ghelardi RJ, 1964. A table for calculating the `equitability' component of species diversity. J. Anim. Ecol. 33:217-225.

Magurran AE, 1988. Ecological diversity and its measurement. Springer, The Netherlands.

McElhinny C, Gibbons P, Brack C, Bauhus J, 2005. Forest and woodland stand structural complexity: Its definition and measurement. For. Ecol. Manage. 218:1-24.

Montes F, Sanchez M, Rio M, del Canellas I, 2005. Using historic management records to characterize the effects of management on the structural diversity of forests. For. Ecol. Manage. 207:279-293.

Neumann M, Starlinger F, 2001. The significance of different indices for stand structure and diversity in forests. For. Ecol. Manage. 145:91-106.

Pommerening A, 2002. Approaches to quantifying forest structures. Forestry 75:305-324.

Pommerening A, 2006. Evaluating structural indices by reversing forest structural analysis. For. Ecol. Manage. 224:266-277.

Pretzsch H, 2010. Forest dynamics growth and yield. Springer Berlin Heidelberg.

Schröder J, von Gadow K, 1999. Testing a new competition index for Maritime pine in northwestern Spain. Can. J. For. Res. 29:280-283.

Shannon CE, 1948. A mathematical theory of communication. Bell Syst. Tech. J. 27:379-423.

Simpson EH, 1949. Measurement of diversity. Nature 163:688-688.

Staudhammer CL, LeMay VM,. 2011. Introduction and evaluation of possible indices of stand structural diversity. Can. J. For. Res. 31:1105-1115.

Sullivan TP, Sullivan DS, Lindgren PMF, Ransome DB, 2006. Long-term responses of ecosystem components to stand thinning in young lodgepole pine forest. For. Ecol. Manage. 228:69-81.

Taboada A, Kotze DJ, Tárrega R, Salgado JM, 2006. Traditional forest management: do carabid beetles respond to human-created vegetation structures in an oak mosaic landscape? For. Ecol. Manage. 237:436-449.

Torras O, Saura S, 2008. Effects of silvicultural treatments on forest biodiversity indicators in the Mediterranean. For. Ecol. Manage. 255:3322-3330.

Zenner EK, Hibbs DE, 2000. A new method for modeling the heterogeneity of forest structure. For. Ecol. Manage. 129:75-87.

Italian Journal of Agronomy 2016; volume 11(s1)

Deadwood as a driver of forest functions

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Introduction

For generations, people have looked on deadwood as something to be removed from forests, either to be used as a fuel, or simply as a necessary part of "correct" forest management. Deadwood is supposed to harbour disease and even veteran trees are often regarded as a sign that a forest is being poorly managed. Breaking up these myths will be essential to preserve healthy forest ecosystems and the environmental services they provide. In international and European political processes, deadwood is increasingly being accepted as a key indicator of naturalness in forest ecosystems (MCPFE and EfE/PEBLDS, 2004). Forest policies have recognized the need to preserve a wide range of forest ecosystem services, such as the conservation of biodiversity (Nelson *et al*., 2009). This can be done by including deadwood in national biodiversity and forest strategies, monitoring deadwood, removing subsidies that pay for its undifferentiated removal, introducing supportive legislation and raising awareness.

The importance of deadwood in forests has been partially documented, and can be divided into the following inter-related categories (Harmon *et al*., 1986):

- Forest productivity;
- Providing habitat and structure to maintain biological diversity;
- Geomorphology of streams and slopes;
- Long-term carbon storage.

The importance of each abovementioned parts varies throughout the bio-geographical areas due to natural disturbance type, climatic zones and moisture regime.

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Key words: biodiversity indicator, forest management, monitoring, deadwood type, wildlife habitat.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

The ecological role of deadwood

Deadwood may add a significant amount of organic matter to the soil, provide habitat for decomposer organisms, retain moisture through dry periods, offer a refuge for ectomycorrhizal roots and their associated soil organisms, provide a site for asymbiotic or associative nitrogen-fixing bacteria, represent a capital pool of nutrients for the ecosystem, provide a site for the regeneration and contribute to soil acidification and podsolization (Christensen *et al*., 2003; Kruys and Jonsson, 1999).

All size classes of decaying pieces of wood contribute to the long-term accumulation of soil organic matter because the lignin and humus of well-decayed wood are rich in carbon constituents (Maser *et al*., 1988). Deadwood improves the water holding capacity and structure of the soil. In order to protect the productive potential of a forest soil, a continuous supply of organic materials is preferable.

Deadwood can also contribute to nutrient storage, which includes the nutrients accumulated in the woody bole, large branches, roots and stumps during tree growth and the nutrients added from litterfall and throughfall (rain falling through the forest canopy) being intercepted by a down log rather than falling on the forest floor. If the nutrients are added faster than they are leached by rain, the result is positive nutrient storage. As the wood decays, the nutrients are added to the available pool. Mechanisms for removing the nutrients from deadwood and adding them to the available pool vary in relation to climatic conditions, forest structure and soil characteristics (Laiho and Prescott, 2004). When these mushrooms fall off the logs and decay, they are returning nutrients from the downed wood into the available nutrient pool. Arthropods and earthworms digest the complex, organic molecules in down wood with the help of microorganisms in their digestive systems and return the nutrients to the forest in their frass. Thus, deadwood can be a reliable and steady source of nutrients over more than 100 years. When coarse woody debris is added to the ecosystem at regular intervals and is well distributed, it represents a long-term source of nutrients (Keenan *et al*., 1993).

In some wet ecosystems, the tree seedlings with the best chance of success are those that germinate on large pieces of woody debris (Harmon *et al*., 1986). The understorey is dense, so no light reaches seedlings on the forest floor. The decaying woody boles provide a platform for successful germination and growth (Lambert *et al*., 1980).

Deadwood also contributes to the soil formation and stabilization, supporting biological organisms and interactions that are precious for the forest ecosystem health. This involves soil arthropods, fungi, bacteria, animal waste and among other things, decaying wood.

There is no doubt that deadwood plays an important part in creating habitat for many plant and animal species in forests ecosystems. Particularly, deadwood provides sites for nests, dens and burrows; habitat for microbial decomposers (*e.g.*, bacteria, fungi and actinomycetes); a primary energy source for a complex food web; hiding cover for predators and protective cover for their prey; moist microsites *(e.g.*, for amphibians, insects, worms, plants, ectomycorrhizal fungi and tree roots); travel-ways across streams, across the forest floor, beneath and through the snow; refugia during disturbance and environmental stress (*e.g.*, low moisture and temperature extremes).

Deadwood represents a structural link with the previous stand form in some natural disturbance types, and continuity of habitats for some species (Hansen *et al*., 1991). Carey and Johnson (1995) reported that along with understorey vegetation, coarse woody debris is the most important habitat factor for small mammals. These latter help to sustain the ecological processes in which they are an integral part (*e.g.*, the dispersal of seeds and mycorrhizal fungi spores, the maintenance of healthy predator populations, and the control of potentially harmful invertebrate populations) (Hanski, 1998).

Arthropods are one of the most diverse groups of animals and one of the least understood. Soil microarthropods, although largely unidentified, are the most important arthropods in terms of their impact on nutrient cycling. Groups of them associated with deadwood have been shown to increase the availability and suitability of organic particles for decomposer communities, and contribute to nutrient cycling and soil formation (Setälä and Marshall, 1994).

Many nonvascular plant species and fungi are associated with deadwood. The diversity of these species is related to the diversity of substrates, including a variety of decay stages, and has been linked to forest health (Amaranthus *et al*., 1994; Stelfox, 1995). Variability in piece size contributes to this diversity. Some bryophytes and fungi are restricted to very large pieces (Soderstrom, 1988).

Deadwood is also important in the geomorphology of terrestrial ecosystems, due to the physical properties of large pieces of wood. Upland sources of deadwood contribute to slope stability, soil surface stability, prevention of erosion and control of storm surface runoff. Particularly, on a steep slope, deadwood plays a crucial role in soil stabilization, controlling the flow of water, soil and litter across the forest floor. Material in any decay class, lying across the slope will reduce soil movement down-slope.

Finally, deadwood plays also a wider role by storing carbon to mitigate global warming as efficiently as many young timber plantations (Stevens, 1997).

As the reality of climate change is widely recognised, carbon sequestration (the storing of carbon in ecosystems) is gaining attention as one way of reducing greenhouses gases (Dixon *et al*., 1994). Major forest carbon pools include trees, understorey vegetation, deadwood, litter, and soil. Deadwood is important as it is both a store and source of carbon but is generally the less studied of the carbon pools. This will now change because national carbon inventories are required under the Kyoto Protocol of the 1992 United Nations Framework Convention on Climate Change (Woldendorp *et al*., 2002). Initial discussion on carbon storage focused on fast-growing rotations of exotic plantations.

However, while these can quickly accumulate carbon, storage is very temporary: average retention time of carbon in plantation trees is only a few years because most of the fibre is used in paper and other short life products that are either burned or degrade quickly in landfill. Deadwood itself releases carbon to the atmosphere -becoming a carbon source- during microbial respiration from decomposer organisms. But in terrestrial ecosystems in cool climates, microbial activity is restricted and decomposition very slow, so that deadwood tends to act as a long-term storage site (Angers *et al*., 2010).

Deadwood in forest ecosystems

In forests, a deadwood biomass, which is mostly result of the mortality (natural and human-induced), is composed of different types of dead and dying woody material, occurring in numerous forms with various decaying rates. Although deadwood has been a subject of many studies, there is a large variability of definitions for deadwood, which manly depend on the aim for which the study is carried out (Rondeux and Sanches, 2010). While some authors distinguish only two types of deadwood (standing and lying deadwood), a more detailed classification with four or five deadwood components is used by others (Merganičová *et al*., 2012). There are also differences concerning the use of terminology. In English-speaking countries most often the term woody detritus or debris instead of deadwood is used to describe dead and decaying pieces of wood. For example, in earlier studies by the term coarse woody debris (CWD) was meant snags, logs, chunks of wood, large branches and coarse roots with variable minimum diameters (Harmon *et al*., 1986). However, some other studies defined CWD as a total woody necromass found in the forest, including the woody fruits, buried wood and stumps (Pyle and Brown, 1999). There also exists a discrepancy in the understanding of snags and stumps between some authors (Merganičová *et al*., 2012). Beside the difficulties with definitions and terminology, another important issue refers to methods employed for deadwood assessment.

A wide range of sampling techniques exists, such as sample plot inventory, strip surveying, line intercept sampling, adaptive cluster sampling, point and transect relascope sampling, and guided transect sampling (Ståhl *et al*., 2001; Ritter and Saborowski, 2012). As there is no unique international standard for terms, definitions and methods for deadwood, the estimates are generally not comparable between different countries (Harmon and Sexton, 1996; Rondeux and Sanchez, 2010), although it may be achieved using two possible approaches, standardization or harmonization (Rondeux *et al*., 2012).

Different quantitative and qualitative indicators may assess deadwood. In Europe, deadwood volume is used as one of the most important indicators of forest biodiversity and is a focal component of forest monitoring (Lassauce *et al*., 2011). The volume of deadwood share is generally smaller in managed forests than in natural forests (Lombardi *et al*., 2008; Jonsson and Siitonen, 2012a). Some studies have reported that quantity of deadwood in managed forest ranges between 2 and 8 m^3 ha^{-1} (Lombardi *et al*., 2008), representing only values of 2-30% of the quantity in unmanaged forests (Fridman and Walheim, 2000; Siitonen, 2001; Lombardi *et al*., 2008). While the amount of deadwood in managed forest depends mostly on the history and type of forest management (Green and Peterken, 1997; Bobiec, 2002; Banaś *et al*., 2014), the amount of deadwood in unmanaged forests is determined by stand productivity and mortality. In these forest stands, the volume of deadwood is usually higher. As example, in natural and semi-natural temperate forests, estimates of deadwood volume are often in the range of 14-222 m^3 ha^{-1} (Bretz Guby and Dobbertin, 1996). The most important primary mortality factor in young stands entering the stem-exclusion stage is competition, whereas in old-growth stands the mortality is mostly governed by the natural disturbances (Jonsson and Siitonen, 2012a). According to the review of Schelhaas *et al*. (2003) natural disturbances in the European forest caused in the period 1950-2000 a damage of 35 million m^3 of trees. In addition to the influence of different forest management and disturbance regimes, the amount of deadwood in forests depends on variables, such as forest type, its developmental stage, local soil and climatic characteristics (Lombardi *et al*., 2008). Opposite to this, Böhl and Brändli (2007) reported that little evidence of correlations between deadwood volume and such parameters as management, site or stand attributes is evident.

At the stand scale, a high amount of deadwood under natural conditions not only leads to a larger diversity of substrates, but also to a higher deadwood surface area (Lachat *et al*., 2013). At first, higher amounts of available deadwood lead to more dead-wood surface area that according to the island theory therefore a higher species number on sampling units with a larger surface can be expected. Secondly, larger surface areas lead to more different available habitats (Müller and Bütler, 2010). Not only the volume, but also maintaining diverse qualities of deadwood in terms of tree species, decomposition stage, diameter, decay class, and type has a positive effect on the conservation of saproxylic species assemblages (Lachat *et al*., 2013).

References

Amaranthus M, Trappe JM, Bednar L, Arthur D, 1994. Hypogeous fungal production in mature Duglas-fir forest fragments and surrounding plantations and its relation to coarse woody debris and animal mycophagy. Can. J. Bot. 24:2157-2165.

Angers VA, Drapeau P, Bergeron Y, 2010. Snag degradation pathways of four North American boreal tree species. For.t Ecol. Manage. 259:246-256.

Banaś J, Drozd M, Bujoczek L, Zięba S, 2014. The effects of different types of management, functions, and characteristics of stands in Polish forests on the amount of coarse woody debris. Eur. J. Forest Res. 133:1095-1107.

Behan-Pelletier VM, 1993. Diversity of soil arthropods in Canada: systematic and ecological problems. Mem. Entomol. Soc. Can. 12:11-50.

Bobiec A, 2002. Living stands and dead wood in the Białowieża forest: suggestions for restoration management. For. Ecol. Manage. 165:125-140.

Böhl J, Brändli UB, 2007. Deadwood volume assessment in the third Swiss National Forest Inventory: methods and first results. Eur. J. Forest Res. 126:449-457.

Bretz Guby NA, Dobbertin M, 1996. Quantitative estimates of coarse woody debris and standing dead trees in selected Swiss forests. Global Ecol. Biogeogr. 5:327-341.

Carey AB, Johnson ML, 1995. Small mammals in managed, naturally young, and old-growth forests. Ecol. Appl. 5:336-52.

Christensen M, Hahn K, 2003. A study on deadwood in European beech forest reserves. Work-package 2 in the Nat-Man project (Nature-based Management of beech in Europe). European Community 5th Framework Programme.

Dixon RK, Solomon AM, Brown S, Houghton RA, Trexier MC, Wisniewski K, 1994. Carbon pools and flux of global forest ecosystems. Science 263:185-190.

Fridman J, Walheim M, 2000. Amount, structure, and dynamics of dead wood on managed forestland in Sweden. Forest Ecol. Man. 131:23-36.

Green P, Peterken GF, 1997. Variation in the amount of dead wood in the woodlands of the Lower Wye Valley, UK in relation to the intensity of management. For. Ecol. Manage. 98:229-238.

Hansen AJ, Spies TA, Swanson FJ, Ohmann JL, 1991.Conserving biodiversity in managed forests. Bioscience 41:382-92.

Hanski I, 1998. Metapopulation dynamics. Nature 396:41-49.

Harmon ME, Franklin JF, Swanson FJ, Sollins P, Gregory SV, Lattin JD, Anderson NH, Cline SP, Aumen NG, Sedell JR, Lienkaemper GW, Cromack K, Cummins KW, 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133-302.

Harmon ME, Sexton J, 1996. Guidelines for Measurements of woody detritus in forest ecosystems. Publication No. 20. U.S. LTER Network Office: University of Washington, Seattle, WA, USA.

Jonsson BG, Siitonen J, 2012a. Dead wood and sustainable forest management. In: N. Stokland, J. Siitonen and B.G Jonsson (eds.), Biodiversity in dead wood. Cambridge University Press, New York, USA.

Jonsson BG, Siitonen J, 2012b. Natural forest dynamics. In: N. Stokland, J. Siitonen and B.G Jonsson (eds.), Biodiversity in dead wood. Cambridge University Press, New York, USA.

Keenan RJ, Prescott CE, Kimmins JP, 1993. Mass and nutrient content of woody debris and forest floor in western red cedar and western hemlock forests on northern Vancouver Island. Can. J. Forest Res. 23:1052-1059.

Kruys N, Jonsson BG, 1999. Fine woody debris is important for species richness on logs in managed boreal spruce forests of northern Sweden. Can. J. Forest Res. 29:1295-1299.

Lachat T, Bouget C, Bütler R, Müller J, 2013. Deadwood: quantitative and qualitative requirements for the conservation of saproxylic biodiversity. In: D. Kraus and F. Krumm (eds.) Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute, Joensuu, Finland.

Laiho R, Prescott CE, 2004. Decay and nutrient dynamics of coarse woody debris in northern coniferous forests: a synthesis. Can. J. Forest Res. 34:763-777.

Lambert RL, Lang GE, Reiners WA, 1980. Loss of mass and chemical change in decaying boles of a subalpine balsam fir forest. Ecology 61:1460-1473.

Lassauce A, Paillet Y, Jactel H, Bouget C, 2011. Deadwood as a surrogate for forest biodiversity: Meta-analysis of correlations between deadwood volume and species richness of saproxylic organisms. Ecol. Indic. 11:1027-1039.

Lombardi F, Lasserre B, Tognetti R, Marchetti M, 2008. Deadwood in relation to stand management and forest type in Central Apennines (Molise, Italy). Ecosystems 11:882-894.

Maser C, Cline, SP, Cromack K, Trappe JM, Hansen E, 1988. What we know about large trees that fall to the forest floor. In: C. Maser, R.F. Tarrant, J.M. Trappe and J.F. Franklin (eds.) From the forest to the sea: a story of fallen trees. USDA Forest Service, Portland, USA, pp. 25-45.

MCPFE, EfE/PEBLDS, 2004. Ad hoc working group on development of the pan European understanding of the linkage between the ecosystem approach and sustainable forest management. Accessed in 2005. Available from: http://www.foresteurope.org/docs/other_meetings/2005/elm/Annex_2.pdf

Merganičová K, Merganič J, Svoboda M, Bače R, Šebeň V. 2012. Deadwood in forest ecosystems. In: J.A. Blanco (ed.) Forest ecosystems - More than just trees. InTech. Available from: http://www.intechopen.com/books/forest-ecosystems-more-than-just-trees/deadwood

Müller J, Bütler R, 2010. A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. Eur. J. Forest Res. 129:981-992.

Nelson E, Mendoza G, Regetz J, Polasky S, Tallis H, Cameron D, Chan KM, Daily GC, Goldstein J, Kareiva PM, Lonsdorf E, Naidoo R, Ricketts TH, Shaw ., 2009. Modeling multiple ecosystem services, biodiversity conservation, commodity

production, and tradeoffs at landscape scales. Front. Ecol. Environ. 7: 4-11.
Pyle C, Brown M., 1999. Heterogeneity of wood decay classes within hardwood logs. For. Ecol. Manage. 144:253-259.
Ritter T, Saborowski J, 2012. Point transect sampling of deadwood: a comparison with well-established sampling techniques for the estimation of volume and carbon storage in managed forests. Eur. J. Forest Res. 131:1845-1856.
Rondeux J, Sanchez C, 2010. Review of indicators and field methods for monitoring biodiversity within national forest inventories. Core variable: Deadwood. Environ. Monit. Assess. 164:617-630.
Rondeux J, Bertini R, Bastrup-Birk A, Corona P, Latte N, McRoberts ER, Ståhl G, Winter S, Chirici G, 2012. Assessing deadwood using harmonized national forest inventory data. Forest Sci. 58:269-283.
Schelhaas MJ, Nabuurs GJ, Schuck A, 2003. Natural disturbances in the European forests in the 19th and 20th centuries. Glob. Change Biol. 9:1620-1633.
Setälä H, Marshall VG, 1994. Stumps as a habitat for Collembola during succession from clear-cuts to old-growth Douglas-fir forests. Pedobiologia 38.307-26.
Siitonen J, 2001. Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecol. Bull. 49:11-41.
Soderstrom L, 1988. The occurrence of epixylic bryophyte and lichen species in an old natural and a managed forest stand in northeast Sweden. Biol. Conserv. 45:168-78.
Ståhl G, Ringvall A, Fridman J, 2001. Assessment of coarse woody debris - a methodological overview. Ecol. Bull. 49:57-70.
Stelfox JB, 1995. Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forests in Alberta. Jointly published by Alberta Environmental Centre (AECV95-R1) and Canadian Forest Service (Project No. 0001A), Edmonton, AB, Canada.
Stevens V, 1997. The ecological role of coarse woody debris, An overview of the ecological importance of CWD in British Columbia forests. B.C. Ministry of Forests, Victoria, Australia.
Woldendorp G, Keenan RJ, Ryan MF, 2002. Coarse woody debris in Australian forest ecosystems. A report for the national greenhouse strategy. Module 6.6 (Criteria and indicators of sustainable forest management). Bureau of Rural Sciences, Canberra.

Wood production. Hereditary management systems and practices in wood-production forests

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Introduction

Silviculture is the art and science of managing forests to obtain a variety of their goods and services for humans (Graham and Jain, 1998; Fujimori, 2001; de Groot *et al*., 2002; Schütz, 2003). Its development goes back to the 19th century, when societies in many European regions began develop concepts for sustainable use of forest resources due to the wood crisis and exacerbating forest conditions, both caused by the former unregulated and intensive wood harvesting (Johann, 2006). Early steps towards sustainable forest management represent the Cotta (1804) and Hartig (1804) forest area and forest volume allotment methods and the Judeich forest age-class method (von Gadow, 2005). The aims of all the three approaches were to establish homogeneous even-aged forest stands with the maximized timber yields (Pukkala and von Gadow, 2011).

A significant breakthrough in silviculture was made by Gayer (1898). Unlike Cotta and Hartig, both advocating pure stands, he promoted irregularly-structured mixed forest stands and thus introduced irregular shelterwood silviculture system and close-to-nature silviculture science and practices (Schütz, 1999a, 1999b; Pommerening and Murphy, 2004; Diaci, 2006a). Equally important are the contributions of Gurnaud, Biolley (Schütz, 1999; Biolley and Favre, 1980) and a number of forest practitioners and scientists from other countries, who independently developed in implemented the selection silvicultural system (Diaci, 2006a; Bončina and Čavlović, 2009). All presently known silvicultural systems have evolved from two contrasting silvicultural systems such as the clearcutting and the selection system. The basic differences between them lay in the harvest and regeneration patterns, both generating either even-aged or uneven-aged stand structures (Fujimori, 2001; Diaci, 2006b). Although both systems are artificial, their impacts are comparable to the impacts of natural forces such as large and small-scale wind and snowstorms, forest fires and other hazards (Perera *et al*., 2007). Between the two extremes reside a large group of shelterwood systems that comprise regular and group shelterwood systems at one side and irregular shelterwood systems at another. While the first two reflect the features of clearcutting systems such as the removal of old-growth tree cohorts in two or more harvests within a short period of time (Fujimori, 2001; Diaci, 2006b), the irregular shelterwood systems are characterized by long regeneration periods, different regeneration patterns (*e.g.* regeneration in patches, extended patches and irregular over a stand) and different concentration of harvests (Table 1). In comparison to regular shelterwood systems, the irregular shelterwood systems are characterized by irregular single-tree and grouped-tree cohorts that are more or less irregularly distributed across forest stands (Raymond *et al*., 2009). For a considerable length of time silvicultural systems have been developed for intensifying the wood production. By contrast, present silvicultural systems, grounded on the principles of spatial order, regeneration and tending of forest stands (Diaci, 2006b) aim to assure and provide a number of additional forest ecosystem goods and services such as water supply, sustaining and improving retention capacity of soils, mitigation of erosion, air filtering, carbon storage, recreation, leisure, and so forth.

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Key words: wood production, management systems, silviculture, ecosystem services.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Types of forests in test sites

Even-aged pure beech forest

The largely prevailing customary technique is the mass tending of standing crop to get stems sized and shaped likewise within the planned rotation. Low (young stage) to mixed (following stages up to harvesting) thinnings rule cultivation criteria following the mass regeneration pattern under the shelterwood system. Such technique is suited to beech requirements and well matches the specific bio-ecological attributes, i.e. the mass regeneration, the shade tolerance of beech, the natural trend to build up evenaged, one-storied stands, and is aimed at getting quality timber (Hofmann, 1991; Del Favero, 1992; Piussi, 1994; Bernetti, 1995; Schütz, 1997). The shelterwood system is applied at different spatial scales according to the ‘group’ or ‘uniform’ system, depending on the evenness of site and standing crop as for dominant age, site class, etc. The group system itself varies as for the area of intervention from a minimum of less than half of hectare up to a few hectares at a time. Much more recently, the technique known as ‘single tree-oriented silviculture’ is being applied into a few pre-alpine forest districts. It foresees the early selection of a variable number of final crop trees which are then submitted to a special tending care to get high quality trees in terms of crown development, optimal stem size and attributes at the end of their cultivation cycle. The catchword of this technique is 'getting 80% of revenue by 20% of crop trees' (Bastien, 1997; Wolynski, 2002a, 2002b).

The Apennines deciduous oak-mixed broadleaved forest

The long-lasting cultivation history and the irregular sequence of manifold uses, to which these forests were submitted over centuries, makes it difficult to define an optimum for wood production, since the type itself of production spans from firewood to timber. The high variability too of physical environment within the vegetation area originates a number of patches differentiated as for site-index and tree species composition, Turkey oak (*Quercus cerris* L.) (main tree sp.), beech (*Fagus sylvatica* L.), common maple (*Acer campestre* L.), hop hornbeam (*Fraxinus ornus* L.), for growth pattern and regeneration ability. Most of standing crops are made up of trees regenerated from the seed and from agamic regeneration on the same ground. The resulting optimum for wood production is a silvicultural management, flexible enough to: i) increase the value of single trees and of tree species valuable for timber production; and ii) harvest firewood, where this production is still the main foreseeable outcome. That means an approach able to recognize in advance the potential target production at the patch scale and to put in practice the more effective tending at each time across the forest (Piussi, 1994; Bernetti, 1995).

The uneven- and even-aged Alpine mixed coniferous forests

Two forest types are grouped here. A typical Alpine, uneven-aged mixed forest and an even- aged forest. Both semi-natural and reforestation forests are represented in a wide range of age-spans within this type. As for the uneven-aged stands, the heritage selection system still provides the more effective operational technique for the production of quality timber. Usually, the more valuable tree species are being promoted over the cultivation cycles and one (two) main species are prevailing in the standing crop, *e.g.* Norway spruce (*Picea abies*. K.) with silver fir (*Abies alba* Mill.) or European larch (*Larix decidua* Mill.) and beech (*Fagus sylvatica* L.) /other broadleaves as accompanying species.

Within the even-aged forests from reforestation, pure as a rule, as well as within the semi-natural pure or mixed forests, the clear-cut system, arranged in all its versions as for spatial arrangement and widths, is the most used harvesting technique. The ways adopted are targeted to promote the regeneration of favourite species. Pre-commercial thinnings are no more undertaken because of their quite null revenue or carried out by machinery (feller/harvester and forwarder). The following crop tending up to regeneration are made up of thinnings aimed to reducing tree competition enough to get a standing crop made by the awaited stem size and quality at the time of final harvesting (Piussi, 1994; Bernetti, 1995, Piussi e Alberti, 2015).

Table 1. Basic features of silvicultural systems (Diaci, 2006b; Raymond *et al.*, 2009).

Silvicultural type	Clearcutting	Clearcutting	Shelterwood	Shelterwood	Irregular shelterwood	Irregular shelterwood	Irregular shelterwood	Selection	Selection
Specific name	Clearcutting	Clearcutting with reserves	Uniform shelterwood	Group-shelterwood	Expanding-gap Bayerischer Femelschlag	Continuous cover Badischer, Schweizerischer Femelschlag	Extended; Delayed regeneration	Group selection	Single-tree selection
Age arrangement	Even-aged/ whole stand	Even-aged/ whole stand	Even-aged/ whole stand	Even-aged/ whole patch	Uneven-aged/ gap, group of trees	Uneven-aged/ parts of a stand, gaps	Uneven-aged/ parts of a stand	Uneven-aged/ even-aged only in groups of trees	Uneven-aged
Regeneration origin	Artificial	Artificial, natural	Artificial, natural, combined	Artificial, natural, combined	Natural	Natural	Natural	Natural	Natural
Regeneration pattern	Concentrated, large foci	Concentrated, large foci	Concentrated, large foci	Concentrated, large foci in patches	Concentrated and irregular foci	Irregular foci, continuous recruitment	Concentrated, large foci	Irregular, continuous recruitment	Irregular, continuous recruitment
Harvesting intensity	Strips, tracts, whole stand	Strips, tracts, whole stand	Tracts, parts of a stand	Seed-cut, final cut of a patch	Single trees, group of trees in a gap	Single tree, group of trees	Single tree, group of trees, tracts	Tree groups, single trees	Single trees
Final cut	Yes	Yes	Yes	Yes	Optional	No	Optional	No	No
Horizontal structure	Single cohort	Single cohort	Two cohorts, single cohort after final harvest	Two cohorts, single cohort after final harvest	Irregular, mosaic of cohorts	Irregular, mix of cohorts and trees	Two cohorts	Irregular, mix of cohorts and trees	Irregular, mix of trees of different DBH
Vertical layer	Regular, one layer	Regular, one layer	Regular, one layer	Regular at patch scale	Regular at gap scale	Irregular	Regular at group or strip scale	Regular at group scale	Irregular

Perspectives: factors and practices putting at risk the wood production, other forest goods and ecosystem services

The recent changes in forest management goals, *i.e.* the fulfilment of emerging other functions besides wood production, the concurrent unclear re-assessment of a prevailing function per forest compartment or per defined forest patches, resulted both in the generalized decrease of wood exploitation and in the prolongation of customary rotations, as well. The age of harvesting has become a somehow flexible concept and forests are experiencing the lengthening of customary stand life span. Consequently, large forest areas are currently managed over the traditional rotation or are in a post-cultivation stage, i.e. no more managed. Where the intermediate harvestings (thinnings) are being applied, right the former criteria of wood production-oriented silviculture are anyway, even if less intensively, practiced. All of this, in spite of the older stand ages reached in the meanwhile and of the perspective of a prolonged life-span. An early, exploratory phase between the technical and the biological permanence-time is therefore in progress in many public forests. (Guidi and Manetti, 2000; Fabbio *et al*., 2000; Becagli *et al*., 2013; Fabbio e Bertini, 2008; Fabbio *et al*., 2016).

Under such conditions, stands are getting thicker and older, growing stocks are increasing and symmetrical tree competition acts as a lasting attribute. The diffuse protection regime in terms of cover, the onset of additional binding forces to the implementation of a pro-active management, the less profitable wood harvesting, the other than productive functions prevailing, contribute to the current condition (MCPFE, 2011).

This occurrence, and the shift towards less favourable environmental conditions, may in short- to medium-term cause the decrease in forest capability for providing the multiple ecosystem goods and benefits through own woody and non-woody productions, the protective and recreational services and the inherent biological diversity as well.

Uneven-aged Dinaric fir-beech forests

A region spanning between the forested plateaus of Kočevski Rog and Trnovo is home to the largest forested complex in Slovenia. Its forests mostly belong to the group of unevenly-aged Dinaric fir-beech forests, which is the nation's second largest by size (Dakskobler, 2008) and the largest in the high Karst region. The forests experience extreme temperatures (min. -30°C, max. 35°C) and annual precipitation exceeding 1500 mm (Puncer, 1980). Less diverse are geological conditions as the largest portion of the area lays on the carbonate parent rocks (Puncer, 1980).

According to phytosociological nomenclature (Weber *et al*., 2000), the forests formerly termed *Abieti-Fagetum dinaricum* (Puncer, 1980) have recently been renamed to *Omphalodo-Fagetum (*Marinček and Košir, 1998; Surina, 2002*)*. Although shade tolerant species such as silver fir (*Abies alba* Mill.) and European beech (*Fagus sylvatica* L.) are the predominant species of this forest association (Puncer, 1980), because of the association's wide ecological amplitude and local influences of edaphic factors, many other tree species such as Norway spruce (*Picea abies* Karst.), sycamore (*Acer pseudoplatanus* L.) and Norway maple (*Acer platanoides* L.), wych elm (*Ulmus glabra* Huds.) may also be admixed (Puncer, 1980).

Because of demands for wood, these forests have undergone intensive management actions for at least two centuries (Kordiš *et al*., 1993). Uncontrolled harvesting, aiming at fulfilling the needs of mines, glassworks, industry and local residents, was replaced by the regular management at the turn of the 19th century. Consequently, previously used purposive cutting and clearcutting have largely been replaced by the seed-tree and selection (plenter) silvicultural systems (Kordiš *et al*., 1993), both favouring fir as the main species. The selection system was introduced by Hufnagel (1892) and Schollmayer (1906).

Centuries long extensive forest management naturally had strong impacts on the stands' tree-species compositions, their horizontal and vertical structures and standing volumes. As most of the stands were even-aged and saw log-sized (Bončina, 2011; Bončina *et al*., 2014), the forests were gradually transformed to uneven-aged by means of selection system, irregular shelterwood (*i.e*., expanding-gap and extended shelterwood) and their combinations (Mlinšek, 1972; Kordiš *et al*., 1993; Klopčič and Bončina, 2011). Finally, since 1990, the nature-based forestry doctrine characterized by natural regeneration, naturalness based on the Tuxen potential natural vegetation models (Westhoff and Van Der Maarel, 1973), tree-species composition as an ideal composition, small-scale management actions and long rotation periods, has been pervading the Slovene forestry (UrL RS, 1993-2014; Čas *et al*., 2011).

The recent assessment of regional forest management plans for the period 2010-2020 has revealed that the current forest management practices used in Slovene forests are not optimal (Čas *et al*., 2011). For a variety of reasons, the annual harvest estimated to the 47% of gross annual increment (ca. 5 million m^3 per year) is considerably smaller than the allowable annual harvest that should have reached 75% of gross annual increment in the period 2010-2020 (UrL RS, 2007; Kovač, 2014). Additionally, about a half of the present mature, that is saw log-sized forests is over-aged, forests in general are insufficiently regenerated and many of them also lack the recruitment of dominant and co-dominant species into the crown canopy (Čas *et al*., 2011; Kovač, 2014). As the historical reference overview shows, many of these problems are long-lasting (Pipan, 1967; Gašperšič and Kotar, 1986).

Similar conditions prevail in the Dinaric fir-beech forests, which do not develop sustainably (Kadunc *et al*., 2011a, 2011b, 2011c). Not only the high shares of old growth forests and the insufficient share of young phases are problematic, an insufficient recruitment of fir into the canopy layer, caused by ubiquitous deer herbivores also represents a serious problem (Klopcic *et al*., 2010; Nagel *et al*., 2014) and the natural expansion of beech, which is taking back the space in which it was suppressed at the turn of the 19th century (Mlinšek, 1964). As assumed, both phenomena are altering these forests into pure beech or mixed broadleaved forests and thus change their ecological character and decrease their spatial extent (Kovač *et al*., 2016). In addition to both factors, also problematic is small-scale forest opening, not allowing more massive recruitment of diverse tree-species into the crown canopy.

A more courageous regeneration process with higher harvesting and regeneration areas is thus a logical management option (Kadunc *et al*., 2011a, 2011b, 2011c). In comparison to the present way of regenerating, its major strengths are: i) potential capability for the recruitment of all kind of tree species (light and shade-tolerant species) into the crown canopy; ii) better chances for potentially sufficient regeneration and, in terms of developmental phases, more balanced forest development, i.e. what can provide ecosystem functions and services to the society in the long run; iii) timely harvesting that helps sustain 'vital and healthy' forests, potentially more resistant to disturbances; iv) good wood quality.

References

Bastien Y, 1997. Pour l'éducation du hêtre en futaie claire et mélangée. Rev. For. Fr. 49:49-68.

Becagli C, Puletti N, Chiavetta U, Cantiani P, Salvati L, Fabbio G, 2013. Early impact of alternative thinning approaches on structure diversity and complexity at stand level in two beech forests in Italy. Ann. Silvic. Res. 37:55-63.

Bernetti G, 1995. Selvicoltura speciale. UTET, Torino.

Biolley H, Favre LA, 1980. Oeuvre écrite. Société forestière Suisse.

Bončina A, Čavlović J, 2009. Perspectives of forest management planning: Slovenian and Croatian experience. Croat. J. For. Eng. 30:77-87.

Cotta H, 1804. Systematische Anleitung zur Taxation der Waldungen. J.D. Sander, Berlin.

Čas M, Jerina K, Kadunc A, Košir B, Kovač M, Kutnar L, Medved M, Pokorny B, Robek R, 2011. Zaključno poročilo presoj gozdnogospodarskih načrtov območij in lovskoupravljavskih načrtov območij 2011-2020. Slovenian Forestry Institute, Ljubljana.

Dakskobler I, 2008. Pregled bukovih rastišč v Sloveniji. Forestry Wood Sci. Technol. Res. Rep. 87:3-14.

Del Favero R, 1992. Modello colturale per la faggeta pura e monostratrificata della foresta del Cansiglio (Belluno). Monti e Boschi 2:11-16.

de Groot RS, Wilson MA, Boumans RLJ, 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 4:393-408.

Diaci J, 2006a. Nature-based forestry in Central Europe: alternatives to industrial forestry and strict preservation. Studia Forestalia Slovenica 126:1-167.

Diaci J, 2006b. Gojenje gozdov: pragozdovi, sestoji, zvrsti, načrtovanje, izbrana poglavja. Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire. Ljubljana.

Fabbio G, Bertini G, 2008. Monitoraggio, gestione, selvicoltura. Atti III Congresso Nazionale Selvicoltura, Taormina, 1:217-225.

Fabbio G, Bruschini S, Manetti MC, 2000. Selvicoltura nelle faggete irregolari: un caso di studio Ann. Ist. Sper. Selvicoltura 28:75-88.

Fabbio G, Cantiani P, Ferretti F, Chiavetta U, Bertini G, Becagli C, Di Salvatore U, Bernardini V, Tomaiuolo M, Matteucci G, De Cinti B, 2016. Adaptive silviculture to face up to the new challenges: the ManForCBD experience. Proc. 2nd Int. Congr. Silviculture, Florence. AISF 1:531-538.

Fujimori T, 2001. Ecological and silvicultural strategies for sustainable forest management. Elsevier, Amsterdam.

Gašperšič F, Kotar M, 1986. Zaključno poročilo o območnih gozdnogospodarskih načrtih v Sloveniji. Republiški komite za kmetijstvo, gozdarstvo in prehrano, Ljubljana.

Gayer K, 1898. Der Waldbau. 4. Parey, Berlin.

Graham RT, Jain TB, 1998. Silviculture's role in managing boreal forests. Conserv. Ecol. 2:8.

Guidi G, Manetti MC. 2000. L'area Pavari nella faggeta della Foresta Umbra: caratteri strutturali e trend evolutivo. Ann. Ist. Sper. Selvicoltura 28:39-46.

Hartig GL, 1804. Anweisung zur Taxation und Beschreibung der Forste, oder zur Bestimmung des Holzertrags der Wälder. Gießen.

Hofmann A, 1991. Il faggio e le faggete in Italia. Ministero Agricoltura e Foreste, Collana Verde, Roma.

Hufnagel L, 1892. Wirtschaftsplan der Betriebsklasse I. Göttenitzer Gebirge. Gottschee.

Johann E, 2006. Historical development of nature-based forestry in Central Europe. Studia Forestalia Slovenica 126:1-17.

Kadunc A, Košir B, Kovač M, Kutnar L, Robek R, 2011a. Poročilo presoje gozdnogospodarskega načrta gozdnogospodarskega območja Kočevje 2011-2020. Slovenian Forestry Institute, Ljubljana.

Kadunc A, Košir B, Kovač M, Kutnar L, Robek R, 2011b. Poročilo presoje gozdnogospodarskega načrta gozdnogospodarskega območja Postojna 2011-2020. Slovenian Forestry Institute, Ljubljana.

Kadunc A, Košir B, Kovač M, Kutnar L, Medved M, Robek R, 2011c. Poročilo presoje gozdnogospodarskega načrta gozdnogospodarskega območja Tolmin 2011-2020. Slovenian Forestry Institute, Ljubljana.

Klopčič M, Bončina A, 2011. Stand dynamics of silver fir (Abies alba Mill.) - European beech (Fagus sylvatica L.) forests during the past century: a decline of silver fir? Forestry 84:259-271.

Klopčič M, Klemen J, Bončina A, 2010. Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor? Eur. J. For. Res. 129:277-288.

Kordiš F, 1993. Dinarski jelovo bukovi gozdovi v Sloveniji. Strokovna in znanstvena dela 112:1-139.

Kovač M, 2014. Stanje gozdov in gozdarstva v luči Resolucije nacionalnega gozdnega programa. Slov. Prof. J. For. 72:59-75.

Kovač M, Kutnar L, Hladnik D, 2016. Assessing biodiversity and conservation status of the Natura 2000 forest habitat types: tools for designated forestlands stewardship. For. Ecol. Manage. 359:256-267.

Marinček L, Košir P, 1998. Dinaric fir-beech forests (Omphalodo-Fagetum (Tregubov 1957) Marinček et al. 1993) on Blegoš. Hladnikia (Ljubljana) 10:29-40.

MCPFE, 2011. State of Europe's Forests 2011. Status and trend in Sustainable Forest Management in Europe. Forest Europe.

Mlinšek D, 1964. Sušenje jelke v Sloveniji - prvi izsledki. Gozdarski vestnik 22:145-159.

Mlinšek D, 1972. Ein Beitrag zur Entdeckung der Postojna Kontrollmethode in Slowenien. Forstwissenschaftliches Centralblatt 4:291-296.

Nagel TA. Diaci J, Jerina K, Kobal M, Roženbergar D, 2014. Simultaneous influence of canopy decline and deer herbivory on regeneration in a conifer-broadleaf forest. Can. J. For. Res. 45:266-275.

Perera AH, Buse LJ, Weber MG, 2007. Emulating natural forest landscape disturbances: concepts and applications. Columbia University Press, New York.

Pipan R, 1967. Nastanek in premagovanje notranjih protislovij na področju urejanja gozdov. Zbornik 5:121-151.

Piussi P, 1994. Selvicoltura generale. UTET, Torino.

Piussi P, Alberti G, 2015. Selvicoltura generale. Boschi, società e tecniche colturali. Compagnia Foreste, Arezzo.

Pommerening A, Murphy S, 2004. A review of the history, definitions and methods of continuous cover forestry with special attention to afforestation and restocking. Forestry 77:27-44.

Pukkala T, von Gadow K, 2011. Continuous cover forestry. Springer, Dordrecht.

Puncer I, 1980. Dinarski jelovo bukovi gozdovi na Kočevskem. SAZU Dissertationes XXII/6.

Raymond P, Bédard S, Roy V, Larouche C, Tremblay S, 2009. The irregular shelterwood system: review, classification, and

potential application to forests affected by partial disturbances. J. For. 107:405-413.
Schollmayer H. 1906. Direktiven für die Bestandesaufnahme und die Betriebseinrichtung auf der F.C. Herrschaft Schneeberg. Kleinmayr-Bamberg, Ljubljana.
Schütz JP, 1997. Sylviculture 2. La gestion des forêts irrégulières et mélangées. Les presses polytechniques et Universitaires Romandes, Lausanne.
Schütz JP, 1999a. Die Plenterung und ihre unterschiedlichen Formen. Vorlesungsunterlagen. ETH Zentrum, Zürich.
Schütz JP, 1999b. Close-to-nature silviculture: is this concept compatible with species diversity? Forestry 72:359-366.
Schütz JP, 2003. Waldbau I. Die Prinzipien der Waldnutzung und der Waldbehandlung. Skript zur Vorlesung Waldbau I. ETH Zentrum, Zürich.
Surina B, 2002. Phytogeographical differentiation in the Dinaric fir-beech forest (Omphalodo-Fagetum s. lat.) of the western part of the Illyrian floral province. Acta Bot. Croat. 61:145-178.
UrL RS, 1993-2014. Zakon o gozdovih Ur L RS 30/93, 56/99 - ZON, 67/02, 110/02 - ZGO-1, 115/06 - ORZG40, 110/07, 106/10, 63/13, 101/13 - ZDavNepr in 17/14.
UrL RS, 2007. Resolucija o nacionalnem gozdnem programu (ReNGP). UrL RS 111/2007 z dne 5.12.2007.
Von Gadow K, 2005. Forsteinrichtung: Analyse und Entwurf der Waldentwicklung. Universitätsverlag Göttingen.
Weber HE, Moravec J, Theurillat JP, 2000. International code of phytosociological nomenclature. J. Veg. Sci. 11:739-768.
Westhoff V, Van Der Maarel E, 1973. The Braun-Blanquet approach. In: R.H. Whittaker (ed.) Ordination and classification of communities. Junk, Der Haag, pp. 617-726.
Wolynsky A, 2002a. Sul trattamento irregolare delle fustaie di faggio. Parte I. Sherwood 74:9-14.
Wolynsky A, 2002b. Sul trattamento irregolare delle fustaie di faggio. Parte II. Sherwood 75:5-13.

Forest management for invertebrate conservation

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Introduction

Insects are a diverse group of terrestrial organisms, counting at least one million of species and undoubtedly the predominant portion of animal biomass, consequently representing an essential component of every terrestrial environment. They are too often simplistically perceived as a simple nuisance or as pests due to the significant economic damages caused by a relatively small, but notable percentage of species. However, the ecological role of insects in forests is significant. Indeed, the present environment is the result of hundreds of millions of years of co-evolution between insects and plants, giving rise to the present biodiversity and complexity (Grimaldi and Engel, 2005). Due to their abundance and prevalence in forests, insects play a very important role in food webs and energy flows through different trophic levels. The variegated relationships between plants and insects vary from antagonist, such as in case of phytophagous and xylophagous species, to strictly mutualistic in case of pollinators. In turn, herbivore species are preyed by insect predators and parasitoids, which are often the best regulators of their populations. The richness of insect populations directly mirrors the diversity and abundance of vertebrates that directly feed upon them or indirectly depend on the plants/insects interactions (Price *et al.*, 2011). Finally, the rich community of detritivore and saprophagous insects contributes to the decomposition of organic matter and recycling of energy and nutrients, facilitating the colonization and the action of bacteria and fungi, thus actively participating in the complex dynamics of pedogenesis (Price *et al.*, 2011). The spatial structure and the presence of dead or decaying wood are key components in forest environments, noticeably influencing insect diversity and their richness by supplying different microhabitats and triggering adaptations to specific niches (Campanaro *et al.*, 2011; Stokland *et al.*, 2012). Saproxylic organisms include a vast array of species depending, in at least one stage of their life cycle, on dead or decaying wood, or upon other organism living on this type of substrate (Speight, 1989); not surprisingly most of them are represented by insects and other arthropods. Many saproxylic insects are xylophagous, therefore directly degrading deadwood by feeding on it; this category includes many species with wood boring larvae, mainly belonging to Coleoptera but also members of other orders such as Hymenoptera Symphyta, Diptera and some Lepidoptera. These groups can be divided in primary and secondary saproxylics, according to the sequence on which they colonize the substrate: the first ones live on recently dead wood, while the seconds settle in more advanced stages of wood degradation (Campanaro *et al.*, 2011; Stokland *et al.*, 2012). A diverse community of predators and parasitoids both at the adult and larval stages attacks xylophagous species, while mycophagous species feed on the fungi growing on the wood. Finally, in the last stages of degradation, when wood loses its structure, it is colonized by a community not dissimilar from that of leaf litter, mainly composed of detritivores and fungivores (Campanaro *et al.*, 2011; Stokland *et al.*, 2012). The important role of insects in these environments, their diverse habitat requirements, ecological niches and notably their rapid responses to environmental changes, allow to consider some insect groups as excellent bioindicators of management and consequently of state of preservation of forests. Indeed, the strict relationship between saproxylic insects and the amount and type of dead wood implies a very strong sensitivity to forest management practices. Optimal management options to preserve this taxon in managed forests are discussed in the following paragraphs and summarised in Table 1.

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Key words: Saproxylic insects, biodiversity, deadwood, habitat tree, structure.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Landscape structure and insect diversity

At the landscape scale, insects populations interact, supplying and receiving colonists, and may suffer local extinctions (Price *et al.*, 2011). The colonization of new habitats is particularly important for saproxylic species since their fundamental substrate, deadwood, decays and progressively vanishes (Jonsson, 2012).The appreciation of the transient nature of the key microhabitats of these organisms is fundamental to understand how their preservation in a forest landscape cannot be ensured considering only habitat amount, but should include temporal and spatial availability (Jonsson and Ranius, 2009). For bark beetles for example, depending on scattered and ephemeral resources, a habitat patch maybe suitable for just one generation

(Lieutier *et al*., 2004). These organisms have evolved high dispersal abilities, and the individuals can travel several kilometres of unfavourable habitat to reach new breeding sites (Bouget *et al.*, 2015). Saproxylic beetles present a very diverse range of dispersal abilities, with sex-dependent variations related to colonization behaviours (Bouget *et al.*, 2015). The importance of forest continuity for species' persistence is probably correlated with the prevailing disturbance regime, with forest types characterized with stand-scale disturbance hosting species with more efficient dispersal compared with forest dominated by gap-phase disturbance (Jonsson, 2012). Forest patches isolation affects the exchange of individuals between populations (Do and Joo, 2013), and suitable habitats could be unoccupied because of isolation from neighbouring populations. Patch size affects the richness of forest species (Ouin *et al*., 2006): in many cases an increase of species diversity with forest patch size has been observed, and a decrease below a certain threshold. For carabid beetles for example, it is known, that they favour forest patches bigger than 1 ha (Malmyszko and Sklodowski, 2011). For less mobile species groups, like Collembola, lower threshold should be sufficient (Heiniger *et al*., 2014). The metapopulation approach could guide landscape management with predictive models, in order to reduce extinction rates and increase colonization rates, through habitat restoration and creating stepping-stones to increase patch connectivity (Thomas and Hanski, 2004).

The implementation of ecological networks requires maintenance of both spatial and temporal heterogeneity, in a complex mosaic of patches of the same seral stage (Pryke and Samways, 2015). Agrosilvopastoral systems contributed to the preservation of high levels of saproxylic diversity (Ramirez-Hernandez *et al*., 2014). This traditional management brought an increase of landscape heterogeneity and a high availability of senescent trees, and could be restored to effectively preserve forest landscape biodiversity. The restoration of natural forest properties should be planned on an extensive landscape scale and the potential species pools. However, if the region has suffered a long and intense exploitation the success of the operations maybe more problematic (Kouki *et al*., 2012). In fragmented landscapes, the consideration of multiple spatial scales together with short and long-term dynamics of substrate availability (Bergman *et al*., 2012) represents the future challenge for saproxylic biodiversity conservation.

Forest management and insect biodiversity

Forest type, stand age, openness, structure, heterogeneity and humus layer influence the distribution of invertebrates. Most of these factors can be affected by forest management. Forest type strongly influences insect species composition (Bankowska, 1980; Franklin *et al.*, 2003; Buse *et al.*, 2013). Thus, the comparison of different forest types, such as mountainous *versus* lowland, deciduous *versus* coniferous, temperate *versus* Mediterranean and pioneer *versus* old growth forests, highlights important differences in species composition. In particular, host specific herbivores and wood boring insects and their specialist natural enemies, such as parasitoids, are confined to certain forest types. Oak forests are known to have the largest diversity of insects. Many insect species included in the Habitats Directive (92/43/EEC) like *Lucanus cervus* and *Cerambyx cerdo* are specialists on oak trees. Beech forests harbour a lower insect diversity, but still host species included in the Habitats Directive (*e.g.*, *Rosalia alpina* and *Morimus funereus*). The smallest diversity maybe found in coniferous forests. Although every forest type is characterized by its own species composition, the tree diversity strongly influences communities. Indeed higher tree diversity equals insect abundance and variety (Sobek *et al*., 2009a; Sobek *et al*., 2009b; Sobek *et al*., 2009c).

Forest age is an important driver of species composition. Assemblages of open habitat species change into old forest species assemblages in a gradient from clear cut to old forests. Woodland species tend to be more abundant between 30 and 60 years after cutting, suggesting a correlation with the canopy closing (Koivula *et al*., 2002; Niemela *et al*., 2007). In a Norway spruce stand it was found that the age category of 70 to 75 years gave the highest number of forest species of multiple taxa, while in later stages the number decreased again (Purchart *et al.*, 2013). The influence of the age stand on forest insect assemblages depends on forest type, however one of the main determining factors is the closing of the canopy.

Forest gaps increase landscape diversity and have great effects on invertebrate diversity. Gaps are mainly used by pioneer species. Forest species facultative use gaps for food resources or group there for reproduction (Chiari *et al.*, 2013). Hoverflies frequent gaps mainly to feed on nectar (Gittings *et al.*, 2006), while some beetles use stumps in gaps for reproduction (Hardersen *et al.*, 2012). The question what gap size would be most beneficial

Table 1. Summary of optimal management recommendations to preserve invertebrate biodiversity.

Landscape structure	• Forest patch size influences the diversity of species. • Increase forest continuity to allow metapopulation dynamics. • Build ecological networks to guarantee spatial and temporal forest heterogeneity.
Forest management	• Forest parameters due to management practices, such as: type, stand age, openness, structure, heterogeneity and humus layer, influence invertebrate biodiversity. • Higher tree diversity equals insect diversity. Broadleaf forests harbour more complex communities. • Insect communities depend on stand age, tending to be more abundant a few decades after cutting, then decreasing again. • Forest gaps increase landscape diversity, influencing insect species composition and abundance. To increase biodiversity larger gaps are fundamental, while to preserve species smaller gaps are preferable. A network of forest gaps, used as stepping stones and corridors, safeguards meta-population. • Forest layers sustain insect communities, therefore, the maintenance of a complex forest structure (herbaceous, shrub and canopy) is recommended. • Humus layer affects species composition: a thicker layer harbours a greater biodiversity.
Deadwood management	• It is a dynamic substrate: ensure continuous availability, diversifying types and decay stages. • Compensate time-lag of deadwood natural restoration actively producing deadwood. • Preserve veteran trees that have developed microhabitats and allow their replacement.

depends on the aim of the nature conservation management. If the main goal is to increase the biodiversity in forest areas, larger gaps would help to maintain subpopulations of some pioneer species which use openings as their habitat. In this case, it is also important to maintain a network of forest gaps, which are used as stepping stones and forest roads may serve as corridors in order to preserve meta-populations (Bertoncelj and Dolman, 2013). If preservation of invertebrates is highlighted, smaller gaps are more advisable (Lange *et al.*, 2014). Forest species are often not even able to cross the edge with the clear cut site or show a strong decline in abundance just a short distance from the forest edge. In non-managed forest ecosystems, small gaps are created by fallen trees. In forest management these small gaps can be created by single tree selection system. Especially, forest specialists take advantage of these small gaps. In the United States, the single tree selection harvesting increased the number of hoverfly and bee species for young stands (<5 years), while click beetles were more species-rich in old logged stands (15-20 years)(Nol *et al.*, 2006). Also in small gaps the hoverflies increased in the gaps in conifer plantages in Western Europe (Gittings *et al.*, 2006).

Insects occur over the whole vertical range of the trees. Most of different insect groups are specialized on particular forest layers (Floren and Gogala, 2002; Floren and Schmidl, 2008; Sobek *et al.*, 2009d; Birtele and Hardersen, 2012). Carabid beetles and hoverflies species are richer in the ground level (Birtele and Hardersen, 2012; Toigo *et al.*, 2013), while Heteroptera are more abundant in the canopy (Sobek *et al.*, 2009d). In the herb layer occur many herbivores and others specialists. For example, in large fields of ramsom (*Allium ursinum*) specialized hoverflies occur (Hövemeyer, 1987). Also habitat generalists are positively influenced by the herbaceous layer (Toigo *et al*., 2013). Shrub layer is important for various herbivores (Sobek *et al*., 2009b)and is also an indicator of forest carabid species (Taboada *et al*., 2006). Many herbivores occur in the canopy. Among hoverflies, larvae feeding in the canopy are often associated with one species of aphid (Rotheray and Gilbert, 2011). It is therefore recommended to have a rich structure in the forest.

The humus layer contains a large diversity of soil invertebrates, which live in the humus layer for food and shelter. Most of species which are occurring in the humus, such as Collembola, are detrivores, which contribute to degrade organic materials. On the other side, many predators, such as spiders and carabid beetles, frequent the humus layer for prey. The humidity should be taken into consideration, since in humid humus layers more forest invertebrate species are present (Toivanen *et al.*, 2014). The availability of the humus layer also affects species presence: a thick layer harbours many species of carabid beetles and other species (Sroka and Finch, 2006). However, when it is removed and the soil is bare, other non-forest species proliferate (Pihlaja *et al*., 2006). The removal of the humus layer is usually correlated with open areas. In these sites, the lack of humus attracts pioneer species such as cicindelid beetles and bees, which dig nests in the bare soil.

Deadwood management for saproxylic insects conservation

A considerable proportion of species of several insects orders, such as Coleoptera and Diptera, relies on the presence of decaying wood (Stokland *et al.*, 2012). Deadwood represents both a key trophic and microhabitat resource. Nevertheless, deadwood tends to be insufficient in managed forests, and several factors concur to its reduced natural input (*e.g.*, whole-tree and veteran trees harvesting, shortened rotations and harvesting of veteran trees) and to its lack of preservation (*e.g.*, fuelwood harvest, destruction by machinery) (Bouget *et al.*, 2012a).

Forest management not only affects the amount of available deadwood, but also influences its quality. In particular, the comparison of natural and managed forests highlights the lack of large logs in advanced decay stage in the latter case (Siitonen *et al.*, 2000). Franklin *et al.*(2000) used the term 'structural legacies' to refer to dead trees and coarse woody debris (CWD), stressing how these elements have the potential of increasing post-harvest complexity, and can promote the survival and reestablishment of forest organisms. The dynamic nature of this substrate, which chemical and physical conditions change over time, make the continuous colonisation of new suitable habitats fundamental for the persistence of saproxylic species (Lachat *et al*., 2013). Populations must counterweigh local extinctions happening at different spatial scales, from individual logs to forest stands, with frequent colonisations to ensure their survival in a forest landscape (Jonsson *et al*., 2005). Forest management should therefore focus on the spatial availability of deadwood and also on its temporal continuity. For deadwood to accomplish its role of structural legacy, a complete range of typologies and decay stages should be available: sufficient diameter to host sensitive beetle species (*e.g.,* Brin *et al*. 2011 suggest more than 30 cm in oak forests), and the importance of fine woody debris (FWD, diameter <10 cm) should not be undervalued (Bouget *et al*., 2012a). Moreover, large snags have proved to support more individuals per volume unite, and diverse and rarer assemblages compared to logs (Bouget *et al*., 2012b) and stumps represent a valuable long-lasting microhabitats (Brin *et al*., 2012). The minimum total volume required to preserve biodiversity in productive forests could be derived from thresholds values associated to the presence of saproxylic single species or communities. For European forests, Müller and Bütler (2010) suggest to establish a landscape scale network of stands with a variable amount of deadwood comprised between 20-30 m^3/ha for boreal coniferous forests, 30-40 m^3/ha for mixed-mountain forests and 30-50 m^3/ha for lowland forests. Increasing the amount of available deadwood to reach these minimum thresholds would take a long time if it relies on the passive self-restoration that follows the abandonment of forest activities (Bouget *et al*., 2014). Harmon (2001) coined the world 'morticulture' to create a parallel between woody detritus production and silviculture. Thus, morticulture, acknowledging the dynamic nature of the forest system, focuses on site-specific goals for the production of deadwood. The techniques presented by Cavalli and Mason (2003) represent cost-effective intervention to actively compensate the natural time-lag of deadwood restoration (Zapponi *et al*., 2014).

Habitat-trees and saproxylic insects

A senescent tree might essentially have two destinies: either go through a rapid death with a consequent decay succession or develop hollow and wounds, that would represent new niches for saproxylic organisms, conserving its vitality (Müller *et al*., 2014). The first scenario would lead, in a variable amount of time, to standing and lying deadwood, while in the second one to the 'habitat-tree' (Figure 1). The slow decay of a biologically mature tree, associated with fungus and insect colonization, increases its value for saproxylic communities (Stokland *et al*., 2012). Since the biological maturity, *i.e.*, the start of the hardwood decay and appearance of dead branches in the canopy, occurs long after the commercial maturity (Alexander, 2008), the preservation of such trees could be based on their exclusion from the harvest applying diameter thresholds, thus the scarce high ecological value elements still present in productive forests would never be logged (Aerts, 2013). Furthermore, considering that stem shape could influence the availability of substrate for epiphytes, and branch orientation affects the suitability for bird nesting and colonisation by lichens and invertebrates, tree form could be used by foresters to target the retained structures (Newton, 2007).

Figure 1. Senescent dead wood microhabitats (nomenclature from Stokland et al., 2012 and Read, 2000). 1, Aerial roots feeding in the hole woody detritus; 2, Bark covered by mosses; 3, Small basal cavity; 4, Wet basal cavity; 5, Bird lime; 6, Bracket fungi; 7, Brocken main trunk with deep cavity; 8, Coarse decaying fallen limbs on the ground; 9, Crevices in the bark; 10, Dead branches in the canopy; 11, Dead roots; 12, Dead sun exposed trunk; 13, Decaying branches; 14, Phytotelm; 15, Detached bark with dry wooded detritus; 16, Dry bark pocket with fine woody detritus; 17, Dry medium dead limbs; 18, Epiphytic plants; 19, Holes in branches; 20, Lichens living on senescent trees (i.e., *Lobaria pulmonaria*); 21, Lightning strike; 22, Natural water pools; 23, Open wound surrounded with callus issue; 24, Proliferation of twigs caused by bacteria; 25, Root damage from browsing; 26, Root fungal colonization; 27, Saproxylic fungal colonization; 28, Suspended dead broken limb; 29, Canker; 30, Wet pocket with fine woody detritus; 31, Woodpecker foraging holes; 32, Woodpecker nesting hole; 33, Wound with sap run flux. *Drawing by F. Mason.*

References

Aerts R, 2013. Old trees: extraction, conservation can coexist. Science 339; 904-904.

Alexander K, 2008. Tree biology and saproxylic Coleoptera: issues of definitions and conservation language. Rev. Ecol-Terre Vie 63:1-6.

Bankowska R, 1980. Fly communities of the family Syrphidae in natural and anthropogenic habitats of Poland. Memorabilia Zool 33:3-93.

Bergman KO, Jansson N, Claesson K, Palmer MW, Milberg P, 2012. How much and at what scale? Multiscale analyses as decision support for conservation of saproxylic oak beetles. Forest Ecol. Manag. 265:133-141.

Bertoncelj I, Dolman PM, 2013. Conservation potential for heathland carabid beetle fauna of linear trackways within a plantation forest. Insect Conserv. Diver. 6:300-308.

Birtele D, Hardersen S, 2012. Analysis of vertical stratification of Syrphidae (Diptera) in an oak-hornbeam forest in northern Italy. Ecol. Res. 27:755-763.

Bouget C, Brin A, Tellez D, Archaux F, 2015. Intraspecific variations in dispersal ability of saproxylic beetles in fragmented forest patches. Oecologia 177:911-920.

Bouget C, Lassauce A, Jonsell M, 2012a. Effects of fuelwood harvesting on biodiversity - a review focused on the situation in Europe. Rev. Can. Rech. For. 42:1421-1432.

Bouget C, Nusillard B, Pineau X, Ricou C, 2012b. Effect of deadwood position on saproxylic beetles in temperate forests and conservation interest of oak snags. Insect Conserv. Diver. 5:264-278.

Bouget C, Parmain G, Gilg O, Noblecourt T, Nusillard B, Paillet Y, Pernot C, Larrieu L, Gosselin F, 2014. Does a set-aside conservation strategy help the restoration of old-growth forest attributes and recolonization by saproxylic beetles? Anim. Conserv. 17:342-353.

Brin A, Bouget C, Brustel H, Jactel H, 2011. Diameter of downed woody debris does matter for saproxylic beetle assemblages in temperate oak and pine forests. J. Insect Conserv. 15:653-669.

Brin A, Bouget C, Valladares L, Brustel H, 2012. Are stumps important for the conservation of saproxylic beetles in managed forests? - Insights from a comparison of assemblages on logs and stumps in oak-dominated forests and pine plantations. Insect Conserv. Diver. 6:255-264.

Buse J, Assmann T, Friedman ALL, Rittner O, Pavlicek T, 2013. Wood-inhabiting beetles (Coleoptera) associated with oaks in a global biodiversity hotspot: a case study and checklist for Israel. Insect Conserv. Diver. 6:687-703.

Campanaro A, Bardiani M, Spada L, Carnevali L, Montalto F, Antonini G, Mason F, Audisio P, 2011. Linee guida per il monitoraggio e la conservazione dell'entomofauna saproxilica. Cierre Grafica, Verona.

Cavalli R, Mason F, 2003. Tecniche di ripristino del legno morto per la conservazione della faune saproxiliche Il progetto LIFE Natura NAT/IT/99/6245 di "Bosco della Fontana". Arcari Editore, Mantova. Corpo Forestale dello Stato, Centro Nazionale per lo Studio e la Conservazione della Biodiversità Forestale. Ed. Arcari, Mantova, Italy.

Chiari S, Bardiani M, Zauli A, Hardersen S, Mason F, Spada L, Campanaro A, 2013. Monitoring of the saproxylic beetle Morimus asper (Sulzer, 1776) (Coleoptera: Cerambycidae) with freshly cut log piles. J. Insect Conserv. 17:1255-1265.

Do Y, Joo GJ, 2013. The effect of fragmentation and intensive management on carabid beetles in coniferous forest. Appl. Ecol. Environ. Res. 11:451-461.

Floren A, Gogala A., 2002. Heteroptera from beech (Fagus sylvatica) and silver fire (Abies alba) trees of the primary forest reserve Rajhenavski Rog, Slovenia. Acta Entomologica Slovenica 10:25-34.

Floren A, Schmid, J, 2008. Canopy arthropod research in Europe: basic and applied studies from the high frontier. Bioform Entomology, Nuremberg.

Franklin AJ, Liebhold AM, Murray K, Donahue C, 2003. Canopy herbivore community structure: large-scale geographical variation and relation to forest composition. Ecol. Entomol. 28:278-290.

Franklin JF, Lindenmayer D, MacMahon JA, McKee A, Magnuson J, Perry DA, Waide R, Foster D, 2000. Threads of continuity. Conservat. Pract. 1:8-17.

Gittings T, O'Halloran J, Kelly T, Giller PS, 2006. The contribution of open spaces to the maintenance of hoverfly (Diptera, Syrphidae) biodiversity in Irish plantation forests. Forest Ecol. Manag. 237:290-300.

Grimaldi D, Enge, MS, 2005. Evolution of the insects. Cambridge University Press, New York.

Hardersen S, Toni I, Cornacchia P, Curletti G, Leo P, Nardi G, Penati F, Piattella E, Platia G, 2012. Survey of selected beetle families in a floodplain remnant in northern Italy. B. Insectol. 65:199-207.

Harmon ME, 2001. Moving towards a new paradigm for woody detritus management. Ecol. Bull. 49:269-278.

Heiniger C, Barot S, Ponge JF, Salmon S, Botton-Divet L, Carmignac D, Dubs F, 2014. Effect of habitat spatiotemporal structure on collembolan diversity. Pedobiologia 57:103-117.

Hövemeyer K, 1987. The population dynamics of Cheilosia fasciata (Diptera, Syrphidae): significance of environmental factors and behavioral adaptations in a phytophagous insect. Oecologia 73:537-542.

Jonsson BG, 2012. Populations dynamics and evolutionary strategies. In: J. Stokland, J. Sittonen and B. Jonsson (eds.) Biodiversity in dead wood. Cambridge University Press, Cambridge, pp. 338-355.

Jonsson BG, Kruys N, Ranius T, 2005. Ecology of species living on dead wood-lessons for dead wood management. Silva Fenn. 39:289-309.

Jonsson BG, Ranius T, 2009. The temporal and spatial challenges of target setting for dynamic habitats: the case of dead wood and saproxylic species in boreal forests. In: M.A. Villard and B.G. Jonsson (eds.) Setting conservation targets for managed forest landscapes. Cambridge University Press, Cambridge, pp. 207-227.

Koivula M, Kukkonen J, Niemelä J, 2002. Boreal carabid-beetle (Coleoptera, Carabidae) assemblages along the clear-cut originated succession gradient. Biodivers. Conserv. 11:1269-1288.

Kouki J, Hyvarinen E, Lappalainen H, Martikainen P, Simila M, 2012. Landscape context affects the success of habitat restoration: large-scale colonization patterns of saproxylic and fire-associated species in boreal forests. Divers. Distrib. 18:348-355.

Lachat T, Bouget C, Bütler R, Müller J, 2013. Deadwood: quantitative and qualitative requirements for the conservation of saproxylic biodiversity. In: D. Kraus and F. Krumm (eds.) Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute, pp. 92-102.

Lange M, Tuerke M, Pasalic E, Boch S, Hessenmoeller D, Mueller J, Prati D, Socher SA, Fischer M, Weisser WW, Gossner MM,

2014. Effects of forest management on ground-dwelling beetles (Coleoptera; Carabidae, Staphylinidae) in Central Europe are mainly mediated by changes in forest structure. Forest Ecol. Manag. 329:166-176.
Lieutier F, Day KR, Battisti A, Grégoire JC, Evans HF, 2004. Bark and wood boring insects in living trees in Europe. A synthesis. Springer, Dordrecht..
Malmyszko M, Sklodowski J, 2011. Structure of carabid communities in forest islands of different size situated in the mosaic landscape. Sylwan 155:660-673.
Müller J, Bütler R, 2010. A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. Eur. J. Forest Res.129:981-992.
Müller J, Jarzabek-Mueller A, Bussler H, Gossner MM, 2014. Hollow beech trees identified as keystone structures for saproxylic beetles by analyses of functional and phylogenetic diversity. Anim. Conserv. 17:154-162.
Newton AC, 2007. Forest ecology and conservation. Oxford University Press, Oxford.
Niemela J, Koivula M, Kotze DJ, 2007. The effects of forestry on carabid beetles (Coleoptera : Carabidae) in boreal forests. J. Insect Conserv. 11:5-18.
Nol E, Douglas H, Crins WJ, 2006. Responses of syrphids, elaterids and bees to single-tree selection harvesting in Algonquin Provincial Park, Ontario. Can. Field-Nat. 120:5-21.
Ouin A, Sarthou JP, Bouyjou B, Deconchat M, Lacombe JP, Monteil C, 2006. The species-area relationship in the hoverfly (Diptera, Syrphidae) communities of forest fragments in southern France. Ecography 29:183-190.
Pihlaja, M., Koivula, M., Niemela, J., 2006. Responses of boreal carabid beetle assemblages (Coleoptera, Carabidae) to clear-cutting and top-soil preparation. Forest Ecol. Manag. 222, 182-190.
Price PW, Denno RF, Eubanks MD, Finke DL, Kaplan I, 2011. Insect ecology: behavior, populations and communities. Cambridge University Press, Cambridge.
Pryke J, Samways M, 2015. Conserving natural heterogeneity is crucial for designing effective ecological networks. Landscape Ecol. 30:595-607.
Purchart L, Tuf IH, Hula V, Suchomel J, 2013. Arthropod assemblages in Norway spruce monocultures during a forest cycle - A multi-taxa approach. Forest Ecol. Manag. 306:42-51.
Ramirez-Hernandez A, Mico E, de los Angeles Marcos-Garcia M, Brustel H, Galante E, 2014. The “dehesa”, a key ecosystem in maintaining the diversity of Mediterranean saproxylic insects (Coleoptera and Diptera: Syrphidae). Biodivers. Conserv. 23:2069-2086.
Read H, 2000. Veteran trees. A guide to good management. English Nature, Petersborough.
Rotheray G, Gilbert F, 2011. The natural history of hoverflies. Forrest text, Ceredigion.
Siitonen J, Martikainen P, Punttila P, Rauh J, 2000. Coarse woody debris and stand characteristics in mature managed and old-growth boreal mesic forests in southern Finland. Forest Ecol. Manag. 128:211-225.
Sobek S, Goßner MM, Scherber C, Steffan-Dewenter I, Tscharntke T, 2009a. Tree diversity drives abundance and spatiotemporal β-diversity of true bugs (Heteroptera). Ecol. Entomol. 34:772-782.
Sobek S, Scherbe, C, Steffan-Dewenter I, Tscharntke T, 2009b. Sapling herbivory, invertebrate herbivores and predators across a natural tree diversity gradient in Germany’s largest connected deciduous forest. Oecologia 160:279-288.
Sobek S, Steffan-Dewenter I., Scherber C, Tscharntke T, 2009c. Spatiotemporal changes of beetle communities across a tree diversity gradient. Divers. Distrib.15:660-670.
Sobek S, Tscharntke T, Scherber C, Schiele S, Steffan-Dewenter I, 2009d. Canopy vs. understory: Does tree diversity affect bee and wasp communities and their natural enemies across forest strata? Forest Ecol. Manag. 258:609-615.
Speight MCD, 1989. Saproxylic invertebrates and their conservation. Council of Europe, Strasbourg.
Sroka K, Finch OD, 2006. Ground beetle diversity in ancient woodland remnants in north-western Germany (Coleoptera, Carabidae). J. Insect Conserv.10:335-350.
Stokland JN, Siitonen J, Jonsson BG, 2012. Biodiversity in dead wood. Cambridge University Press, Cambridge.
Taboada A, Kotze DJ, Tarrega R, Salgado JM, 2006. Traditional forest management: do carabid beetles respond to human-created vegetation structures in an oak mosaic landscape? Forest Ecol. Manag. 237:436-449.
Thomas CD, Hanski I, 2004. Metapopulation dynamics in changing environments: butterfly responses to habitat and climate change. In: I. Hanski and O.E. Gaggiotti (eds.) Ecology, genetics, and evolution of metapopulations. Elsevier, Burlington, pp. 489-514.
Toigo M, Paillet Y, Noblecourt T, Soldati F, Gosselin F, Dauffy-Richard E, 2013. Does forest management abandonment matter more than habitat characteristics for ground beetles? Biol. Conserv. 157:215-224.
Toivanen T, Heikkila T, Koivula MJ, 2014. Emulating natural disturbances in boreal Norway spruce forests: Effects on ground beetles (Coleoptera, Carabidae). Forest Ecol. Manag. 314:64-74.
Zapponi L, Minari E, Longo L, Toni I, Mason F, Campanaro A, 2014. The habitat-trees experiment: using exotic tree species as new microhabitats for the native fauna. iForest 8:464-470.

Conservation of herpetofauna as a function of forestry

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Introduction

Herpetofauna includes both amphibians and reptiles. Despite the fact that these two vertebrate groups are often considered together in the study of herpetology, they are quite different. They come from independent lineages since 300 million years ago (Zug *et al*., 2001) and have quite different reproductive systems, behavioural traits and ecological requirements. Despite their biological and ecological differences, amphibians and reptiles may be considered together regarding their conservation status. Both groups, in the last decades, generated a lot of interest among researchers and wildlife managers because of their worldwide decline (Stuart *et al*., 2004; Gibbons *et al*., 2000). As a consequence of their different biology and ecology, causes of amphibians and reptiles decline should be studied separately: for example they are both ectotherm, but while reptiles have integument covered with scales, amphibians have a permeable skin that makes them more vulnerable to pollutants and desiccation. The major part of amphibians have a biphasic life cycle with an aquatic life stage (Wells, 2010) and are exposed both to terrestrial and aquatic habitat disturbances. Both groups are threatened in the same way by habitat disturbance and fragmentation. In the present chapter a brief overview on the main effects of forest management practices in relation to herpetofauna conservation is reported. The suitability of different approaches and indicators used in literature to study the effect of forest harvesting on herpetofauna is also discussed. Finally, the effects at multiple scales, identifying at the same time the best forestry practice for optimal conservation, are reported at three levels: i) at landscape scale, ii) at forest level and iii) at microsite level, related to deadwood retention.

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Key words: amphibians, reptiles, deadwood retention, forest management, population trends.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Indicators of herpetofauna response to forest management - their suitability

Forests with many water bodies have generally higher amphibian species diversity compared to reptiles. In the last years, amphibians and reptiles conservation received an increased interest within groups of researchers and wildlife managers focused on a multitude of different approaches and indices to identify and understand the causes of this decline. A large literature on this topic, mainly focusing on papers related to forest management, was reviewed as well as the state of the art of the methodologies currently employed in quantitative ecology and population biology, that may be considered suitable for assessing and monitoring the effects of forest management on herpetofauna. Although the major part of the literature on this topic is referred to North-American species and habitats nevertheless indices/approach selection and application, field methodologies, data analysis and observed effects (see following paragraphs) are fully transposable, as a main guideline, to the European context.

One of the main concerns planning to estimate the effect of forestry practices is the temporal scale of the study, and in particular the adoption of temporally and spatially stratified samplings. In the major part of the examined literature the effects of forest management is estimated comparing different indices between unharvested and harvested sites. The best option is to conduct forest experiments, including different treatment levels, along with control treatments, and to compare the selected metrics between different treatments and between pre- and post- treatment (Todd and Rothermel, 2006; Todd and Andrews, 2008; Todd *et al*., 2009); such approach allows to discriminate variations due to forest management options, taking into account pre-existent discrepancies between different sites. Even if the aforementioned option is the most preferable, practically it is really expensive in terms of time and sampling effort; then another suitable approach is to compare sites with different management histories (Welsh *et al*., 2008), if possible selecting sites with in-depth knowledge of pre-existent herpetofauna assemblages. Even if the second option is not preferable to compare the effects of different treatments, due to the absence of pre-existent information on study sites, it allows comparing long term effects of different forest practices on herpetofauna (Welsh *et al*., 2008; Sung *et al*., 2012). As regards sampling techniques and metrics commonly employed to study herpetofauna responses to forest management a main distinction concerns the target of the study: major part of the examined literature focuses at population or community level, while at a lesser extent some studies focus on individual metrics. As regards the individual level approach, a lot of metrics can be employed and compared between harvested and unharvested sites: for example measurement of body mass (Chazal and Niewiarowski, 1998), body length and juvenile growth (Chazal and Niewiarowski, 1998; Todd and

Rothermel, 2006), lipid and energy storage (Chazal and Niewiarowski, 1998) and female fecundity (Chazal and Niewiarowski, 1998; Wahbe *et al*., 2004; Welsh *et al*., 2008) have been successfully employed for this purpose both on amphibian and reptiles. Although there is a large use of different metrics, probably the most suitable one is the Body Condition Index (Karraker and Welsh., 2006; Wahbe *et al*., 2004; Welsh *et al*., 2008), which uses body length and mass of individuals and is a good predictor of individual physiological status (Jakob *et al*., 1996; Peig and Green, 2009). On the other side, even if individual metrics are suitable, a population or community approach is preferable; however the study of population dynamics, demography and abundance is more time and effort consuming but give more accurate estimates. Many authors employed different metrics such as species occurrence and richness (Ashton *et al*., 2006; Sung *et al*., 2012), population abundance (Ash, 1988; Harpole and Haas, 1999; Homyack and Haas, 2009), population structure (Todd and Rothermel, 2006; Welsh *et al*., 2008) and immigration-emigration dynamics (Rittenhouse and Semlitsch, 2009; Todd *et al*., 2009). In order to study population abundance or other demographic parameters (such as survival, stage-specific survival or recruitment) the most suitable method is to perform a capture-mark-recapture study (CMR; for a comprehensive overview see Amstrup *et al*., 2010). This kind of study is quite time and sampling effort expensive but, allowing precise estimates of detection probabilities, it gives the most accurate estimates of abundance and other parameters of interest; furthermore, in the last years, new statistical models (such as N-mixture model; Royle, 2004) have been employed to analyse, less expensively, spatially and temporally repeated count data, obtaining reliable estimates of detection probability and abundance, comparable to those obtained with CMR studies.

Forest management effects at a landscape scale

Considering the effect of forestry practices at a landscape scale, in relation to herpetofauna conservation, the major threat is connected with habitat loss and their fragmentation. Herpetofauna in general, and amphibians particularly, are highly vulnerable to habitat fragmentation for many reasons: for example amphibians have low vagility and they suffer high mortality rates if crossing inhospitable patches (Cushman, 2006). Habitat connectivity is therefore a key function for herpetofauna conservation: a large number of studies shows that low connectivity between terrestrial habitats (*e.g.*, forested areas) and aquatic reproductive sites is a cause of low survival and, consequently, population decline (Cushman, 2006). In a similar way low, habitat connectivity between reproductive sites and forested areas affects, at a larger extent, juvenile survival and dispersal (Rothermel, 2004). Since in amphibians post-metamorphic dispersal contributes for the major part to regional persistence of the species (Preisser *et al*., 2001), to ensure high levels of habitat connectivity is a main goal for amphibian conservation at a landscape scale.

Forest structure effect on herpetofauna

The major part of the studies focused on the effects of clearcuts on herpetofauna and, at a lesser extent, fewer studies took in account multiple forest treatments and structural diversity. The

Table 1. Indicators of herpetofauna response to forest management.

Sampling Framework			
Temporal and spatial stratification	Comparison of Herpetofauna indices/ metrics between harvested/ unharvested sites	Plan different treatments and compare pre- and post- treatment values for the selected metric	Allows to better discriminate the effect of forest management, accounting for pre-existent discrepancies between different sites
More expensive		Compare metrics between sites with different management histories	Less expensive Allows to detect long term effects In-depth knowledge of pre-existent herpetofauna assemblages and forest management is required
Choice of indices and metrics			
Target of the study	Population or community	Species occurrence and richness Population abundance and structure Immigration-emigration dynamics Survival and recruitment	Capture-mark-recapture (CMR) is the most suitable method to estimate population abundance and demographic parameters; however this technique is time and sampling effort expensive. The analysis of repeated count data with N-mixture model (see text for details) gives unbiased estimates of population abundance and is less expensive in terms of time and sampling effort.
	Individuals	Body mass Body length Juvenile growth Female Fecundity Lipid and energy storage Body Condition Index (BCI)	Although there is a large use of different metrics, probably the most suitable one is the use of Body Condition Index, which is a good predictor of individual physiological status

major part of the authors agrees that clearcutting negatively affects both for amphibians and reptiles. Todd and Andrews (2009) estimated the abundance of six snake species between unharvested controls and clearcuts of *Pinus* sp. and reported a significant decrease of abundance for all six species in clearcuts; similarly Todd and Rothermel (2006) observed decreased survival of adult toads (*Bufo terrestris*) in clearcuts and reduced growth of juveniles in harvested areas. Taking into account frog (*Ascaphus truei*) movements and shelter availability between unharvested and clearcuts, Wahbe *et al*. (2004) reported a variation in post reproductive shelter use and migration, probably due to microclimatic variation in clearcut areas. Welsh *et al*. (2008) studied the population structure of Plethodontid salamanders in young harvested forest and old growth forest and reported a decreased survival of adults in recently harvested plots. Similarly Ash (1988, 1997) reported that Plethodontid salamanders disappeared from clearcut plots and returned to harvested sites after 4-6 years and estimated that population abundance will equal the uncut areas after 25 years from cut. As regards structural complexity McKenny *et al*. (2006), studying the abundance of *Plethodon cinereus* in different forest treatments, reported that forest treatments accounting for structural complexity enhancement can maintain important microhabitat characteristics for salamanders populations. Peterman *et al*. (2011) focused on riparian forest structure and highlighted how riparian forest harvesting can cause salamander emigration and, in long term, decrease population abundance and viability. Finally, Knapp *et al*. (2003) reported that even if timber harvesting reduces the abundance of salamanders, such negative effect might be mitigated concentrating high-intensity timber harvesting in small sized areas.

Effects of deadwood retention on herpetofauna

Another fundamental aspect on herpetofauna conservation and forest management is the retention of deadwood in harvested areas; amphibians use deadwood in forest ecosystems for multiple purpose such as feeding, mating and overwintering (Otto *et al*., 2013). Many authors agree that deadwood retention in harvested forest has a positive effect on amphibian populations (Ross *et al*., 2000; Todd *et al*., 2009) especially for salamanders (Patrick *et al*., 2006). The mitigating effect of deadwood retention is more important during first years after cut when few shelters are available due to biomass removal (Otto *et al*., 2013). Even if a lot of studies enhanced the importance of deadwood for amphibians, there is a lack of knowledge of amphibian response on deadwood structure (*e.g.*, deadwood dimensions); furthermore many studies give contradictory results, reporting a positive effect of deadwood retention before cutting but not after (Morneault *et al*., 2004); these inconsistencies are probably due to a biased estimate of abundance (Otto *et al*., 2013; Schmidt, 2004). As a general approach deadwood retention has to be considered as highly ameliorative practice for herpetofauna conservation, and for amphibians in particular; availability of deadwood as cool and moist refugia is a primary needed for lungless salamanders (*e.g.*, Plethodontids) and was reported in many studies (Homyack *et al*, 2011; Otto *et al*., 2013).

Table 1 synthesizes the indicators of herpetofauna response to forest management discussed in this chapter.

References

Amstrup SC, McDonald TL, Manly BF, 2010. Handbook of capture-recapture analysis. Princeton University Press.

Ash AN, 1988. Disappearance of salamanders from clearcut plots. J. Elisha Mitchell Sci. Soc. 104:116-122.

Ash AN, 1997. Disappearance and return of plethodontid salamanders to clearcut plots in the southern Blue Ridge Mountains. Conserv. Biol. 11:983-989.

Ashton DT, Marks SB, Welsh HH, 2006. Evidence of continued effects from timber harvesting on lotic amphibians in redwood forests of northwestern California. Forest Ecol. Manage. 221:183-193.

Chazal AC, Niewiarowski PH, 1998. Responses of mole salamanders to clearcutting: using field experiments in forest management. Ecol. Appl. 8:1133-1143.

Cushman SA, 2006. Effects of habitat loss and fragmentation on amphibians: a review and prospectus. Biol. Conserv. 128:231-240.

Gibbons JW, Scott DE, Ryan TJ, Buhlmann KA, Tuberville TD, Metts BS, Greene JL, Mills T, Leiden Y, Poppy S, Winne C, 2000. The global decline of reptiles, deja vu amphibians. Bioscience 50:653-666.

Harpole DN, Haas CA, 1999. Effects of seven silvicultural treatments on terrestrial salamanders. Forest Ecol. Manage. 114:349-356.

Homyack JA, Haas CA, 2009. Long-term effects of experimental forest harvesting on abundance and reproductive demography of terrestrial salamanders. Biol. Conserv. 142:110-121.

Homyack JA, Haas CA, Hopkins WA, 2011. Energetics of surface-active terrestrial salamanders in experimentally harvested forest. J. Wildlife Manage. 75:1267- 1278.

Jakob EM, Marshall SD. Uetz GW, 1996. Estimating fitness: a comparison of body condition indices. Oikos 77:61-67.

Karraker NE, Welsh HH, 2006. Long-term impacts of even-aged timber management on abundance and body condition of terrestrial amphibians in Northwestern California. Biol. Conserv. 131:132-140.

Knapp M, Haas CA, Harpole DN, Kirkpatrick RL, 2003. Initial effects of clearcutting and alternative silvicultural practices on terrestrial salamander abundance. Conserv. Biol. 17:752-762.

McKenny HC, Keeton WS, Donovan TM, 2006. Effects of structural complexity enhancement on eastern red-backed salamander Plethodon cinereus) populations in northern hardwood forests. Forest Ecol. Manag. 230:186-196.

Morneault AE, Naylor BJ, Schaeffer LS, Othmer DC, 2004. The effect of shelterwood harvesting and site preparation on eastern red-backed salamanders in white pine stands. Forest Ecol. Manag. 199:1-10.

Otto CR, Kroll AJ, McKenny HC, 2013. Amphibian response to downed wood retention in managed forests: A prospectus for future biomass harvest in North America. Forest Ecol. Manag. 304: 75-285.

Patrick DA, Hunter ML, Calhoun AJK, 2006. Effects of experimental forestry treatments on a Maine amphibian community. Forest Ecol. Manag. 234:323-332.

Peig J, Green AJ, 2009. New perspectives for estimating body condition from mass/length data: the scaled mass index as an alternative method. Oikos 118:883-1891.

Peterman WE, Crawford JA, Semlitsch RD, 2011. Effects of even-aged timber harvest on stream salamanders: Support for the evacuation hypothesis. Forest Ecol. Manag. 262:2344-2353.

Preisser EL, Kefer JY, Lawrence JD, 2001. Vernal pool conservation in Connecticut: an assessment and recommendations. Environ. Manage. 26:503-513.

Rittenhouse TA, Semlitsch RD, 2009. Behavioral response of migrating wood frogs to experimental timber harvest surrounding wetlands. Can. J. Zool. 87:618-625.

Ross B, Fredericksen T, Ross E, Hoffman W, Morrison ML, Beyea J, Lester MB, Johnson BN, Fredericksen NJ, 2000. Relative abundance and species richness of herpetofauna in forest stands in Pennsylvania. Forest Sci. 46:139-146.

Rothermel BB, 2004. Migratory success of juveniles: a potential constraint on connectivity for pond-breeding amphibians. Ecol. Appl. 14:1535-1546.

Royle JA, 2004. N-Mixture models for estimating population size from spatially replicated counts. Biometrics 60:108-115.

Schmidt BR, 2004. Declining amphibian populations: the pitfalls of count data in the study of diversity, distributions, dynamics and demography. Herpetol. J. 14:167-174.

Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues AS, Fischman DL, Waller RW, 2004. Status and trends of amphibian declines and extinctions worldwide. Science 306:1783-1786.

Sung YH, Karraker NE, Hau BC, 2012. Terrestrial herpetofaunal assemblages in secondary forests and exotic Lophostemon confertus plantations in South China. Forest Ecol. Manag. 270:71-77.

Todd BD, Andrews KM, 2008. Response of a reptile guild to forest harvesting. Conserv. Biol. 22:753-761.

Todd BD, Rothermel BB, 2006. Assessing quality of clearcut habitats for amphibians: effects on abundances versus vital rates in the southern toad Bufo terrestris). Biol. Conserv. 133:178-185.

Todd BD, Luhring TM, Rothermel BB, Gibbons JW, 2009. Effects of forest removal on amphibian migrations: implications for habitat and landscape connectivity. J. Appl. Ecol. 46:554-561.

Wahbe TR, Bunnell FL, Bury RB, 2004. Terrestrial movements of juvenile and adult tailed frogs in relation to timber harvest in coastal British Columbia. Can. J. Forest Res. 34:2455-2466.

Wells KD, 2010. The ecology and behavior of amphibians. University of Chicago Press.

Welsh HH, Pope KL, Wheeler CA, 2008. Using multiple metrics to assess the effects of forest succession on population status: A comparative study of two terrestrial salamanders in the US Pacific Northwest. Biol. Cons. 141:1149-1160.

Zug GR. Vitt LJ, Caldwell J,. 2001. Herpetology: an introductory biology of amphibians and reptiles. Academic Press.

Conservation of birds as a function of forestry

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Introduction

Forests, typical habitats for birds in many regions, contribute to the greater proportion of vertebrate species richness. Several bird species live exclusively in forest, but what resources specifically contribute to the suitability of forest habitat for birds?

The composition and the vertical structure of the forest greatly affect its biological diversity (Puumalainein, 2001). If we analyse the vertical layers of forests, we would understand how resources belonging to different layers are exploited by different species. Forest resources, most likely to influence bird presence and their abundance are nesting, shelter sites and food availability (Martin, 1988; Verner, 1984). The ground is exploited by birds mostly for food and nesting. Birds of prey hunt on small vertebrates, generalist insectivorous searches for insects and other invertebrates, frugivorous and granivorous harvest the fallen fruits and seeds. Specialists, like the woodcock (*Scolopax rusticola*), that catches especially annelids, using the long bill as a probe, or the numerous species that feed on saproxylic insects, dwelling in the deadwood on the ground are also present. Few species nest directly on the ground, like the nightjars (*Caprimulgidae*) and grouses (*Phasianidae*), characterized by a mimetic plumage. The shrub layer, that may vary from the sparse shrubs found in many managed European beech forests to the dense and intricate vegetation association at lower latitude, offers a lot of nest sites to several bird species and guilds, and especially to song birds (*Passeriformes*). These species build their nests among small branches in the bushes, usually feed on berries or invertebrates found on the same bushes, or directly on the ground. They have usually a mimetic plumage and strong vocalizations (Cramp, 1988). The stem and the biggest branches represent the main feeding grounds of many insectivorous birds, like treecreepers (*Certhidae*) or woodpeckers (*Piciformes*). Onto the bark, often covered in mosses, lichens and mushrooms, a great variety of invertebrate constitute the greater proportion of the food of these birds. Indeed, woodpeckers hunt saproxylic insect, which excavate their tunnels inside the trunk. Snags, in fact, are fundamental for these species to sustain a huge biomass of saproxilic insects. The trunk is also characterized by many cavities, created by both the natural detachment of dead branches and by cavity excavators, like woodpeckers. Cavities are the primary nest site of many birds, some of which are obliged cavity nesters, as they can provide shelter from the majority of predators.

The canopy is essentially shaped by branches and filled by fruits and leafs. The biggest branches provide support for the large nests of many birds of prey (*e.g., Accipitriformes*), while the smallest ones are occupied by smallest birds. This level, actually, is the most complex, taking into account that it varies also horizontally, due to the presence of clearings or streams and the different tree species.

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Key words: Forest management, avifauna, population, guilds, community, birds directive.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Norway spruce, European Beech, and Oak forests and avifauna

The European forests usually show little variation among bird communities, due to their relative small extant. Different forest types could share many species, while differences between communities originate mostly from different relative abundance of species, than from species diversity. Exclusive or specialist birds of a certain forest type are relatively few, compared to the overall forest bird inventory of Europe (Fornasari *et al*., 2010).

Conifers, like the Norway spruce (*Picea abies*) has a fluctuating seed production, that has a strong influence on the demography of many seed-eater birds (Newton, 2006). A typical consequence is the wide fluctuation in birds' population abundance in forests, due to the altered survival, reproductive success and erratic or invasive movements. An emblematic *genus* strictly connected with conifer is *Loxia* that includes various crossbill species. The breeding season of these species is not limited to a particular period of the year, but they could eventually nest at every time in the year, which is an extremely rare attribute for European birds. Crossbills follow conifer fructification from region to region, causing invasive and irregular movements both in time and space. Some species, which are characteristic for conifer forests are the coal tit (*Periparus ater*), the goldcrest (*Regulus regulus*), the firecrest (*Regulus ignicapilla*) and the capercaillie (*Tetrao urogallus*).

Beech forests may be an uniform and homogenous habitat in Italy, mainly because forestry generated a structurally monotonous landscape and also promoted a monospecific environment with sparse underwood. Birds live in this forest type usually at variable densities according to their ecological requirements and period of the year, due to different phenology of each species (Balestrieri *et al*., 2015). During winter beech forests are less suitable for insectivorous and granivorous birds, while in the late spring they are populated by many migratory species. Those, *e.g,*. the members of *taxa Phylloscopus*, *Ficedula*, *Silvia*, occur from late April, determining an increase in the number of species and individuals until late summer. These species exploit the beech forest during the most flourishing period of the year. Few species are resident all year round, principally the ones that can feed on resources constantly available during the year, like saproxilic insects. Birds like the red-breasted flycatcher (*Ficedula parva*), the woodwarbler (*Phylloscopus sibilatrix*) are frequently observed breeding in these forests. Oak forests usually present a mix of tree species, representing an heterogeneous habitat that can results in a greater bird community, with more species and individuals (Bergner *et al*., 2015). Also the structure of the forest is usually more complex, with a dense underwood and a greater variation in canopies. Mixed oak forests are found mostly at low altitude, so that many birds exploit this habitat during winter. The majority of the species occurring in oak forests belong to the group of the short-distance migrants, that is they do not migrate across the Sahara, but remain within the Mediterranean basin (Cramp, 1988). The phenology of these birds is often described as partial-migrant, that means that only a portion of the population migrate, while the remaining is sedentary (Berthold, 2001). The breeding season of the bird community in oak forests, indeed, can be longer than the other forests, as the community is composed by early nester, which season starts in March, and late nester, the same as the beech forests (Bütler *et al*., 2004). Moreover early nesters can have multiple nesting event during the season, usually up to three broods. The breeding bird species typical of this type of forest are middle spotted woodpecker (*Dendrocopos medius*), black stork (*Ciconia nigra*) and common redstart (*Phoenicurus phoenicurus*) (Angelstam and Mikusinski, 1994).

Forest management and avifauna

The recent National Forest Inventory (2015) has shown a slight increase of the surface covered by forest in Italy. This process seems to be shared in Europe, at least in the Mediterranean basin, dating back from the early years of the XX century, due to the gradual abandonment of pastures and farms (Farina, 1995; Vos and Stortelder, 1992). As a consequence, secondary forests began to cover the abandoned areas, creating a more fragmented landscape than the original one (Noss and Csuti, 1997), that lacks of the substantial structural characteristics of the primary forests (Perry, 1994). These features have affected birds, changing communities composition and species abundances (Burfield and Van Bommel, 2004). Forest specialist birds (*e.g.*, *Dryobates minor*, *Dendrocopos major*, *Sitta europaea*, *Certhia* sp.) benefited the most from this semi-spontaneous reforestation, contrarily to generalist birds (Tellini Florenzano, 2004). Major benefits may come from the increased ageing of forests (Ferry and Frochot, 1970), resulting in improved habitat characteristics like the augmentation of deadwood (Peace, 1962).

The increase of forest surface has matched the beginning of an enhanced attention to biological conservation in forestry (Hansen *et al*., 1991). Researches focusing on conjugating wood production and biological conservation have determined the birth of the sustainable forestry. In this context, 'sustainable' highlights a forestry that attempt to maintain the ecosystem integrity, reducing the alteration to forest structure, as well as to biodiversity, within the range of natural disturbance (Lindenmayer *et al*., 2006). Unfortunately, different species respond in different ways to forestry and for generalists taxa it can be expected a neutral, or even positive impact on abundance (Bengtsson *et al*., 2000).

Forest specialist birds are those whose resources, needed for survival and reproduction, as well as to maintain a minimum viable population, are found exclusively in forests. Usually, cavity nester and bark feeder are included among specialist species (Verner, 1984). Forestry may affect negatively the abundance of these species at many ecological levels: i) population, ii) guilds, and iii) community.

Population

Within the order of *Piciformes* can be found the species which are affected the more by forestry, due to their strong connection with veteran, senescent and dead trees (Brichetti and Fracasso, 2007). Tree age is correlated with the abundance of natural cavities, created after the detachment of dead branches (Peace, 1962). In this way the amount of deadwood increase, causing the proliferation of saproxilic invertebrates (*sensu* Mason *et al*., 2003) that, in turn, improve food availability for woodpeckers (Newton, 1994). Older trees, indeed, are more prone to necrotic processes in the stem, and, as a consequence, have a softer bark, that could be easily more excavated by woodpeckers, that contribute to increase the number of cavities, favouring the presence of other specialist, like secondary cavity nester (Newton, 1994). Forestry can result in the decrease of these microhabitats that could be replaced at a very slow rate, and can consequently cause the disappearing of specialist birds, *e.g. Certhia brachydactyla*, *Picoides tridactylus, Dendrocopos leucotos* or *Sitta europaea* (Roberge *et al*., 2008; Robles *et al*., 2012). A fragmented landscape is another consequence of forestry that could be harmful for bird population (Fahrig, 2003). Edge sensitive species, like *Dendrocopos medius*, could decline after the reduction of forest plot area (Kosiński, 2006). Fragmentation could also determine physiological stress among nestlings (Suorsa *et al*., 2003).

Guilds

Since species that exploit the same resources could be grouped into guilds (Root, 1967), which is a group of *taxa* sharing a similar niches, forestry-dependent alterations that affect a species may also affect the other species within the same guild (Severinghaus, 1981). Mature and old-growth forests are suitable for those species included in cavity nester or bark foraging guilds (Bergner *et al*., 2015; Nikolov, 2009), while forest harvesting may negatively affects the species composition and abundance of insectivorous guild (Czeszczewik *et al*., 2014).

Community

Forest alteration, however, affects the whole community, changing the proportion of specialist and generalist and influencing their richness. Forest features, likely to influence avian community, are the age of the patch, timber biomass and the area/perimeter ratio (Caprio *et al*., 2008; Donald *et al*., 1998; Zipkin *et al*., 2009). The alteration of these characteristics usually results in a decrease of the specialists *taxa* within the community. Fragmentation, actually, could have different impacts on community composition, resulting in a decrease, as well as an increase, of species richness (Jansson and Andre, 2003; Zipkin *et al*., 2009). Indeed, fragmentation increases the heterogeneity of the landscape, making available habitat features shared from both dense forest and open habitat dwellers, attracting more species (Fahrig, 2003). However, mature forest, with high tree species richness, usually results in a greater bird species diversity (Donald *et al*., 1998; Gil-tena *et al*., 2007).

Forest management implications may be difficult to deduct, due to the different and often unclear responses of birds. Usually, researchers advices consist in the retention of older trees and in the avoidance of logging activity during the breeding seasons. However, some more specific advices and detailed cases can be found in the literature. The correlation between the presence of *Picoides tridactylus* and snag density led Bütler *et al*. (2004) to suggest retaining a snag density at ≥5% of total basal area per 100 ha, as a measure to improve the presence of this species. King and DeGraaf (2000) observed greater bird diversity in shelterwood forests than both in clear-cut and mature forests. Birds are influenced also by tree age truncation due to thinning, short-time rotation plantation forestry and other form of intensive forest management that create an even-aged forest (Kendrick *et al*., 2014; Thompson *et al*., 2003). On the other hand, intensive logging that leave undisturbed patches among harvested gaps is preferable for cavity nester to a more uniform, although less intense, forest cutting (Tozer *et al*., 2010).

Forest management and species in the Birds Directive

Most forest bird species are under strong human pressures, their populations are declining or have the potential to decline. Therefore several of them have been listed in the Annex I of the Directive 2009/147/CE of the European Parliament and of the Council on the conservation of wild birds (Birds Directive) in order to preserve their populations. Many species are forest specialists, but some are only facultative forest users, or forests provide only some of the resources they need to fulfill their biological cycle. There are many species through many *orders*, which are related to conifer, beech and oak forests in Central-Southern Europe. The aim of this section is to describe the preferred forest characteristics for several selected bird species within the Birds Directive, which can be used as a paradigm for sustainable forest management. The Collared flycatcher life history requisites theoretically could met our goals, however no studies exist to our knowledge which quantitatively assess its resource selection at relevant habitat levels and we will not examine this species. The woodlark too is enclosed in Annex 1 of the Birds Directive but it uses almost only forest edges; these, for practical reasons, have few if any interest in forest management as they are usually left untouched to meet a protection function against adverse climatic factors.

The **Black stork** (*Ciconia nigra*) on a macro scale prefers large continuous forest complexes (Treinys *et al*., 2009a) with negligible human disturbances (Rosenvald and Lohmus, 2003). Nest sites are in older stands with greater share of deciduous forests with grey alders in Lithuania (Treinys *et al*., 2009b), while in Greece and Spain Black storks were mainly breeding in pines with a smaller share of Oaks (Cano Alonso, 2006; Vlachos *et al*., 2008). The nesting trees had, on average, the following characteristics: average DBH = 51 cm, average height = 14.5 m, average canopy height = 6.5 m and average age of 93 years. In the vicinity of the nest sites, the total tree density was 32.35 trees/0.1 ha (±2.97), with a mature tree (>46 years) and a density of 3.18 trees/0.1 ha on average (Vlachos *et al*., 2008).

Honey buzzard (*Pernis apivorus*) prefers mostly coniferous and mature forest stands. In Austria, the most common trees for nesting of Honey buzzard were Scots Pine and Norway Spruce, however in the areas that lacked of conifers, nests were always placed on deciduous trees (Gamauf *et al*., 2013). They also prefer mature tree stand, older than 50 year, wherein the most suitable are tree stands older than 70 years (Keller *et al*., 2008). In Southern Norway, the mean forest age where Honey buzzard's nests were located was 86.7 years and the mean number of trees in the nesting sites was 86.4±33.4 (Selas, 1997). Tree diameter is also an important factor in choosing the suitable nesting site as these species usually select trees with greater diameter (Gamauf *et al*., 2013).

White-tailed sea-eagle (*Haliaeetus albicilla*) uses the lowland forest for breeding. On a macro-scale the forest should be in within 4 km of a large stream or water body. Eagles do not seem to be affected by the type of management at the nesting site, and the presence and the proximity of anthropogenic infrastructure (roads and settlements) did not affect breeding. The protection status did not seem to affect the breeding in Finland (Santangeli *et al*., 2013). However in Croatia the White tailed sea eagle breeds on minimally 425 m, but on average 2,742 m away from human settlements (Radović and Mikuska, 2009). Bird prefers penduncultate oaks, narrow leafed ash and white poplars as nesting sites. The preference is for mature trees with an average DBH of 84.3 cm and stand average age of 114 years. The minimum distance between breeding sites is 348 m. (Radović and Mikuska 2009).

Short-toed eagle (*Circaetus gallicus*) prefers on a landscape scale open forests with nearby open shrubland (Bakaloudis, 2009; Lopez Iborra *et al*., 2011; Barrientos *et al*., 2014). The nesting trees have a large DBH (>40 cm) and trees are 12 m high with a 30-70% of tree cover around them (Barrientos *et al* 2014). Preferred forests are mature pine forests with *Pinus nigra* and *P. brutia* with a density of 236.13 trees/ha (±24.68) and a 36.5% average canopy closure. The nests are on average 273 m (±40.3) from the nearest forest opening (>0.5 ha). The dominant trees are 86.6 years old (±2.7) and have a DBH of 46.9 cm (±0.9) and are 13.9 m high (±0.3) (Bakaloudis *et al*., 2001).

The **Capercaillie** (*Tetrao urogallus*) is a forest specialist, which is strongly affected by forest fragmentation (Rueda *et al*., 2013). The species is mainly occurring in conifer forests with open canopy cover with bilberry (Moss and Picozzi, 1994). In Finland, the most frequently occurring DBH classes are between 10.5 to 14.5 cm in summer habitats while the winter habitats contained trees with DBH classes between 14.5 and 18.5 cm (Miettinen *et al*., 2010). The suitable age of the forest for the Capercaillie is highly debated. Some studies mention more than 90 years (Aberg *et al*., 2003), while others report that age classes of 30-40 years and more are already suitable for Capercaillie (Miettinen *et al*., 2010). It is suggested that thinning is a suitable way to maintain the habitat of the Capercaillie (Miettinen *et al*., 2009), but also understory management, longer rotations and multicohort forest management are considered as suitable tools (Miettinen *et al*., 2010). Setting fences should be avoided because they can injure females while flying (Baines and Summers, 1997). Clearcutting on the other hand is not a suitable tool as this increases the predation of the eggs. Also preparing forest tracks are not sustainable for the Capercaillie as they avoid them (Summers *et al*., 2007) and they are more stressed by increasing recreation (Thiel *et al*., 2006; Thiel *et al*., 2008).

The **Hazel grouse** (*Tetrastes bonasia*) is a forest specialist confined to continuous forests (Kajtoch *et al*., 2012). The Hazel grouse only occurs in patches closer than 100 m from forest edge in agricultural forest and 2 km from suitable habitat in intensively managed forest. The Hazel grouse needs a minimum size of deciduous forest patch of 92 ha (±5.4) (Aberg *et al*., 1995). The species prefers forests with an average of 25% spruce, with 5-40% deciduous trees, un-thinned forest stands of an age between 20-50 years, dense understory; other tree species which are favored are alder, mountain ash and willow (Aberg *et al*., 2003; Muller *et al*., 2009; Sachot *et al*., 2003; Swenson 1993). The recommended forest practice is natural regeneration of gaps or small-scale fellings (Klaus 1991; Sachot *et al*., 2003).

For the conservation of **Ural owl** (*Strix uralensis*) populations, it is essential to retain large cavity-forming trees in the forest. The results of studies from Estonia, that were performed in forest with 46% Birch (*Betula* spp.), 17% Scots pine (*Pinus sylvestris*) and 15% Norway spruce (*Picea abies*), showed that in managed forests the lack of large snags and tree cavities may limit the numbers of Ural owls. Ural owls prefer to breed in tree cavities than in stick nests (Lohmus 2003). Also in Slovenia, large tree holes are the most frequently used nest-sites of Ural owls (Vrezec and Kohek, 2002).

Tengmalm's owl (*Aegolius funereus*) is a species that occupies mature and old forests (Hakkarainen *et al*., 2008; Hayward *et al*., 1993; Laaksonen *et al*., 2004) with complex physical structure (Hayward *et al*., 1993). The amount of old forest in the territory influences not only reproduction and breeding success, but also survivorship of male Tengmalm's owls (Hakkarainen *et al*., 2008). In a long-term population study in Finland, lifetime reproductive success of Tengmalm's owls strongly correlated with the amount of old forests (Laaksonen *et al*., 2004). Old and dense forests provide better protection against predators, as well as greater availability of food (Hakkarainen *et al*., 2008; Laaksonen *et al*., 2004). Clearcuts can have positive impact on Tengmalm's owl (Hakkarainen *et al*., 1996, 2003). In Spruce and Pine forests in Finland, the owl pairs, nesting in territories with high (>30%) percentage of clearcut areas and plantations, had more fledglings than areas with less cut areas. This was mostly connected with the abundance of voles in clearcut areas, which represent a food source for Tengmalm's owl (Hakkarainen *et al*., 1996). Tree composition influences their behavior - in western Finland, the size of home ranges of male owls decreased with increasing cover of spruce forests, which indicates that such forests are richer in prey than pine forests and clearcut areas (Santangeli *et al*., 2012).

Pygmy owls (*Glaucidium passerinum*) do not depend so much on coniferous woodlands as the Tengmalm's owls (Blutz von Blotzheim, 1980). In Oregon (USA) authors conclude that the Pygmy-owls are limited primarily to closed-canopy forests dominated by conifers, but are otherwise habitat generalists that occur in a broad range of plant species associations (Sater, 2000). They prefer mature and older forests (Giese and Forsman 2003; Strom and Sonerud, 2001) that are structurally diverse and have abundance of dead trees with cavities excavated by woodpeckers, where they can nest (Giese and Forsman, 2003). They are strongly forest-dependent species, what was also confirmed on the basis of radio-tracking of 8 individuals in south-eastern Norway (Strom and Sonerud, 2001). The same study also confirmed that Pygmy owls express affinity towards forest edges, which is also connected with the availability of prey in open areas.

The **Black woodpecker** (*Dryocopus martius*) is a forest specialist that is not so sensitive to forest fragmentation (Rueda *et al*., 2013). The main forests where it occurs are those with Scotch pine and beech (Bocca *et al*., 2009; Domokos and Cristea, 2014). The forest stands should have a dominant height of 22.8 m, age 104.9 year, with an average tree diameter of 27.4 cm, stand age >50 years and a basal area of 22.1 m^3/ha (Garmendia *et al*., 2006; Rolstad *et al*., 1998). The characteristics of the nest trees are an average DBH of 63.33 cm and an average tree height of 26.67 m (Domokos and Cristea, 2014). They mainly breed in living beech, aspen and Scots pine (Zahner *et al*., 2012; Rolstad *et al*., 2000)

The **White-backed woodpecker** (*Dendrocopos leucotos*) is a forest specialist and prefers mainly broad-leaved forests (Glutz von Blotzheim and Bauer, 1980), low proportion of spruce plantations, and a large amount of deadwood (fallen timber: 50-58.2 m^3/ha, snags >11-20 cm DBH, 56 snags/ha) (Czeszczewik and Walankiewicz, 2006; Czeszczewik, 2009; Gjerde *et al*., 2005; Kajtoch *et al*., 2013). According to forest type there is a strong difference in the amount of deadwood which can be considered as suitable for such a species: 36-58m^3/ha in beech forests, and 10-20 m^3/ha for coniferous (Mueller and Butler, 2010). The nesting trees are mainly oaks and beech. The dominant height of the dominant layer of these trees is 21.8 m, with an age 109.9 years, and an average DBH of 31.5 to 50 cm (Garmendia *et al*., 2006; Melletti and Penteriani, 2003). A threshold was calculated that a landscape should have 13% of suitable habitat before a population would go extinct (Carlson, 2000). A forest management option that showed positive effect is girdling and notching deciduous trees (Aulen, 1991).

In deciduous forests in Poland, **Middle spotted woodpeckers** (*Dendrocopos medius*) selected older and oak-dominated forests. They also avoided smooth-barked or young stands (<80 years old) (Kosinski, 2006). In deciduous forests, oaks are the most commonly used tree species for nesting and the mean DBH of the nesting tree is around 56 cm (Kosinski and Kempa, 2007). Forest management, suitable for Middle spotted woodpecker should therefore focus on large deciduous trees (dbh >40 cm), mainly oaks (Kosinski and Kempa, 2007; Pasinelli, 2000). The stand structure is an important factor in nest tree selection of Middle spotted woodpeckers, as they like to nest near the forest edges. They also prefer sites characterised by a higher diversity of vegetation (Kosinski and Winiecki, 2004).

The **Three-toed woodpecker** (*Picoides tridactylus*) is a forest specialist (Rueda *et al*., 2013), which prefers mainly old growth stands with uneven vertical structures (Stachura-Skierczynska *et al*., 2009). The typical stand characteristics are trees with a mean DBH of 30.6 cm, an average spruce density of 578 trees/ha, and an average deciduous trees density of 23 trees/ha (Pechaceck and D'Oleire, 2004). The species occurs in forest landscapes with a deadwood basal area of 1.3 m^2/ha. The amount of deadwood is between 11-30 m^3/ha, with 15 m^3/ha of standing snags (Pechaceck and D'Oleire, 2004).

European nightjar (*Caprimulgus europaeus*) mostly occurs in shrubs and forest edges (Bartolommei *et al*., 2013; Sierro *et al*., 2001) and prefer open places, such as clear-felled areas, young stands, windfall clearings etc. (Verstraeten *et al*., 2011). In Switzerland, nightjars select oak scrubland and avoid dense forests (Sierro *et al*., 2001). They also choose places with greater biodiversity (Stasiak *et al*., 2013). In North Yorkshire, where the forest composition consists of Scots pine (*Pinus sylvestris*), Sitka spruce (*Picea sitchensis*) and Japanese or hybrid larches (*Larix* sp.) and smaller areas of native broadleaves and other conifers, nightjars settled in younger and more opened plantations (Scott *et al*., 2010). They can also settle in old and open stands that had wide forest tracks, which represent smaller patches suitable for nightjars. Therefore, building a network of gap-like microhabitats within the forest could positively affect nightjar populations (Verstraeten *et al*., 2011).

Red-breasted flycatcher (*Ficedula parva*) is a species that occurs in broadleaved forests and is mainly a cavity breeder (Mitrus and Socko, 2004). The main forest characteristics of the breeding sites are lying dead trunks, the amount of hornbeams and the age of the stand. In the breeding sites tree density is on average 550 trees/ha, mean DBH is 31.2 to 47.5 cm, the number of lying dead trunks is on average 0.3 in a radius of 8 m around the counting point, percentage of hornbeams are 28.6 %; stand age was on average 196.4 years (range=44-382 yrs) and the top canopy had a closure of 79.3% (Wichmann and Frank 2007).

In almost all species older forests are preferred. Especially for woodpeckers a large amount of available deadwood makes a significant difference. However, in some cases species have opposite habitat preferences, which could be given conflicting situations like between forest specialists and species, which use the forests only facultative, or between Capercaillie and Hazel grouse. Therefore, at a stand scale is important to consider the status of the occurring species (at a local or country level, independently from Birds Directive) to prioritize forest management choices. At the same time on a landscape scale, a diversified forest management strategy allowing the co-occurrence of forest patches with different forest structures and different management goals should help favoring the coexistence of viable populations of species with contrasting or dissimilar habitat preferences.

References

Aberg J, Jansson G, Swenson JE, Angelstam P, 1995. The effect of matrix on the occurrence of hazel grouse (*Bonasa bonasia*) in isolated habitat fragments. Oecologia 103:265-269.

Aberg J, Swenson JE, Angelstam P, 2003. The habitat requirements of hazel grouse (*Bonasa bonasia*) in managed boreal forest and applicability of forest stand descriptions as a tool to identify suitable patches. Forest Ecol. Manag. 175:437-444.

Angelstam P, Mikusinski G, 1994. Woodpecker assemblages in natural and managed boreal and hemiboreal forest - a review. Ann. Zool. Fenn. 31:157-172.

Aulen G, 1991. Increasing insect abundance by killing deciduous trees - a method of improving the food situation for endangered woodpeckers. Holarctic Ecol. 14:68-80.

Baines D, Summers RW, 1997. Assessment of bird collisions with deer fences in Scottish forests. J. Appl. Ecol. 34:941-948.

Bakaloudis DE, 2009. Implications for conservation of foraging sites selected by Short-toed Eagles (Circaetus gallicus) in Greece. Ornis Fennica 86:89-96.

Bakaloudis DE, Vlachos C, Papageorgiou N, Holloway GJ, 2001. Nest-site habitat selected by Short-toed Eagles Circaetus gallicus in Dadia forest (northeastern Greece). Ibis 143:391-401.

Balestrieri R, Basile M, Posillico M, Altea T, De Cinti B, Matteucci G, 2015. A guild-based approach to assessing the influence of beech forest structure on bird communities. Forest Ecol. Manag. 356:216-223.

Barrientos R, Arroyo B, 2014. Nesting habitat selection of Mediterranean raptors in managed pinewoods: searching for common patterns to derive conservation recommendations. Bird Conserv. Int. 24:138-151.

Bartolommei P, Mortelliti A, Pezzo F, Puglisi L, 2013. Distribution of nocturnal birds (Strigiformes and Caprimulgidae) in relation to land-use types, extent and configuration in agricultural landscapes of Central Italy. Rend. Lincei-Sci. Fis. 24:13-21.

Bengtsson J, Nilsson SG, Franc A, Menozzi P, 2000. Biodiversity, disturbances, ecosystem function and management of European forests. Forest Ecol. Manag. 132:39-50.

Bergner A, Avci M, Eryiğit H, Jansson N, Niklasson M, Westerberg L, Milberg P, 2015. Influences of forest type and habitat structure on bird assemblages of oak (Quercus spp.) and pine (Pinus spp.) stands in southwestern Turkey. Forest Ecol. Manag. 336:137-147.

Berthold P, 2001. Bird migration. A general survey, 2nd ed. Oxford University Press.

Bocca M, Carisio L, Rolando A, 2007. Habitat use, home ranges and census techniques in the Black Woodpecker Dryocopus martius in the Alps. Ardea 95:17-29.

Brichetti P, Fracasso G, 2007. Ornitologia Italiana, vol. 4 Apodidae - Prunellidae. Oasi Alberto Perdisa Editore, Bologna, Italy.

Burfield IJ, Van Bommel F, 2004. Birds in Europe. Population estimates, trends and conservation status. BirdLife Conservation Series. BirdLife International, Cambridge, UK.

Bütler R, Angelstam P, Ekelund P, Schlaepfer R, 2004. Dead wood threshold values for the three-toed woodpecker presence in boreal and sub-Alpine forest. Biol. Conserv. 119:305-318.

Caprio E, Ellena I, Rolando A, 2008. Assessing habitat/landscape predictors of bird diversity in managed deciduous forests: a seasonal and guild-based approach. Biodivers. Conserv. 18:1287-1303.

Carlson A, 2000. The effect of habitat loss on a deciduous forest specialist species: the White-backed Woodpecker (Dendrocopos leucotos). Forest Ecol. Manag. 131:215-221.

Cramp S, 1988. The birds of the Western Paleartic. Oxford University Press, Oxford, UK.

Czeszczewik D, 2009. Marginal differences between random plots and plots used by foraging White-backed Woodpeckers demonstrates supreme primeval quality of the Bialowieza National Park, Poland. Ornis Fennica 86:30-37.

Czeszczewik D, Walankiewicz W, 2006. Logging affects the white-backed woodpecker Dendrocopos leucotos distribution in the Bialowieza Forest. Ann. Zool. Fenn. 43:221-227.

Czeszczewik D, Zub K, Stanski T, Sahel M, Kapusta A, Walankiewicz W, 2014. Effects of forest management on bird assemblages in the Bialowieza Forest, Poland. iForest. 8:377-385. 07.

Domokos E, Cristea V, 2014. Effects of managed forests structure on woodpeckers (Picidae) in the Niraj valley (Romania): Woodpecker populations in managed forests. Northwestern J. Zool. 10:110-117.

Donald PF, Fuller RJ, Evans AD, Gough SJ, 1998. Effects of forest management and grazing on breeding bird communities in plantations of broadleaved and coniferous trees in western England. Biol. Conserv. 85:183-197.

Fahrig L, 2003. Effects of habitat fragmentation on biodiversity. Annu. Rev. Ecol. Evol. Syst. 34:487-515.

Farin, A, 1995. Upland farming systems of the Northern Apennines. In: P. Halladay and D.A. Gilmour (eds.), Conserving biodiversity outside protected area. The role of traditional agro-ecosystems. IUCN, AMA Andalucìa and Centro de Investigaciòn F. Gonzàles-Bernàldez, Gland, Switzerland, and Cambridge, UK, pp. 123-135.

Ferry C, Frochot B, 1970. L'avifaune nidificatrice d'une forêt de chênes pédonculés en la Bourgogne: étude de deux successions écologiques. Terre Vie-Rev. Ecol. A. 2:153-250.

Fornasari L, Londi G, Tellini Florenzano G, La Gioia G, Pedrini P, Brichetti P, De Carli E, 2010. Distribuzione degli uccelli nidificanti, 2000-2004. Avocetta 34:5-224.

Gamauf A, Tebb G, Nemeth E, 2013. Honey Buzzard Pernis apivorus nest-site selection in relation to habitat and the distribution of Goshawks Accipiter gentilis. Ibis 155:258-270.

Garmendia A, Carcamo S, Schwendtner O, 2006. Forest management considerations for conservation of Black Woodpecker Dryocopus martius and White-backed Woodpecker Dendrocopos leucotos populations in Quinto Real (Spanish Western Pyrenees). Biodivers.

Conserv. 15:399-1415.
Giese AR, Forsman ED, 2003. Breeding season habitat use and ecology of male northern pygmy-owls. J. Raptor Res. 37:117-124.
Gil-tena A, Saura S, Brotons L, 2007. Effects of forest composition and structure on bird species richness in a Mediterranean context: implications for forest ecosystem management. Forest Ecol. Manag. 242:470-476.
Gjerde I, Saetersdal M, Nilsen T, 2005. Abundance of two threatened woodpecker species in relation to the proportion of spruce plantations in native pine forests of western Norway. Biodivers. Conserv. 14:377-393.
Glutz von Blotzheim U, Bauer K, 1980. Handbuch der Vögel Mitteleuropas, Bd. 9, Columbiformes-Piciformes. Akademische Verlagsgesellschaft, Wiesbaden.
Hakkarainen H, Koivunen V, Korpimaki E, Kurki S, 1996. Clear-cut areas and breeding success of Tengmalm's owls Aegolius funereus. Wildlife Biol. 2:253-258.
Hakkarainen H, Korpimaeki E, Laaksonen T, Nikula A, Suorsa P, 2008. Survival of male Tengmalm's owls increases with cover of old forest in their territory. Oecologia 155:479-486.
Hakkarainen H, Mykra S, Kurki S, Korpimaki E, Nikula A, Koivunen V, 2003. Habitat composition as a determinant of reproductive success of Tengmalm's owls under fluctuating food conditions. Oikos 100:162-171.
Hansen AJ, Spies TA, Swanson FJ, Oman JL, 1991. Conserving biodiversity in managed forests. Bioscience 41:382-392.
Hayward GD, Hayward PH, Garton EO, 1993. Ecology of boreal owls in the northern Rocky-Mountains, USA. Wildlife Monog. 124.
Jansson G. Andre H, 2003. Habitat Composition and Bird Diversity in Managed Boreal Forests. Scand. J. Forest Res. 18:225-236.
Kajtoch L, Figarski T, Pelka J, 2013. The role of forest structural elements in determining the occurrence of two specialist woodpecker species in the Carpathians, Poland. Ornis Fennica 90:23-40.
Kajtoch L, Zmihorski M, Bonczar Z, 2012. Hazel Grouse occurrence in fragmented forests: habitat quantity and configuration is more important than quality. Eur. J. Forest Res. 131:1783-1795.
Keller M, Buczek T, Rozycki AL, 2008. Birds of prey habitat preferences vs. age structure of forest - Parczew forest case study. Sylwan 152:30-35.
Kendrick SW, Porneluzi PA, Thompson FR III, Morris DL, Haslerig JM, Faaborg J, 2014. Stand-level bird response to experimental forest management in the Missouri Ozarks. J. Wildlife Manage. 79:50-59.
King DI, DeGraaf RM, 2000. Bird species diversity and nesting success in mature, clearcut and shelterwood forest in northern New Hampshire, USA. Forest Ecol. Manag. 129:227-235.
Klaus S, 1991. Effects of forestry on grouse populations - case-studies from the Thuringian and Bohemian forests, central-Europe. Ornis Scand. 22:218-223.
Kosiński Z, 2006. Factors affecting the occurrence of middle spotted and great spotted woodpeckers in deciduous forests - a case study from Poland. Ann. Zool. Fenn. 43:198-210.
Kosinski Z, Kempa M, 2007. Density, distribution and nest-sites of woodpeckers Picidae, in a managed forest of Western Poland. Pol. J. Ecol. 55:519-533.
Kosinski Z, Winiecki A, 2004. Nest-site selection and niche partitioning among the Great Spotted Woodpecker Dendrocopos major and Middle Spotted Woodpecker Dendrocopos medius in riverine forest of Central Europe. Ornis Fennica 81:145-156.
Laaksonen T, Hakkarainen H, Korpimaki E, 2004. Lifetime reproduction of a forest-dwelling owl increases with age and area of forests. P. Roy. Soc. Lond. B-Bio. 271:S461-S464.
Lindenmayer DB, Franklin JF, Fischer J, 2006. General management principles and a checklist of strategies to guide forest biodiversity conservation. Biol. Conserv. 131:433-445.
Lohmus A, 2003. Do Ural owls (Strix uralensis) suffer from the lack of nest sites in managed forests? Biol. Conserv. 110:1-9.
Londi G, Tellini Florenzano G, Mini L, Caliendo MF, Campedelli T, De Carli E, 2009. Assessing woodland ecological characters through a new objective bird community index, the WBCI. Avocetta 33:107-114.
Lopez-Iborra GM, Liminana R, Pavon D, Martinez-Perez JE, 2011. Modelling the distribution of short-toed eagle (Circaetus gallicus) in semi-arid Mediterranean landscapes: identifying important explanatory variables and their implications for its conservation. Eur. J. Wildlife Res. 57:83-93.
Martin TE, 1988. Habitat and area effects on forest bird assemblages: is nest predation an influence? Ecology. 69:74-84.
Mason F, Nardi G, Tisato M, 2003. Proc. Int. Symp. 'Dead wood: a key to biodiversity'. Mantova, Italy. Sherwood 95(Suppl.2): 1-100.
Melletti M, Penteriani V., 2003. Nesting and feeding tree selection in the endangered White-Backed Woodpecker, Dendrocopos leucotos lilfordi. Wilson Bull. 115:299-306.
Miettinen J, Helle P, Nikula A, Niemelä P, 2008. Large-Scale Landscape Composition and Capercaillie (Tetrao urogallus) Density in Finland. Ann. Zool. Fenn. 45:161-173.
Miettinen J, Helle P, Nikula A, Niemelä P, 2010. Capercaillie (Tetrao urogallus) Habitat Characteristics in North-Boreal Finland. Silva Fenn. 44:235-254.
Mitrus C, Socko B, 2004. Natural nest sites of the Red-breasted Flycatcher Ficedula parva in a primeval forest. Acta Ornithol. 39: 53-57.
Mueller D, Schroeder B, Mueller J, 2009. Modelling habitat selection of the cryptic Hazel Grouse Bonasa bonasia in a montane forest. J. Ornithol. 150:717-732.
Müller J, Bütler R, 2010. A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. Eur. J. Forest Res. 129:981-992.
Newton I, 1994. The role of nest sites in limiting the numbers of hole-nesting birds: a review. Biol. Conserv. 70:265-276.
Newton I, 2006. Movement patterns of Common Crossbills Loxia curvirostra in Europe. Ibis (Lond 1859) 148:782-788.
Nikolov SC, 2009. Effect of stand age on bird communities in late-successional Macedonian pine forests in Bulgaria. Forest Ecol. Manag. 257:580-587.
Noss RF, Csuti B, 1997. Habitat fragmentation. In: G.K. Meffe and R.C. Carrol (eds.) Principles of conservation biology. Sinauer, Sunderland, MA, USA, pp. 269-304.
Odum E, Barrett GW, 2004. Fundamentals of ecology. 5 ed. Belmont Brooks/Cole.
Pasinelli G, 2000. Oaks (Quercus sp.) and only oaks? Relations between habitat structure and home range size of the middle spotted woodpecker (Dendrocopos medius). Biol. Conserv. 93:227-235.
Peace TR, 1962. Pathology of trees and shrubs. Clarendon Press, Oxford, UK.
Pechacek P, d'Oleire-Oltmanns W, 2004. Habitat use of the three-toed woodpecker in central Europe during the breeding period. Biol. Conserv. 116:333-341.
Perry DA, 1994. Forest ecosystems, nature. Johns Hopkins University Press, Baltimore and London.
Puumalainein J, 2001. Structural, compositional and functional aspects of forest biodiversity in Europe. Geneva Timber and Forest Discussion Pape. Geneva, Switzerland.
Radovic A, Mikuska T, 2009. Population size, distribution and habitat selection of the white-tailed eagle Haliaeetus albicilla in the allu-

vial wetlands of Croatia. Biologia 64:156-164.
Roberge J, Angelstam P, Villard MA, 2008. Specialised woodpeckers and naturalness in hemiboreal forests - Deriving quantitative targets for conservation planning. Biol. Conserv. 141:997-1012.
Robles H, Ciudad C, Matthysen E, 2012. Responses to experimental reduction and increase of cavities by a secondary cavity-nesting bird community in cavity-rich Pyrenean oak forests. Forest Ecol. Manag. 277:46-53.
Rolstad J, Majewski P, Rolstad E, 1998. Black woodpecker use of habitats and feeding substrates in a managed Scandinavian forest. J. Wildlife Manage. 62:11-23.
Rolstad J, Rolstad E, Saeteren O, 2000. Black woodpecker nest sites: characteristics, selection, and reproductive success. J. Wildlife Manage. 64:1053-1066.
Root RB, 1967. The niche exploitation pattern of the blue-gray gnatcatcher. Ecol. Monogr. 37: 317-350.
Rosenvald R, Lohmus A, 2003. Nesting of the black stork (Ciconia nigra) and white-tailed eagle (Haliaeetus albicilla) in relation to forest management. Forest Ecol. Manag. 185:217-223.
Rueda M, Hawkins BA, Morales-Castilla I, Vidanes RM, Ferrero M, Rodriguez MA, 2013. Does fragmentation increase extinction thresholds? A European-wide test with seven forest birds. Global Ecol. Biogeogr. 22:1282-1292.
Sachot S, Perrin N, Neet C, 2003. Winter habitat selection by two sympatric forest grouse in western Switzerland: implications for conservation. Biol. Conserv. 112:373-382.
Santangeli A, Hakkarainen H, Laaksonen T, Korpimaki E, 2012. Home range size is determined by habitat composition but feeding rate by food availability in male Tengmalm's owls. Anim. Behav. 83:1115-1123.
Santangeli A, Högmander J, Laaksonen T, 2013. Returning white-tailed eagles breed as successfully in landscapes under intensive forestry regimes as in protected areas. Anim. Conserv. 16:500-508.
Santiago Cano-Alonso L, Luis Telleria J, 2013. Breeding productivity in relation to nesting substrate and nest site accessibility to humans in the black stork Ciconia nigra. Ardeola 60:357-363.
Sater DM, 2000. Distribution and habitat associations of the northern pygmy owl in Oregon. Oregon University, Oregon p. 41.
Scarascia Mugnozza G, 1999. Ecologia strutturale e funzionale di faggete Italiane. Edagricole.
Scott GW, Jardine DC, Hills G, Sweeney B, 1998. Changes in Nightjar Caprimulgus europaeus populations in upland forests in Yorkshire. Bird Study 45:219-225.
Selas V, 1997. Nest-site selection by four sympatric forest raptors in southern Norway. J. Raptor Res. 31:16-25.
Severinghaus WD, 1981. Guild theory development as a mechanism for assessing environmental impact. Environ. Manage. 5:187-190.
Sierro A, Arlettaz R, Naef-Daenzer B, Strebel S, Zbinden N, 2001. Habitat use and foraging ecology of the nightjar (Caprimulgus europaeus) in the Swiss Alps: towards a conservation scheme. Biol. Conserv. 98: 325-331.
Stachura-Skierczynska K, Tumiel T, Skierczynski M, 2009. Habitat prediction model for three-toed woodpecker and its implications for the conservation of biologically valuable forests. Forest Ecol. Manag. 258:697-703.
Stasiak K, Grzywaczewski G, Gustaw W, Cios S, 2013. Effect of the forest structure on the number and territory size of nightjar Caprimulgus europaeus. Sylwan 157:306-312.
Strom H, Sonerud GA, 2001. Home range and habitat selection in the Pygmy Owl Glaucidium passerinum. Ornis Fennica 78:145-158.
Summers RW, McFarlane J, Pearce-Higgins JW, 2007. Measuring avoidance by capercaillies Tetrao urogallus of woodland close to tracks. Wildlife Biol. 13:19-27.
Suorsa P, Huhta E, Nikula A, Nikinmaa M, Jäntti A, Helle H, Hakkarainen H, 2003. Forest management is associated with physiological stress in an old-growth forest passerine. P. Roy Soc. Lond. B-Bio. 270:963-969.
Swenson JE, 1993. The importance of alder to hazel grouse in fennoscandian boreal forest - evidence from 4 levels of scale. Ecography. 16:37-46.
Tellini Florenzano G, 2004. Birds as indicators of recent environmental changes in the Apennines (Foreste Casentinesi National Park, central Italy). Ital. J. Zool. 71:317-324.
Thiel D, Jenni-Eiermann S, Braunisch V, Palme R, Jenni L, 2008. Ski tourism affects habitat use and evokes a physiological stress response in capercaillie Tetrao urogallus: a new methodological approach. J. Appl. Ecol. 45: 845-853.
Thiel D, Menoni E, Brenot JF, Jenni L, 2007. Effects of Recreation and Hunting on Flushing Distance of Capercaillie. J. Wildlife Manage. 71:1784-1792.
Thompson ID, Baker JA, Ter-Mikaelian M, 2003. A review of the long-term effects of post-harvest silviculture on vertebrate wildlife, and predictive models, with an emphasis on boreal forests in Ontario, Canada. Forest Ecol. Manag. 177:441-469.
Tozer DC, Burke DM, Nol E, Elliott KA, 2010. Short-term effects of group-selection harvesting on breeding birds in a northern hardwood forest. Forest Ecol. Manag. 259:1522-1529..
Treinys R, Skuja S, Augutis D, Stoncius D, 2009a. Nest-site use by Black Stork and Lesser Spotted Eagle in relation to fragmented forest cover: case study from Lithuania. Ekologija 55:182-188.
Treinys R, Stoncius D, Augutis D, Skuja S, 2009b. Breeding Habitat of the Black Stork Ciconia nigra in Lithuania: Implications for Conservation Planning. Baltic Forestry 15:33-40.
Verner J, 1984. The guild concept applied to management of bird populations. Environ. Manage. 8:1-13.
Verstraeten G, Baeten L, Verheyen K, 2011. Habitat preferences of European Nightjars Caprimulgus europaeus in forests on sandy soils. Bird Study 58:120-129.
Vlachos CG, Bakaloudis DE, Alexandrou OG, Bontzorlos VA, Papakosta MA, 2008. Factors affecting the nest site selection of the black stork, Ciconia nigra in the Dadia-Lefkimi-Soufli National Park, North-Eastern Greece. Folia Zool. 57:251-257.
Vos W, Stortelder A, 1992. Vanishing Tuscan landscapes. Landscape ecology of a Submediterranean-Montane area (Solano Basin, Tuscany, Italy). Pudoc Scientific Publishers, Wageningen.
Vrezec A, Kohek K, 2002. Some breeding habits of the Ural Owl Strix uralensis in Slovenia. Acrocephalus 23:179-183.
Wichmann G, Frank G, 2007. Habitat choice of Red-breasted Flycatchers Ficedula parva is dependent on forestry management and game activity in a deciduous forest in Vienna (Austria). Bird Study 54:289-295.
Zahner V, Sikora L, Pasinelli G, 2012. Heart rot as a key factor for cavity tree selection in the black woodpecker. Forest Ecol. Manag. 271:98-103.
Zipkin EF, DeWan A, Andrew Royle J, 2009. Impacts of forest fragmentation on species richness: a hierarchical approach to community modelling. J. Appl. Ecol. 46:815-822.

Conservation of flora as a function of forestry

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Forest management – multipurpose aims and sustainable way

Sustainable use and conservation of forest ecosystem became the most important environmental aims, even in reason of the goals laid down in International Conventions and agreements especially about climate change and conservation of biodiversity (CBD, 1992; UNFCCC, 1992; Habitats Directive, 1992; MCPFE, 2003). As first consequence, in last decades private and public forest ownership focused to diversify structure in tree species, implementing the improvement of forest production too. On the other hand little importance had been given to understory vegetation until some years ago.

Forest management practices have mostly focused on increasing efficiency of growing and harvesting trees to achieve economic goals. However, preserving and enhancing biodiversity have become desirable forest management objectives in light of species loss and climate changes worldwide (Roberts and Gilliam, 1995; Brunet *et al*., 2000; Odion and Sarr, 2007; Ares *et al*., 2010). In recent decades, the conservation of biodiversity has become one of the important goals of managing forests in an ecologically sustainable way (Lindenmayer *et al*., 2000).

To support or even to increase the current biodiversity level, forest managers need to apply appropriate management measures. Forest management is one of the primary drivers of diversity and, according to the applied measures, may act as a factor of enhancement or depletion of biodiversity. Especially within the managed forests with significant biodiversity value, appropriate management options need to be tested and implemented.

The scope of forest management practices recently expanded beyond economic goals to promote and maintain heterogeneous and variable stand structures (Bormann *et al*., 2007; Thomas *et al*., 2006). These practices, *e.g.*, variable density thinning intermixed with gaps, lead to small-scale variability of resource availability, microclimate differentiation with diverse physical disturbances, and competitive and facilitative interactions between overstory and understory plant communities (Fahey and Puettmann, 2008; Hale, 2003; Roberts, 2004; Neill and Puettmann, 2013). Thinning and gaps impacts have been linked to greater abundance of forest understory vegetation (Ares *et al*., 2010; Canham *et al*., 1990; Thomas *et al*., 1999), greater plant species richness (Ares *et al*., 2010; Chan *et al*., 2006; Reich *et al*., 2012; Thomas *et al*., 1999), and associated impacts on wildlife habitat.

The main efforts of modern silvicultural management focus on a balanced use of the forest ecosystem resources (Siry *et al*., 2005). Attempts to achieve this are done by mimicking the processes naturally occurring in forest ecosystems (Gamborg and Larsen, 2003). However, it is not well known to what extent the close-to-nature silvicultural system improves the stability of the forest ecosystem in terms of biodiversity (Durak, 2012). Within this array of close-to-nature options, different types of management may be implemented, and different effects on forest ecosystem functioning are expected according to the type of management used (Decocq *et al*., 2004, 2005; Schmidt, 2005). Therefore, it is crucial to verify the outcomes of different types and the intensities of forest management methods and measures.

Forest management on understory vegetation in forest ecosystem

The use of term *understory* is generally restricted to species of shrub size and smaller (herb); so trees are not included, even if there are some tree species small and occur below other trees.

Understory plant communities represent most of the vascular plant diversity in temperate forests, and the species present there characterize a wide variety of growth forms and functional groups. Moreover, understory plants identify important sources of food and habitat for a large number of wildlife species (Felton *et al*., 2010), as well as they influence on nutrient cycling (Hart and Chen, 2006). Species composition and structure of understory provide to maintain complex structure and indigenous floras within forest (Halpern and Spies, 1995; Thomas *et al*., 1999). Despite their importance and a growing consciousness that understory plants avail a special role in maintaining the structure and function of forests, this component remains an underestimated aspect of forest ecosystems. In particular, more information is needed on how and how much different forest types influence the understory composition and how understory vegetation response to different management practices (Rad and Seyyedi, 2012).

Many researches on the consequences of forest management for plant species diversity and composition have focused on the success of regeneration tree species and stand structure. Not many

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Key words: Understory vegetation, plant diversity, forest management, Natura 2000.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

studies have concerned on response of understory plants to forest silviculture. Even if information about this important biological feature are scarce, significant knowledge and helpful consideration are available to direct sustainable forest management guidelines.

Multiple role, played by understory plant communities in forest ecosystem, can both affect and be affected by forest management activities (Roberts, 2004; Gilliam, 2007; Barbier *et al*., 2008), first among everything tree cutting (Selmants and Knight, 2003; Ares *et al*., 2010; Halpern and Lutz, 2013; Roberts and Gilliam, 2003). Different methods of tree cutting can differentially influence understory vegetation (Puettmann and Duvall, 1998) and a peculiar cutting scheme could affect plant cover differently than it affects species richness (Kreyling *et al*., 2008; Knapp *et al*., 2013).

In literature, different response of understory plant species diversity to clearcutting has been monitored and evaluated; small effects on understory species richness in consequence to clearcutting has been described for late successional forests types of northeast North America (Moola and Vasseur, 2008); in forest stand after less than 20 years clearcut harvesting has been observed an increases of understory plant diversity, as a probably effect of early successional colonizers (Moola and Vasseur, 2008; Kreyling *et al*., 2008; Loya and Jules, 2008).

Studies evaluating thinning treatments also show inconsistent effects on understory plant species richness, on the other hand some of them show positive effects on diversity (Thomas *et al*., 1999; Metlen and Fiedler, 2006), others negative (Wyatt and Silman, 2010), and some others no effect (Wayman and North, 2007; Schwilk *et al*., 2009). Many of these results may depend on condition and successional age of the forest, forest type examined and harvest treatment intensity and on which group of plant species has been investigate; residual (Smart *et al*., 2006; Moola and Vasseur, 2008), competitive, colonizing, or total. Successional age of forest is an important consideration, comparing even-aged silvicultural regeneration methods and uneven-aged methods. In first case, the structure and amount of competition and resources available on the forest floor changes more dramatically, and phases of development move through time more uniformly (initiation, stem exclusion, understory reinitiation, old growth), than in the second case (Oliver and Larson, 1996; Smith *et al*., 2008). Harvesting treatments differ significantly depending on whether the aim is to promote regeneration (clearcut, seed tree, shelterwood), promote growth of the existing stand (thinning) or a combination (selection).

Forest gaps and disturbances

In last decades particular attention has be paid to effects of gaps on understory vegetation in different forests (Ehrenfeld, 1980; Thompson, 1980; Metzger and Schultz, 1984; Collins and Pickett, 1987; Reader, 1987; Reader and Bricker, 1992; Hammond and Brown, 1998; Fredericksen *et al*., 1999; Götmark *et al*., 2005; Gilliam *et al*., 1995; Meier *et al*., 1995; Gilliam, 2002; Fahey and Puettmann, 2008; Roberts and Zhu, 2002; Hart and Chen, 2006).

According to Runkle (1992), a gap refers to an area within the forest where the canopy (leaf height of the tallest stems) is noticeably lower than in adjacent areas. It is formed by the death (absence from the canopy) of at least one-half of a tree. The largest gap is created by the death of ten canopy trees or has a ratio of canopy height to gap diameter equal to 1.0. Small canopy gaps are usually a result of the natural mortality of trees or felling of individual trees, while larger canopy gaps are often a consequence of an external abiotic or biotic environmental factors, *e.g.* wind, fire, snow, extensive bark beetles attacks (Bončina and Diaci, 1998). However, gap influence is not always limited to the physical canopy opening (Canham *et al*., 1990; Van Pelt and Franklin, 2000; Gray *et al*., 2002), and the extent of gap influence on the surrounding forest were discussed too (Menard *et al*., 2002). Gap formation in forests can have impacts on forest ecosystems beyond the physical boundary of the canopy opening. The extent of gap influence may affect responses of many components of forest ecosystems to gap formation on stand and landscape scales (Fahey and Puettmann, 2008). The gap size, shape, orientation and spatial dynamics have important effects on many ecological factors and processes in gaps. Both canopy release and gap creation induce sudden changes in solar radiation and other micro-climate variables, such as air and soil temperature, rainfall, air humidity and wind (Morecroft *et al*., 1998; Aussenac, 2000; Proe *et al*., 2001). Gap formation effects forest processes within the gap area, such as tree regeneration, stand structural development, and dynamics of the understory layer (Canham and Marks, 1985; Collins and Pickett, 1988; Spies *et al*., 1990; York *et al*., 2004; Čater *et al*., 2014; Kutnar *et al*., 2015). Micro-climatic changes (Ritter *et al*., 2005; Renaud and Rebetez, 2009) and the undesirable loss of nutrients (Ritter and Vesterdal, 2006) are less pronounced in small canopy gaps than in large areas of open space.

Seedling establishment may be favoured by creating small and irregular gaps and by successive extension of gaps along the sun-exposed gap edge. Circular gaps with diameters greater than stand height contribute to increased ground vegetation coverage and hinder tree regeneration (Vilhar *et al*., 2014). Variation in understory plant communities may be a useful tool in quantifying gap influence extent and may be a good indicator of overall response of biodiversity to gap creation (Fahey and Puettmann, 2008).

According to Vilhar *et al*. (2014) the overall regeneration success of beech in such conditions was greater along the gap edges, which suggests that irregular gap shapes of small sizes should be created to provide as many of optimal micro-sites as possible or that the gaps should be expanded accordingly while accounting for the specific micro-relief (*e.g.* avoiding larger canopy gaps on steep south-facing slopes).

Functional groups and life traits

The niche concept is of prime importance in ecology, but the quantification of plant species´ niches still remains open. Plant functional traits developed by plants throughout the evolution to increase their survival and dispersal rate in the high competitive environment may be useful tools for quantifying species niche parameters over environmental gradients (Silvertown *et al*., 2001; Violle and Jiang, 2009). Plant traits are used as ecologists´ common language in order to make comparisons across regions and scales, pool data and maximize the utility of the data (Evan *et al*., 1999). An analysis of species traits is a useful tool to overcome the problems of describing effects across borders of regions and countries and to overcome differences in taxonomy (Lavorel *et al*., 1997). Also differences that are often difficult to detect because of differences in species composition, stand ages, soil conditions, and regional differences of species pools could be potentially revealed by analyses of species traits (Graae and Sunde, 2000). Moreover, it is intuitive that biological traits are potentially important for understanding mechanisms of plant species responses to modification of local habitat conditions, due to natural or anthropogenic causes. Forest harvesting even if applied with sustainable methods can be results as a disturbance in forest ecosystem, influencing stand- and landscape-scale patterns of forest structure and biodiversity. Species differ in biological attributes (traits) that are evolutionarily adapted to a range of conditions (Levins, 1968; Kassen, 2002; Violle *et al*., 2007) and these characterize the species' capacity to reproduce, disperse and to persist in a habitat. The ability of some of them to sprout from rhizomes, roots and various kinds of storage organs, allow them to produce new shoots even after different year from disturbance. So functional traits are considered measurable physiological and morphological characteristics that drive the performance of an organism (McGill *et al.,* 2006).

Species with different traits might respond in dissimilar ways to habitat modification, with local changes in diversity structure and composition as consequence of habitat alteration (Keddy, 1992; Lavorel and Garnier, 2002; Hewitt *et al*., 2005). Therefore, species traits may be very important as indicators of processes in forest ecosystems, as these often operate on long time-scales and are therefore difficult to record (Gitay and Noble, 1997). Even though introduced long ago (Raunkiaer, 1934; Grime, 1977; Noble and Slatyer, 1980; Box, 1981, 1996), the concept of Plant Functional Traits has received new attention as one possible framework for predicting ecosystem response to human-induced changes at a global scale.

Utilizing characteristics of understory plants, for example classifying the understory community into functional groups, may further aid in detection of gap influence and of other silviculture practices. Functional groups based on plant strategies such as those of Grime (1977), may be especially informative in this type of analysis. Grime advocates three strategies that have evolved in response to combinations of stress and disturbance intensity: i) competitor species (adapted to low stress and low levels of disturbance); ii) ruderal species (adapted to low stress and high levels of disturbance); and iii) stress-tolerator species (adapted to high stress and low levels of disturbance). In forest understory plants, stress is most likely to be manifested in low availability of light and other resources under a closed canopy (Grime, 1977), and high intensity natural disturbance in these forests is primarily related to wildfire (Franklin *et al*., 2002).

Another trait-based approach is possible for assessment of impacts of forest management practices on the adaptive capacity of ecosystems. The relationship between overstory trees and understory vegetation for species grouped by traits that reflect food availability for wildlife, for instances production of flowers, fleshy fruit, and palatable leaves, was studied in different silviculture options (Neill and Puettmann, 2013).

Functional group approach is likely to be useful in highlighting the mechanisms responsible for understory community response to forest management. The understory also provides important habitat for other taxa in forest ecosystems and may be a good indicator of biodiversity in general (Hayes *et al*., 1997).

Natura 2000 forest areas

Among the most significant nature-conservation areas in Europe is the Natura 2000, which is a coherent ecological network of special areas. Nearly 50% of Natura 2000 habitats are forests, and approximately 23% of all EU forests are located within Natura 2000 sites (EU Forests and Other Wooded Land cover more than 42 % of EU land area) (European Commission, 2014). Natura 2000 has been designated under the EU m (European Commission, 1992) and EU Bird Directive (European Commission, 1979) to assist in the maintenance of biodiversity on European territory, and to preserve biodiversity and habitats in a favourable conservation status. These two directives provide an integrated framework for the identification, maintenance and protection of sites of high biodiversity value; they represent the European Union's most concrete act towards the achievement of international biodiversity policy commitments, such as the Convention on Biological Diversity (CBD, 1992), and they make standardized ecological monitoring of biodiversity legally binding for the first time (Bock *et al*., 2005).

Forest ownership enclosed in sites of network Natura 2000 are subjected to particular management guidelines and recommendations, in order to maintain and protect the high naturalistic value that they represent. It is widely recognised that one of the most effective ways of maintaining biodiversity is to preserve habitats in a favourable conservation status (Cantarello and Newton, 2006, 2008). On the other hand, Habitats Directives (1992) only indicate the result to be achieved through national implementation, but does not prescribe any concrete conservation measures, which need to be applied for each habitat type and species. The implementation of Natura 2000 in forests has led to conflicts related to different interests and land use paradigms, *e.g.*, balancing nature conservation and sustainable timber production (Niemelä *et al*., 2005; Bouwma *et al*., 2010). However, forest management done in a sustainable manner could even contribute to increasing biodiversity (Lindenmayer *et al*., 2000). Therefore the Commission must assure that the objectives of conservation are reached, but it does not have any direct influence on the regional and local negotiation of the management measures on Natura 2000 sites. It is task of local or regional administrations to provides good practices of management for habitat. In this crucial stage, scientific component can help administrations in the draft of sustainable management guidelines.

Mountain and high mountain forest represent a wide part of habitat Natura 2000, but they also are ecosystems sensitive to environmental alteration and to anthropogenic disturbances. Main goal is to protect biodiversity represent by these habitat and adopt sustainable management practices.

In light of all precedent considerations, the aim of this study is to analyse the effect of different management practices, with different harvesting density in various forest types.

In particular, it's focused knowledge on the gap's influences on biodiversity on stand and landscape scales and understory community response to gap creation, since it is especially considerable in biodiversity important forest areas. In considered forest areas, gap formation and other silvicultural options may be use as valuable tool for preserving and increasing the current biodiversity level in forests.

Generally, the overall biodiversity of a forested area depends on the biodiversity of individual communities and the spatial heterogeneity of the area. In these respects, the measures can be targeting either of two levels. Spatial heterogeneity may be significantly increased by gap formation and other similar silvicultural options (Kutnar *et al*., 2015).

In Slovenia, Dinaric fir-beech forests (association *Omphalodo-Fagetum* s. lat.) are one of the most extensive forest communities within Natura 2000 in this part of Europe, and also one of the most widespread forest types in Slovenia. They account for more than 10% of the Slovenian forest area (Dakskobler 2008) and belong to the 91K0 - Illyrian *Fagus sylvatica* (*Aremonio-Fagion*) habitat type of Natura 2000 (Kutnar *et al*., 2011, 2015.). This habitat type includes different forests of common beech (*Fagus sylvatica*) growing in the Dinaride range and in associated ranges and hills, with outliers in the South-eastern Alps, in the south-western Carpathians and in the mid-Pannonic hills. In these forests, species diversity is greater than in the Central European beech forests, and the beech forests of the alliance *Aremonio-Fagion* are important source of species diversity (European Commission, 2007). Beside common beech other important tree species of these forests are following: *Fagus moesiaca, Acer obtusatum, Ostrya carpinifolia, Abies alba, Quercus cerris, Sorbus graeca, Tilia tomentosa* (European Commission, 2007).

Dinaric fir-beech forests are an example in which possible conflicting interests may appear. These forests are close-to-nature managed, and the adaptive management and appropriate intensity of forest management must be adjusted to the specifics, functions and goals of Dinaric fir-beech forests, including biodiversity conservation (Kutnar *et al*., 2015).

In Slovenia, current standard practice in forest management and silviculture is focused on small-area forest treatment, where attention is paid to the smallest detail in forest ecosystems and to the external influences and interests that affect forest development (Debevc, 2005). Forests are managed without clearcutting by implementing regular thinning to encourage natural forest regeneration.

In Italy, 30% of natural habitat types Natura 2000 are represented by forest (Genovesi *et al*., 2014), part of these forest are primarily used for biomass production and for industrial raw material, in particular beech forest, Turkey oak forest and Norway spruce forest. ManFor Italian sites were selected from forest areas within Natura 2000, for example beech habitat types of 9110 *Luzulo-Fagetum* beech forests, 9130 *Asperulo-Fagetum* beech forests, 9210 Apennine beech forests with *Taxus* and *Ilex*, 9220 Apennine beech forests with *Abies alba* (and beech forests with *Abies nebrodensis*), and spruce habitat type of 9410 Acidophilous *Picea* forests of the montane to alpine levels (*Vaccinio-Picetea*), and Turkey oak habitat type of 91L0 Illyrian oak-hornbeam forests (*Erythronio-Carpinion*).

Because of the own definition of biodiversity[1], there are not specific management practices to support increased biodiversity; the definition does not entail only a variety of life, but includes also genotypes and even ecological process and their inter-relationships (Hunter, 1990; Oliver, 1992; Reid and Miller, 1989).Thus, different species are functionally different, but they can coexist because they are specialized for different niche (Hutchinson, 1957; McGill *et al*., 2006). The best way to support a variety and abundance of species is to provide a diversity of structure and vegetation (Allen *et al*., 1996; Harris *et al*., 1979; Marion *et al*., 1986; Sharitz *et al*., 1992). This includes both within and between-stand diversity (Marion and Harris, 1982; Thill, 1990). Generally, an important way to increase within-stand structural diversity is to maintain a lower overstory density. A more open canopy lets a differentiated understory to develop, providing indirectly forage and habitat for wildlife too. Thinning early and often in rotation can allow to maintaining an open canopy. Moreover, within and among stands, it could be important for maintaining species and functional diversity, maintaining or restoring a mosaic of forest structural classes, the diversity of native tree species, and the distribution of features (*e.g.*, abiotic features, corridors, edges) (Dale *et al*., 2000).

[1] "Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. (CBD, 1992).

Rerefences

Allen AW, Bernal YK, Moulton RJ, 1996. Pine plantations and wildlife in the southeastern United States: an assessment of impacts and opportunities. US Dept. of the Interior National Biological Service Information and Technology Report 3.

Ares A, Neill AR, Puettmann KJ, 2010. Understory abundance species diversity and functional attribute response to thinning in coniferous stands. Forest Ecol. Manag. 260:1104-1113

Aussenac G, 2000. Interactions between forest stands and microclimate: Ecophysiological aspects and consequences for silviculture Ann. Forest Sci. 57:287-301.

Barbier S, Gosselin F, Balandier P, 2008. Influence of tree species on understory vegetation diversity and mechanisms involved - a critical review for temperate and boreal forests. Forest Ecol. Manag. 254:1-15.

Bock M, Rossner G, Wissen M, Remm K, Langanke T, Lang S, Klug H, Blaschke T, Vrščaj B, 2005. Spatial indicators for nature conservation from European to local scale. Ecol. Indic. 5:322-338.

Bončina A, Diaci J, 1998. Contemporary research on regeneration patterns of Central European virgin forests with recomendation for future research. Zbornik gozdarstva in lesarstva 56:33-53.

Bormann BT, Haynes RW, Martin JR, 2007. Adaptive management of forest ecosystems: did some rubber hit the road? Bioscience 57:186-191.

Bouwma IM, van Apeldoorn R, Kamphorst DA, 2010. Current practices in solving multiple use issues of Natura 2000 sites: Conflict management strategies and participatory approaches. Alterra, Wageningen.

Box EO, 1981. Macroclimate and plant forms: an introduction to predictive modelling in phytogeography. Springer, The Hague.

Box EO, 1996. Plant functional types and climate at the global scale. J. Veg. Sci. 7:309-320.

Brunet J, von Oheimb G, Diekmann M, 2000. Factors influencing vegetation gradients across ancient-recent woodland borderlines in southern Sweden. J. Veg. Sci. 11:515-524.

Canham CD, Denslow JS, Platt WJ, Runkle JR, Spies TA, White PS, 1990. Light regimes beneath closed canopies and tree-fall gaps in temperate and tropical forests. Can. J. Forest Res. 20:620-631.

Canham CD, Marks PL, 1985. The responses of woody plants to disturbance: patterns of establishment and growth. In: S.T.A. Pickett and P.S. White (eds.) The ecology of natural disturbance and patch dynamics. Academic Press New York, pp. 197-217.

Cantarello E, Newton A, 2006. Towards cost-effective indicators to maintain Natura 2000 sites in favourable conservation status. Preliminary results from Cansiglio and New Forest. Forest 3:574-583.

Cantarello E, Newton A, 2008. Identifying cost-effective indicators to assess the conservation status of forested habitats in Natura 2000 sites. Forest Ecol. Manag. 256:815-826.

Čater M, Diaci J, Roženbergar D, 2014. Gap size and position influence variable response of Fagus sylvatica L and Abies alba Mill. Forest Ecol. Manag. 325:128-135.

CBD, 1992. Convention on Biological Diversity, Rio de Janeiro 5th June 1992, 1760 UNTS 79;31 ILM 818 (1992).

Chan SS, Larson DJ, Maas-Hebner KG, Emmingham WH, Johnston SR, Mikowski DA, 2006. Overstory and understory development in thinned and underplanted Oregon Coast Range Douglas-fir stands. Can. J. Forest Res. 36:2696-2711.

Collins BS, Pickett STA, 1987. Influence of canopy opening on the environment and herb layer in a northern hardwood forest. Vegetatio 70:3-10.
Collins BS, Pickett STA, 1988. Response of herb layer cover to experimental canopy gaps. Am. Midland Nat. 119:282-290.
Dale VH, Brown S, Haeuber RA, Hobbs NT, Huntly N, Naiman RJ, Riebsame WE, Gaston KJ, Spicer JI, 1998. Biodiversity: An introduction. Blackwell Science Ltd., Oxford.
Dakskobler I, 2008. Pregled bukovih rastišč v Sloveniji. Zbornik gozdarstva in lesarstva 87:3-14.
Debevc B, 2005. Slovenia Forest Service: Caring for forest to benefit nature and people. Ljubljana Slovenia Forest Service.
Decocq G, Aubert M, Dupont F, Alard D, Saguez R, Wattez-Franger A, de Foucault B, Delelis-Dusollier A, Bardat J, 2004. Plant diversity in a managed temperate deciduous forest: understorey response to two silvicultural systems. J. Appl. Ecol. 41:1065-1079.
Decocq G, Aubert M, Dupont F, Bardat J, Wattez-Franger A, Saguez R, de Foucault B, Alard D, Delelis-Dusollier A, 2005. Silviculture-driven vegetation change in a European temperate deciduous forest. Ann. Forest Sci. 62:313-323.
Dìaz S, Cabido M, 1997. Plant functional types and ecosystem function in relation to global change. J. Veg. Sci. 8:463-474.
Durak T, 2012. Changes in diversity of the mountain beech forest herb layer as a function of the forest management method. Forest Ecol. Manag. 276:154-164.
European Commission, 1979. Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds. Available from: http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm
European Commission, 1992. Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
European Commission, 2007. Interpretation Manual of European Union Habitats - EUR27 DG Environment July 2007. Available from: http://eceuropaeu/environment/nature/legislation/ habitatsdirective/docs/2007_07_impdf
European Commission, 2014. EU Forests and Forest Related Policies. Available from: http://eceuropaeu/environment/forests/home_enhtm
Ehrenfeld JG, 1980. Understory response to canopy gaps of varying size in a mature oak forest. Bull. Torr. Bot. Club 107:29-41.
Evan W, van der Werf A, Thompson K, Roderick M, Garnier E, Eriksson O, 1999. Challenging Theophrastus: A common core list of plant traits for functional ecology. J. Veg. Sci. 10:609-620.
Fahey RT, Puettmann KJ, 2008. Patterns in spatial extent of gap influence on understory plant communities. Forest Ecol. Manag. 255:2801-2810.
Felton A, Knight E, Wood J, Zammit C, Lindenmayer D, 2010. A meta-analysis of fauna and flora species richness and abundance in plantations and pasture lands. Biol. Conserv. 143:545-554.
Franklin JF, Spies TA, Van Pelt R, Carey AB, Thornburgh DA, Berg DR, Lindenmayer DB, Harmon ME, Keeton WS, Shaw DC, Bible K, Chen J, 2002. Disturbances and structural development of natural forest ecosystems with silvicultural implications using Douglas-fir forests as an example. Forest Ecol Manag. 155:399-423.
Fredericksen TS, Ross BD, Hoffman W, Morrison ML, Beyea J, Johnson BN, Lester MB, Ross E, 1999. Short-term understory plant community responses to timber-harvesting intensity on non-industrial private forestlands in Pennsylvania. Forest Ecol. Manag. 116:129-139.
Gamborg C, Larsen JB, 2003. 'Back to nature' - a sustainable future for forestry? Forest Ecol. Manag. 179:559-571.
Genovesi P, Angelini P, Bianchi E, Dupré E, Ercole S, Giacanelli V, Ronchi F, Stoch F, 2014. Specie e habitat di interesse comunitario in Italia: distribuzione stato di conservazione e trend. ISPRA Serie Rapporti 194/2014.
Gilliam FS, 2002. Effects of harvesting on herbaceous layer diversity of a central Appalachian hardwood forest in West Virginia, USA. Forest Ecol. Manag. 155:33-43.
Gilliam FS, 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. Bioscience 57:845-858.
Gilliam FS, Turrill N, Adams M, 1995. Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. Ecol. Appl. 5:947-955.
Gitay H, Noble IR, 1997. What are functional types and how should we seek them? In: T.M. Smith H.H. Shugart and F. Woodward (eds.) Plant functional types - their relevance to ecosystem properties and global change. IGBP Book Ser 1, Cambridge University Press, pp. 3-19.
Götmark F, Paltto H, Nordén Götmark E, 2005. Evaluating partial cutting in broadleaved temperate forest under strong experimental control: short-term effects on herbaceous plants. Forest Ecol. Manag. 214:124-141.
Graae BJ, Sunde PB, 2000. The impact of forest continuity and management on forest floor vegetation evaluated by species traits. Ecography 23:720-731.
Gray AN, Spies TA, Easter MJ, 2002. Microclimatic and soil moisture responses to gap formation in coniferous forests. Can. J. Forest Res. 32:332-343.
Grime JP, 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. Am. Nat. 111:1169-1194.
Hale SE, 2003. The effect of thinning intensity on the below-canopy light environment in a Sitka spruce plantation. Forest Ecol. Manag. 179:341-349.
Halpern CB, Lutz JA, 2013. Canopy closure exerts weak controls on understory dynamics: a 30-year study of overstory-understory interactions. Ecol. Monogr. 83:221-237.
Halpern CB, Spies TA, 1995. Plant species diversity in natural and managed forests of the Pacific Northwest. Ecol. Appl. 5:913-934.
Hammond DS, Brown VK, 1998. Seed size of woody-plants in relation to disturbance dispersal soil type in wet neotropical forests. Ecology 76:2544-2561.
Harris LD, Hirth DH, Marion WR, 1979. The development of silvicultural systems for wildlife. In: C.L. Shilling and J.R. Toliver (eds.) Recreation in the South's third forest, XXVIII Annual Forestry Symp., Louisiana State University. Baton Rouge, LA, USA, pp. 65-80.
Hart SA, Chen HYH, 2006. Understory vegetation dynamics of North American boreal forests. Crit. Rev. Plant Sci. 25:381-397.
Hayes JP, Chan S, Emmingham WH, Tappeiner JC, Kellog LD, Bailey JD, 1997. Wildlife responses to thinning in young forests in the Pacific Northwest. J. Forestry 95:28-33.
Hewitt JE, Thrush SF, Halliday J, Duffy C, 2005. The importance of small-scale habitat structure for maintaining beta diversity. Ecology 86:1619-1626.
Hunter ML Jr,1 990. Wildlife forests and forestry: Principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs.

Hutchinson GE, 1957. Concluding remarks. Cold Spring Harbor Symp. Quant. Biol. 22:415-427.

Kassen R, 2002. The experimental evolution of specialists generalists and the maintenance of diversity. J. Evol. Biol. 15:173-190.

Keddy PA, 1992. Assembly and response rules: two goals for predictive community ecology. J. Veg. Sci. 3:157-164.

Knapp EE, Skinner CN, North MP, Estes BL, 2013. Long-term overstory and understory change following logging and fire exclusion in a Sierra Nevada mixed-conifer forest. Forest Ecol. Manag. 310:903-914.

Kreyling J, Schmiedinger A, Macdonald E, Beierkuhnlein C, 2008. Slow understory redevelopment after clearcutting in high mountain forests. Biodiv. Conserv. 17:2339-2355.

Kutnar L, Matijašić D, Pisek R, 2011. Conservation status and potential threats to Natura 2000 forest habitats in Slovenia. Šumarski list. 135:215-231.

Kutnar L, Eler K, Marinšek A, 2015. Effects of different silvicultural measures on plant diversity - the case of the Illyrian Fagus sylvatica habitat type (Natura 2000). iForest (early view). doi: 10.3832/ifor1587-008.

Lavorel S, Garnier E, 2002. Predicting changes in community composition and ecosystem functioning from plant traits: revisiting the Holy Grail. Funct. Ecol. 16:545-556.

Lavorel S, McIntyre S, Landsberg J, Forbes TDA, 1997. Plant functional classifications: from general groups to specific groups based on response to disturbance.Trends Ecol. Evol. 12:474-47.8

Levins R, 1968. Evolution in changing environments. Princeton University Press, Princeton.

Lindenmayer D, Margules C, Botkin D, 2000. Indicators of biodiversity for ecologically sustainable forest management. Conserv. Biol. 14:941-950.

Loya DT, Jules ES, 2008. Use of species richness estimators improves evaluation of understory plant response to logging: a study of redwood forests. Plant Ecology 194:179-194.

McGill BJ, Enquist BJ, Weiher E, Westoby M, 2006. Rebuilding community ecology from functional traits. Trends Ecol. Evol. 21:178-185.

MCPFE, 2003. Improved pan-European indicators for sustainable forest management as adopted by the MCPFE Expert Level Meeting. In: Ministerial Conference on the Protection of Forests in Europe, Vienna.

Marion WR, Harris LD, 1982. Relationships between increasing forest productivity and fauna in the flatwoods of the southeastern coastal plain. pp. 215-222 in Proc. 1981 Convention of the Society of American Foresters.

Marion WR, Werner M, Tanner GW, 1986. Management of pine forests for selected wildlife in Florida. Circular No. 706 Florida Cooperative Extension Service Institute of Food and Agricultural Sciences, University of Florida.

Menard A, Dube P, Bouchard A, Marceau DJ, 2002. Release episodes at the periphery of gaps: a modeling assessment of gap impact extent. Can. J. Forest Res. 32:1651-1661.

Metlen KL, Fiedler CE, 2006. Restoration treatment effects on the understory of ponderosa pine/Douglas-fir forests in western Montana, USA. Forest Ecol. Manag. 222:355-369.

Metzger F, Schultz J, 1984. Understory response to 50 years of management of a Northern hardwood forest in Upper Michigan. Am. Midl. Nat. 112:209-223.

Moola FM, Vasseur L, 2008. The maintenance of understory residual flora with even-aged forest management: A review of temperate forests in northeastern North America. Environ. Rev. 16:141-155.

Morecroft MD, Taylor ME, Oliver HR, 1998. Air and soil microclimates of deciduous woodland compared to an open site. Agric. Forest Meteorol. 90:141-155.

Neill AR, Puettmann KJ, 2013. Managing for adaptive capacity: thinning improves food availability for wildlife and insect pollinators under climate change conditions. Can. J. Forest Res. 43:428-440

Niemelä J, Young J, Alard D, Askasibar M, Henle K, Johnson R, Kurttila M, Larsson T-B, Matouch S, Nowicki P, Paiva R, Portoghesi L, Smulders R, Stevenson A, Tartes U, Watt A, 2005. Identifying managing and monitoring conflicts between forest biodiversity conservation and other human interests in Europe. Forest Policy Econ. 7:877-890.

Noble IR, Slatyer RO, 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. Vegetatio 43:5-21.

Norton MR, Hannon SJ, 1997. Songbird response to partial-cut logging in the boreal mixedwood forest of Alberta. Can. J. Forest Res. 27 44-53.

Odion DC, Sarr DA, 2007. Managing disturbance regimes to maintain diversity in forested ecosystems of the Pacific Northwest. Forest Ecol. Manag. 246:57-65.

Oliver CD, 1992. A landscape approach: Achieving and maintaining biodiversity and economic productivity. J. Forest 90:20-25.

Oliver CD, Larson BC, 1996. Forest stand dynamics. J. Wiley & Sons, New York.

Proe MF, Griffiths JH, McKay HM, 2001. Effect of whole tree harvesting on microclimate during establishment of second rotation forestry. Agric. Forest Meteorol. 110:141-154-

Puettmann KJ, Duvall MD, 1998. Overstory density and harvesting methos affect competition from understory vegetation. In: Proc. Conf. Improving Forest Productivity or Timber: A Key to Sustainability, Duluth, MN, USA.

Rad JE, Seyyedi N, 2012. Effects of strip and single-tree selection methods on woody species diversity in Caspian forests (Iran). Int. J. Forest Soil Eros. Accessed on: 04 December 2015. Available from: http://www.ijfse.com/index.php/IJFSE/article/view/IJFSE-Vol%202%284%29-2012-5.

Reid WV, Miller KR, 1989. Keeping options alive: the scientific basis for conserving biodiversity. World Resources Institute, Washington, DC.

Ramovs BV, Roberts MR, 2003. Understory vegetation and environment responses to tillage forest harvesting and conifer plantation development. Ecol. Appl. 13:1682-1700.

Ramovs BV, Roberts MR, 2005. Response of plant functional groups within plantations and naturally regenerated forests in southern New Brunswick Canada. Can. J. Forest Res. 35:1261-1276.

Raunkiaer C, 1934. The life forms of plants and statistical plant geography; being the collected papers of C. Raunkiaer, Clarendon Press Oxford.

Reader RJ, 1987. Loss of species from deciduous forest understory immediately following selective tree harvesting. Biol. Conserv. 42:231-244.

Reader RJ, Bricker BD, 1992. Value of selectively cut deciduous forest for understory herb conservation: an experimental assessment. Forest Ecol. Manag. 51:317-327.

Reich PB, Frelich, LE, Voldseth RA, Bakken P, Adair C, 2012. Understorey diversity in southern boreal forests is regulated by productivity and its indirect impacts on resource availability and heterogeneity. J. Ecol. 100:539-545.

Renaud V, Rebetez M, 2009. Comparison between open-site and below canopy climatic conditions in Switzerland during the exceptionally hot summer of 2003. Agric. Forest Meteorol. 149:873-880.

Ritter E, Dalsgaard L, Einhorn KS, 2005. Light temperature and soil moisture regimes following gap formation in a semi-natural beech dominated forest in Denmark. Forest Ecol. Manag. 206:15-33.

Ritter E, Vesterdal L, 2006. Gap formation in Danish beech (*Fagus sylvatica*) forests of low management intensity: soil moisture and nitrate in soil solution. Eur. J. Forest Res. 125:139-150.

Roberts M, 2004. Response of the herbaceous layer to natural disturbance in North American forests. Can. J. Bot. 82:1273-1283.

Roberts MR, Gilliam FS, 1995. Patterns and mechanisms of plant diversity in forested ecosystems: implications for forest management. Ecol. Appl. 5:969-977.

Roberts MR, Gilliam FS, 2003. Response of the herbaceous layer to disturbance in eastern forests In: F.S. Gilliam and M.R. Roberts (eds.) The herbaceous layer in forests of Eastern North America. Oxford, New York, pp. 302-320.

Roberts MR, Zhu LX, 2002. Early response of the herbaceous layer to harvesting in a mixed coniferous-deciduous forest in New Brunswick Canada. Forest Ecol. Manag. 155:17-31.

Runkle JR 1992 Guidelines and sample protocol for sampling forest gaps US Dept of Agriculture Forest Service Pacific Northwest Research Station

Sharitz RR, Boring LR, Van Lear DH, Pinder III JE, 1992. Integrating ecological concepts with natural resource management of southern forests. Ecol. Appl. 2:226-237.

Schmidt W, 2005. Herb layer species as indicators of biodiversity of managed and unmanaged beech forests. For. Snow. Landsc. Res. 79:111-125.

Schwilk DW, Keeley JE, Knapp EE, McIver J, Bailey JD, Fettig CJ, Fiedler CE, Harrod RJ, Moghaddas JJ, Outcalt KW, Skinner CN, Stephens SL, Waldrop TA, Yaussy DA, Youngblood A, 2009. The national fire and fire surrogate study: effects of fuel reduction methods on forest vegetation structure and fuels. Ecol. Appl. 19:285-304.

Selmants PC, Knight DH, 2003. Understory plant species composition 30-50 years after clearcutting in Southeastern Wyoming coniferous forests. Forest Ecol. Manag. 185:275-289.

Silvertown J, Dodd M, Gowing D, 2001. Phylogeny and the niche structure of meadow plant communities. J. Ecol. 89:428-435.

Siry JP, Cubbage FW, Ahmed MR, 2005. Sustainable forest management: global trends and opportunities. Forest Policy Econ. 7:551-561.

Smart SM, Marrs RH, Le Luc MG, Thompson K, Bunce RGH, Firbank LG, Rossall MJ, 2006. Spatial relationships between intensive land cover and residual plant species diversity in temperate farmed landscapes. J. Appl. Ecol. 43:1128-1137.

Smith KJ, Keeton WS, Twery MJ, Tobi DR, 2008m Understory plant responses to uneven-aged forestry alternatives in northern hardwood-conifer forests, Can. J. Forest Res. 38:1303-1318.

Spies TA, Franklin JF, Klopsch M, 1990. Canopy gaps in Douglas-fir forests of the Cascade Mountains, Can. J. Forest Res. 20:649-658.

Thomas JW, Franklin JF, Gordon J, Johnson KN, 2006. The Northwest Forest Plan: origins components implementation experience and suggestions for change. Conserv. Biol. 20:277-287.

Thomas SC, Halpern CB, Falk DA, Liguori DA, Austin KA, 1999. Plant diversity in managed forests: understory responses to thinning and fertilization. Ecol. Appl. 9:864-879.

Thompson JN, 1980. Treefalls and colonization patterns of temperate forest herbs. Am. Midl. Nat. 104:176-184.

Thill RE, 1990. Managing southern pine plantations for wildlife. pp. 58-68 in Proc. 19th IUFRO World Congr. Canadian Int. Union of Forestry Research Organizations, Montreal, Canada.

Thysell DR, Carey AB, 2000. Effects of forest management on understory and overstory vegetation: a retrospective study. Gen. Tech. Rep. PNW-GTR-488. US Department of Agriculture, Forest Service Pacific Northwest Research Station, Portland, OR, USA.

UNFCCC, 1992. United Nations Framework Convention on Climate Change. Text Geneva World Meteorological Organization and United Nations Environment Program.

Van Pelt R, Franklin JF, 2000. Influence of canopy structure on the understory environment in tall old-growth conifer forests Can. J. Forest Res. 30:1231-1245.

Vilhar U, Roženbergar D, Simončič P, Diaci J, 2014. Variation in irradiance soil features and regeneration patterns in experimental forest canopy gaps. Ann. Forest Sci. 72:253-266.

Violle C, Jiang L, 2009. Towards trait-based quantification of species niche. J. Plant Ecol. 2:87-93.

Wayman RB, North M, 2007. Initial response of a mixed-conifer understory plant community to burning and thinning restoration treatments. Forest Ecol. Manag. 239:32-44.

Wyatt JL, Silman MR, 2010. Centuries-old logging legacy on spatial and temporal patterns in understory herb communities. Forest Ecol. Manag260:116-124.

York RA, Heald RC, Battles JJ, York JD, 2004. Group selection management in conifer forests: relationships between opening size and tree growth Can. J. Forest Res. 34 630-641.

Improving carbon sequestration and stocking as a function of forestry

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Introduction

Indicators are parameters which can be measured and correspond to a particular criterion. They measure and help to 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.

Several indicators have been proposed to assess Sustainable Forest Management (SFM). At European level, the Pan-European Indicators for Sustainable Forest Management (SFM), organised in six criteria, were developed in 2002 by the Ministerial Conference on the Protection of Forests in Europe. The first criterion of this document (C1) promotes sustainable forest management by describing the evolution and status of forest resources in Europe and explaining/addressing forests' contribution to the global carbon cycles**.**

Carbon sequestration in forest ecosystems contributes to reduce the concentration of greenhouse gases in the atmosphere. Carbon accumulates in forest ecosystems through absorption (sequestration) of atmospheric CO_2 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 and below ground biomass); litter, deadwood and soils. Since the growth of European forests in general has predominated over logging and other biomass removals, Europe forests are major carbon sinks**.** Between 2005 and 2010, the average annual sequestration of carbon in forest biomass reached 870 million tons for the whole European region (including also not EU countries) 430 million tons corresponds to the EU-27 (Forest Europe, 2011). This corresponds to 10% of the greenhouse gas emissions of the European countries. The stock of dead organic matter and soil organic carbon also seems to be increased (Forest Europe, 2011).

As forests are harvested, certain amount of carbon gets stored and accumulated in forest products. So forest products play a fundamental role in the carbon cycle and for this reason they should be considered in evaluating sustainability of forest management.

In Table 1 a list of carbon SFM indicators found in MCPFE, Canadian Council of Forest Ministers and National Report on Sustainable Forests (USA) are presented.

Sometimes indicators do not reflect real ecological situation, and for this reason we have modified some of them. In cases where indicators did not consider important ecosystem components, new ones were proposed (ManFor C.BD Indicators).

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Key words: Carbon cycle, forest management, soil organic carbon, soil respiration, dead wood.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

From net primary production to net biome production

Carbon cycling in forests varies significantly over time (*e.g.*, annual, decadal) and space (regional, global), (Figure 1) while both are directly regulated and affected by natural events (*e.g.*, climate change, drought, wildfires, pest or disease outbreaks) and human activities (*e.g.*, deforestation, plantation establishment, urbanization, management practices).

Below a description of the parameters of carbon cycling is presented.

Gross primary production (GPP) refers to the total amount of carbon fixed in the process of photosynthesis by plants in an ecosystem. Global GPP is estimated to be about 123±8 PgC yr^{-1} (Beer *et al*., 2010). Net Primary Production (NPP) refers to the net production of organic carbon by plants in an ecosystem usually measured over a period of a year or more. It is obtained from GPP by reduction of the amount of carbon respired by plants themselves (leaves, branches, stems and roots) in autotrophic respiration (Ra):

$$NPP = GPP - Ra$$

NPP constitutes the total annual growth increment (both above and below ground) and the amount grown and shed in senescence, reproduction or death of short-lived individuals in a stand with the amounts consumed by herbivores. Only the amount of carbon produced and lost in the year for which NPP is being calculated is counted.

The Net Ecosystem Exchange (NEE) and Net Ecosystem

Production (NEP) refer to net primary production reduced for carbon losses in heterotrophic respiration (Rh):

$$NEP=NEE = NPP - Rh$$

These terms are used somewhat interchangeably, with NEE used more often to refer to fluxes when they are addressed from a measurement of gas exchange rates using atmospheric measurements over time scales of hours, whereas NEP is more often used to refer to the same processes if measurements are based on ecosystem-carbon stock changes, typically measured over a minimal period of one year. However, these differences in usage are not firmly embedded in formal definitions.

Total global NEE is estimated to be about 10 GtC yr^{-1} (Steffen *et al.*, 1998), with wide range of uncertainty and interannual variability around this estimate. Individual ecosystems may be positive, negative or in balance.

Net Biome Exchange (NBE) or Net Biome Production (NBP) refers to the change in carbon stocks after episodic carbon losses due to natural or anthropogenic disturbances have been taken into account where Ld is the loss by major episodic disturbances (Kirschbaum *et al.*, 2001)

$$NBE = NEE - Ld$$
$$NBP = NEP - Ld$$

Some systems are not typically affected by irregular disturbances. In those systems, NBE = NEE. Eventually, the carbon may be lost in a massive disturbance, such as in fire or after harvesting. The loss due to disturbance would therefore be much greater than the annual increment in carbon, so that in that period NBE <<0. Summed over a longer time period, NBE will be close to zero, with the many small positive annual increments balanced by the large loss in the year of forest harvesting (i.e., NBE = SNEE - Ld).

NBE could be monitored at the plot level over long periods, which might include disturbance events or at larger spatial scales.

Changes in carbon fluxes and storage across forest landscapes (i.e., across multiple ecosystems arranged in a cohesive mosaic) have been difficult to understand and measure due to the complex interactions between landscape structure and ecosystem processes and changes in these interactions over time. The two critical issues that should be accounted for any landscape-scale research are heterogeneity and scaling. Although both topics have received extensive attention during the past 20 years, much less effort has been spent on their relationship to carbon cycles, due mostly to the high costs of such studies and a lack of effective methods. At the ecosystem level, several methods (*e.g.*, micrometeorological technique, biometric sampling, chamber-based flux measurement, ecosystem modelling) can provide us with reliable estimates of both fluxes and storage (Chen *et al.*, 2004). However, scaling-up of ecosystem-level carbon fluxes and storage to a landscape level is not always accurate because of the presence of many smaller elements (*e.g.*, corridors) and of interactions among patches (Desai *et al.*, 2008).

Interaction between structure, management and carbon cycling

The strong connection between forest structure, microclimatic parameters, and tree ecophysiological behaviour, is well known (Figure 2) (Aussenac, 2000). The first management result is the modification of forest structure; this affects microclimatic parameters and tree physiology.

In mature stands, characterized by closed canopies and higher amounts of accumulated carbon stock, natural modifications (the death of one or several trees) or silvicultural interventions modify the forest structure and consequently climatic characteristics depending on canopy opening.

Consequently, all the modifications of microclimatic parameters affect carbon cycle (*e.g.*, growth, litter decomposition, soil respiration). Thinning and cutting causes changes in the ecophysiological behaviour of the trees (photosynthesis and transpiration phenomena).

In general the canopy is 'organised' to maximize carbon fixation and usually in stands with high vertical variability sun leaves are

Table 1. Indicators for Sustainable Forest Management (Canadian Council of Forest Ministers and National Report on Sustainable Forests, USA).

Indicator	Criteria	References
Age structure and/or diameter distribution	Carbon stock and productivity	1.3 MCPFE
Carbon stock		1.4 MCPFE
Growing stock		1.2 MCPFE
Increment and fellings		3.1 MCPFE
Net change in forest ecosystem carbon		4.1.1 CCFM
Forest ecosystem carbon storage by forest types and age class		4.1.2 CCFM
Total forest ecosystem carbon pools and fluxes		5.22 NRSF-USDA
Soil condition	Soil	2.2 MCPFE
Humus forms		ManFor Indicators
CO_2 emission of soil		ManFor Indicators
Rate for compliance with locally applicable soil disturbance standards		3.1 CCFM
Deadwood	Deadwood	4.5 MCPFE
Energy from wood resources	Post management	6.9 MCPFE
Net change in forest products carbon		4.1.3 CCFM
Forest sector carbon emission		4.1.4 CCFM
Avoided fossil fuel carbon emission by using forest biomass for energy		5.24 NRSF-USDA
Total forest products carbon pools and fluxes		5.23 NRSF-USDA

more frequent. The upper canopy leaves have higher photosynthetic rates as a consequence of higher quality and quantity of light (De Angelis and De Luca, 1998; Matteucci *et al*., 1999).

When canopy homogeneity is disturbed by gaps, some of the crown leaves would benefit from light stimulation (intermediate zone leaves), while shade leaves in the lower parts of the crown would not be able to adapt if radiation intensity is too high (Aussenac, 2000).

Usually, the direct effect of cutting increases light intensity and provides higher photosynthesis rate. In firstly dense and after heavily thinned stands effects of temperature stress or photo-inhibition phenomena are possible (Aussenac, 2000).

Under silvicutural treatments, one of the consequences of the described phenomena is the stem circumference growth, that is influenced by the:
- Increase of light in the lower parts of the tree crown, which increase photosynthesis
- Increase of soil water availability and reduction of water consumption, which influences photosynthesis and stimulates growth.
- Increase of nitrogen compounds released through faster humus mineralization as a consequence of improved light under the cover and an increase in the surface soil temperature.

Forest management affects soil C and N storage, due to the variation of microclimatic characteristics and input of new organic matter.

The general trends found by Johnson and Curtis (2001) indicate that of high C/N ratio of residues becoming incorporated into soils over the short-term with soil C re-equilibrating to lower levels and to C/N ratios more similar to background as time passes.

Regarding Carbon Cycling, silviculture residues, considering the permanence time in the ecosystem, represent a point to analyse in the organization of work during harvesting. If residues don't have positive effect on mineral soil carbon pool, for example in warmer hardwood forest where they will be decomposed quickly, should be better to remove them from forest and use as biomass to burn instead of fossil fuel. Conversely, the residues input of nutrients, which may result in long term carbon gains in above ground biomass, should be considered.

If the latter is true, how do the C and economic costs of fertilization compare with the costs of leaving residues on site (Johnson and Curtis, 2001)?

Harvesting operation can affect the soil carbon pool. Forest floor comprises the most dynamic part of SOC stock, estimating the effects of these activities on SOC dynamics are critical to predicting the local effects on ecosystem sustainability and global C exchange with the atmosphere (Yanai *et al*., 2003).

Many studies have shown that the observed post-harvesting decline in SOC is generally due to mixing and movement of the organic material or litter layer into the mineral soil (Yanai *et al*., 2003), soil erosion (Elliot, 2003), and leaching of dissolved organic carbon (Kalbitz *et al*., 2000). A good organization can reduce these processes and consequently decrease SOC loss.

Forest structure and management also affect soil respiration. Soil temperature (driver of soil respiration) is affected by forest structure particularly by the density of canopy. In general, soils under forest cover are warmer in the winter and colder in the summer (Aussenac, 2000).

Soil respiration is one of the major components of the ecosystem C balance and contributes 50–95% of total ecosystem respiration (Law *et al*., 1999; Xu and Qi, 2001; Janssens *et al*., 2001; Yuste *et al*., 2005). It is the sum of multiple processes, such as root respira-

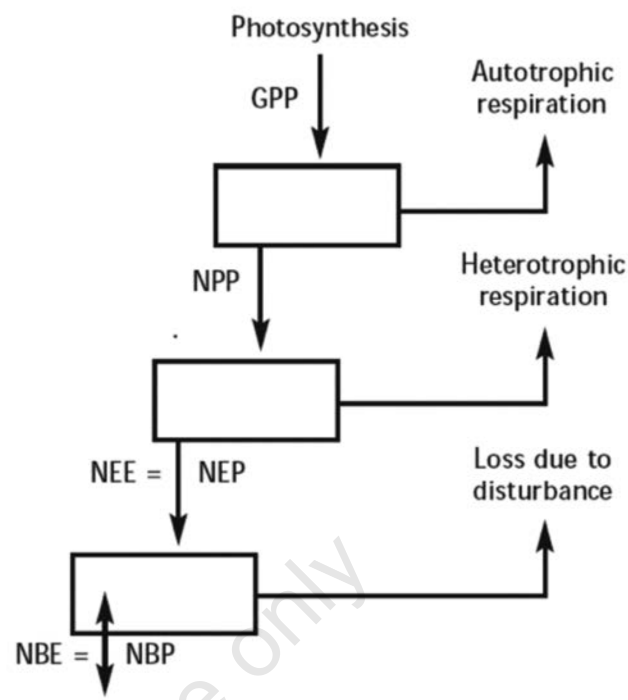

Figure 1. Diagrammatic representation of the main terms describing system carbon balances. Arrows indicate that GPP and NPP are always positive (carbon gains by the system), NEE is usually, but not always, positive, and NBE be positive or negative (Kirschbaum *et al*., 2001).

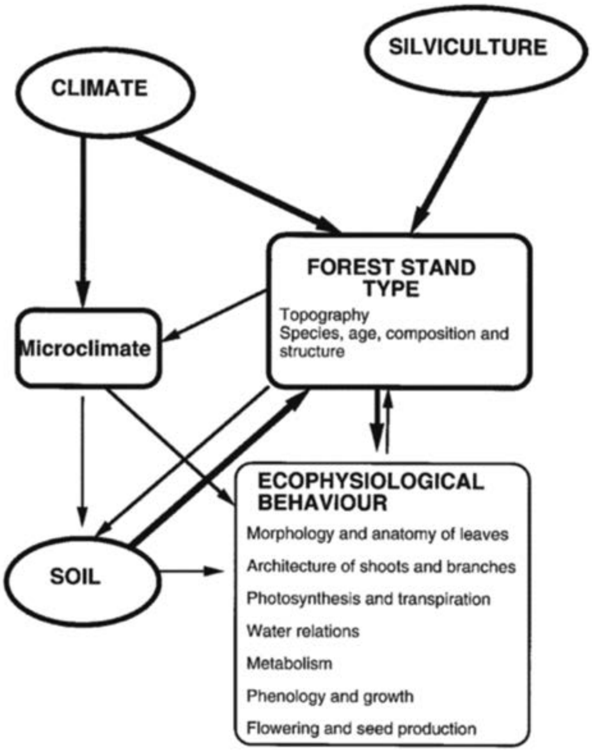

Figure 2. Interactions between climate and forest stand (Aussenac, 2000).

tion and microbial decomposition (Hanson *et al*., 2000; Kuzyakov, 2006) and varies significantly in time and space according to small- and large-scale changes in the biological, physical, and chemical properties of the soil (*e.g.*, Xu and Qi, 2001; Hibbard *et al*., 2005).

Roots contribute to total soil respiration through root respiration and root litter C decomposition due to fine root turnover and root exudates (Gower *et al*., 1996). Since root respiration and root litter C decomposition depend on belowground C allocation by trees, they can be closely linked to the forest structures (Stoyan *et al*, 2000; Savin *et al*., 2001; Søe and Buchmann, 2005). A significant correlation exists between soil respiration and forest structural parameters such as the mean DBH, total basal area, and maximum DBH (Katayama *et al*., 2009). Thinning decreases stand density, increase light and nutrient availability and changes soil temperature and moisture, and the amount of roots. Response of soil respiration is very variable. It is probable that thinning can induce or reduce root and microbial respiration. Thinning can directly affect living roots (consequently root respiration) removing trees. However, thinning can also reduce competition for soil moisture/water and nutrients that stimulate production of surviving trees, consequently with a higher roots production and roots respiration (Ma *et al*., 2004).

A new carbon pool: deadwood

Deadwood is a fundamental component of natural forests (Christensen *et al*., 2005) and it is among the most important indicators to distinguish natural from managed forests (Debeljak, 2006), as a consequence of reduced or no logging activities (Emborg *et al*., 2000; von Oheimb *et al*., 2005). In a review on deadwood amounts over 86 beech forest reserves across Central Europe, Christensen *et al*. (2005) found that mean deadwood volume was 130 m^3 ha^{-1} with a high level of variation (from ~0 to 550 m^3 ha^{-1}). Abundance of deadwood in natural forests varies greatly depending on the present structural phase (Debeljak, 2006).

Deadwood may act as a sink for atmospheric carbon and is an important structural and functional component of forest ecosystems (Harmon *et al*., 1986).

The role of deadwood in nutrient cycling has been the subject of many debates over the past decade. Policies encouraged and/or required that woody debris to be left in the forest after the cutting due to its inherent ability to retain essential nutrients. Deadwood contains a substantial amount of carbon. If woody debris represents a high proportion of stored C in the forest, then management that maintains debris on post-harvested sites would aid in retaining C in the ecosystem and retard its return to the atmosphere.

According to Wolynski (2001) deadwood volume should approach 10-15% of total live plus dead trees volume in adult stands, increasing up to 25-30% in the ageing phase. In the traditional forest management the presence of deadwood is considered negatively for several reasons. Historically, deadwood has been removed in order to decrease firewood risk as well as to protect timber from insect and fungal attacks (Radu, 2006). Consequence of this type of management is a scarcity of deadwood in Italian forests with only 8.8 m^3 ha^{-1} on average.

Woody debris can serve as a temporary storage site for macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (Krankina and Harmon, 1994; Holub *et al*., 2001). Like C, these nutrients remain in woody debris for a period of time but are released by decomposition eventually. Nutrients can be immobilized in woody debris, rendering them unusable to plants for long (or short) periods of time, but they are eventually released through mineralization by microorganisms (Kopra and James, 2005).

Management suggestions in view of the carbon cycle

Carbon cycle is affected by climatic, physiologic and human factors (management). All are linked and response of one has direct effect on the others.

Considering the role of forest inside the carbon cycle, the forest management should:
i) Maintain and preserve existing forests;
ii) Increase the area of the forestland;
iii) Increase the carbon stock density on the forested land (C/ha);
iv) Produce good quality wood.

These targets can be reached applying good management practices (Di Salvatore *et al*., 2016).

References

Aussenac G, 2000. Interactions between forest stands and microclimate: Ecophysiological aspects and consequences for silviculture. Ann. Forest Sci. 57:287-301.

Beer C, Reichstein M, Tomelleri E, Ciais P, Jung M, Carvalhais N, Rödenbeck C, Altaf Arain M, Baldocchi D, Bonan GB, Bondeau A, Cescatti A, Lasslop G, Lindroth A, Lomas M, Luyssaert S, Margolis H, Oleson KW, Roupsard O, Veenendaal E, Viovy N, Williams C, Woodward FI, Papale D, 2010. Terrestrial gross carbon dioxide uptake: global distribution and covariation with climate. Science 329:834-838.

Chen WJ, Zhang QF, Cihlar J, Bauhus J, Price DT, 2004. Estimating fine-root biomass and production of boreal and cool temperate forests using above- ground measurements: a new approach. Plant Soil 265:31-46.

Christensen M, Hahn K, Mountford EP, Odor P, Standovar T, RozenbergarD, Diaci J, Wijdeven S, Meyer P, Winter S, Vrska T. 2005. Dead wood in European beech Fagus sylvatica forest reserves. Forest Ecol. Manag. 210:267-282.

De Angelis P, De Luca A, 1998. Andamento stagionale della fotosintesi lungo il profilo verticale delle chiome in una faggeta dell'Appennino Centro Meridionale. In: Funzionalità dell'ecosistema Faggeta, vol. 1. CNR-RAISA, Roma, pp. 203-218.

Debeljak M, 2006. Coarse woody debris in virgin and managed forest. Ecol. Indic. 6:733-742.

Desai AR, Noormets A, Bolstad PV, Chen JQ, Cook BD, Davis KJ, Euskirchen ES, Gough C, Martin JG, Raccmto DM, Schimd HE Tang JW, Wang WG, 2008. Influence of vegetation and seasonal forcing on carbon dioxide fluxes across the Upper Midwest, USA: implications for regional scaling. Agr. Forest Meteorol. 148:288-308.

Di Salvatore U, Ferretti F, Zapponi L, Cantiani P, Bombi P, Simončič P, Matteucci G, De Cinti B, 2016b. How results from test area can be suggested as 'good practice'. Ital. J. Agron. 11(s1):1-175.

Elliot WJ, 2003. Soil erosion in forest ecosystems and carbon dynamics. In: J.M., Kimble, L.S. Heath, R.A. Birdsey and R. Lal (eds.) The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. CRC Press, Boca Raton, pp. 175-190.

Emborg J, Christensen M, Heilmann-Clausen J. 2000. The structural dynamics of Suserup Skov, a near-natural temperate deciduous forest in Denmark. Forest Ecol. Manag. 126:173-189.

Forest Europe, 2011. Criterion 1: Maintenance and appropriate enhancement of forest resources and their contribution to global carbon cycles. Available from: http://www.foresteurope.org/sfm_criteria/criteria/carbon

Gower ST, Pongracic S, Landsberg JJ, 1996. A global trend in belowground carbon allocation: Can we use relationship at smaller scales? Ecology 77:1750-1755.

Hanson PJ, Edwards NT, Garten CT, Andrews JA, 2000. Separating root and soil microbial contributions to soil respiration: a review of methods and observations. Biogeochemistry 48:115-146.

Harmon ME, Franklin JF, Swanson FJ, Sollins P, Gregory SV, Lattin JD, Anderson NH, Cline SP, Aumen NG, Sedell JR, Lienkaemper GW, Cromack K Jr, Cummins KW, 1986. Ecology of coarse woody debris in temperate ecosystems. Adv. Ecol. Res. 15:133-302.

Hibbard KA, Law BE, Reichstein M, Sulzman J, 2005. An analysis of soil respiration across northern hemisphere temperate ecosystems. Biogeochemistry 73:29-70.

Holub SM, Spears JDH, Lajtha K, 2001. A reanalysis of nutrient dynamics in coniferous coarse woody debris. Can. J. Forest Res. 31:1894-1902.

Janssens I, Lankreijer H, Matteucci G, Kowalski AS, Buchmann N, Epron D, Pilegaard K, Kutsch W, Longdoz B, Grünwald T, Montagnani L, Dore S, Rebmann C, Moors EJ, Grelle A, Rannik Ü, Morgenstern K, Oltchev S, Clement R, Guðmundsson J, Minerbi S, Berbigier P, Ibrom A, Moncrieff J, Aubinet M, Bernhofer C, Jensen NO, Vesala T, Granier A, Schulze E-D, Lindroth A, Dolman AJ, Jarvis PG, Ceulemans R, Valentini R, 2001 Productivity over- shadows temperature in determining soil and ecosystem respiration across European forests. Global Change Biol. 7:269-278.

Johnson DW, Curtis PS, 2001. Effects of forest management on soil C and N storage: meta analysis. Forest Ecol. Manag. 140:227-238.

Kalbitz KS, Solinger S, Park JH, Michalzik B, Matzer E, 2000. Controls on the dynamics of dissolved organic matter in soils: a review. Soil Sci. Soc. 165:277-304.

Katayama A, Kume T, Komatsu H, Ohashi M, Nakagawa M, Yamashita M, Otsuki K, Suzuki M, Kumagai T, 2009. Effect of forest structure on the spatial variation in soil respiration in a Bornean tropical rainforest. Agr. Forest Meteorol. 149:1666-1673.

Kirschbaum UF, Eamus D, Giffor RM, Roxburgh, Sands PJ, 2001. Definitions of some ecological terms commonly used in carbon accounting. pp. 2-5 in Proc. Net Ecosystem Exchange Workshop, Canberra, Australia.

Krankina ON, Harmon ME, 1994. The impact of intensive forest management on carbon stores in forest ecosystems. World Res. Rev. 6:161-177.

Kopra K, Fyles J, 2005. Woody debris and nutrient cycling: should we care??? SFMN Research Note Series No. 8. Available from: http://www.sfmn.ales.ualberta.ca/Portals/88/Documents/ResearchNotes/RN_en_Deadwood_and_nutrients.pdf?ver=2016-02-23-155809-690

Kuzyakov Y, Gavrichkova O, 2010. Time lag between photosynthesis and carbon dioxide efflux from soil: a review of mechanisms and controls. Global Change Biol. 16:3386-3406.

Law B, Ryan M, Anthoni P, 1999. Seasonal and annual respiration of a ponderosa pine ecosystem. Global Change Biol. 5:169-182.

Ma S, Chen, J, North M, Erickson HE, Bresee M, Moine JL, 2004. Short-term effects of experimental burning and thinning on soil respiration in an old-growth, mixed-conifer forest. Environ. Manage. 33:S148-S159.

Matteucci G, De Angelis P, Dore S, Masci A, Valentini R, Scarascia-Mugnozza G, 1999. Il bilancio del carbonio delle faggete: dall'albero all'ecosistema. In: G. Scarascia-Mugnozza (ed.) Ecologia strutturale e funzionale di faggete italiane. Edagricole, Bologna, pp. 133-183.

Radu S, 2006. The ecological role of deadwood in natural forests. Environ. Sci. Eng. 3:137-141.

Savin MC, Gorres JH, Neher DA, Amador JA. 2001. Biogeophysical factors influencing soil respiration and mineral nitrogen content in an old field soil. Soil Biol. Biochem. 33:429-438.

Søe ARB, Buchmann N, 2005. Spatial and temporal variations in soil respiration in relation to stand structure and soil parameters in an unmanaged beech forest. Tree Physiol. 25:1427-1436.

Steffen W, Noble I, Canadell J, Apps M, Schulze E-D, Jarvis PG, Baldocchi D, Ciais P, Cramer W, Ehleringer J, Farquhar G, Field CB, Ghazi A, Gifford R, Heimann M, Houghton R, Kabat P, Körner C, Lambin E, Linder S, Mooney HA, Murdiyarso D, Post WM, Prentice C, Raupach MR, Schimel DS, Shvidenko A, Valentini R, 1998. The terrestrial carbon cycle: implications for the Kyoto Protocol. Science 280:1393-1394.

Stoyan H, De-Polli H, Bohm S, Robertson GP, Paul EA, 2000. Spatial hetero-geneity of soil respiration and related properties at the plant scale. Plant Soil 222:203-214.

von Oheimb G, Westphal C, Tempel H, Hädtle W, 2005. Structural pattern of a near natural beech forest Fagus sylvatica Serrahn, North-east Germany. Forest Ecol. Manag. 212:253-263.

Wolynski A, 2001. Significato della necromassa legnosa in bosco in un'ottica di gestione forestale sostenibile. Sherwood 67:5-12.

Xu M, Qi Y, 2001 Separating the effects of moisture and temperature on soil CO2 efflux in a coniferous forest in the Sierra Nevada mountains. Plant Soil 237:15-23.

Yanai RD, Arthur MA, Siccama TG, Federer CA, Boyle JR, Powers RF, 2000. Challenges of measuring forest floor organic matter dynamics: repeated measures from a chronosequence. Forest Ecol. Manag. 138:273-283.

Yuste J, Janssens IA, Carrara A, Ceulemans R, 2004. Annual Q10 of soil respiration reflects plant phenological patterns as well as temperature sensitivity. Global Change Biol. 10:161-169.

From sectorial-optimum to multipurpose silviculture. How to compromise

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The primary aim of our work is to provide an overview of the compromises we did to match traditional silvicultural and a multipurpose approach.

Clearly, we had to consider the framework of the general aim of ManFor C.BD Project, or the possibility to manage a forest maintaining the coexistence of different results such as a level of wood production acceptable by local stakeholder, greenhouse effect mitigation and biodiversity guardianship.

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. In other words we do not consider to preserve some habitat trees, or to establish senescent island reducing the wood production surface. Similarly we do not take into account if the carbon fluxes are positive or negative.

In Table 1 we resume the main topics and the desired silvicultural practices suggested by different sectorial experts (Basile *et al*., 2016; Chiavetta *et al*., 2016; Costa *et al*., 2016; D'Andrea *et al*., 2016; de Groot *et al*., 2016; Frate *et al*., 2016; Kovac and Fabbio, 2016; Kutnar *et al*., 2016; Lombardi and Mali, 2016).

The results of the work carried out by the specialists of the ManFor C.BD Project (Table 1) indicate that to improve biodiversity level and carbon storage, while maintaining the economic sustainability of silvicutural interventions, it is necessary to select appropriate silvicultural treatments contemplating some good practices both at stand and territorial scale, and combining silvicultural adaptive strategies with technical and economic feasibility. So we can summarize the specialists' suggestions as follows:
- to increase diversity at stand and landscape scale;
- to reduce habitat fragmentation at landscape scale;
- to increase deadwood amount;
- to increase retention of veteran and senescent trees.

The innovative silvicultural treatments proposed (selective thinning and crown thinning) are intended to demonstrate that it is possible to carry out thinning interventions characterized by high levels of multifunctionality and to promote:
- the improve of economic value of the forest through increased incremental reaction;
- the increase mechanical stability of the standing trees (htot/dbh ratio decrease);
- the vertical structural diversity to improve photosynthesis and carbon storage;
- the production of good quality wood for marking durable products for competing materials having a larger atmospheric CO_2 footprint;
- the increases in overall biodiversity: the opening of small gaps in the canopy cover determines the possible coexistence of different species both animal and vegetal;
- 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.

Furthermore, as regards the increase of biodiversity level, of deadwood and so of the amount of organic matter to the soil and of the presence of microhabitat-bearing trees in the forest, the innovative treatments provide some measures easy to apply and economically sustainable:
- the retention, during thinning operations, of a fixed number (6-8 per hectare at Pennataro-Montedimezzo) of veteran and senescent trees (habitat trees) and trees that have a suitable structure to be a microhabitat-bearing tree in the future (future habitat trees);
- girdle or cut some selected trees in order to increase deadwood availability and favour the growth of the trees with the highest diameter, more likely to develop microhabitats;
- plan a forest area where implementing an 'ageing patch' literally from the French 'îlot de sénescence' (Cansiglio, Pennataro-Montedimezzo). It consists of an area wide up to a few hectares where trees are left to an indefinite ageing up to their death and decay; where holes on standing trees and snags are being created, where a part of living stems are partially cut along outer circumference up to cambium to make them becoming dead standing trees or felled and left on the ground to establish micro-habitats, niches and corridors to insects and micro-fauna.

Finally, some different silvicultural techniques for managing forest-dominated layer have been adopted and compared. In some cases the thinning provides the release of intercropping trees or removed only along hauling courses. In such way, the overall stand structure moves both at stem and at crown level. The high tree density of intercropped stand would promote regular mortality and the enrichment of the deadwood on the ground and standing dead trees. In other cases (Pennataro-Montedimezzo) techniques for the containment of the dominated layers have been adopted with the aim to facilitate the renewal of the forest in the future: in the low strata stumps are treated by releasing the dominated shoot, while monocormic individuals would not harvested to avoid a new growth from the stump.

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Key words: traditional silviculture, multipurpose approach, compromise, habitat fragmentation, deadwood, veteran trees, senescent trees management plan, biodivrsity, carbon retention.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Table 1. List of main suggestions derived from sectorial experts contribution.

Topics and main suggestions proposed	Aspects involved and main suggestions proposed
Increase diversity at stand and landscape scale **How.** Changing silvicultural system. Avoiding systematic thinning or cutting on large areas (more than 1 ha); selective thinning should be preferred since it promotes higher structural diversity.	**Invertebrates**. Forest patch size influences the diversity of invertebrates' species. **How.** Increasing diversity larger gaps is fundamental, whilst preserving species' smaller gaps is preferable. **Flora.** Supporting variety and abundance of species. **How.** An important way to increase within-stand structural diversity is maintaining a lower overstory density. Thinning early and often in rotation can allow to maintaining an open canopy, maintaining or restoring a mosaic of forest structural classes **Carbon stock.** increase carbon sequestration and carbon retention ability. **How.** i) Increment of the vertical structural diversity; ii) Production of good durable quality wood; iii) Residues management and deadwood release; iv) Organization of harvesting operations to reduce soil mixing (erosion, leaching, etc.) and engines emission
Increase deadwood amount **How.** Not only the volume, but also maintaining diverse qualities of deadwood in terms of tree species, decomposition stage, diameter, decay class, and type has a positive effect on the conservation.	**Invertebrates.** Deadwood represents both a key trophic and microhabitat resource. **How.** Sufficient diameter to host sensitive beetle species (more than 30 cm in oak forests); the importance of fine woody debris (diameter <10 cm). Large snags have proved to support more individuals per volume unite, and diverse and rarer assemblages compared to logs and stumps represent valuable long-lasting microhabitats. The minimum total volume required for European forests: deadwood comprised between 20-30 m^3/ha for boreal coniferous forests, 30-40 m^3/ha for mixed-mountain forests and 30-50 m^3/ha for lowland forests. Herpetofauna. Amphibians use deadwood in forest ecosystems for multiple purpose such as feeding, mating and overwintering. **Avifauna.** Some species use deadwood in forest ecosystems for multiple purpose such as feeding and nesting. In almost all the three considered woodpecker species, the older forests are preferred.However, in some cases species have opposite habitat preferences, which could cause conflicting situations. **Carbon stock.** Deadwood may act as a sink for atmospheric carbon and is an important structural and functional component of forest ecosystems
Retention of veteran and senescent trees **How.** While many researchers consider the release of 10 trees per hectare as adequate, the rules of the various European countries, as well as being quite dissimilar, provide a minimum release well below those values.	**Invertebrates.** A considerable proportion of species of several insects' orders, such as Coleoptera and Diptera, relies on the presence of decaying wood. Deadwood represents both a key trophic and microhabitat resource. **Herpetofauna.** As a general approach deadwood retention has to be considered as highly ameliorative practice for herpetofauna conservation, and for amphibians in particular; availability of deadwood as cool and moist refugia. **Carbon stock.** Increasing the amount of stored carbon in living trees.
Reduce habitat fragmentation at landscape scale	**Invertebrates.** Forest patches isolation affects the exchange of individuals between populations and suitable habitats could be unoccupied because of isolation from neighbouring populations. Patch size affects the richness of forest species: in many cases an increase of species diversity with forest patch size has been observed, and a decrease below a certain threshold. **How.** The restoration of natural forest properties should be planned on an extensive landscape scale and the potential species pools. In fragmented landscapes, the co sideration of multiple spatial scales together with short and long-term dynamics of substrate availability represents the future challenge for saproxylic biodiversity conservation. **Herpetofauna.** Habitat connectivity is a key function for herpetofauna conservation: a large number of studies show that low connectivity between terrestrial habitats (*e.g.*, forested areas) and aquatic reproductive sites is a cause of low survival and, consequently, population decline. In a similar way low habitat connectivity between reproductive sites and forested areas affects at a larger extent juvenile survival and dispersal. **Avifauna.** Unfortunately, different species respond in different ways to forestry and for generalists taxa it can be expected a neutral, or even positive impact on abundance.

Based on this silvicultural approach, the Forest Management Plan results as the ideal tool to implement the outcomes of the ManFor C.BD Project, and through which to take the most appropriate silvicultural techniques for optimizing multifunctionality of forests.

It 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.

References

Basile M, Balestrieri R, de Groot M, Flajšman K, Posillico M, 2016. Conservation of birds as a function of forestry. Ital. J. Agron. 11(s1):1-175.

Chiavetta U, Skudnik M, Becagli C, Bertini G, Ferretti F, Cantiani P, Di Salvatore U, Fabbio G, 2016. Diversity of structure through silviculture. Ital. J. Agron. 11(s1):1-175.

Costa A, Posillico M, Basile M, Romano A, 2016. Conservation of herpetofauna as a function of forestry. Ital. J. Agron. 11(s1):1-175.

D'Andrea E, Micali M, Sicuriello F, Cammarano M, Ferlan M, Skudnik M, Mali B, Čater M, Simončič P, De Cinti B, Matteucci G, Levanic T, Marinsek A, Kobal M, 2016. Improving carbon sequestration and stocking as a function of forestry. Ital. J. Agron. 11(s1):1-175.

de Groot M, Zapponi L, Badano D, Corezzola S, Mason F, 2016. Conservation of invertebrates as a function of forestry. Ital. J. Agron. 11(s1):1-175.

Frate L, Carranza ML, Tonti D, Ferreira A, Marchetti M, 2016. Landscape as a driver of forest. Ital. J. Agron. 11(s1):1-175.

Kovač M, Fabbio G, 2016. Wood production. Hereditary management systems and practices used in wood-production forests. Ital. J. Agron. 11(s1):1-175.

Kutnar L, Marinšek A, Giancola C, 2016. Conservation of flora as a function of forestry. Ital. J. Agron. 11(s1):1-175.

Lombardi F, Mali B, 2016. Deadwood as a driver of forest functions. Ital. J. Agron. 11(s1):1-175.

ManFor C.BD sites and the drivers of forest functions

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Sites description

For the Italian sites, the geographic coordinates refer to the centroid of the total Forest Management Unit (FMU) and the altitudinal ranges refer to the small area (10 km^2) (small square frame presented for each site). For both Italian and Slovenian sites, the landscape characteristics of sites refer to the 100 km^2 area (big square frame presented for each site).

In description of landscape driving force at Italian sites, the percentage amount of land uses classes refers to the Corine Land Cover (CLC) data (1:100,000) from 2006. Urban areas percentages refer to the class 1.1.1: 'Continuous urban fabric' and 1.1.2: 'Discontinuous urban fabric'. Agricultural areas percentages refer to the class 2: 'Agricultural areas'. The percentage of forest areas refers to the class 3.1: 'Forests'. The other semi-natural lands percentages refer to the class 3.2: 'Shrubs and/or herbaceous vegetation associations'. For Slovenian sites the main landscape characteristics of landscape refer to Agricultural land cover data (1:5000) from 2012 (Ministry of Agriculture and Environment). The forest core area, defined as the forest area sufficiently far from the forest edge in percentage is provided. The distance from the forest edge was uniformly defined for Italian (100 m) and for Slovenian sites (300 m). A summary description of driving forces is also provided for each site. General characteristics of plots and structural diversity indexes for test site are provided.

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Key words: management options, forest functions, silviculture, biodiversity, carbon retention, Life ManFor C.BD, landscape driving forces silviculture driving forces, Slovenia, Italy

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

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 mesuring parameters (species, dbh, height, tree position, social rank, crown projections, etc.). At Lorenzago site a different approach was applied, six plots only were established.

For each site, the results presented in the relevant Tables are the average of the circular sampling plots with their standard deviations (SD).

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), Schröder and von Gadow (1999), Staudhammer and LeMay (2011).

Site 1. Cansiglio, Italy

General description of site

The area is located in the Veneto Region, in Province of Belluno (at the border with the Province of Treviso) (Figures 1-5; Tables 1-4).

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

The total area is 667 ha, and the dominant species is the beech. The main management type is high forest treated with shelterwood cuttings. Generally, 700-1000 m^3 of wood is extracted per intervention, over 10 to 15 ha.

Table 1. Cansiglio. General characteristics of site.

Nation	Italy
Region	Veneto
Management authority	National Forestry Service
Geographic coordinates	46°2'33.727" N - 12°22'41.519" E (WGS84-UTM)
Altitudinal range (m asl)	1040 ÷ 1450
Site protection	Natural Biogenetic Reserve: Pian Parrocchia-Campo di Mezzo; Special Protection Zone (ZPS, 79/409/CEE) and Sites of Community Importance (SIC, 92/43/CEE).
Forest type	Illyrian mountainous beech forest

Figure 1. Cansiglio. Site location.

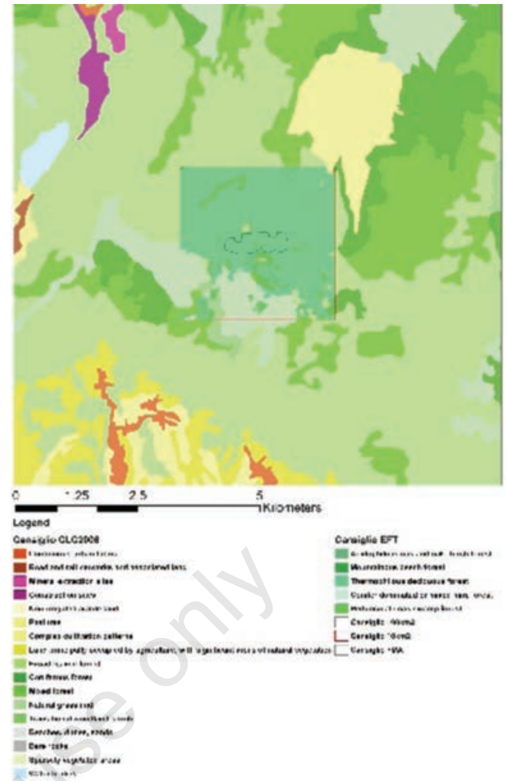

Figure 2. Cansiglio. Landscape map (100 km^2).

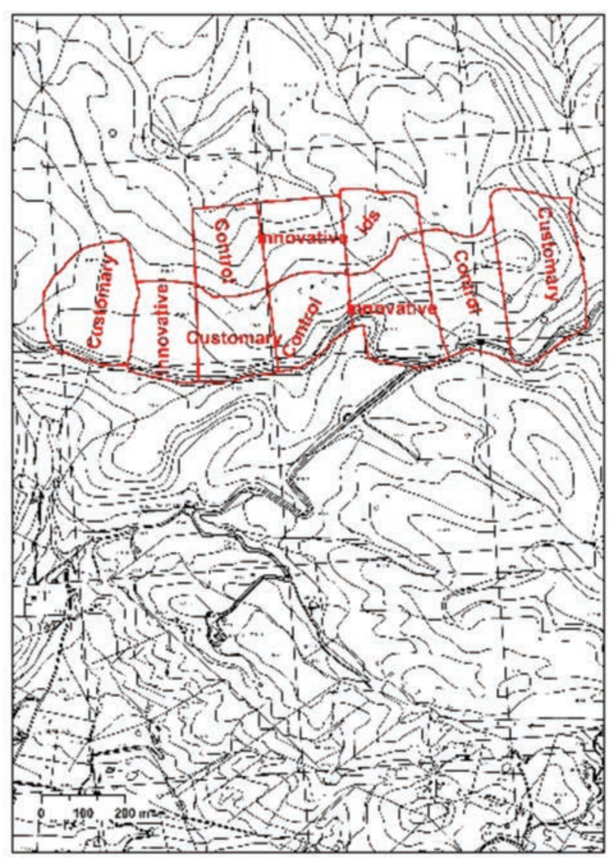

Figure 3. Cansiglio. Forest management area map.

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Table 2. Cansiglio. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Control	mean	332	40.2	342.4	39.5	26.5	56.2	28.3
	st. dev.	75	4.8	35.2	2.4	0.4	4.4	0.2
Innovative	mean	321	41.9	561.2	41.6	26.7	53.9	28.2
	st. dev.	40	3.3	31.0	1.6	0.2	1.9	1.2
Customary	mean	339	39.6	524.0	39.5	26.5	51.8	27.8
	st. dev.	15	5.8	96.3	2.5	0.4	1.2	0.9
After thinning								
Innovative	mean	179	26.6	360.1	44.1	27.1		
	st. dev.	21	1.8	8.0	1.7	0.2		
Customary	mean	226	29.8	397.1	41.0	26.7		
	st. dev.	17	4.0	66.2	1.3	0.2		

Table 3. Cansiglio. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Control	mean	0.77	0.81	1.00	1.22	0.25	0.11	0.53	0.16
	st. dev.	0.11	0.23	0.19	0.13	0.06	0.03	0.25	0.07
Innovative	mean	0.66	0.77	0.97	1.22	0.19	0.07	0.31	0.05
	st. dev.	0.07	0.07	0.09	0.08	0.03	0.02	0.09	0.02
Customary	mean	0.67	0.79	0.95	1.24	0.19	0.06	0.28	0.06
	st. dev.	0.05	0.08	0.06	0.05	0.03	0.01	0.11	0.06
After thinning									
Innovative	mean	0.46	0.34	0.47	1.38	0.19	0.07	0.27	0.04
	st. dev.	0.04	0.04	0.03	0.04	0.02	0.02	0.09	0.02
Customary	mean	0.53	0.47	0.59	1.34	0.18	0.06	0.26	0.07
	st. dev.	0.03	0.10	0.12	0.02	0.04	0.00	0.09	0.08

Table 4. Cansiglio. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
1.32	11.69	76.55	8.61	65.89

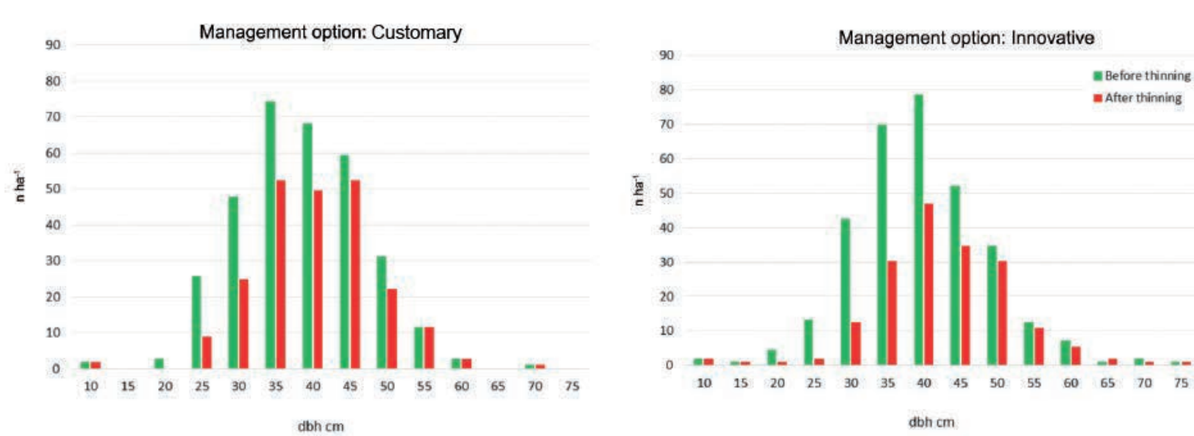

Figure 4. Cansiglio. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

The forest is included in Special Protection Zones (ZPS, 79/409/CEE) and in 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).

Total area of the FMU is 35 ha. Altitude within FMU ranges from 1100 m to 1200 m asl.

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 thinning 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, this 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).

The traditional silvicultural system

The traditional system was optimal when framed within 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 provide longer rotations. The achievement of older stand ages implies to maintain the current sequestration ability and higher growing stocks as long as possible. Furthermore, the present homogeneous structure of cultivated beech forests clashes with structural diversity connected to the landscape and functional values of mature forest stands.

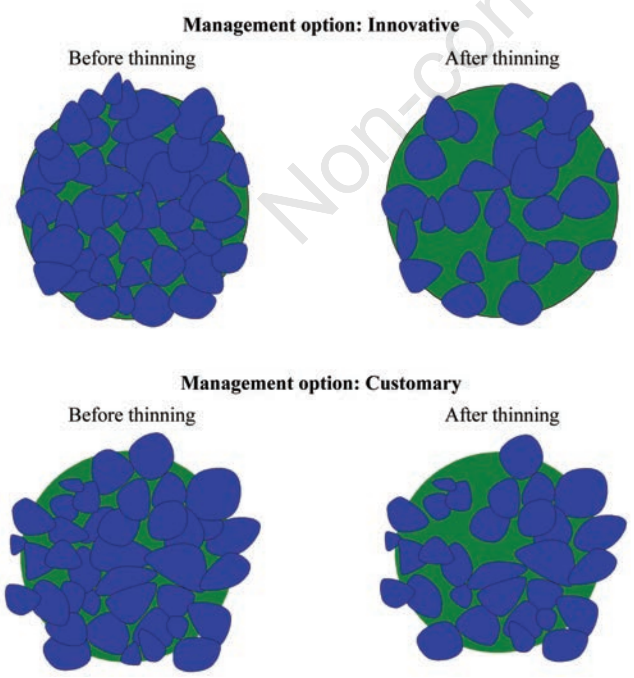

Figure 5. Cansiglio. Effect of the silvicultural treatment on canopy cover.

The innovative criteria applied: proposed management options

The demonstrative/innovative criteria consisted of the identification of a non-fixed number of scattered, well-shaped trees (usually in the predominant-dominant social classes) and crown thinning of neighbouring competitors to promote better growth ability of selected trees at crown, stem and root level in the future. These would be the main key-actions able to reach the final, overmature stages and to regenerate the forest. The resulting harvested amount of wood is not far from the one extracted by traditional thinning, but its spatial arrangement is different on the ground and at crown level. Shape, size and distribution of canopy gaps are also different between the traditional and the new practice approach. The remaining standing crop is fully maintained and would produce differentiation in crown layer, stem distribution and stem size. Mortality of dominated or defective trees would 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, with also no-intervention or delayed-intervention measure, which in the context of beech high forests has sound reasons to be tested because of its wide application in similar conditions.

In addition, a further area has been planned where implement an 'ageing patch' literally from French 'îlot de sénescence'. It consists of an area wide up to a few hectares where trees are left to an indefinite ageing up to their death and decay; where holes on standing trees and snags are being created, where a part of living stems are partially cut along outer circumference up to cambium to make them becoming dead standing trees or felled and left on the ground to establish micro-habitats, niches and corridors to insects and micro-fauna.

Site 2. Chiarano Sparvera, Italy

General description of site

The area is located in the Abruzzo 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 site (SIC IT7110053) (Figures 6-10; Tables 4-6).

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

The main historical management type is coppice with standards, and is now under conversion to high forest. During last 20 years, the treatments aimed towards converting coppice to high forest and towards thinnings to increase structural diversity (also under LIFE NAT/IT/006244 and LIFE04 NAT/IT/00190). The selected stand is not included in Sites of Community Importance (SIC) or Special Protection Zones (ZPS) of Natura 2000 network.

Total area of Forest Management Unit is ~ 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 asl (Table 8).

The site lies in a beech forest located at the upper tree vegetation layer in the Central Apennines and has been managed as the coppice system up to mid 19th century. Following the suspension

Table 5. Chiarano Sparvera. General characteristics of site.

Nation	Italy
Region	Abruzzo
Management authority	Regional Forests
Geographic coordinates	41°50'40.92" N - 13°58'2.999" E (WGS84-UTM)
Altitudinal range (m asl)	1525 ÷ 2085
Site protection	External zone of the National Park of Abruzzo-Lazio-Molise and partially in Natura 2000 sites
Forest type	Apennine Corsican mountainous beech forest

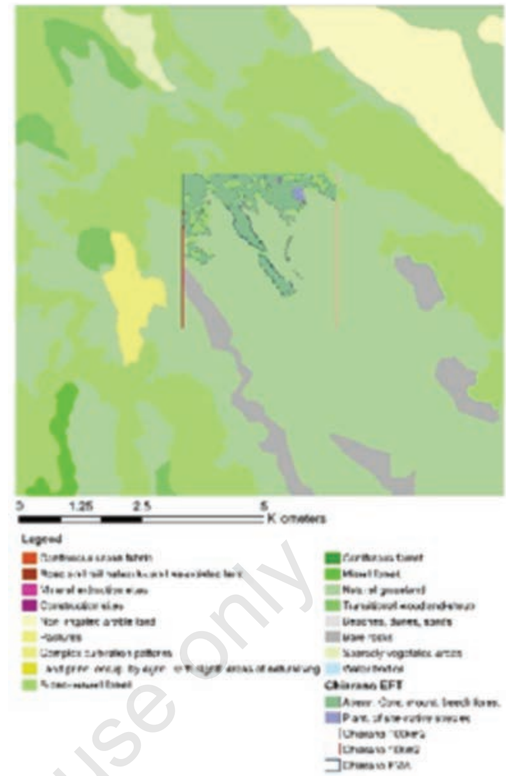

Figure 7. Chiarano Sparvera. Landscape map (100 km^2).

Figure 6. Chiarano Sparvera. Site location.

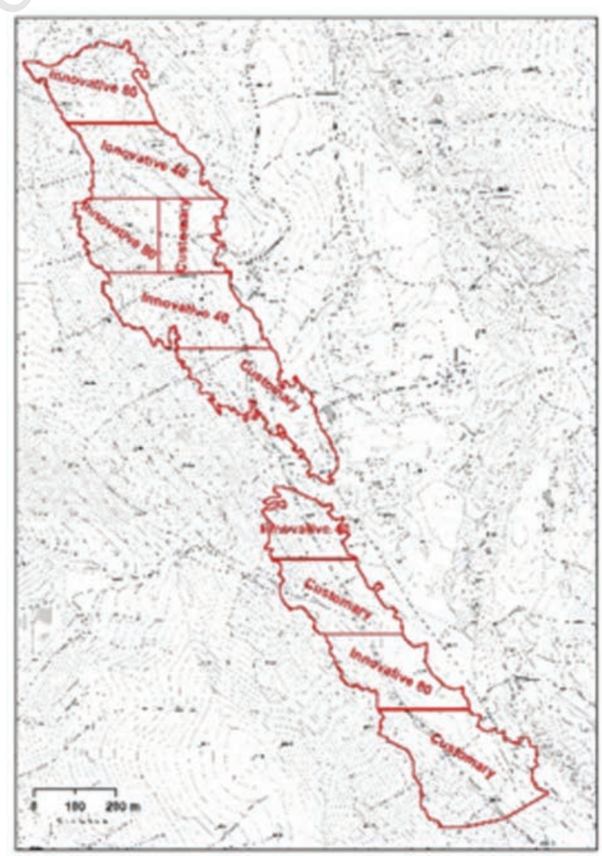

Figure 8. Chiarano Sparvera. Forest management area map.

of fuelwood harvesting, the conversion into high forest has been applied on two-thirds of the original coppice cover, while the remaining forest consists of aged coppice structures. The designated area, 70 years old, 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 for the first time few years after the end of former rotation and up to the age of regeneration establishment from seed. This step closes the conversion stage and opens the high forest cycle. The abovementioned silvicultural system is applied throughout the Apennines and pre-Alpine area of the country.

The traditional silvicultural system

The traditional system works well if site-index is sufficient (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, with limited dbh range and a homogeneous distribution of trees and crown volumes.

The innovative criteria applied: proposed management options

The applied demonstrative/innovative criteria 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 of cutting all surrounding competitors. Intercropping trees were fully released or removed only along hauling courses. In such way, the overall stand structure has been moved both at stem and at crown level. The high tree density of

Table 6. Chiarano Sparvera. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Innovative 40	mean	1530	40.2	296.6	18.6	14.1	29.3	16.7
	st. dev.	110	2.6	31.7	1.3	0.4	1.0	0.4
Innovative 80	mean	1295	40.4	303.8	20.3	14.6	31.7	17.1
	st. dev.	215	1.8	35.2	2.1	0.6	3.2	1.0
Customary	mean	1277	36.7	267.3	19.7	14.4	30.3	16.5
	st. dev.	330	5.0	45.7	2.0	0.6	3.9	0.8
After thinning								
Innovative 40	mean	659	23.0	177.1	21.5	14.9		
	st. dev.	66	1.0	10.9	1.1	0.3		
Innovative 80	mean	645	24.8	192.1	22.7	15.3		
	st. dev.	172	0.6	9.7	2.7	0.7		
Customary	mean	594	23.1	177.2	23.3	15.4		
	st. dev.	198	3.8	22.7	3.2	0.8		

Table 7. Chiarano Sparvera. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Innovative 40	mean	0.68	2.27	2.29	1.11	0.26	0.14	0.20	0.06
	st. dev.	0.02	0.07	0.08	0.01	0.01	0.01	0.05	0.01
Innovative 80	mean	0.63	1.67	1.91	1.19	0.27	0.14	0.22	0.06
	st. dev.	0.06	0.16	0.05	0.09	0.03	0.02	0.09	0.03
Customary	mean	0.59	1.77	1.88	1.19	0.25	0.13	0.20	0.05
	st. dev.	0.08	0.65	0.48	0.09	0.03	0.01	0.11	0.02
After thinning									
Innovative 40	mean	0.39	0.73	0.81	1.23	0.23	0.11	0.17	0.04
	st. dev.	0.02	0.08	0.06	0.01	0.01	0.01	0.06	0.01
Innovative 80	mean	0.40	0.64	0.78	1.29	0.24	0.12	0.18	0.04
	st. dev.	0.02	0.17	0.18	0.10	0.02	0.02	0.04	0.01
Customary	mean	0.33	0.66	0.79	1.29	0.18	0.08	0.13	0.02
	st. dev.	0.05	0.30	0.29	0.11	0.02	0.01	0.09	0.01

Table 8. Chiarano Sparvera. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
-	9.03	34.78	51.42	22.05

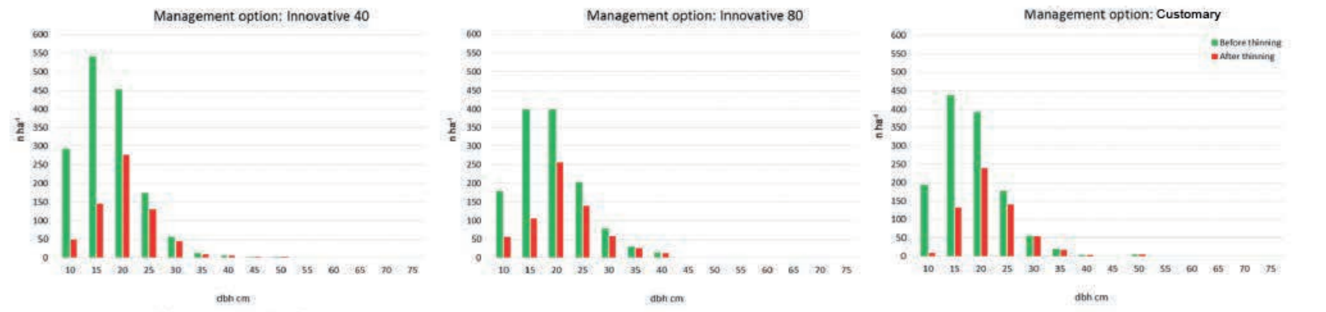

Figure 9. Chiarano Sparvera. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

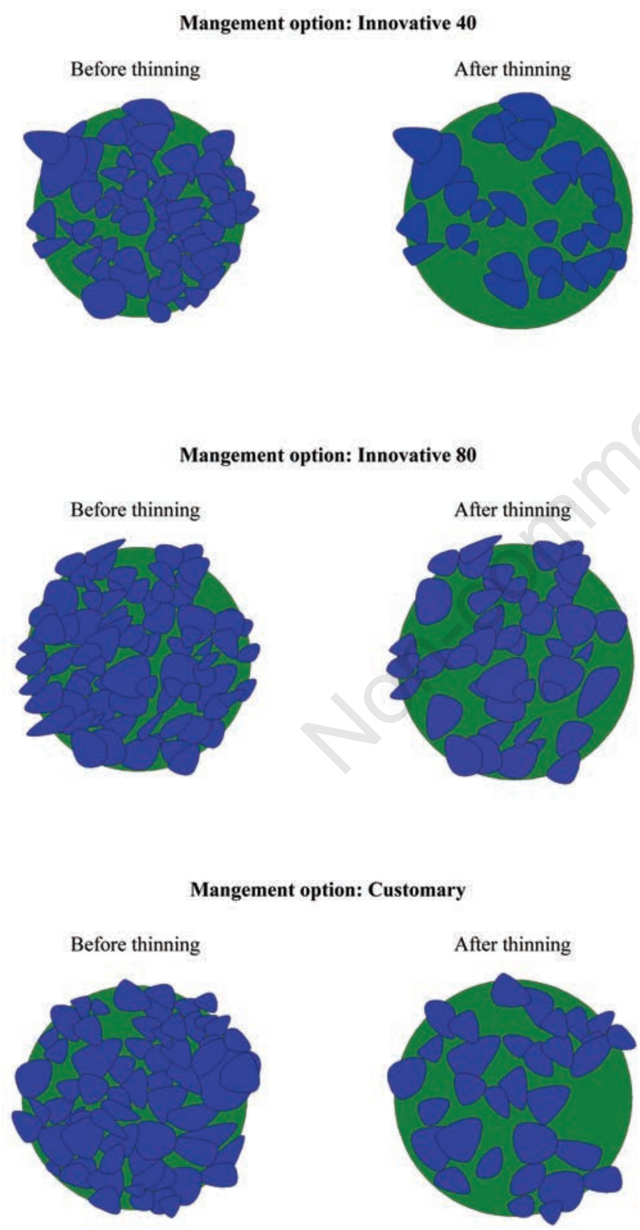

Figure 10. Chiarano Sparvera. Effect of the silvicultural treatment on canopy cover.

intercropped stand would promote regular mortality and deadwood enrichment, where the establishments of further habitats and related niches would be favoured. The trial compares the traditional technique and two innovative approaches different as for the selected tree number (40-80) per unit area.

Site 3. Lorenzago di Cadore, Italy

General description of site

The area located in the territory of the town of Lorenzago di Cadore, province of Belluno where the forest is owned by the village of Lorenzago di Cadore (Figures 11-16; Tables 8-13).

The total area is 1100 ha in size. It is bordering Friuli Venezia Giulia Region. The climate is of Mesalpic type and the altitudinal range is 800-1800 m asl.

According to altitude, the forest types are different:

fir forests of carbonatic and siliceous soils (800 - 1300 m);

secondary montane 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), natural regeneration is present in all 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 - 1220 m asl (Table 13). 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 already-established 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.

The traditional silvicultural system

Mature trees and groups of dense intermediate-sized trees determine

Table 9. Lorenzago di Cadore. General characteristics of site.

Nation	Italy
Region	Veneto
Management authority	Village of Lorenzago di Cadore
Geographic coordinates	46°28'21.713" N - 12°28'13.079"E (WGS84-UTM)
Altitudinal range (m asl)	694 ÷ 1425
Site protection	Special Protection Zone of the Alps (ZPS - IT3230089: 'Dolomiti of Cadore and Comelico') containing two Sites of Community Importance (SIC, 92/43/CEE). Forests of Lorenzago are certified for Sustainable Forest Management by PEFC
Forest type	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest; subalpine larch arolla pine and dwarf pine forest.

Figure 11. Lorenzago di Cadore. Site location.

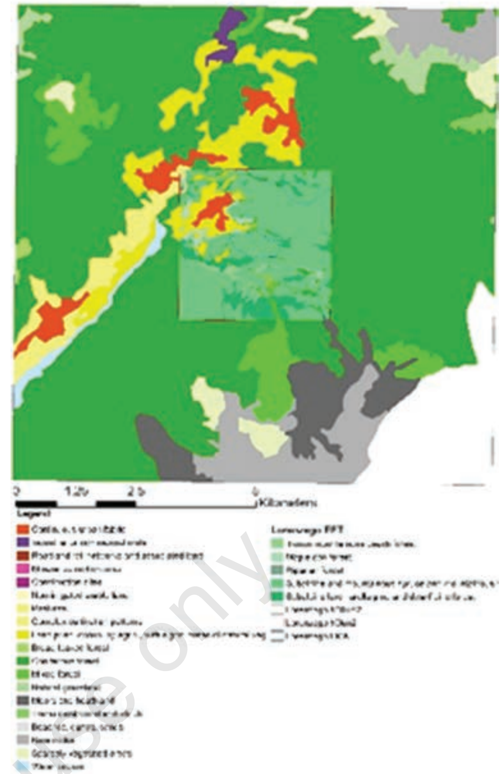

Figure 12. Lorenzago di Cadore. Landscape map (100 km²).

Figure 13. Lorenzago di Cadore. Forest management area map.

Table 10. Lorenzago di Cadore. Main mensurational parameters before and after thinning.

Area 1	Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning							
Control	750	63.5	847.1	32.8	30.7	63.4	34.5
Innovative	686	53.3	748.1	31.4	29.9	68.9	37.1
Customary	580	58.8	937.0	35.9	32.4	71.5	42.5
After thinning							
Innovative	608	43.1	596.5	30.0	29.0		
Customary	488	46.4	719.6	34.8	31.8		

Table 11. Lorenzago di Cadore. Main mensurational parametres before and after thinning.

Area 2	Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning							
Control	520	55.1	875.5	36.7	32.8	68.2	38.5
Innovative	481	54.6	828.2	38.0	33.5	58.4	38.3
Customary	676	58.0	904.2	33.0	30.82	59.0	37.6
After thinning							
Innovative	216	28.1	424.1	40.7	34.7		
Customary	389	43.2	693.1	37.6	33.3		

Table 12. Lorenzago di Cadore. Main structural diversity index before and after thinning.

Area 1	BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning								
Control	3.00	2.37	2.75	0.98	0.41	0.36	0.93	0.82
Innovative	3.46	1.56	2.37	0.90	0.41	0.46	1.00	0.99
Customary	3.44	1.60	2.19	1.00	0.44	0.43	1.00	1.00
After thinning								
Innovative	3.22	1.09	1.91	0.86	0.47	0.46	1.00	0.99
Customary	3.02	1.39	1.80	0.99	0.44	0.43	1.00	1.00

Table 13. Lorenzago di Cadore. Main structural diversity index before and after thinning.

Area 2	BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning								
Control	2.80	2.21	2.42	0.92	0.43	0.34	0.83	0.85
Innovative	2.18	1.82	2.00	1.03	0.36	0.27	0.67	0.62
Customary	2.97	1.21	1.65	1.03	0.50	0.46	1.00	1.00
After thinning								
Innovative	1.32	0.82	0.97	0.80	0.32	0.25	0.60	0.55
Customary	1.80	1.31	1.23	0.94	0.35	0.25	0.60	0.60

Table 14. Lorenzago di Cadore. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
2.55	7.82	68.04	6.13	57.49

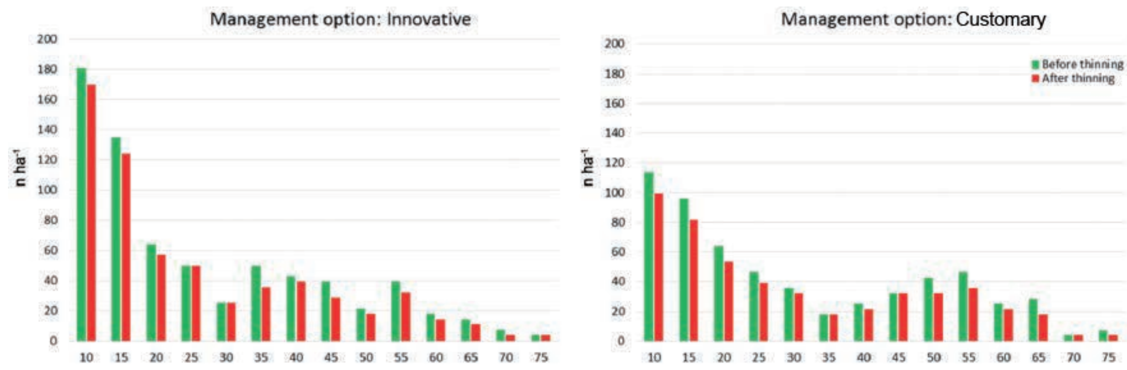

Figure 14. Lorenzago di Cadore, Area 1. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

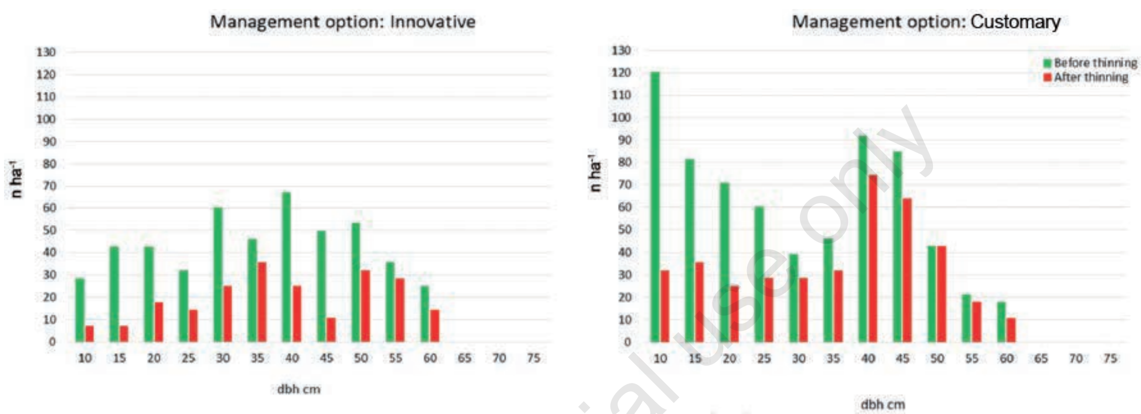

Figure 15. Lorenzago di Cadore, Area 2. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

growing stock that is exceeding regular stocking. Such condition raises because of shading, affecting survival and growth of the established regeneration and preventing 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: proposed management options

The contemporary harvesting of a few mature trees and thinning of intermediate-sized trees is arranged into small groups, and allows minimal interventions with 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 top height). Such practice contributes to a more balanced structure, triggering establishment of regeneration (canopy opening) and consenting 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 along the strips are being released. Cutting, as usual, connects strips. Beech regeneration (eradicated in the past because of low value compared to fir or spruce timber) is always favoured to enhance tree species diversity.

The different management options were applied in two different areas (Area 1 and Area 2).

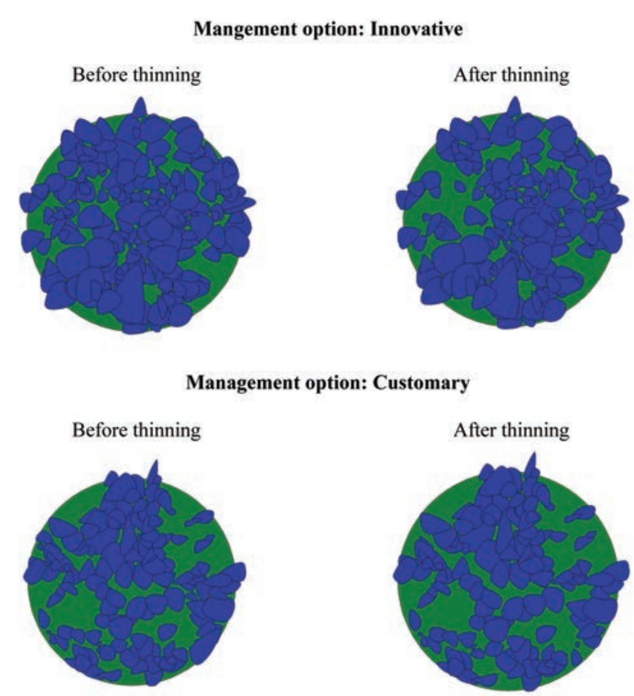

Figure 16. Lorenzago di Cadore, Area 1. Effect of the silvicultural treatment on canopy cover.

Site 4. Mongiana, Italy

General description of site

The area is located in the Calabria Region, Province of Vibo Valentia. The management is directly carried on by the National Forestry Service of Italy (CFS) (Figures 17-21; Tables 15-18).

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 asl.

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 interventions

Table 15. Mongiana. General characteristics of site.

Nation	Italy
Region	Calabria
Management authority	Italian State forests
Geographic coordinates	38°29'52.433" N - 16°14'28.316" E (WGS84-UTM)
Altitudinal range (m asl)	894 ÷ 1276
Site protection	Marchesale Biogenetic Reserve and Natura 2000 site
Forest type	Subatlantic submountainous beech forest

Figure 17. Mongiana. Site location.

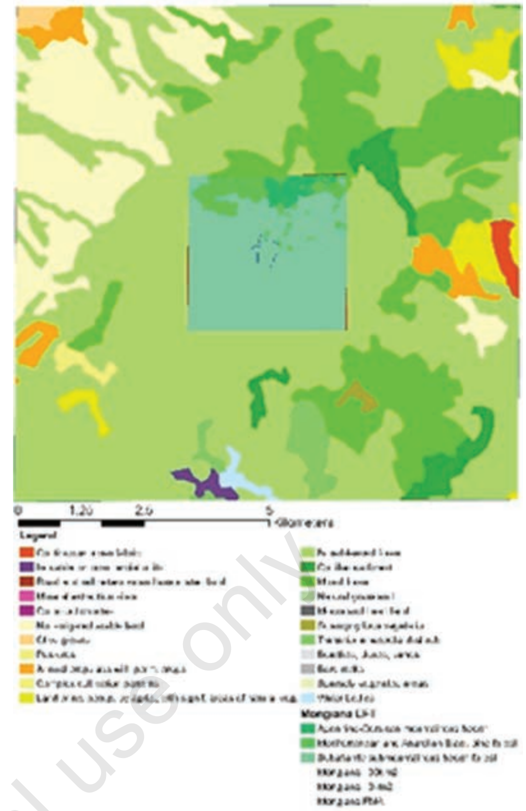

Figure 18. Mongiana. Landscape map (100 km²).

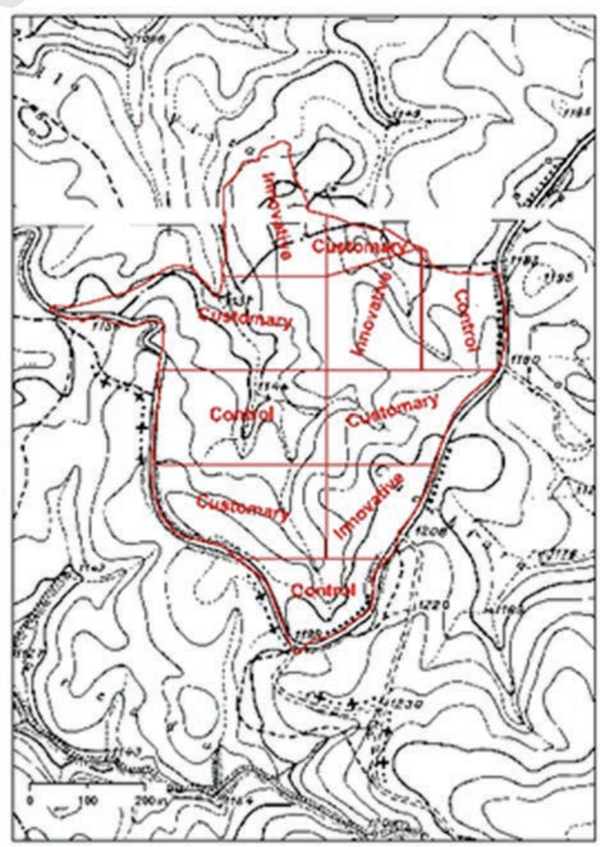

Figure 19. Mongiana. Forest management area map.

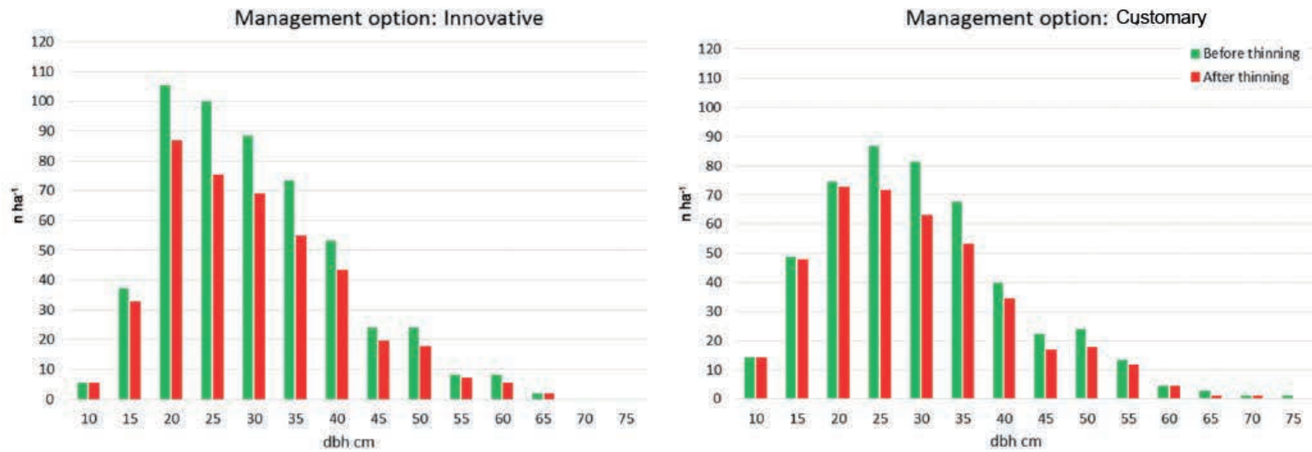

Figure 20. Mongiana. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

Table 16. Mongiana. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Control	mean	523	41.2	495.4	32.2	23.2	50.5	26.9
	st. dev.	71	2.0	16.2	2.9	0.7	4.9	1.1
Innovative	mean	528	41.6	484.3	32.3	23.2	49.9	25.4
	st. dev.	90	7.0	112.3	5.2	1.4	7.2	1.3
Customary	mean	480	38.7	471.7	33.5	23.4	51.2	26.8
	st. dev.	94	5.2	101.6	6.2	1.5	7.6	2.2
After thinning								
Innovative	mean	418	32.6	380.2	32.1	23.1		
	st. dev.	78	6.2	61.5	4.7	1.3		
Customary	mean	408	31.4	381.3	33.2	23.3		
	st. dev.	112	1.9	51.1	5.8	1.3		

Table 17. Mongiana. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Control	mean	0.95	1.13	1.31	1.13	0.24	0.12	0.53	0.15
	st. dev.	0.10	0.33	0.20	0.01	0.01	0.00	0.14	0.04
Innovative	mean.	0.93	1.22	1.25	1.14	0.24	0.11	0.46	0.10
	st. dev.	0.06	0.22	0.16	0.13	0.02	0.01	0.12	0.02
Customary	mean	0.95	1.19	1.24	1.16	0.25	0.12	0.50	0.14
	st. dev.	0.08	0.23	0.19	0.25	0.02	0.02	0.12	0.05
After thinning									
Innovative	mean	0.84	0.84	0.96	1.21	0.25	0.11	0.49	0.11
	st. dev.	0.07	0.16	0.20	0.10	0.02	0.01	0.12	0.02
Customary	mean	0.86	0.90	0.89	1.21	0.25	0.13	0.49	0.15
	st. dev.	0.13	0.27	0.23	0.09	0.03	0.02	0.08	0.06

Table 18. Mongiana. General landscape characteristics

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
0.82	17.33	78.81	1.81	68.34

were implemented over 108 ha.

Total area of Foret Management Unit is ~30 ha. Altitude within FMU ranges from 1000 m to 1100 m asl (Figure 19).

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 to the end of the World War II. The designated compartment is about 70 years old. Its location in the upper part of the mountain system is typical for beech forests in Southern Apennines. The interception of fogs, wet winds and rain originated on the sea makes the physical environment sufficiently moist all over the year. As for the 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.

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 and Spampinato, 2006).

The innovative criteria applied: proposed management options

The demonstrative/innovative criteria consisted of the identification of 45-50 trees per hectare i.e. 'the candidate trees' and removal of direct competitors. Couples of neighbouring trees have been selected for 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 the one applied at the Cansiglio forest. 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.

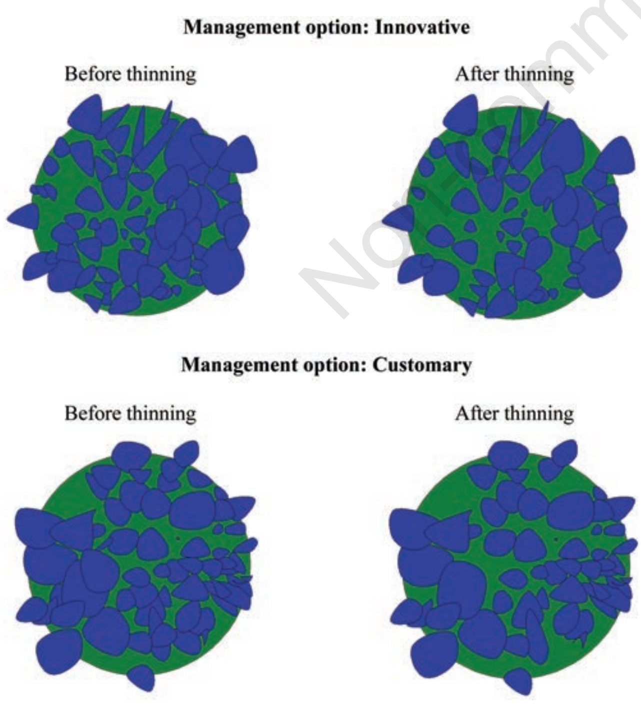

Figure 21. Mongiana. Effect of the silvicultural treatment on canopy cover.

Site 5. Montedimezzo-Pennataro, Italy

General description of site

The area is located in the Molise Region, Province of Isernia, close (or included in) to Montedimezzo Natural State Reserve, established 1971; MAB-UNESCO Biosphere Reserve; Natura 2000 SIC and ZPS sites (Figures 22-26; Tables 19-22).

The total area is ~400 ha and its altitudinal range is 900-1300 m asl. The forest type: pure or mixed stands of Turkey oak (*Quercus cerris*) (lower elevation) beech forest, generally monolayered (higher elevation). The main management type is high forest.

The future management plan includes measures especially for experimental and educational purpose 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 Foret Management Unit is ~30 ha. Altitude within FMU ranges from 900 m to 1000 m asl (Figure 24).

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; steep slopes and presence of large rocky outcrops make forests 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 main stand ages prevail: young and overgrown forest, originated from the coppice system applied in the past and from the management under the high forest system.

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 from the end of 1800.

The traditional silvicultural system

The traditional system performed extensive low thinnings over the last 40 years and a few seed cuttings in the aged forest patches - not followed by the removal of seed trees - suspended any active forest management. Such condition favoured other species like than oaks to provide mixed forest. The main management type is high forest and aged coppice, partly in conversion to high forest (Garfi e Marchetti, 2011; Marchetti, 2008).

Table 19. Montedimezzo-Pennataro. General characteristics of site.

Nation	Italy
Region	Molise
Management authority	Italian State forests
Geographic coordinates	41°44'21.124" N - 14°11'37.679" E (WGS84-UTM)
Altitudinal range (m asl)	821 ÷ 1206
Site protection	Collemeluccio Natural State Reserve; MAB-UNESCO Biosphere Reserve; Natura 2000 SIC and ZPS sites.
Forest type	Downy oak forest; Subatlantic submountainous beech forest

Figure 22. Montedimezzo-Pennataro. Site location.

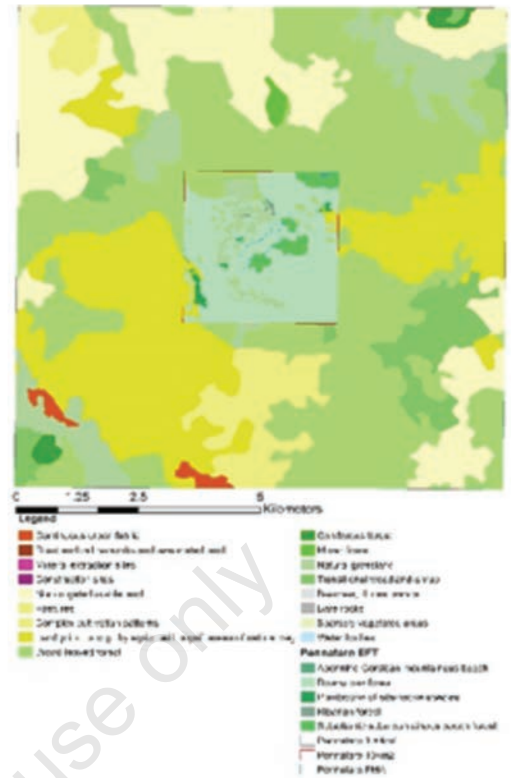

Figure 23. Montedimezzo-Pennataro. Landscape map (100 km²).

Figure 24. Montedimezzo-Pennataro. Forest management area map.

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Table 20. Montedimezzo-Pennataro. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Turkey oak forest	mean	2281	43.7	457.1	16.3	17.1	41.9	23.3
	st. dev.	345	2.2	54.7	1.1	0.8	4.6	1.2
Mixed forest	mean	1684	38.6	402.6	16.7	17.4	44.1	25.5
	st. dev.	303	4.6	63.3	1.3	0.7	2.7	1.3
After thinning								
Turkey oak forest	mean	943	25.3	275.1	19.4	18.8		
	st. dev.	266	3.5	54.0	2.2	1.1		
Mixed forest	mean	817	24.9	274.1	20.1	19.2		
	st. dev.	139	4.4	58.8	2.7	1.2		

Table 21. Montedimezzo-Pennataro. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Turkey oak forest	mean	1.28	1.98	1.99	1.05	0.41	0.31	0.77	0.56
	st. dev.	0.06	0.45	0.29	0.03	0.02	0.02	0.14	0.08
Mixed forest	mean	1.39	2.12	2.11	0.97	0.40	0.29	0.88	0.63
	st. dev.	0.15	0.26	0.12	0.05	0.02	0.02	0.06	0.12
After thinning									
Turkey oak forest	mean	0.83	0.72	0.76	1.15	0.43	0.32	0.75	0.51
	st. dev.	0.08	0.19	0.11	0.05	0.03	0.02	0.16	0.13
Mixed forest	mean	1.00	0.82	0.92	1.13	0.42	0.30	0.83	0.63
	st. dev.	0.17	0.09	0.08	0.10	0.03	0.03	0.18	0.16

Figure 25. Montedimezzo Pennataro. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

The innovative criteria applied: proposed management options

Two pro-active theses have been 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 the inner areas of Central Apennines. The other thesis aimed towards natural evolution of mixed forest, which is now prevailing as the extensive management practice. The first option consists of the identification of 60 trees per hectare, *i.e.* 'tree candidate', of Turkey oak among the best individuals. Around the candidate a selective thinning is performed to facilitate the expansion of the crown and growth, while individuals of Turkey oak that are not competitiors are left. Low to crown thinning has been applied 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 would not harvested to avoid a new growth from the stump. The second treatment consists of the identification of tree candidates of different species from the Turkey oak 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 view of biodiversity, in both options, living or dead trees that provide ecological niches (microhabitats) such as cavities, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot are preserved.

In addition, a further area has been planned where implement an 'ageing patch' literally from French 'îlot de sénescence'. It consists of an area wide up to a few hectares where trees are left to an indefinite ageing up to their death and decay; where holes on standing trees and snags are being created, where a part of living stems are partially cut along outer circumference up to cambium to make them becoming dead standing trees or felled and left on the ground to establish micro-habitats, niches and corridors to insects and micro-fauna.

Table 22. Montedimezzo Pennataro. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
0.53	43.86	42.46	12.23	36.68

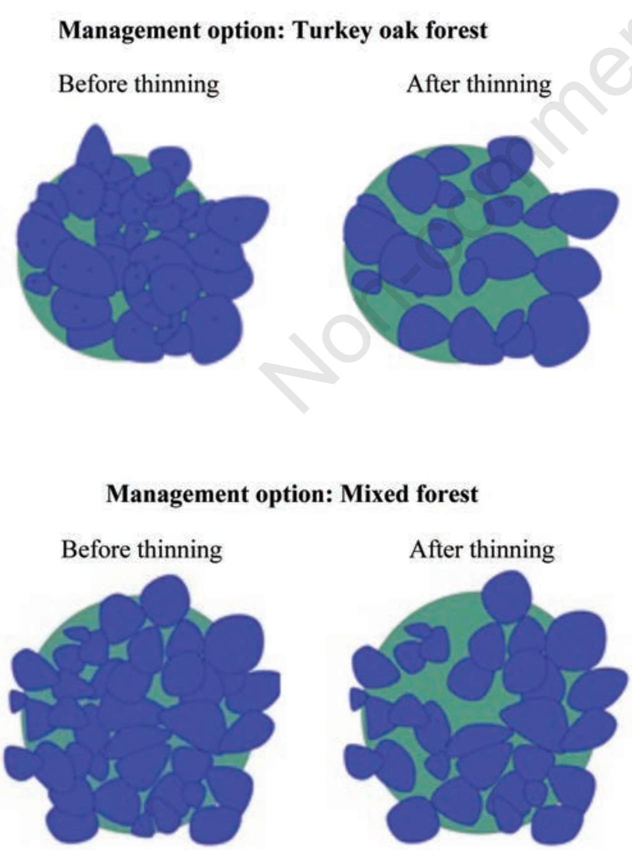

Figure 26. Montedimezzo Pennataro. Effect of the silvicultural treatment on canopy cover.

Site 6. Tarvisio, Italy

General description of site

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 (Figures 27-31; Tables 23-26).

The total area is 23.362 ha, 15.152 ha with forests. The altitudinal range is 750-2750 m (asl) with two main forest types: mixed forests of spruce, beech, pine (8946 ha) and 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 forests 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 (*Pinus sylvestris*) (4,5%). The average growing stock is 280 m^3/ha, the increment 4.58 m3 ha^{-1} yr^{-1}. Annual cuttings is of 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 asl (Figure 29).

The designated forest compartment is a Norway spruce and silver fir pole stage forest 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 are in the upper part only; scattered broadleaves (mainly beech) reach the main crop layer as co-dominant and dominant trees.

The traditional silvicultural system

This stage of the life cycle was traditionally submitted to pre-commercial thinnings to reduce inter-tree competition and manage the release of main crop population. Now, no such practices

Table 23. Tarvisio. General characteristics of site.

Nation	Italy
Region	Friuli-Venezia Giulia
Management authority	'Fondo Edifici del Culto' of Ministry of Internal Affairs, under direct management by UTB-Tarvisio
Geographic coordinates	46°29'16.084" N - 13°36'10.08" E (WGS84-UTM)
Altitudinal range (m asl)	1000 ÷ 1100
Site protection	The forest is partly included in Special Protection Zones (ZPS, 79/409/CEE) and in Sites of Community Importance (SIC, 92/43/CEE)
Forest type	Subalpine and mountainous spruce and mountainous mixed spruce silver fir forest; Subalpine larch arolla pine and dwarf pine forest; Alpine Scots pine and Black pine forest.

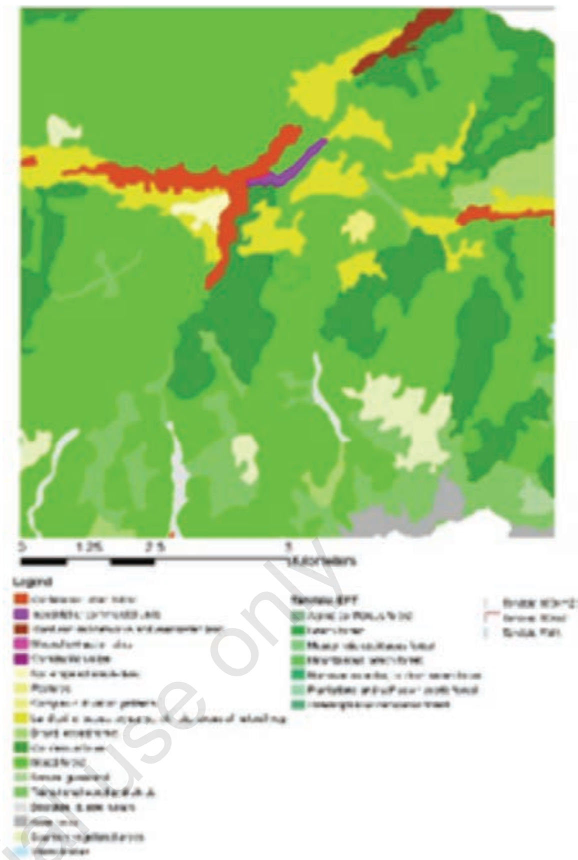

Figure 28. Tarvisio. Landscape map (100 km^2).

Figure 27. Tarvisio. Site location.

Figure 29. Tarvisio. Forest management area map.

Table 24. Tarvisio. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Innovative 1	mean	1501	47.7	424.7	20.4	18.2	35.0	22.3
	st. dev.	171	3.5	41.3	0.5	0.1	1.6	0.4
Innovative 2	mean	1513	37.9	326.6	18.8	17.5	33.3	21.5
	st. dev.	279	2.2	18.8	1.1	0.6	2.1	0.7
Customary	mean	1438	35.7	320.3	18.3	17.3	33.7	21.7
	st. dev.	250	9.8	104.6	1.4	0.5	2.1	1.5
After thinning								
Innovative 1	mean	590	25.8	246.7	24.1	19.5		
	st. dev.	79	3.9	42.1	1.1	0.2		
Innovative 2	mean	904	24.7	219.6	21.0	18.3		
	st. dev.	525*	4.1	27.4	2.8	1.2		
Customary	mean	1073	28.5	259.5	19.2	17.7		
	st. dev.	369	5.1	44.4	2.8	1.1		

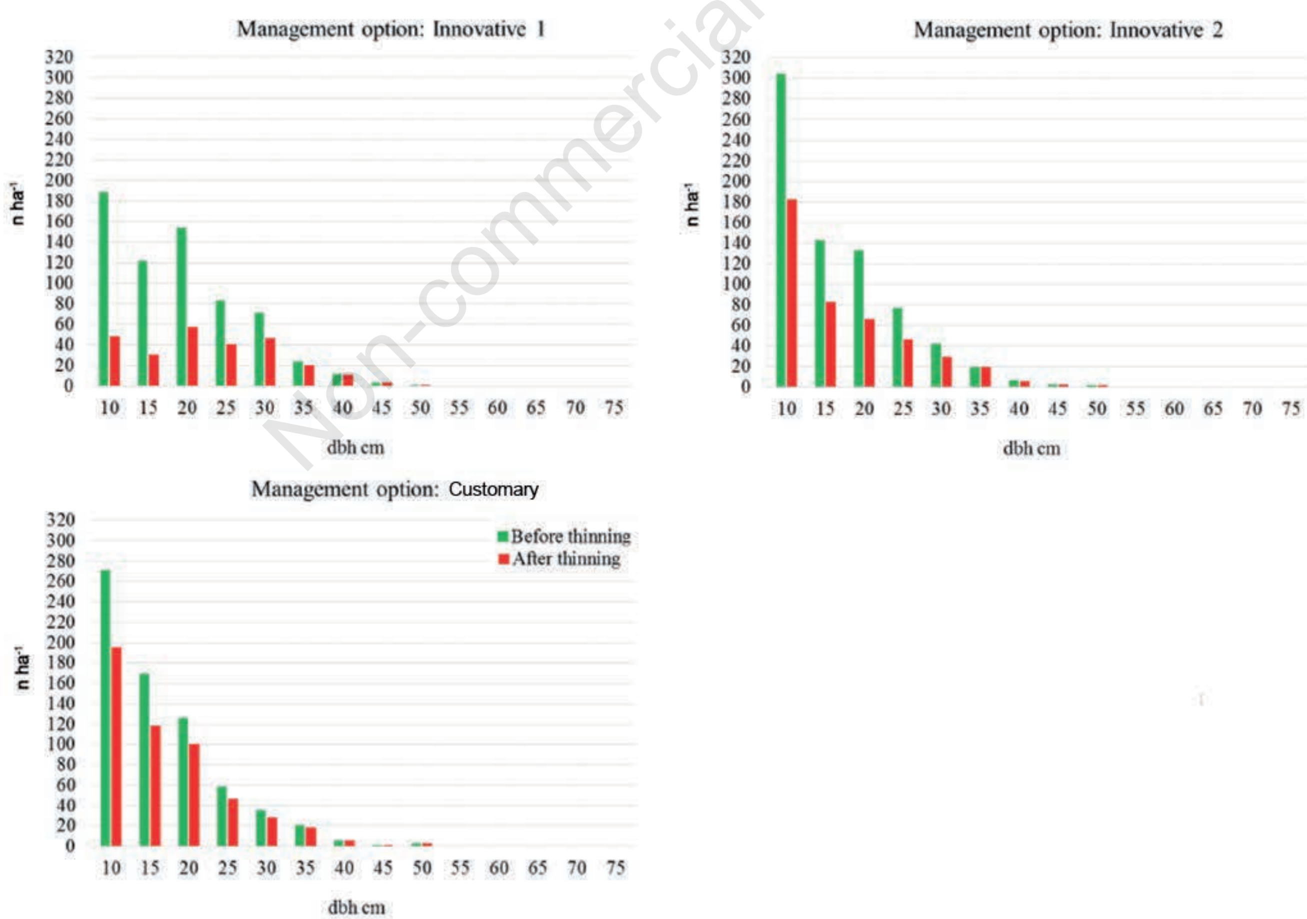

Figure 30. Tarvisio. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

Table 25. Tarvisio. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Innovative 1	mean	1.04	3.14	2.84	0.94	0.32	0.24	0.37	0.27
	st. dev.	0.04	0.38	0.29	0.05	0.01	0.02	0.04	0.04
Innovative 2	mean	1.02	3.24	2.70	0.92	0.30	0.21	0.36	0.24
	st. dev.	0.02	0.37	0.13	0.06	0.02	0.04	0.08	0.12
Customary	mean	1.07	2.81	2.57	0.95	0.30	0.22	0.42	0.29
	st. dev.	0.15	0.56	0.61	0.06	0.01	0.06	0.11	0.10
After thinning									
Innovative 1	mean	0.55	1.05	1.04	1.07	0.32	0.18	0.33	0.15
	st. dev.	0.08	0.14	0.06	0.10	0.05	0.05	0.06	0.03
Innovative 2	mean	0.74	1.68	1.40	1.05	0.32	0.20	0.36	0.20
	st. dev.	0.18	1.21	0.85	0.09	0.03	0.03	0.08	0.03
Customary	mean	0.88	2.16	1.85	0.95	0.31	0.21	0.41	0.23
	st. dev.	0.17	0.87	0.55	0.07	0.02	0.02	0.12	0.01

Table 26. Tarvisio. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
3.41	7.55	74.05	9.92	57.71

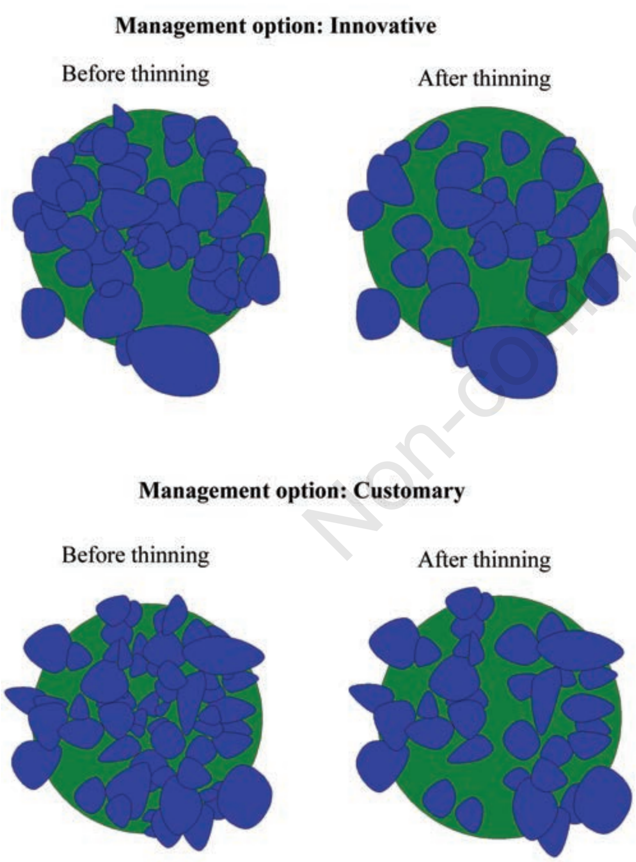

Figure 31. Tarvisio. Effect of the silvicultural treatment on canopy cover.

are feasible at this stage because of the high cost of manpower as compared with neglected revenue (Hoffman, 1971).

The innovative criteria applied: proposed management options

The only way to solve the traditional silvicultural problem and implement a sustainable silviculture is with the mechanization of thinnings. Such practice has been already addressed in neighbouring Austria, where specific machineries for Alpine forests have been developed and tested successfully. Local forest responsible already experienced a positive test 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-mentioned machinery (innovative for our country). The design will compare the thesis of mechanization by 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 criteria resulting in a higher density release and a shorter time of repetition. Instructions to the operator would include in both cases the full release of canopy trees whenever species diversity occurs (*e.g.*, broadleaved trees). A supplementary thesis would 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 would be analytically described ex ante to allow the comparison of 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), would be reserved untouched to make possible further comparisons with neighbouring.

Site 7. Vallombrosa, Italy

General description of sites

The area is located in the Toscana Region, Province of Firenze. The management is carried on 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. (Figures 32-35; Tables 27-30).

The total area is 1279 ha (forest cover: 99%). The altitudinal range is 450-1450 m (asl) with: i) pure fir forests (50%); ii) beech forests 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 man-

Table 27. Vallombrosa. General characteristics of site.

Nation	Italy
Region	Toscana
Management authority	Italian State forests
Geographic coordinates	43°44'21.48" N - 11°34'34.679" E (WGS84-UTM)
Altitudinal range (m asll)	839 ÷ 1450
Site protection	Biogenetic reserve of Vallombrosa (Natura 2000); part of area (100 ha) of pure fir is included in the 'Silvomuseo' (silvicultural museum)
Forest type	Apennine Corsican mountainous beech forest; Mediterranean and Anatolian fir forest.

Figure 32. Vallombrosa. Site location.

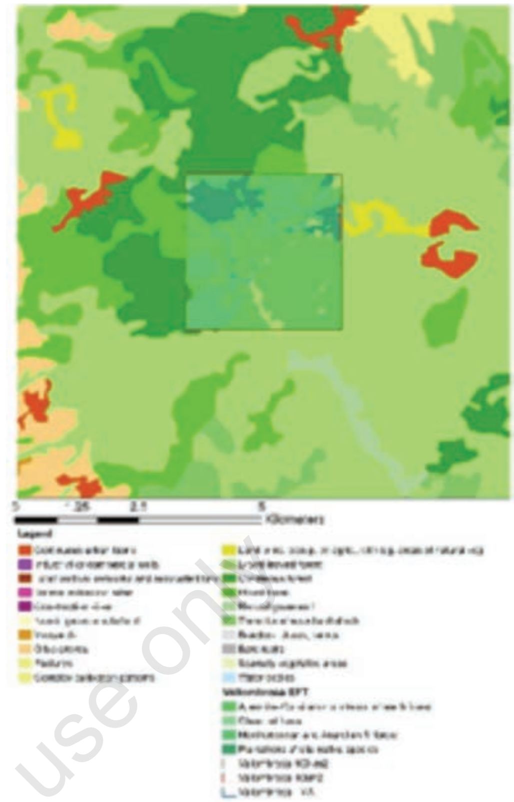

Figure 33. Vallombrosa. Landscape map (100 km^2).

Figure 34. Vallombrosa. Forest management area map.

Table 28. Vallombrosa. Main mensurational parameters before and after thinning.

		Tree density (n ha^{-1})	Basal area (m^2 ha^{-1})	Standing volume (m^3 ha^{-1})	Mean dbh (cm)	Mean height (m)	Dominant dbh (cm)	Dominant height (m)
Before thinning								
Control	mean	503	54.5	781.5	39.7	28.5	53.0	31.3
	st. dev.	196	4.0	129.4	10.1	2.7	8.3	2.6
Innovative	mean	508	56.9	826.9	38.7	28.4	52.8	31.7
	st. dev.	95	2.9	93.8	4.6	1.3	5.7	1.8
Customary	mean	588	54.3	751.8	34.5	27.2	46.8	30.2
	st. dev.	96	1.9	22.4	2.0	0.7	1.2	0.7
After thinning								
Innovative	mean	316	36.7	538.2	39.5	28.6		
	st. dev.	43	2.7	72.8	4.4	1.2		
Customary	mean	572	53.2	737.4	34.6	27.2		
	st. dev.	89	2.2	30.5	1.7	0.6		

Table 29. Vallombrosa. Main structural diversity index before and after thinning.

		BAL_{MOD}	Hg	Hg mod	CE	TD	TH	$STVI_{dbh}$	$STVI_{htot}$
Before thinning									
Control	mean	0.72	1.23	1.34	1.22	0.28	0.17	0.46	0.19
	st. dev.	0.15	0.48	0.40	0.16	0.02	0.02	0.12	0.02
Innovative	mean	0.77	1.29	1.31	1.32	0.25	0.12	0.42	0.12
	st. dev.	0.04	0.22	0.14	0.09	0.04	0.04	0.15	0.05
Customary	mean	0.78	1.45	1.39	1.31	0.22	0.12	0.29	0.10
	st. dev.	0.12	0.36	0.23	0.09	0.03	0.04	0.04	0.03
After thinning									
Innovative	mean	0.62	0.72	0.70	1.41	0.28	0.14	0.47	0.14
	st. dev.	0.04	0.11	0.06	0.04	0.07	0.06	0.18	0.08
Customary	mean	0.77	1.40	1.33	1.32	0.23	0.12	0.29	0.10

Table 30. Vallombrosa. General landscape characteristics.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
2.24	6.39	85.5	5.87	74.19

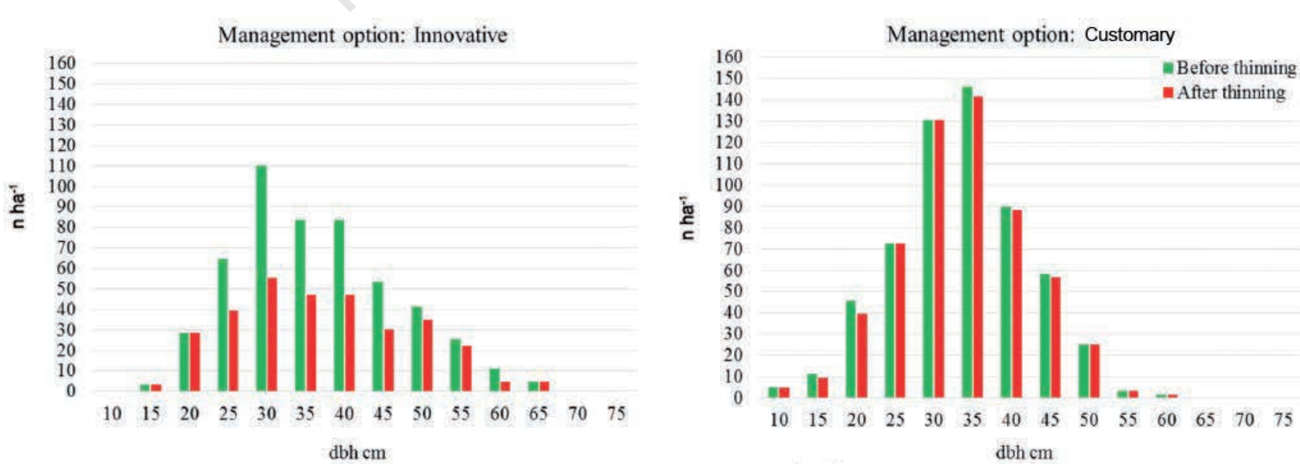

Figure 35. Vallombrosa. Number of trees per hectare for 5 cm dbh class (before and after thinning and for each silvicultural options).

agement is carried on following the Management Plan 2006-2025 with the main objective to revive the naturalness of the present forest stands. An area of 100 ha of pure fir is included in the 'Silvomuseo' (silvicultural museum), where the traditional management of clear-cutting 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 its 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 reforestation of pastures beyond the pristine forest edge.

Physiognomy varies between the more regular structure of the even aged 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, grown-up standards and the stems selected on the original stools, now indiscernible from trees originated from seed. Such composite heritage is still recognized in the current physiognomy of the beech forest, 110-160 years old at the test area. At Vallombrosa, similarly to other public-owned forests, the age of final cutting is being shifted; such adjustment well-matches the merging recreational, scenic and mitigation functions of the forests. Site parameters (elevation, position, soil, rainfall amount and pattern) are optimal for beech vegetation; such conditions also well support the prolongation of stand permanence time. Total area of Foret Management Unit is ~30 ha. Altitude within FMU ranges from 900 m to 1000 m asl.

The study area is positioned within adult, 100-170 years-old beech high forest compartment. 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, matching and optimizing 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.

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 well-addresses the emerging functions, no updating of silvicultural techniques has been proposed to match longer rotations nowadays. The achievement of older stand ages implies to maintain the status of 'health and vitality' both at individual and at stand level, to ensure current sequestration ability and higher growing stocks. 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: proposed management options

The demonstrative/innovative criteria 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. Shape, size and distribution of canopy gaps are also different between the traditional and new practice. The remaining standing crop is fully maintained and would 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, Slovenia

General description of sites

The area is located in the southeastern part of Slovenian Dinaric region. The majority of forest area is owned by the state. The research plots are located within forest management unit (FMU) Črmošnjice within the forest compartments N° 3, 6 and 12 (Figures 36-41; Tables 31-34).

The total area of FMU is 6580.08 ha (5910.39 ha of forest - 89.8%). The altitude ranges from 230 m to 1077 m (Kopa). Average yearly precipitation is 1590 mm (ARSO, 2014). Parent material is limestone and dolomite, where leptosols, cambisols and luvisols are present.

Omphalodo-Fagetum with European beech, silver fir, and Norway spruce as main tree species is the predominant forest type. Wych elm, sycamore maple and some other tree species are also present (Kutnar *et al*., 2015).

The average standing volume amounts to 351.6 m^3 ha^{-1} and the increment to 9.4 m^3 ha^{-1} yr^{-1}. A significant part of these forestlands is included in the NATURA 2000 network (Slovenian Forest Service, Forest management plan FMU Črmošnjice 2007-2016).

Table 31. Kočevski Rog. General characteristics of site.

Nation	Slovenia
Region	Kočevje
Management authority	Slovenia forest service (SFS) and Farmland and Forest Fund of the Republic of Slovenia (SKZG RS), Local unit Črmošnjice
Geographic coordinates	45.668°N, 15.033°E (WGS84-UTM)
Altitudinal range (m asl)	799 ÷ 896
Site protection	Forest is included in Special Protection Zones (ZPS, 79/409/CEE) and in Sites of Community Importance (SIC, 92/43/CEE)
Forest type	Mixed forest of European beech, silver fir and Norway spruce (Dinaric fir-beech forest)

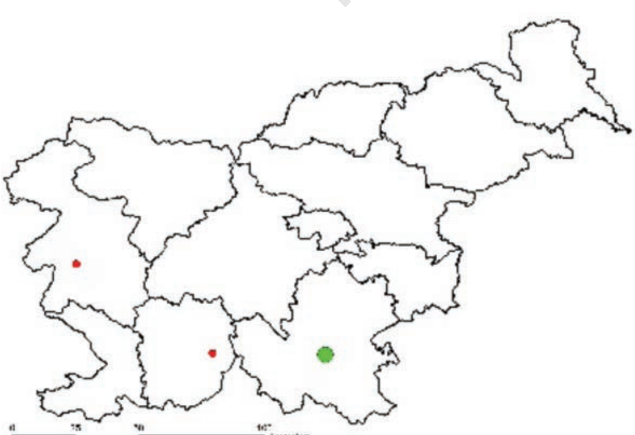

Figure 36. Kočevski Rog. Site location.

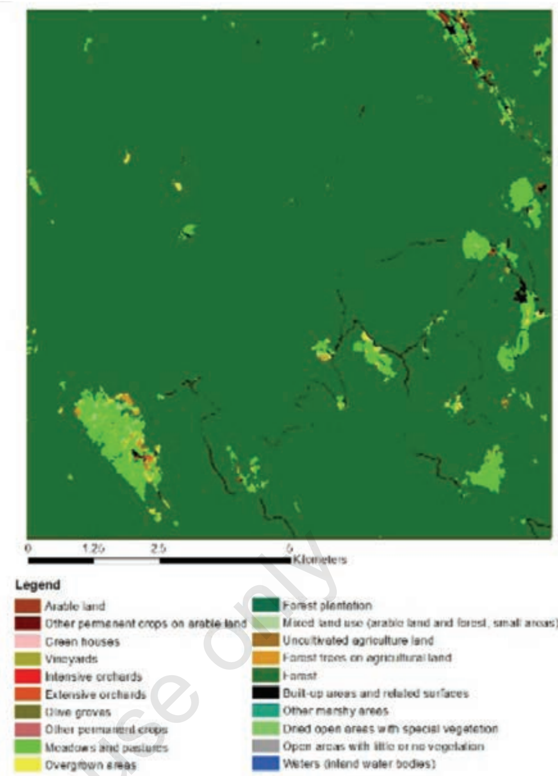

Figure 37. Kočevski Rog. Landscape map (100 km²).

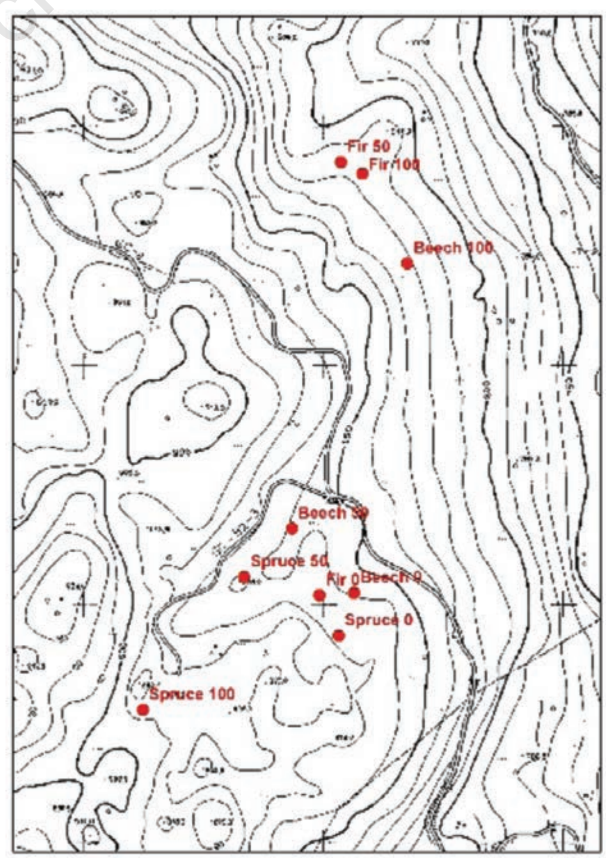

Figure 38. Kočevski Rog. Forest management area map and precise locations of research plots.

Table 32. Kočevski Rog. General characteristics of nine plots and structural diversity indexes. On each plot three different treatments were tested (cut of 100% GS, 50% GS and 0% GS).

		Pre-treatment									
		General characteristics					Structural diversity indexes*				
Treatment	Main species	N ha^{-1}	BA m^2/ha^{-1}	GS m^3/ha^{-1}	RI	SH	SI	EV	Aggr.	Ming	SizDiff
100%	Beech	325	26.68	352.65	3	2.43	0.90	1.53	0.59	0.08	0.51
100%	Fir	463	27.74	389.82	4	2.54	0.90	1.27	0.62	0.21	0.52
100%	Spruce	595	38.26	467.23	4	2.58	0.92	1.29	0.60	0.49	0.54
Mean		461	30.89	403.23	4	2.52	0.91	1.36	0.60	0.26	0.52
St. dev.		135	6.40	58.46	1	0.08	0.01	0.15	0.02	0.21	0.02
50%	Beech	325	27.70	325.66	4	2.25	0.88	1.13	0.62	0.45	0.52
50%	Fir	580	24.39	306.66	3	2.54	0.91	1.60	0.60	0.22	0.50
50%	Spruce	493	41.20	536.82	4	2.79	0.94	1.40	0.61	0.55	0.51
Mean		466	31.10	389.71	4	2.53	0.91	1.38	0.61	0.41	0.51
st. dev.		130	8.90	127.75	1	0.27	0.03	0.24	0.01	0.17	0.01
0%	Beech	478	34.49	447.04	6	2.54	0.91	0.98	0.61	0.50	0.51
0%	Fir	328	32.51	443.64	5	2.79	0.93	1.20	0.61	0.68	0.51
0%	Spruce	328	35.05	543.00	5	2.61	0.92	1.13	0.59	0.72	0.55
Mean		378	34.02	477.89	5	2.65	0.92	1.10	0.60	0.63	0.52
st. dev.		87	1.33	56.41	1	0.13	0.01	0.11	0.01	0.12	0.02
100%	Beech	0	0.00	0.00	0	0.00	0.00	0.00			
		Post-treatment									
100%	Fir	0	0.00	0.00	0	0.00	0.00	0.00			
100%	Spruce	0	0.00	0.00	0	0.00	0.00	0.00			
Mean		0	0.00	0.00	0	0.00	0.00	0.00			
St. dev.		0	0.00	0.00	0	0.00	0.00	0.00			
50%	Beech	433	20.84	241.74	3	2.19	0.88	1.38	0.62	0.50	0.52
50%	Fir	153	9.22	117.49	2	2.29	0.89	2.29	0.67	0.14	0.52
50%	Spruce	325	23.76	306.40	4	2.69	0.93	1.34	0.58	0.59	0.50
Mean		303	17.94	221.88	3	2.39	0.90	1.67	0.62	0.41	0.51
st. dev.		141	7.69	96.01	1	0.26	0.03	0.54	0.05	0.24	0.01
0%	Beech	478	34.49	447.04	6	2.54	0.91	0.98	0.61	0.50	0.51
0%	Fir	328	32.51	443.64	5	2.79	0.93	1.20	0.61	0.68	0.51
0%	Spruce	328	35.05	543.00	5	2.61	0.92	1.13	0.59	0.72	0.55
Mean		378	34.02	477.89	5	2.65	0.92	1.10	0.60	0.63	0.52
st. dev.		87	1.33	56.41	1	0.13	0.01	0.11	0.01	0.12	0.02

*Description of calculated indexes are provided in Chiavetta *et al.* (2016).

Table 33. Kočevski Rog. Forest characteristics at stand level.

	Before			After		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Relief (elevation: m asl)	853	772	930	853	772	930
Relief (slope: °)	16	0	45	16	0	45
Tree canopy (height: m)	19.4	0.0	36.3	16.5	0.0	35.0
Tree canopy (cover: %)	73.0	0.0	100.0	57.0	0.0	100.0

Table 34. Kočevski Rog. General landscape characteristics of site.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
0.7	4.5	94.8	0.0	68

Traditional silviculture system and innovative criteria applied

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. 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).

The innovative criteria refer to the size of the regeneration gaps. 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). Consequently, it will be possible to investigate the most convenient type of gap for particular species as well to make trade-offs between biodiversity poorer and richer forest stands.

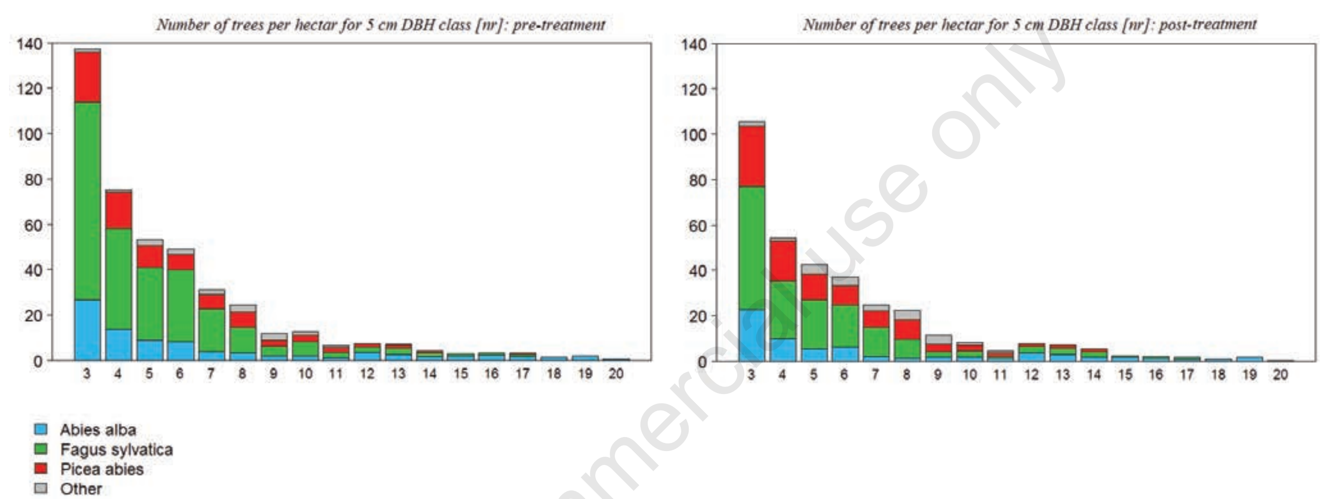

Figure 39. Kočevski Rog. Number of trees per hectare for 5 cm DBH class for three main tree species.

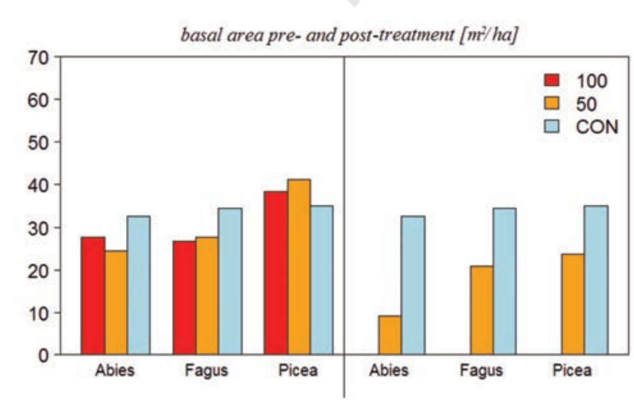

Figure 40. Kočevski Rog. Basal area for three main tree species. Left, pre-treatment; right, post-treatment.

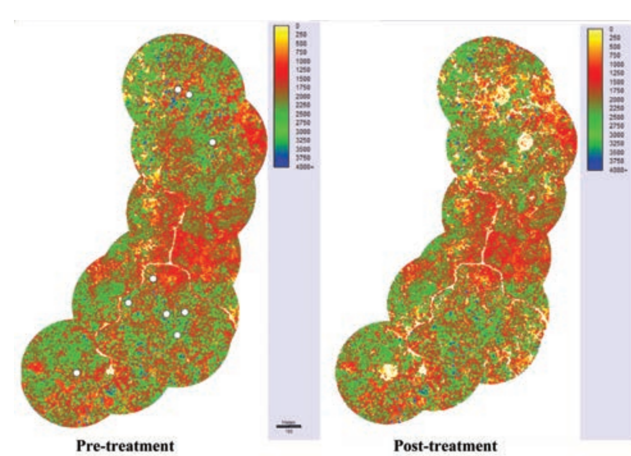

Figure 41. Kočevski Rog. Forest pattern at stand level.

Site 9. Snežnik, Slovenia

General description of sites

The area is located in the southern part of Slovenian Dinaric region. The majority of forest area is owned by the state. Research plots are located within the FMU Snežnik within the forest compartments N° 1 and 2 (Figures 42-47; Tables 35-38). The total area of the FMU is 1983.02 ha (1894.22 ha of forest - 95.5%). The altitude ranges from 600 m to 1095 m. Average yearly precipitation (ARSO, 2014). Parent material is limestone and dolomite, where leptosols, cambisols and luvisols are present. The predominant forest type is *Omphalodo-Fagetum* characterized by European beech, silver fir, and Norway spruce as main tree species. Wych elm, sycamore maple and some other tree species are also present (Kutnar *et al*., 2015). The mean standing volume is 442 m^3 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 and the innovative criteria applied

A systematic and organized forest management planning has been present in the area since the beginning of the 20th century when Schollmayer (1906) introduced his approach to selection cutting. The current silviculture system is close-to nature silviculture promoting regular group-shelterwood and improved irregular shelterwood system. Similarly to the previous site, the innovation applies to the investigation of the sizes of the regeneration cuts.

Table 35. Snežnik. General characteristics of site.

Nation	Slovenia
Region	Snežnik
Management authority	Slovenian Forestry Service (SFS) and Farmland and Forest Fund of the Republic of Slovenia (SKZG RS), Local unit Snežnik
Geographic coordinates	45.6718° N; 14.4599° E (WGS84-UTM)
Altitudinal range (m asl)	731 ÷ 774
Site protection	Forest is included in Special Protection Zones (ZPS, 79/409/CEE) and in Sites of Community Importance (SIC, 92/43/CEE)
Forest type	Mixed forest of European beech, silver fir and Norway spruce (Dinaric fir-beech forest)

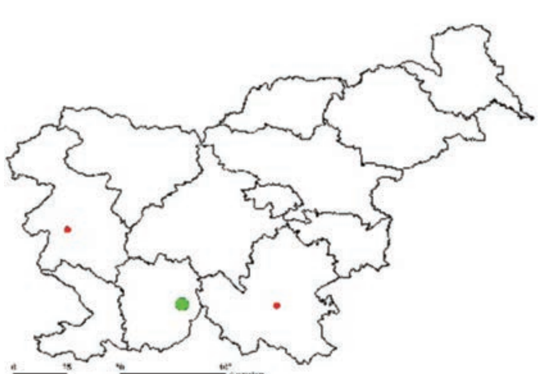

Figure 42. Snežnik. Site location.

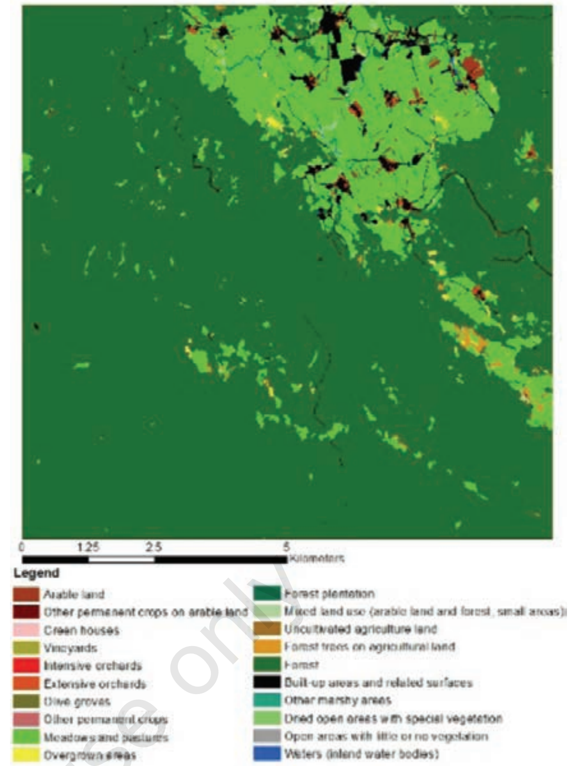

Figure 43. Snežnik. Landscape map (100 km^2).

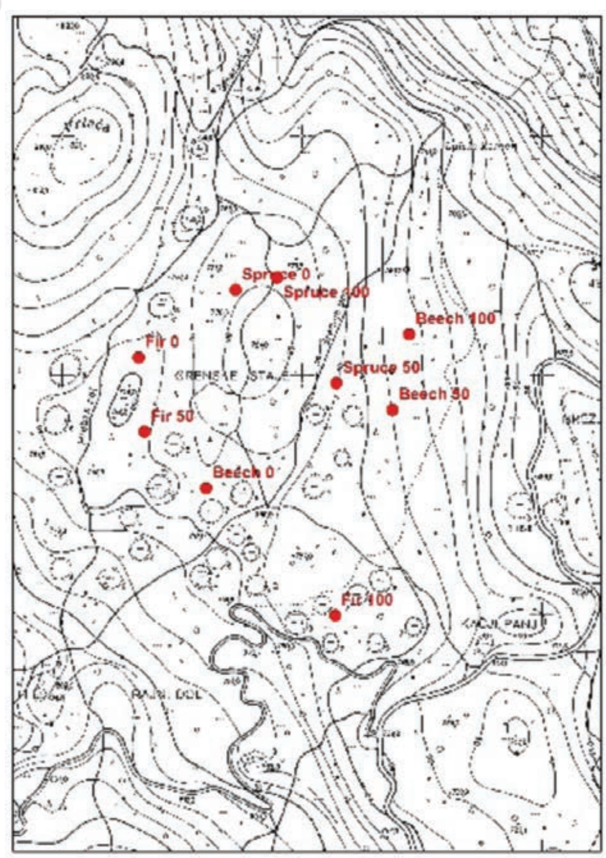

Figure 44. Snežnik. Forest management area map.

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Table 36. Snežnik. General characteristics of plots and structural diversity indexes. On each plot three different treatments were tested (cut of 100% GS, 50% GS and 0% GS).

		Pre-treatment									
		General characteristics					Structural diversity indexes*				
Treatment	Species	N ha^{-1}	BA m^2/ha^{-1}	GS m^3/ha^{-1}	RI	SH	SI	EV	Aggr.	Ming	SizDiff
100%	Beech	220	37.67	651.52	4	2.21	0.87	1.11	0.58	0.16	0.49
100%	Fir	388	38.26	496.25	2	2.53	0.91	2.53	0.60	0.50	0.51
100%	Spruce	408	47.05	669.50	4	2.18	0.87	1.09	0.56	0.39	0.52
Mean		338	40.99	605.76	3	2.31	0.88	1.58	0.58	0.35	0.51
St. dev.		103	5.25	95.26	1	0.19	0.02	0.83	0.02	0.17	0.02
50%	Beech	383	41.73	646.98	4	2.20	0.87	1.10	0.56	0.05	0.52
50%	Fir	380	45.27	587.54	2	2.38	0.89	2.38	0.54	0.40	0.49
50%	Spruce	465	49.59	651.01	3	2.24	0.88	1.41	0.59	0.51	0.50
Mean		409	45.53	628.51	3	2.27	0.88	1.63	0.56	0.32	0.50
st. dev.		48	3.94	35.54	1	0.10	0.01	0.67	0.03	0.24	0.02
0%	Beech	325	32.02	437.50	4	2.45	0.91	1.22	0.58	0.45	0.51
0%	Fir	315	42.30	579.08	3	2.52	0.91	1.59	0.58	0.46	0.52
0%	Spruce	510	44.91	594.18	5	1.99	0.83	0.86	0.55	0.52	0.53
Mean		383	39.74	536.92	4	2.32	0.88	1.22	0.57	0.48	0.52
st. dev.		110	6.81	86.43	1	0.29	0.04	0.37	0.02	0.04	0.01
		Post-treatment									
100%	Beech	0	0.00	0.00	0	0.00	0.00	0.00			
100%	Fir	0	0.00	0.00	0	0.00	0.00	0.00			
100%	Spruce	0	0.00	0.00	0	0.00	0.00	0.00			
Mean		0	0.00	0.00	0	0.00	0.00	0.00			
St. dev.		0	0.00	0.00	0	0.00	0.00	0.00			
50%	Beech	198	25.85	412.11	4	1.99	0.83	0.99	0.55	0.08	0.49
50%	Fir	178	25.06	326.65	2	2.05	0.83	2.05	0.57	0.15	0.53
50%	Spruce	210	26.23	354.35	3	1.99	0.84	1.26	0.59	0.44	0.54
Mean		195	25.71	364.37	3	2.01	0.84	1.43	0.57	0.22	0.52
st. dev.		16	0.60	43.60	1	0.03	0.00	0.55	0.02	0.19	0.03
0%	Beech	325	32.02	437.50	4	2.45	0.91	1.22	0.58	0.45	0.51
0%	Fir	315	42.30	579.08	3	2.52	0.91	1.59	0.58	0.46	0.52
0%	Spruce	510	44.91	594.18	5	1.99	0.83	0.86	0.55	0.52	0.53
Mean		383	39.74	536.92	4	2.32	0.88	1.22	0.57	0.48	0.52
st. dev.		110	6.81	86.43	1	0.29	0.04	0.37	0.02	0.04	0.01

*Description of calculated indexes are provided in Chiavetta *et al.* (2016).

Table 37. Snežnik. Forest characteristics at stand level.

	Before			After		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Relief (elevation: m. asl)	754	658	793	754	658	793
Relief (slope: °)	14	0	41	14	0	41
Tree canopy (height: m)	25.1	0.0	37.4	21.3	0.0	36.7
Tree canopy (cover: %)	74.7	0.0	100.0	56.3	0.0	100.0

Table 38. Snežnik. General landscape characteristics of site

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
1.7	17.7	80.4	0.2	39

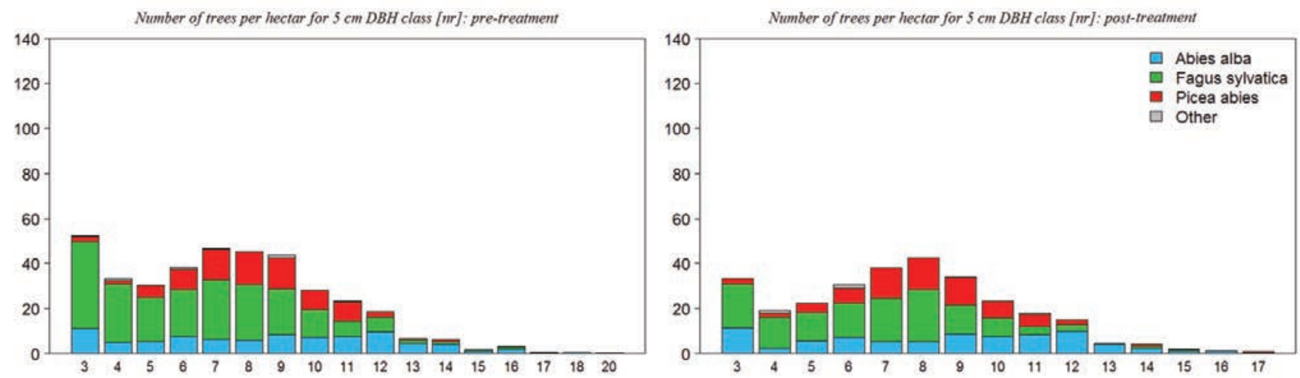

Figure 45. Snežnik. Number of trees per hectare for 5 cm DBH class for three main tree species.

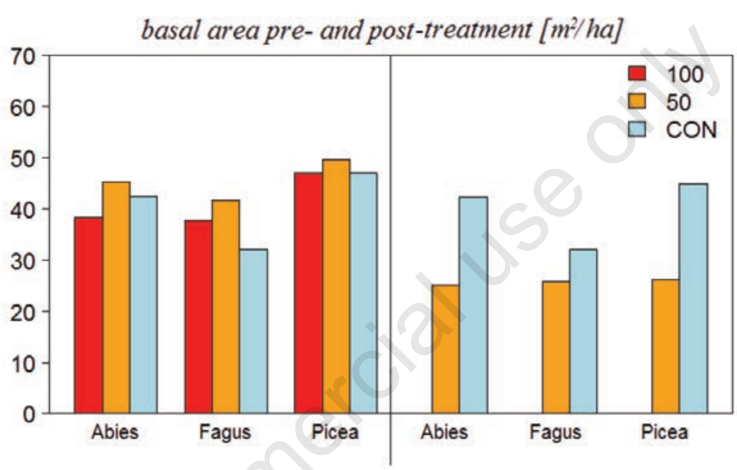

Figure 46. Snežnik. Basal area for three main tree species. Left, pre-treatment; right, post-treatment.

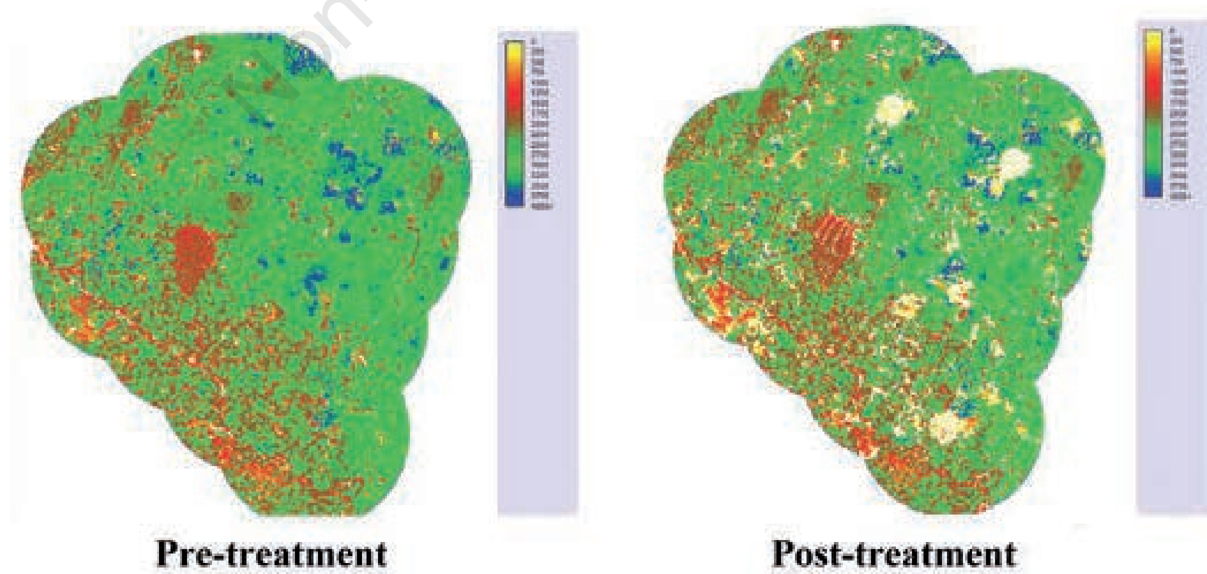

Figure 47. Snežnik. Forest pattern at stand level.

Site 10. Trnovo, Slovenia

General description of sites

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 the FMU of Trnovo within the forest compartment N° 30 (Figures 48-53; Tables 39-42).

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 (ARSO, 2014). 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. Wych elm, sycamore maple and some other tree species are also present (Kutnar *et al*., 2015).

The mean standing volume amounts to 292.0 m^3 ha^{-1} and the

Table 39. Trnovo. General characteristics.

Nation	Slovenia
Region	Snežnik
Management authority	Slovenian Forestry Service (SFS) and Farmland and Forest Fund of the Republic of Slovenia (SKZG RS), Local unit Trnovo
Geographic coordinates	45.9889° N, 13.7589° E (WGS84-UTM)
Altitudinal range (m asl)	772 ÷ 824
Site protection	Forest is included in Sites of Community Importance (SIC, 92/43/CEE)
Forest type	Mixed forest of silver fir, European beech and Norway spruce (Dinaric fir-beech forest)

Figure 48. Trnovo. Site location.

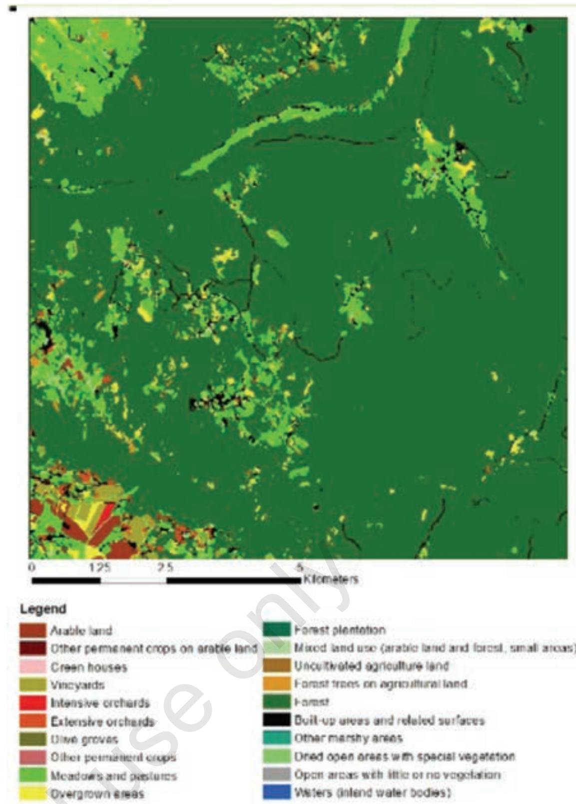

Figure 49. Trnovo. Landscape map (100 km²).

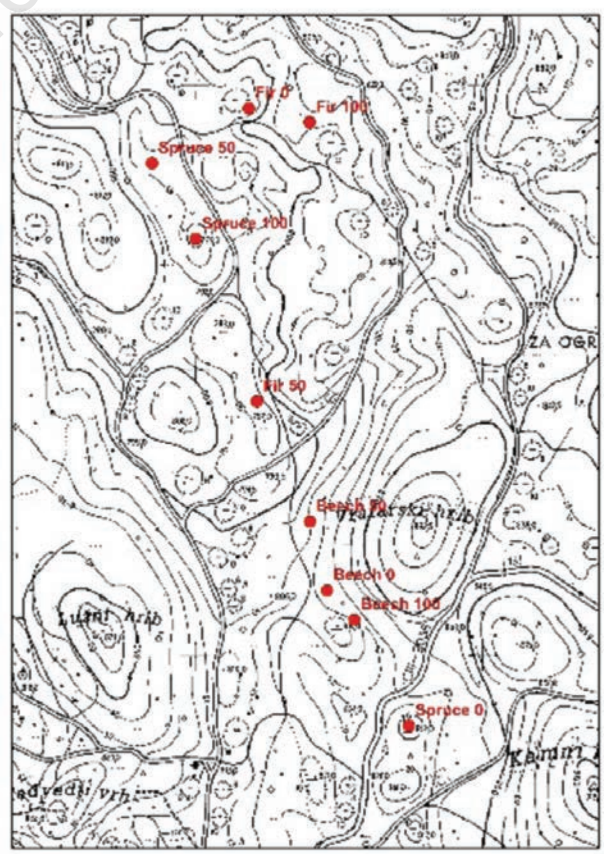

Figure 50. Trnovo. Forest management area map.

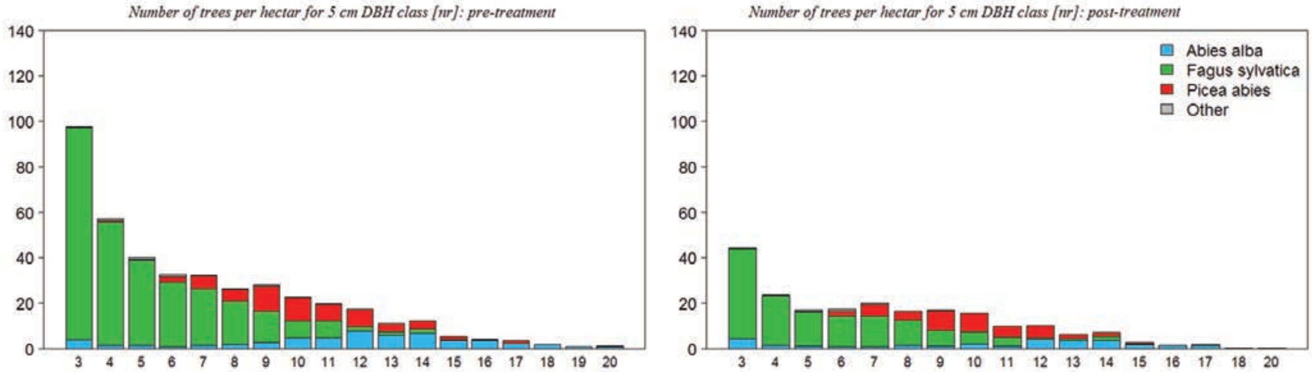

Figure 51. Trnovo. Number of trees per hectare for 5 cm DBH class for three main tree species.

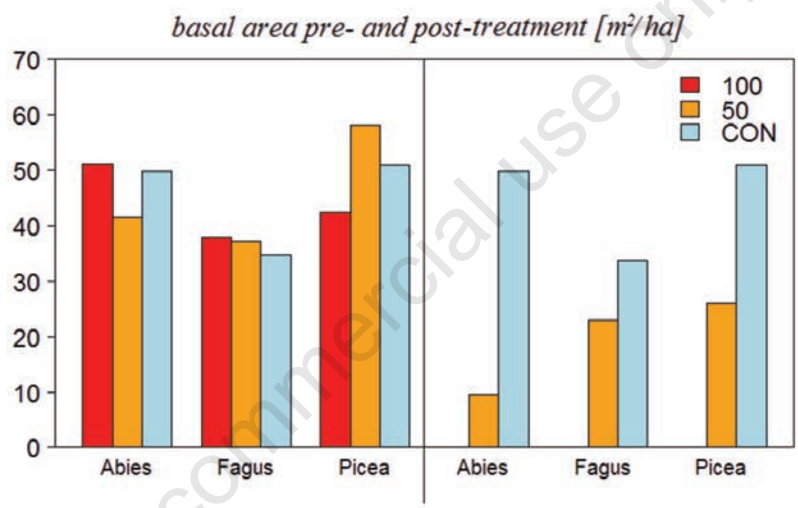

Figure 52. Trnovo. Basal area for three main tree species. Left, pre-treatment; right, post-treatment.

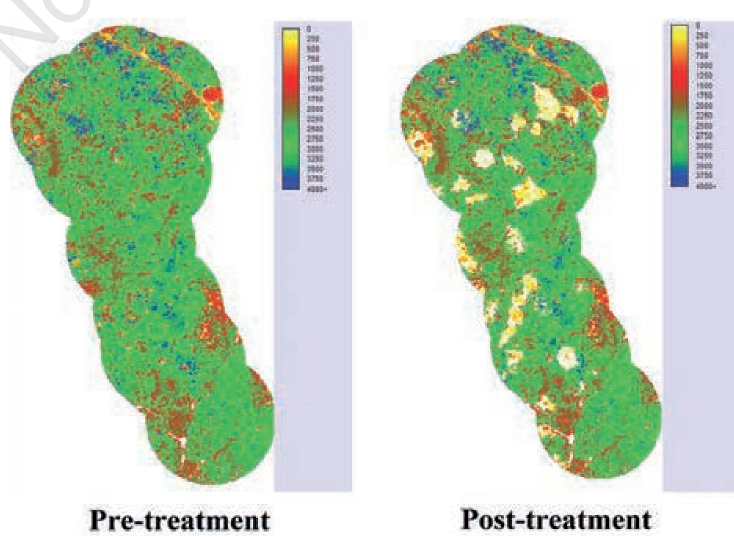

Figure 53. Trnovo. Forest pattern at stand level.

Table 41. Trnovo. Forest characteristics at stand level.

	Before			After		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Relief (elevation: m asl)	811	770	889	811	770	889
Relief (slope: °)	18	0	44	18	0	44
Tree canopy (height: m)	25.3	0.0	37.7	21.5	0.0	37.2
Tree canopy (cover: %)	72.9	0.0	100.0	56.4	0.0	100.0

Table 42. Trnovo. General landscape characteristics of site.

Urban areas (%)	Agricultural areas (%)	Forests (%)	Other semi-natural lands (%)	Forest core area (%)
1.7	15.2	83.0	0.1	34

increment to 6.2 m^3 ha^{-1} yr^{-1}. The large portions of forests are included in the NATURA 2000 network (Slovenian Forest Service, Forest management plan FMU Trnovo 2003-2012).

Description of the traditional silvicultural system and the innovative criteria applied

Long history of forest management planning is present in the area. The first forest plans were published in the 18th century (Flamek, 1771). However, the first ordinances used for forest regulation come from the 15th century. The main management type today is close-to nature silviculture. While forests with the larger shares of broadleaves are treated with the group-shelterwood (Femmelschlag) system, mixed fir-beech-spruce forests are managed with the improved irregular shelterwood silviculture system.

Similarly to both earlier mentioned sites, the innovation criteria refer to the sizes of the regeneration cuts. 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.

References

ARSO, 2014. Climatic maps, Slovenian Environment Agency.
Bessega A, 2008. Evoluzione storica delle tecniche selvicolturali nella Foresta del Cansiglio. Tesi di laurea. Università degli Studi di Udine.
Bortoluzzi A, 2002. Piano economico di riassetto forestale dei beni silvo-pastorali del comune di Lorenzago di Cadore 2002-2011.
CFS UTB Mongiana (Vibo Valenzia), 2011. Piano A.I.B. per la R.S.N. Biogenetica Cropani-Micone e per la R.N. S. Biogenetica Marchesale per il periodo 2012-2016.
Chiavetta U, Skudnik M, Becagli C, Bertini G, Ferretti F, Cantiani P, Di Salvatore U, Fabbio G, 2016. Diversity of structure through silviculture. Ital. J. Agron. 11(s1):1-175.
Ciancio O, 2009. Riserva Naturale Statale Biogenetica di Vallombrosa. Piano di Gestione e Silvomuseo 2006-2025. CFS.
Clark P, Evans F, 1954. Distance to nearest neighbor as a measure of spatial relationships in populations. Ecology 35:445-453.
Flamek F, 1771. Holz-schätz oder Überschlagung auch geometrische Einteilung in die Stallungen oder jährliche Gehau sammentlicher ternovaner landesfürstlichen Hoch und Schhwartzwaldungen so vorgenommen worden anno 1771.
Garfì V, Marchetti, 2011. Tipi forestali e preforestali della Regione Molise. Ed. dell'Orso, Alessandria.
Hegyi F, 1974. A simulation model for managing jack pine stands. pp. 74-90 Proc. IUFRO Meeting, Royal College of Forestry, Stockholm, Sweden.
Hofman A, 1967. Piano di Assestamento per il quindicennio 1967-1981. Regione Friuli Venezia Giulia, Foresta del Cansiglio.
Hofmann A, 1971. Piano di assestamento per il quindicennio 1971-1985. Distretto di Rutte. A.S.F.D. Tarvisio.
Hufnagel L, 1892. Wirtschaftsplan der Betriebsklasse I. Göttenitzer Gebirge, Gottschee.
Kutnar L, Eler K, Marinšek A, 2015. Effects of different silvicultural measures on plant diversity - the case of the Illyrian Fagus sylvatica habitat type (Natura 2000). iForest doi: 10.3832/ifor1587-008.
La Marca, 1980. Piano di gestione naturalistic della foresta di Chiarano Sparvera per il decennio 1980 1989. Tip. Coppini, Firenze.
Marchetti M, 2008. Piano di gestione della Foresta demaniale Regionale 'Pennataro' di Vasto Girardi (Isernia) 2008-2017.
Mercurio R, Spampinato G, 2006. I tipi forestali delle Serre calabresi. Laruffa ed.
Muzzi S, 1953, Vicende storiche ed economiche della foresta inalienabile del Cansiglio, in Annali Accademia Italiana di Scienze Forestali.
Pommerening A, 2002. Approaches to quantifying forest structures. Forestry 75:305-324.
Pretzsch H, 2010. Forest dynamics, growth and yield. Springer, Berlin.
Schollmayer H, 1906. Direktiven für die Bestandesaufnahme und die Betriebseinrichtung auf der F.C. Herrschaft Schneeberg. Kleinmayr-Bamberg, Ljubljana.
Šubic J, 2007. Stanje in razvoj prebiralnega gozda Volčji štant v GG Ravne. [The state and development of the selection forest Volcji štant in the FMU Ravne]. Degree Diss., University of v Ljubljana.

Šubic J, Klopčič M, Bončina A, 2010. Struktura prebiralnih gozdov v raziskovalnem objektu Volčja preža na Goteniški gori. Gozd V 68:347-360.

Schröder J, von Gadow K , 1999. Testing a new competition index for Maritime pine in northwestern Spain. Can. J. For. Res. 29:280-283.

Staudhammer CL, LeMay VM, 2011. Introduction and evaluation of possible indices of stand structural diversity. Can. J. For. Res. 31:1105-1115.

Tabacchi G, Di Cosmo L, Gasparini P, Morelli S, 2011 Stima del volume e della fitomassa delle principali specie forestali italiane. Equazioni di previsione, tavole del volume e tavole della fitomassa arborea epigea. Consiglio per la Ricerca e la sperimentazione in Agricoltura, Unità di Ricerca per il Monitoraggio e la Pianificazione Forestale, Trento.

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Wood production. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services?

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Introduction

The project titled 'Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing' inherently reflects its goals such as: i) the demonstration of the effectiveness of forest management options in meeting multiple objectives (slope protection, climate change mitigation, biodiversity conservation, wood and non-wood productions, aesthetical and recreational values); and ii) the provision of the data and guidelines for best-practices. Any multipurpose management is expected to address different forest functions (ecosystem services) in the same forest compartment. However, in practice, multipurpose forestry may be established in different management units or groups of units according to their position, site index, tree species composition, outstanding qualities, etc. In practice this system is known as the 'small-scale segregation theory' (Paletto, 2001; see also Ammer and Puettmann, 2009). It implies that a prevailing function is addressed on different patches of the same compartment and the choice repeated on the full forest cover. Under this assumption, the compliance and fulfilment are scaled throughout the forest, this accomplishing as a whole the awaited goals.

For wood production, the working hypothesis was developed as follows: i) taking into account the heritage techniques ruling wood-oriented cultivation experienced and validated for each forest type; ii) considering the main driving forces currently acting *i.e.* the climate/environmental/operational shift in progress; iii) adjusting and designing well-grounded techniques to overcome possible constraints limiting nowadays the practice of forestry; iv) implementing the new techniques as a pro-active adaptive management process, *i.e.* provide a set of practices at the operational scale open to check and further tuning by a continuous monitoring as in the basic assumptions of the 'adaptive approach'; v) comparing new and customary management practices, in addition to no-management where this option is being practiced or where it well-simulates a more extensive management practice.

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Key words: wood production, selvicoltural treatment, selective thinning.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

The evenaged pure beech forests

The customary technique, common to all the case studies, is the mass tending of standing crop according to the main, but not exclusive, wood production purpose.

The working hypothesis moved from the following rationale: i) finding out effective cultivation techniques to maintain and improve quality timber production; ii) facing up to the emerging changes by a pro-active, adaptive silviculture; iii) meeting the mitigation demand whilst maintaining tree 'health and vitality'; iv) promoting types and levels of biological diversity at the stand level, *i.e.* at the operational level of silvicultural practices. This assuming that their spatial/temporal repetition as in forest planning will ensure the establishment and maintenance of the mosaic at the upper scales; v) taking into account the evidence of the delayed culmination of growth pattern in progress, mostly due to climate warming and nitrogen fertilization (Bertini *et al.*, 2011a, 2011b; Ferretti œ., 2012, 2014).

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 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, it means to move from a mass tending aimed at growing trees sized and shaped likewise as in the customary practice, to a targeted crop tending. This is aimed to support and promote both the growth pattern and the more balanced development of best phenotypes (crown thinning) or a set of selected trees (selective thinning) within the dominant layer. 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 customary application ruling each thinning type since the earlier stages of stand development.

Both method and context of practices' enforcement inform the typical attributes of an adaptive approach. 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 of Cansiglio (age 120-145) and Vallombrosa (age 100-170); (b) the selective thinning releasing a prefixed number of trees (40-80 per unit area) and removing direct crown competitors at the younger sites of Chiarano and Mongiana (age 70). The thesis of no-intervention has been added at the three high forest sites both as 'control' and as current management choice.

The sites of Cansiglio and Vallombrosa

The demonstrative/innovative criterion consisted of the identification of a not-prearranged number of scattered, well-shaped trees (usually in the predominant-dominant social classes) and of crown thinning, *i.e.* removal of neighbouring competitors to promote the growth ability of selected trees at crown, stem and root level. The resulting harvested wood (Table 1) is higher than the one extracted by the traditional thinning, its spatial arrangement is quite diverse both at the ground and at the crown level. Shape, size and distribution of canopy gaps are also different between the traditional and new practice. The remaining standing crop is fully maintained and will produce differentiation in the 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 will be in this way reached. The trial compared the 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 practice in similar conditions.

The current, conservative plan ruling management at Vallombrosa did not foresee any cutting within the compartment for the time of its enforcement. That is why the marking by local staff was limited to a few, heavily defective or damaged trees. The amount of harvested wood is therefore nearly null as compared with the innovative thinning and, in general, with removals implemented at the other sites.

As for the assortments, the 88.3% was allotted as firewood and the 11.7% as parquet.

The site of Chiarano

The demonstrative/innovative criteria applied at this beech site under conversion into high forest consisted of the preliminary choice of a number of 40 and 80 well-shaped phenotypes per hectare and removal of all neighbouring competitors. Stem form and crown development were the relevant attributes of the selection. Intercropped dominated trees were cut according to the local manager advice because it (i) made easier the hauling process; (ii) provided a further revenue in terms of harvesting. The uniform phenotypes making up the current stand originated from stools, as compared with stems from seed aged likewise, will be sensitive to the selective thinning applied. In this way, the overall stand structure will be moved and an individual differentiation will be triggered at the crown level. The intercropped stand will promote regular mortality and deadwood enrichment, the establishment of further habitats and related niches. The customary technique, i.e, low to mixed thinning over the full standing crop, is the comparative thesis.

Removals (Table 1) are more similar here at both options. The stock is fully made of firewood.

The site of Mongiana

The demonstrative/innovative criterion consisted of the identification of 45-50 candidate trees per hectare and removal of direct competitors. Also couples of neighbouring trees were selected at this purpose. No thinning was applied in the space between candidates. The silver fir patches scattered within the beech forest were fully released and set free around from the broadleaved cover. The thesis of delaying any intervention was also addressed here because of the young age of standing crop and of the variable stand texture made of different tree densities. The traditional low to mixed thinning technique supplemented the trial.

Removals (Table 1) are a bit higher as for the innovative criterion. The assortments were made by saw-logs: 56.1 and 47.0%; logs: 24.6 and 27.7%; firewood: 19.3 and 25.3% for the innovative and customary tecniques (I.&C.), respectively.

The Apennines deciduous oak-mixed broadleaved forest

The site of Pennataro

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

Within the experimental area, two different silvicultural options were tested. The option 1 was aimed at maintaining the typical structure and composition of the 'cerreta', *i.e.* the oak-dominated forest and the historical model of management in these inner areas of Central Apennines. The adopted criterion consisted of the identification of 60 Turkey oak trees per hectare or 'candidates', selected among the best phenotypes (distance about 13-14 m). Competitors were felled all around the candidate trees. Low to crown thinning was applied on the whole intercropped cover according to the variable stand structure. Stools in the understorey were managed releasing one dominated shoot to avoid new resprouting.

The option 2 was aimed at better addressing natural evolution towards a mixed forest as in the criterion at now prevailing under the extensive management applied. It consisted of the identification of species different from oak as 'candidate trees' and of the selective thinning of neighbouring competitors to promote canopy expansion and the more balanced development of candidates. Stools in the understorey were thinned releasing one shoot to avoid resprouting.

The harvested amount (Table 1) is higher at option 1. The stock is fully made of firewood.

The unevenaged and evenaged Alpine mixed coniferous forests

The site of Lorenzago

The mixed, uneven-aged coniferous forest (silver fir 51%, Norway spruce 46%, European larch 2%, beech 1%) (Lorenzago 1) was traditionally managed according to the selection system *i.e.*, the contemporary (every *n* years) i) harvesting of mature trees, ii) thinning of the intermediate storey, iii) side cuttings around the already-established regeneration patches to promote their successful growth, iv) felling of defective stems and of withering trees throughout. The less-intensive harvesting over the last decades promoted the increase of growing stock over the threshold usual to the uneven-aged type. This condition resulted in a less-balanced distribution of mature and intermediate age classes (*i.e.*, large and medium-sized trees) currently prevailing on young classes, in the shading of the established regeneration layer affecting both its survival and growth, but also preventing the establishment of new regeneration patches. The hauling system with a local breed of horses used in the past allowed the frequent harvesting of scattered mature trees; the use of tractors nowadays makes harvest still feasible, but fellings need to be more concentrated on the ground. The criterion tested here implemented the contemporary harvesting of a few mature trees and the thinning of intermediate-sized trees both of them arranged per small groups. It made possible the mechanized harvesting. Such demonstrative/innovative practice was implemented by the opening of clear-cut strips 60 m long and 20 m wide (½ of top height). Cuttings as usual made strips connected. This practice contributed a more balanced equilibrium of the storied structure, triggering regeneration establishment (canopy opening) and allowing to concentrate side log harvesting along each strip. These 'light thinnings' were oriented along the slope. Broadleaved trees and young regeneration on the strips were released. Beech regeneration eradicated in the past because not valuable as compared with fir and spruce timber, was always favoured to enhance tree specific diversity.

A second exp. site (Lorenzago 2) was established in an evenaged management unit where current tree composition made of Norway spruce (dominant) and European larch (complementary sp.), is shifting towards the pure Norway spruce stand. The aim here was to promote the successful regeneration of larch to maintain both the specific diversity and the presence of the more valuable sp. as for timber production. The requirements of larch, light-demanding since the time of regeneration, have been fulfilled with the opening of clear cuts all around single trees or small groups of larch trees to promote suited environmental conditions to the specific regeneration. Norway spruce is the case the species removed. A further applied criterion was aimed at maintaining the presence of both tree species within a unevenaged stand structure (*i.e.*, the local customary technique into these mixed crops made up of valuable conifers). A third thesis is the control (no thinning) to address the monitoring of natural succession in progress.

The harvested amount (Table 1) is higher with the customary criterion at site 1, whilst the opening of gaps following the innovative criterion at site 2, makes harvesting nearly double within this thesis in terms of basal area and standing volume removals.

Assortments provided are mostly made of timber for structural uses: 88.4 and 85.1%; pallets: 11.6 and 14.9% (I.&C.), respectively at site 1. The resulting mass is quite exclusively made of structural timber at site 2 (99.8%) for both the applied criteria.

The site of Tarvisio

The designated forest compartment was a Norway spruce (91%) and silver fir (2%) pole stage originated from regeneration following the harvesting of previous crop. A few other species, mainly larch and beech (7%), were scattered within the standing crop. Stand structure was naturally dense with many standing and lying dead trees under the main storey. Scattered broadleaves (beech) reached the co-dominant to the dominant crop layer. This stage of the life cycle was traditionally submitted to pre-commercial thinnings to reduce inter-tree competition and manage the release of main crop population. At now, this practice is no more feasible because of the high manpower cost compared with the quite null revenue of harvesting. The only way to implement a sustainable silviculture was the mechanization of thinnings, practice already addressed in neighbouring countries as in Austria where specific machinery for the Alpine forests have been developed and tested successfully. The feller/harvester, suited to work also into pole stage stands, is 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. The demonstrative/innovative trials were based on the use of the above machinery (innovative for our country). The design compared two different densities of tree release: i) a prevailing pre-commercial thinning criterion resulting in a lower density release with an estimated time of repetition of 40 years; ii) a higher density release and a shorter time of repetition. Instructions to the operator included in both cases the full release of canopy trees whenever a dendrological diversity occurred (*e.g.*, broadleaved trees). A supplementary thesis compared the manually implemented thinning into patches of compositional diversity, randomly occurring

Table 1. Charasteristics of the thinnings.

Removals percentage	Tree density	Basal area	Standing volume
Cansiglio			
Innovative	44.2	36.5	35.8
Customary	33.3	24.7	24.2
Vallombrosa			
Innovative	37.8	35.5	34.9
Customary	2.7	2.0	1.9
Chiarano			
Innovative 40	56.9	42.8	40.3
Innovative 80	50.2	38.6	36.8
Customary	53.5	37.1	37.1
Mongiana			
Innovative	20.8	21.6	21.5
Customary	15.0	18.9	19.2
Pennataro			
Turkey oak forest	58.7	42.1	39.8
Mixed forest	51.5	35.5	31.9
Lorenzago 1			
Innovative	11.4	19.1	20.3
Customary	15.9	21.1	23.2
Lorenzago 2			
Innovative	55.1	48.5	48.8
Customary	42.5	25.5	23.3
Tarvisio			
Mechanized 1	60.7	45.9	41.9
Mechanized 2	40.3	34.8	32.8
Manual	25.4	20.2	19.0

throughout the predominant coniferous texture, with the mechanically implemented thinning into an adjacent patch. Areas characterized by both younger and more adult stages and specific habitats (*e.g.*, wet grounds or natural clearings in the tree texture), were reserved untouched to make possible further comparisons with the neighbouring forest crop submitted to thinning.

The harvested amounts (Table 1) are well scaled across the theses tested. As for the assortments, the 79.6 is made by saw logs, the 18.6 by tree biomass and 1.8 by firewood, as a whole.

Perspectives: Pros and Cons of the approach

Each innovative criterion applied at the test-sites has first taken into account the forest management type ruling the test-sites, wood-production in the case. All the concurring goals building up the project aims were considered in the design of the operational techniques. The assembly of more than one function on the same ground is always a compromise among a set of targeted goals. The resulting goodness of fit will be verifiable within the planned monitoring activity in the follow-up of the project. The definition of an 'adaptive approach' seems basic because it implies the continuous check of outcomes as well as their adjustment under the current dynamic condition.

The Dinaric fir-beech forests

Dinaric fir-beech forests form the dominant forest type in the Slovenian test sites of Kočevski Rog, Snežnik and Trnovo. According to forest management plans, more than 75% of these forests are managed by the group shelterwood and irregular shelterwood silviculture systems, while once prevalent single tree and the group selection systems are practiced only on ca. 5% of forestlands (ZGS/OE-Kočevje, 2012; ZGS/OE-Postojna, 2012; ZGS/OE-Tolmin, 2012). For more than 40 years these forests have been subject to the process of over-ageing. Specifically, within the last four decades the rotation periods of the forests have been prolonged and presently last between 150-170 years (ZGS/OE-Kočevje, 2012; ZGS/OE-Postojna, 2012; ZGS/OE-Tolmin, 2012). Additionally, the forests managed by the shelterwood silviculture systems lack young growth and the selection forests suffer insufficient recruitment into the canopy (Klopčič *et al*., 2015). Because of these interacting processes, significant changes are detected among the tree species compositions, which normally would consist of European beech, silver fir, Norway spruce, sycamore and wych elm. However, once considerably high shares of fir in the standing volume, which is the dominant species, diminished from 25-50% to 5-15% (ZGS/OE-Kočevje, 2012; ZGS/OE-Postojna, 2012; ZGS/OE-Tolmin, 2012) and are still declining. At present they are sufficient only in old growth reserves (Klopcic *et al.*, 2010; ZGS/OE-Kočevje, 2012; ZGS/OE-Postojna, 2012; ZGS/OE-Tolmin, 2012). According to the explanations of forest science, the current state of these forests is the result of the following sequence of events: Changed management system and steadily increasing ungulate browsing first caused the insufficient regeneration of fir and the prevalence of beech (Čater *et al*., 2014; Klopcic *et al*., 2010; Nagel *et al*., 2014), in turn, this in terms of tree species composition unfavourable regeneration caused insufficient harvesting that lead to over-ageing (Gašperšič and Kotar, 1986).

To withstand the process of fir decline in the shelterwood forests as well as to increase the shares of other dominant and co-dominant species, a regeneration experiment (two-factor design with three pseudo-replications) was designed. Its main aim was to test whether or not more intense regeneration harvests (no cut = control; ca. 50% canopy reduction = intermediate intensity; 100% canopy removal = high intensity) on the plots with the diameters of ca. two stand heights would accelerate spatially more extensive and species-richer regeneration (Table 2).

Perspectives: Pros and Cons of the approach

Current forest science and practices promote several techniques to be used in managing mixed fir-beech forests (Bončina, 2011). The proposed approach, characterized by spatially larger harvest and regeneration areas, is not really a new one and it has occasionally been applied to some areas in the region. The regeneration pattern has its origin in the natural disturbances and it can be found in many stands exposed to wind disturbances and snow and ice storms (Diaci *et al*., 2010). In comparison to the current regeneration pattern in the region, the proposed approach has the following advantages:

i) Capability of regeneration of light-demanding tree species and the establishment of micro-site conditions for potential regeneration of shade-tolerant tree species such as beech and silver fir. Potential regeneration of shade-tolerant species is to be understood as the regeneration under the shelter of the light-demanding tree species that usually occurs much later after the initial regeneration (Diaci *et al*., 2010; Čater *et al*., 2014).

ii) In terms of growth phases, the potentially more intensive regeneration contributes to more balanced forest development that only can provide ecosystem functions and services in the long run;

iii) Timely harvesting helps sustain vital and healthy forests, which are potentially more resistant to all kind of disturbances and pests;

iv) Larger openings, initially regenerated by a variety of light-demanding and bush species, not only represent shelters for incoming shade-tolerant species, but they are also forage areas for wildlife. Consequently, their occurrence reduces the pressure of herbivory of palatable species in the openings (from the edge

Table 2. Basal area before and after management actions

Removals percentage Basal area	0% Before/after*	ca. 50% Before/after*	ca. 100% Before/after*
Kocevski Rog - European beech	34.5	27.7/20.8	26.7/0.0
Kocevski Rog - silver fir	32.5	34.4/9.2	27.7/0.0
Kocevski Rog - Norway spruce	35.1	41.2/23.8	38.3/0.0
Sneznik - European beech	32.0	41.7/25.9	32.0/0.0
Sneznik - silver fir	42.3	45.3/25.1	42.3/0.0
Sneznik - Norway spruce	44.9	49.6/26.2	44.9/0.0
Trnovo - European beech	33.7	37.1/22.9	37.8/0.0
Trnovo - silver fir	49.7	41.4/9.51	51.0/0.0
Trnovo - Norway spruce	50.9	58.0/26.0	42.5/0.0

*Before/after action (harvest); Kocevski Rog - European beech/silver fir/Norway spruce, the prevalent species on the plot is European beech/silver fir/Norway spruce.

towards the centre of regeneration area) and in the other areas.
v) Potentially good wood quality.
The approach also has shortcomings as follows:
vi) Greater exposure to erosion in steep terrains and increased germination of weedy plants;
vii) Larger variation of ecological conditions; wider temperature extremes and more intense transpiration;
viii) Prevalence of light-demanding species in the first regeneration stages;
ix) More demanding tending and tree-species mixture regulation.

References

Ammer C, Puettmann KJ, 2009. Waldbau, quo vadis? Waldbewirtschaftung zwischen Funktionenorientierung und Multifunktionalität. Forstarchiv 80:90-96.

Bertini G, Amoriello T, Fabbio G, Piovosi M, 2011a. Forest growth and climate change. Evidences from the ICP-Forests Intensive Monitoring in Italy. iForest 4:262-267.

Bertin G, Piovosi M, Fabbio G, 2011b. Long-term forest monitoring: evidences of sensitivity to climate change coupled with management shift in Italy. How to handle this dynamics? Summer school on adaptation to climate change in forest management. Vienna.

Boncina A2011. History, current status and future prospects of uneven-aged forest management in the Dinaric region: an overview. Forestry 84:467-478.

Čater M, Diaci J, Roženbergar D, 2014. Gap size and position influence variable response of Fagus sylvatica L. and Abies alba Mill. Forest Ecol. Manage 325:128-135.

Diaci J, Roženbergar D, Nagel TA, 2010. Sobivanje jelke in bukve v Dinaridah: usmeritve za ohranitveno gospodarjenje z jelko. Zbornik gozdarstva in lesarstva 91:59-74.

Ferretti M, Marchetto A, Bussotti F, Calderisi M, Canullo R, Carnicelli S, Cecchini G, Fabbio G, Bertini G, Matteucci G, De Cinti B, Pompei E, Salvati L, 2012. Nitrogen deposition and Critical Load exceedence: effects on health, growth and diversity of forest vegetation in Italy. Proc. Int. Conf. 'Biological reactions of forest to climate change and air pollution', Kaunaus, Lithuania.

Ferretti M, Marchetto A, Arisci S, Bussotti F, Calderisi M, Carnicelli S, Cecchini G, Fabbio G, Bertini G, Matteucci G. De Cinti B, Salvati L, Pompei E, 2014. On the tracks of Nitrogen deposition effects on temperate forests at their southern European range - an observational study from Italy. Global Change Biol. 20:3423-3438.

Gašperšič, F., Kotar M., 1986. Zaključno poročilo o območnih gozdnogospodarskih načrtih v Sloveniji [Final report on Slovenia's regional forest management plans]. Ljubljana, Republiški komite za kmetijstvo, gozdarstvo in prehrano: 41p.

Klopčič M, Jerina K, Boncina A, 2010. Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor? Eur. J. For. Res. 129: 277-288.

Klopčič M, Simončič T, Bončina A, 2015. Comparison of regeneration and recruitment of shade-tolerant and light-demanding tree species in mixed uneven-aged forests: experiences from the Dinaric region. Forestry, doi: 10.1093/forestry/cpv021.

Nagel TA, Diaci J, Jerina K, Kobal M, Rozenbergar D, 2014. Simultaneous influence of canopy decline and deer herbivory on regeneration in a conifer-broadleaf forest. Can. J. For. Res. 45:266-275.

Paletto A, 2001. Il multi-uso forestale. Evoluzione del concetto. Linea Ecologica-Economia Montana 5:16-20.

ZGS/OE-Kočevje, 2012. Gozdnogospodarski načrt gozdnogospodarskega območja Kočevje 2011-2020 . Kočevje, Zavod za gozdove Slovenije, območna enota Kočevje.

ZGS/OE-Postojna, 2012. Gozdnogospodarski načrt gozdnogospodarskega območja Postojna 2011-2020. Postojna, Zavod za gozdove Slovenije, območna enota Postojna.

ZGS/OE-Tolmin, 2012. Gozdnogospodarski načrt gozdnogospodarskega območja Tolmin 2011-2020. Tolmin, Zavod za gozdove Slovenije, območna enota Tolmin.

Did ManFor C.BD forest treatments influence diversity and composition of invertebrate communities?

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Indicators adopted to estimate the response

Coleoptera

Coleoptera are the largest insect order, being almost ubiquitous in terrestrial environments, such as forests. They occupy an extremely wide range of ecological niches, with a broad range of specializations both at the adult and larval stages (New, 2010), and are the predominant group of saproxylic organisms and the main xylophagous insects in Europe, and consequently particularly adequate as bio-indicators to evaluate the preservation of forest environments (Stokland *et al*., 2012). As a single group may not be sufficient to assess the richness or abundance of other taxa, an integrate approach, combining different beetle families representative of different communities, habitat requirements or functional groups, is preferable (Koivula, 2011). Among beetle families, Carabidae, Scarabeoidea, Buprestidae, Cerambycidae and other xylophagous groups are commonly used as bio-indicators. Due to their abundance in beech forests, three families illustrative of different trophic levels and functional groups, Carabidae, Cerambycidae and Curculionidae Scolytinae, have been selected to evaluate the effect of forest management. Carabidae, or 'ground beetles', are one of the largest families of the order. Most species are predators of other invertebrates at the larval and adult stages but they also include granivores and mycophagous species. As betrayed by their common name, most carabids are ground or soil dwellers but a considerable number of species lives on trees or in association with aquatic environments (New, 2010). Arboricolous carabids are often associated with deadwood, living under barks or preying upon xylophagous insects (Campanaro *et al*., 2011). Ground-dwelling species are also affected by the presence of dead wood, as they often find shelter or overwinter under fallen logs, stumps or other woody debris. Carabid beetles are renowned for their role as bio-indicators: their taxonomy is relatively stable, their ecology and life histories are well known, they are widespread and easily collected by means of standardized methods, and an extensive literature on their ecological importance is available (Koiwula, 2011). Cerambycidae, or 'longhorn beetles', are conspicuous insects for their often remarkable dimensions, body pattern and long antennae. They are well known from the taxonomic point of view, easing their identification. These beetles are one of the best example of xylophagous insects, as their larvae bore into the wood usually under bark, albeit they also include species feeding on roots or herbs (Turnbow and Thomas, 2002). Cerambycidae comprise both primary and secondary saproxylics; some species are strictly associated with particular tree species and/or well defined conditions, such as old trees or type of woody debris on forest floor (Campanaro *et al*., 2011). Longhorn beetles also include species of great economic importance, being important forest pests. The adults of some species feed on pollen, therefore they are directly influenced by the presence of open environments (Turnbow and Thomas, 2002; New, 2010). Curculionidae Scolytinae, commonly known as 'bark and ambrosia beetles', are a very important group of xylophagous insects of ecological and economical importance. Bark beetles typically colonize fresh wood, attacking recently dead, dying or weakened trees, therefore representing an example of primary saproxylics (Campanaro *et al*., 2011). Most species live between bark and wood, leaving characteristic marks and many have a strict symbiosis with fungi, carrying spores and cultivating hyphe in their galleries. However, due to their habits, some species are considered serious pest, being prone to outbreaks and transmitting fungal diseases (Rabaglia, 2002). Forest management practices influence beetle species composition and abundance not only by varying the amount of dead wood or presence of old trees but also by changing environmental conditions such as shade, moisture or presence of herbaceous vegetation, with a direct impact on soil-dwelling or nectarivores species.

Syrphidae

Hoverflies (Diptera, Syrphidae) are a worldwide spread family that live in a variety of habitats (e.g. grassland, woodlands), where

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Key words: Cerambycidae, Carabidae, Forest management, Forest structure, Scolytinae, Syrphidae.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

they form diverse and species rich communities (Speight, 1989). The Italian fauna is the richest in Europe, counting about 530 species (Birtele 2011), while Slovenia with 307 species, is the country with the highest number of species per surface unit (de Groot and Govedič, 2008; Van Steenis *et al*., 2013). Adults are anthophilous and heliophilous, their appearance resembles bees and wasps, while their larvae have very diverse trophic needs, related to their elected habitat (Birtele, 2011). In forests, adults can be mainly found along the margins and in clearings, and in the transition areas between woodland and open habitats, where there the availability of flowers is highest (Gittings *et al*., 2006).

The choice of hoverflies as a target group is justified by the fact that they are good bio-indicators (Sommaggio, 1999; Burgio and Sommaggio, 2007). Their larvae use many ecological niches in forests (Sommaggio, 1999), and larvae of saproxylic species tend to be very sensitive to stress and environmental changes. These larvae are highly bounded to microhabitat related to deadwood, such as holes and stumps; hence the presence in forests of different typologies of deadwood is fundamental for their conservation. Finally, the ecology of many species has been studied thoroughly, using standardized sampling methods, and the data has been gathered in a European database developed by Martin Speight (Speight, 2014).

Methods used for measuring the indicators

The abundances and occurrences of target groups, such as saproxylic beetles and flies were studied with different methods to maximize the range of species recorded. Thus, the sampling involved the use of five types of traps: Malaise, window, pitfall, emergence traps and sticky traps. Malaise traps were used to catch mainly Diptera, actively flying through the forest understory (Ausden and Drake, 1997; Ozanne, 2005).These kind of traps have widely been used in surveys of insect abundance and diversity (Campbell and Hanula, 2007), usually because they collect vast numbers of insects, giving an excellent return for effort than any other single trap (Ausden and Drake, 1997). Window traps were used to collect flying beetles (Ausden and Drake, 1997), associated with specific understory resources, such as dead wood (Ozanne, 2005). These traps are known to respond to the immediate surroundings of the trap location (Sverdrup-Thygeson and Birkemoe, 2009), and thus are particularly suitable for monitoring and comparing forest habitats (Alinvi *et al*., 2007). In Slovenia, the pheromone Galloprotect 2D was used in association with the window traps to attract longhorn beetles. Pitfall traps were used to sample Carabidae (Woodcock, 2005). Emergence traps were used to sample adult insects emerging from high stumps, since it is the most relevant method to obtain insights into substratum association for most saproxylic species (Brin *et al*., 2012). Transects were performed to survey hoverflies using a sweep net (Ssymank, 2004). The transects were only done when there was a temperature above 17°C and less than 1/5 of cloudiness.

On the Italian sites the sampling design included 1 Malaise trap and 3 window traps per plot, activated for all the adults flight season, using 70° ethanol as preservative. Samples were collected every second week and target groups were successively determined. Emergence traps were set only in Lorenzago di Cadore site, taking advantage of the widespread presence of high stumps. In this latter case, the sampling design took into account two diameter classes (32-42 and 54-64 cm) and two decay stages (2 and 3 of Hunter's decay scale) of stumps, with 7 traps for each combination, for a total of 28 emergency traps distributed inside the stand.

In Slovenia the sampling activities took place after the harvesting. Carabid beetles and hoverflies were sampled on all plots while the longhorn beetles only on plots characterised by Norway spruce and silver fir. Hoverflies were sampled with one sticky trap and one transect per plot three times per year. For carabid beetles, in one plot, five pit fall traps were set using salt and water as conserving method. One in the centre, and the rest in the 4 cardinal points, 12 meters east from the centre. The sampling was done during three periods of one week, at the beginning of June, July and August. For longhorn beetles, on every plot with Norway spruce and silver fir, the traps were set from the beginning of May till the end of October. Every month the samples were collected. The samples were determined in the laboratory. Transects were conducted every month to monitor the abundance of *Morimus funereus*.

Observed response to the different forest treatments

Syrphidae

In Slovenia, the forest treatments were very small scale, and since hoverflies are very mobile, they did not have strong effect on the number of hoverfly species. The abundance was highest on plots with 50% reduction of living stock. Different species were observed in completely open plots, plots with 50% reduction of living stock and plots without harvesting. Guilds also reacted contrastingly to the cutting intensity. The saproxylic species occurred in low densities. There was a small increase of species on plots of 50% intensity and the open plot. In the controlled areas, the saproxylic species *Brachypalpus laphriformis* was found. In the completely open areas, the saproxylic species *Xylota ignava* and *X. segnis* were found. The species which feed on microorganisms were most abundant on the total clear cut. The species that feed on plants had low abundances and therefore no response was observed. Most of the hoverfly species, which were observed on the plots, were feed on aphids and other animals. From these, the lowest number of species was observed on the completely open areas while in the areas without cutting and only 50% cutting

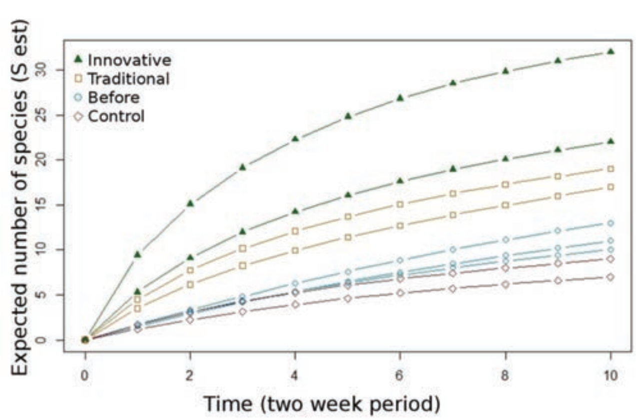

Figure 1. Estimated Syrphidae richness (S est) in the Cansiglio forest found increasing sampling duration, in the plots where the different management options were performed: innovative (n=2), traditional (n=2), control (n=2) and before the harvesting (n=3).

intensity the number of predatory hoverflies was higher. In general, cutting did not affect hoverflies.

In Italy, an increase in species richness associated with the innovative forest management practices was observed in both beech and spruce-fir forests, suggesting the suitability, in the short term, of this treatment to preserve biodiversity. In the Cansiglio beech forest (Figure 1), the plots where the innovative and traditional forest management were performed showed a higher species richness compared to both the control plots and the survey performed a year before the harvesting. Considering the ecology of the recorded species (preferred forest type and age, clearing use and larvae diet) there were not remarkable trends in their distribution in the different plots. Three metrics derived from the analysis of forest structure significantly correlated with the axes of the detrended correspondence analysis (DCA): PI (Pielou's distribution index), CE (Clark and Evans' aggregation index) and Cl2000 (foliage clumping) (Figure 2). Thus, the variation of horizontal heterogeneity, in terms of tree distribution and canopy closure, could represent one of the driving forces of the observed pattern. For the Lorenzago forest, the highest species richness was observed in the innovative and control plots. The innovative plots showed the highest abundance of individuals associated with over-mature forests, saproxylic species with larvae that develop in decaying wood. Conversely the traditional and control samples showed a dominance of individuals with aphid-feeding larvae.

Coleoptera

In Slovenia, the long horn beetles responded significantly to the harvesting regime. Different species were observed in control and completely open plots. A large increase of species was observed from the control to the completely open plots. The species *Raghium inquisitor, R. mordax, Monochamus* species and *Sticuleptura rubra* were more associated with open areas. *Oxymirus cursor* was more associated with the controlled and 50% intensity plots. Large differences in species composition were confirmed between sites. In Kočevski Rog was observed the smallest and in Trnovo the biggest number of individuals. Species in this group are clearly associated with harvesting regime, which makes

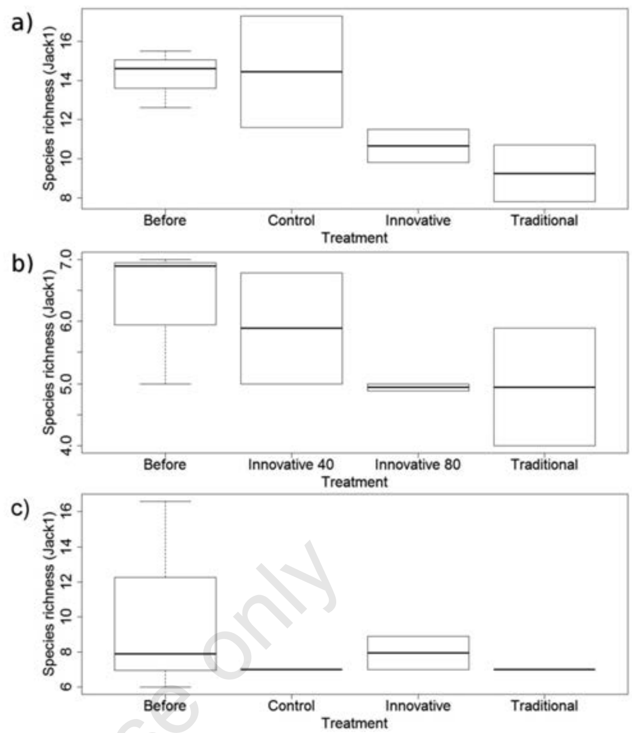

Figure 3. Bark beetle (Curculionidae, Scolytinae) species richness estimated by first-order Jackknife richness estimator (Jack1), in the plots where the different management options were performed: a) Cansiglio, b) Chiarano and c) Mongiana.

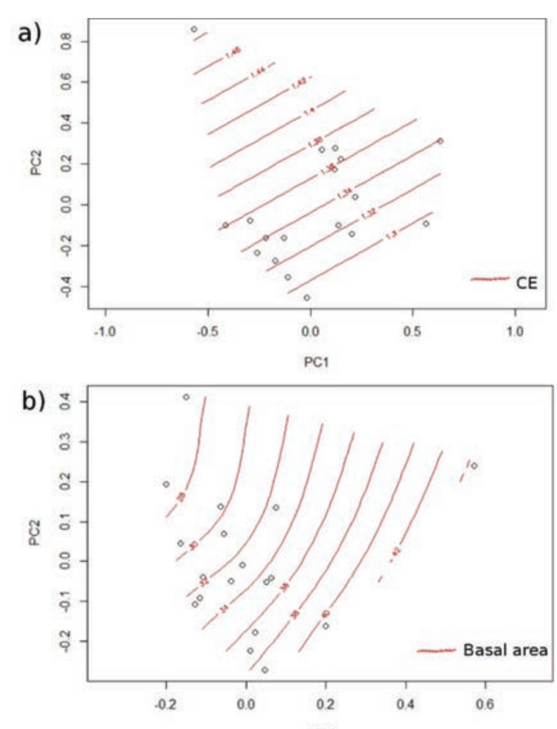

Figure 4. Principal component analysis (PCA) of bark-beetle (Curculionidae, Scolytinae) species collected in: a) Cansiglio and b) Mongiana. Lines show the variation of environmental variables significantly correlated with the ordination axes, Clark and Evans' aggregation index (CE) and basal area respectively.

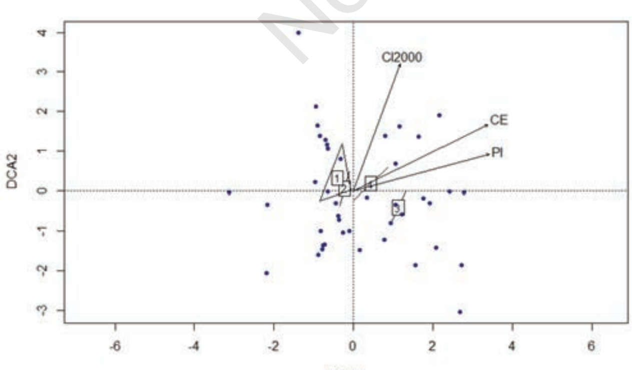

Figure 2. Detrended correspondence analysis (DCA) of hoverfly (Syrphidae) species, displaying species (blue points) and sites (traps in the different plots): ante (1), control (2), traditional (3) and innovative (4). Arrows identify the forest structure metrics that significantly correlated with the DCA axes: PI (Pielou's distribution index), CE (Clark and Evans aggregation index) and Cl2000 (foliage clumping).

them good indicators.

The carabid beetles are predatory species and are less related to trees as they are highly mobile. Such pattern was also observed in the response to the harvesting regime. No differences in number of species between the cutting regimes were registered. However, several pioneer species like *Cicindela germanica*, *C. sylvicola, C. campestris* and *Amara* sp. were observed on the completely open plots. In general, intensive harvesting did not affect the carabid species composition; harvesting was in positive correlation with the presence of the pioneer species in the forests.

In Italy, for the Cansiglio forest the results highlighted a higher species richness of Cerambycidae in the innovative plots, and a decrease in the number of observed species in the control plots compared to the survey performed before the harvesting. We can thus infer a shift of the individuals towards the innovative sectors with the impoverishment of contiguous sectors. In Lorenzago as well, the highest species richness of Cerambycidae was observed on the plot where the innovative treatment was experimented.

For what concerns bark-beetles, species richness did not vary significantly among the different harvest methods tested by the project (Figure 3). The principal component analysis highlighted the effect of different structural variables (Figure 4): in Cansiglio, the Clark and Evans' aggregation index was significantly correlated with the PCA axes (r^2=0.36, P=0.032) while for Mongiana the basal area was the most relevant variable (r^2=0.49, P=0.005). None of the considered structural parameters was significant for the ordination of the species collected in Chiarano. Our results support the influence of specific structural factors only for the sites historically managed as high forest.

References

Alinvi O, Ball JP, Danell K, Hjältén J, 2007. Sampling saproxylic beetle assemblages in dead wood logs: comparing window and eclector traps to traditional bark sieving and refinement. J. Insect Conserv. 11:99-112.

Ausden M, Drake M, 1997. Invertebrates. In: W.J. Sutherland (ed.) Ecological census techniques: a handbook. Cambridge University Press, Cambridge, pp. 214-249.

Birtele D, 2011. Contributo alla conoscenza dei Syrphidae della Sardegna (Diptera). In: G. Nardi, D. Whitmore, M. Bardiani, D. Birtele, F. Mason, L. Spada and P. Cerretti (eds.) Biodiversity of Marganai and Montimannu (Sardinia). Cierre Edizioni, Verona, pp. 659-715 .

Brin A, Bouget C, Valladares L, Brustel H, 2012. Are stumps important for the conservation of saproxylic beetles in managed forests? - Insights from a comparison of assemblages on logs and stumps in oak-dominated forests and pine plantations. Insect Conserv. Divers. 6:255-264.

Burgio G, Sommaggio D, 2007. Syrphids as landscape bioindicators in Italian agroecosystems. Agric. Ecosys. Environ. 120:416-422.

Campanaro A, Bardiani M, Spada L, Carnevali L, Montalto F, Antonini G, Mason F, Audisio P, 2011. Linee guida per il monitoraggio e la conservazione dell'entomofauna saproxilica. Cierre Grafica, Verona.

Campbell JW, Hanula JL, 2007. Efficiency of Malaise traps and colored pan traps for collecting flower visiting insects from three forested ecosystems. J. Insect Conserv. 11:399-408.

de Groot M, Govedič M, 2008. Checklist of the hoverflies (Diptera: Syrphidae) of Slovenia. Acta Entomol. Slov. 16:67-87.

Gittings T, O'Halloran J, Kelly T, Giller PS, 2006. The contribution of open spaces to the maintenance of hoverfly (Diptera, Syrphidae) biodiversity in Irish plantation forests. Forest Ecol. Manage. 237:290-300.

Koivula MJ, 2011. Useful model organisms, indicators, or both? Ground beetles (Coleoptera, Carabidae) reflecting environmental conditions. In: D. Kotze, T. Assmann, J. Noordijk, H. Turin and R. Vermeulen (eds.), Carabid beetles as bioindicators: biogeographical, ecological and environmental studies. Pensoft, Sofia, page 573.

New TR, 2010. Beetles and conservation. Wiley-Blackwell, Chichester, UK.

Ozanne CMP, 2005. Sampling methods for forest understory vegetation. In: S.R. Leather (ed.) Insect sampling in forest ecosystems. Blackwell, Oxford, pp. 58-76.

Rabaglia RJ, 2002. Curculionidae Scolytinae Latreille 1807. In: R.H. Arnett, M.C. Thomas, P.E. Skelley and J.H. Frank (eds.), American beetles. Vol. II: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press LLC, Boca Raton, pp. 722-815.

Sommaggio D, 1999. Syrphidae: can they be used as environmental bioindicators? Agric. Ecosys. Environ. 74:343-356.

Speight M, 2014. Species accounts of European Syrphidae (Diptera) 2014. Syrph the Net, the database of European Syrphidae. Syrph the Net publications, Dublin.

Speight MCD, 1989. Saproxylic invertebrates and their conservation. Council of Europe, Strasbourg.

Ssymank, A., 2004. Hoverfly communities (Diptera, Syrphidae) in vegetation complexes of river valleys near Bonn (Germany). Volucella 7:157-184.

Stokland JN, Siitonen J, Jonsson BG, 2012. Biodiversity in dead wood. Cambridge University Press, Cambridge.

Sverdrup-Thygeson A, Birkemoe T, 2009. What window traps can tell us: effect of placement, forest openness and beetle reproduction in retention trees. J. Insect Conserv. 13:183-191.

Turnbow MHJ, Thomas MC, 2002. Cerambycidae Leach 1815. In: R.H. Arnett, M.C. Thomas, P.E. Skelley and J.H. Frank (eds.), American beetles. Vol. II: Polyphaga: Scarabaeoidea through Curculionoidea. CRC Press LLC, Boca Raton, pp. 568-601.

Van Steenis W, de Groot M, Van Steenis J, 2013. New data on the hoverflies (Diptera: Syrphidae) of Slovenia. Acta Entomol. Slov. 21:131-162.

Woodcock BA, 2005. Pitfall trapping in ecological studies. In: S.R. Leather (ed.), Insect Sampling in forest ecosystems. Blackwell, Oxford, pp. 37-57.

Did ManFor C.BD forest treatments influence species biodiversity of amphibians and reptiles?

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Introduction

Amphibians and reptiles species diversity in the Manfor C.BD sites was assessed using herpetological standard census methodologies (Heyer *et al*., 1994; McDiarmid *et al*., 2012). Species diversity greatly varies among sites (Table 1; Figure 1). The site areas range between 30 and 35 hectares with the exception of the site Monte di Mezzo - Pennataro (about 400 ha).

Species richness, for both amphibians and reptiles, did not vary before and after silvicultural treatments, and even on control sites without treatment. Aquatic sites used by amphibians as breeding sites before forest harvesting were used by the same species after treatments as well. The number of reptile species, generally recorded as a result of the encounter of single individuals since their abundance in forest environment is often very low, was also confirmed. New treatments in studied forests did not affect herpetofauna species richness. However, we have to interpret such results with caution, since effects were measured within a very short time interval after thinning treatments and, consequently, they have therefore little significance. Low vagile species (amphibians and reptiles) disappear from environment only in the event of a drastic and sudden environmental change (habitat destruction or loss).

Amphibians and reptiles are quite different and their response to forest management may be opposite and conflicting (Verschuyl *et al*., 2011). As a general rule, amphibians are more susceptible to timber harvesting than reptiles.

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Key words: Habitat alteration, harvesting, Bombina variegata, Body Condition Index, forestry

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Reptiles may benefit by clearcutting or thinning because such measures provide environment with higher solar radiation, which is an important habitat characteristic for ectothermic vertebrates (Kiester, 1971) but, at the same time, effect may be also negative, as clearcutting may not provide adequate night-time thermal cover. Thinning, on the other hand, may provide a more suitable environment for many reptiles than closed-canopy forest stands (Todd and Andrews, 2008).

Conversely, for amphibians that require minimal environmental moisture, clearcutting causes negative effects (DeMaynadier and Hunter, 1995; Pough *et al*., 1987; Ash, 1997; Semlitsch *et al*., 2009). Effects of thinning and partial harvesting on amphibians species richness and populations are more complicated than in reptiles, because available data show contrasting response patterns (Pough *et al*., 1987; Harpole and Haas, 1999; Grialou *et al*., 2000; Renken *et al*., 2004; Semlitsch *et al*., 2009). In thinned forests, we did not confirm extreme variation in biophysical characteristics, and in particular in moisture, to make habitats unsuitable for the occurrence of amphibians. Comparisons of species richness before and after harvesting could not provide significant differences (Ford *et al*., 2000). Robust results may be obtained by analysing finer parameters at population level rather than those related to species richness.

A more detailed example: the study of *Bombina variegata* (Linnaeus, 1758) in the Tarvisio forest

The Yellow-bellied toad (*Bombina variegata*, Figure 2) is a small anuran distributed in central and southern Europe; with regard to LIFE+ ManFor C.BD areas this species occupies the major part of the Slovenian territory while in Italy it is mainly distributed in the north-eastern part of the country (Di Cerbo and Bressi, 2007). *Bombina variegata* is surely one of the best candidate to study the effects of alternative forestry practices, since it is considered threatened and listed on Appendix II of the Bern Convention and on Annexes II and IV of Natural Habitat Directive, it depends on small and ephemeral reproductive sites that are more susceptible to desiccation, and is more exposed to microhabitat alteration (Scheele *et al*., 2014).

One of Yellow-bellied toad population has been studied using two different approaches to evaluate the effect of forestry practices on the biology and demography of the species. In Tarvisio forest, the study site consisted of a reproductive pond, located in spruce (*Picea abies*) forest, and was included into an area subjected to two different treatments, performed in September 2013: an

Table 1. Species inventory in the seven Italian sites. Occurrence of a given species is shown for each site.

	In Dir. 92/43/CEE as	Cansiglio	Chiarano Sparvera	Lorenzago di Cadore	Mongiana	Monte di Mezzo–Pennataro	Tarvisio	Vallombrosa
AMPHIBIA								
Salamandra salamandra	Not included			X	X		X	
Ichthyosaura alpestris	Not included	X					X	
Lissotriton italicus	*Triturus italicus*				X			
Lissotriton vulgaris	Not included						X	
Salamandrina perspicillata	*Salamandrina terdigitata*					X		
Bufo bufo	Not included					X	X	
Bombina variegata	*Bombina variegata*						X	
Hyla intermedia	*Hyla arborea*				X			
Rana italica	*Rana italica*			X		X		
Rana temporaria	*Rana temporaria*						X	
REPTILIA								
Iberolacerta horvathi	*Lacerta horvathi*						X	
Anguis fragilis	Not included				X		X	
Podarcis muralis	*Podarcis muralis*		X			X		X
Natrix natrix							X	
Vipera aspis	Not included							X
Vipera berus	Not included						X	

innovative/demonstrative treatment and a traditional one. The demonstrative/innovative treatment consisted of the identification of a not-fixed number of scattered, well-shaped trees in the dominant social classes and crown thinning of neighbouring competitors to increase the future growth ability of selected trees. The traditional treatment consisted in a pre-commercial thinning to reduce inter-tree competition and manage to release the main crop population. For the study of forest harvesting effects on *Bombina* two different metrics/approaches were employed: the study of individual physiological status, through the analysis of body condition index (BCI) (Jakob *et al*., 1996), and the study of demographic parameters estimated with capture-mark-recapture analysis. With regards to BCI, the Scaled Mass Index (SMI), basically calculated on the residuals obtained from the regression of body mass and body length, was selected as the more accurate index and the more representative of the individuals physiological status (Peig and Green, 2009); while, taking into account the analysis of population demography, a capture-mark-recapture study (Amstrup *et al*., 2010) has been conducted, using the robust design (Pollock, 1982). This particular model employs a stratified sampling design and fully reflects the data as they are recorded by researchers: it consists in primary periods, between two of them the population is considered open to birth/mortality and immigration/emigration, and secondary periods, when the population is considered closed and the abundance can be estimated (Pollock, 1982). For both BCI and demographic analysis, data were collected during two years (2012-2013) before the forest treatment and one year (2014) after the forest treatment. Sampling were performed monthly from May to August/September, depending on the seasonal activity of the species. During sampling individuals were captured on reproductive site; sex, snout-urostyle length (SUL) and mass were determined, while a picture of the ventral pattern was taken in order to perform individual photo identification. With regard to the analysis of BCI we also collected data on a similar site, 330 meters away, where no forestry practices were applied, to evaluate if observed variations are attributed to forest treatment or to seasonal trend. In 2013 we obtained data for BCI from 129 individuals (93 and 36 in treatment and control site respectively) while in 2014 we measured

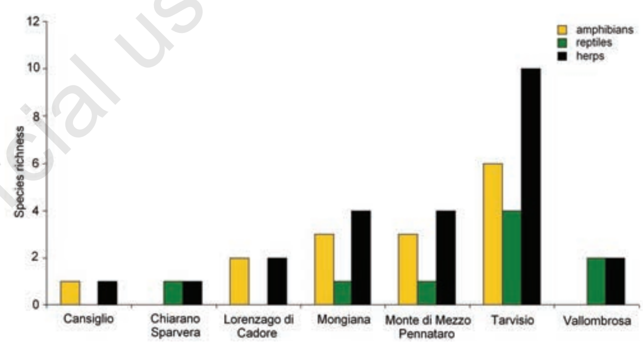

Figure 1. Species number separated for amphibians, reptiles and their sum (herps) in Italian sites.

Figure 2. Yellow-bellied toads (*Bombina variegata*) during the mating season in a pond of the Tarvisio forest.

62 individuals (41 and 21 in treatment and control site, respectively). In both sites the SMI was significantly lower after forest treatment was applied (Mann Whitney U test; P<0.001; full data reported in Table 2). In analysis of capture-mark-recapture data, between 2012 and 2014 data from 105 distinct individuals were obtained. Three main demographic parameters were selected as mainly representative of a possible effect of forest management: i) the estimated abundance of the population, ii) survival of individuals, iii) parameters of emigration (Kendall and Bjorkland, 2001). Different models were built and model ranking evaluated using AIC (Akaike, 1973) and considering that models with a difference in AIC lower than 2 points have the same empirical support (Burnham and Anderson, 2002). Taking into account the estimated abundance of the population the models with more empirical support accounted for abundance variation between sessions but not for a treatment effect (Figure 3); in the same way the best ranked model accounted for constant survival, not affected by forest treatments and, with respect to immigration and emigration, all the high ranked models accounted for a random movement of individuals to and from the reproductive pond. In conclusion, with regard to the studied population of *Bombina variegata,* no significant effect of forest harvesting has been detected on the physiological status and demographic parameters of this amphibian. Even if observed decrease of body condition index between 2013 and 2014 in the treatment site could be interpreted as a negative effect of forest harvesting, the employment of a control site similar to the treatment, as discussed in Costa *et al*. 2016, avoided erroneous interpretations of the observed metric.

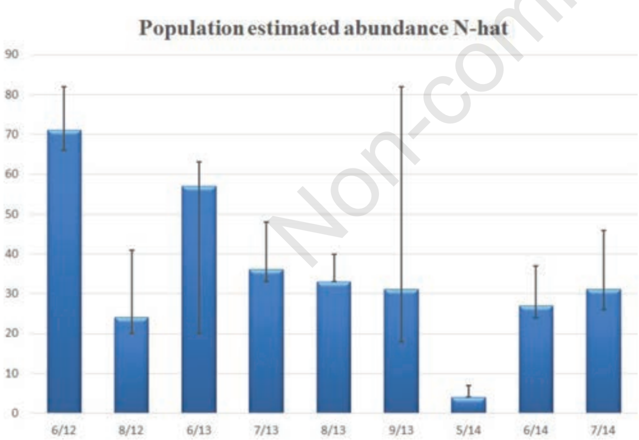

Figure 3. Graphical interpretation of population estimated abundance N-hat from CM analysis.

Table 2. Results of Scaled Mass Index of *Bombina variegata* in the Tarvisio forest before (2013) and after (2014) forest treatment.

SMI	2013		2014	
	Mean	Std. Err.	Mean	Std. Err.
Control	5.27	0.15	4.86	0.08
Treatment	7.85	0.06	7.48	0.10

References

Akaike H, 1973. Information theory and an extension of the maximum likelihood principle. In: B.N. Petrov and F. Cazakil (eds.) Proc. II Int. Symp. Information Theory, Akademiai Kidao, Budapest, Hungary, pp. 267-281.

Amstrup SC, McDonald TL, Manly BF, 2010. Handbook of capture-recapture analysis. Princeton University Press.

Ash AN, 1997. Disappearance and return of plethodontid salamanders to clearcut plots in the southern Blue Ridge Mountains. Conserv. Biol. 11:983-989.

Burnham KP, Anderson DR, 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer Science & Business Media.

Costa A, Posillico M, Basile M, Romano A, 2016. Conservation of herpetofauna as a function of forestry. Ital. J. Agron. 11(s1):1-175.

DeMaynadier PG, Hunter ML, 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environ. Rev. 3, 230-261.

Di Cerbo AR, Bressi N, 2007. Bombina variegata (L., 1758). Fauna d'Italia, Vol. XLII - Amphibia. pp. 280-287.

Ford WM, Menzel MA, McCay TS, Gassett JW, Laerm J, 2000. Woodland salamander and small mammal responses to alternative silvicultural practices in the Southern Appalachians of North Carolina. pp 241-250 in Proc. Ann. Conf. Southeast. Assoc. Fish and Wildl. Agencies.

Harpole DN, Haas CA, 1999. Effects of seven silvicultural treatments on terrestrial salamanders. Forest Ecol. Manag. 114:349-356.

Heyer RW, Donnelly MA, McDiarmid RW, Hayek LAC, Foster MS, 1994. Measuring and monitoring biological diversity. Standard methods for amphibians. Biological diversity handbook. Smithsonian Institution, Washington, DC, USA.

Grialou JA, West SD, Wilkins RN, 2000. The effects of forest clearcut harvesting and thinning on terrestrial salamanders. J. Wildlife Manage. 64:105-113.

Jakob EM, Marshall SD, Uetz GW, 1996. Estimating fitness: a comparison of body condition indices. Oikos 77: 61-67.

Kendall WL, Bjorkland R, 2001. Using open robust design models to estimate temporary emigration from capture - recapture data. Biometrics 57:1113-1122.

Kiester AR, 1971. Species density of North American amphibians and reptiles. Syst. Biol. 20:127-137.

McDiarmid RW, Foster MS, Guyer C, Gibbons JW, Chernoff N, 2012. Reptile biodiversity: standard methods for inventory and monitoring. University of California Press.

Peig J, Green AJ, 2009. New perspectives for estimating body condition from mass/length data: the scaled mass index as an alternative method. Oikos 118:1883-1891.

Pollock KH, 1982. A capture-recapture design robust to unequal probability of capture. J. Wildlife Manage. 46:752-757.

Pough FH, Smith EM, Rhodes DH, Collazo A, 1987. The abundance of salamanders in forest stands with different histories of disturbance. Forest Ecol. Manag. 20:1-9.

Renken RB, Gram WK, Fantz DK, Richter SC, Miller TJ, Ricke KB, Russell B, Wang X, 2004. Effects of forest management on amphibians and reptiles in Missouri Ozark forests. Conserv. Biol. 18:174-188.

Scheele BC, Boyd CE, Fischer J, Fletcher AW, Hanspach J, Hartel T, 2014. Identifying core habitat before it's too late: the case of Bombina variegata, an internationally endangered amphib-

ian. Biodivers. Conserv. 23:775-780.
Semlitsch RD, Todd BD, Blomquist SM, Calhoun AJM, Gibbons JW, Gibbs JP, Graeter GJ, Harper EB, Hocking DJ, Hunter Jr MJ, Patrick DA, Rittenhouse TAG, Rothermel BB, 2009. Effects of timber harvest on amphibian populations: understanding mechanisms from forest experiments. Bioscience 59:853-862.
Todd BD, Andrews K, 2008. Response of a reptile guild to forest harvesting. Conserv. Biol. 22:753-761.
Verschuyl J, Riffell S, Miller D, Wigley TB, 2011. Biodiversity response to intensive biomass production from forest thinning in North American forests - A meta-analysis. Forest Ecol. Manag. 261:221-232.

Italian Journal of Agronomy 2016; volume 11(s1)

Did ManFor C.BD forest treatments influence diversity and composition of the bird community?

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The Italian experience

Study area

Bird species richness and diversity have been assessed on each project site before and after applied treatments but for Lorenzago di Cadore site, where bird community surveys have been conducted after the first portion of the site has been treated. The effects of different treatments were not considered relevant, due to the small spatial scale. Indeed, the considered effect was 'before' and 'after' applied logging. In addition, the extant study areas have been extended beyond the boundary of the ManFor plot to assess the effects of logging on an area more likeable to represent the whole forest bird community. At two sites (Chiarano and Tarvisio) the plot and the buffer area were different in structure compared to other research plots. The core stand in Chiarano-Sparvera was managed as coppice with standard until early 70's of XX century, when a conversion to even-aged high forest took place in the late 80's. Differently from every other ManFor site, Chiarano-Sparvera it is not embedded into a forest matrix but it is surrounded by primary and secondary grassland and pastures, but for the northern edge. This last one borders a beech stand managed as coppice with standard but heavily exploited in the early-to-mid 80's, where the control sampling points are located as it is the only available portion of forest bordering the ManFor site. Tarvisio site is characterised by a 'subalpine spruce forest' with dense regeneration stands of Norway spruce and silver fir with interspersed beech. The buffer area is characterised mainly by mature conifer stands and beech.

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Key words: Management, indicator, eveness, forestry.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Methods

Survey consisted of a 5 minutes unbounded point count. Sampling has been carried out in year 2012-2015 from early-May to late-June. Surveys started at sunrise, ending at 11 a.m. (local time: UTC+2h); every bird detected has been recorded to the species level by both aural and visual cues (Balestrieri *et al*., 2015). Non-forest species, *i.e.* species occasionally detected while crossing the area, were not involved in the analysis.

Presence of significant bird species was compared before and after applied measures. Targeted species are listed as threatened in the Italian IUCN Red List (Peronace *et al*., 2012) and in the Annex I of the Directive 2009/147/CE of the European Parliament and of the Council on the conservation of wild birds (Birds Directive). In addition, a focus on the guild of bird specialists was provided, comparing the presence of insectivorous cavity nesters (Newton, 1994; Verner, 1984). Such approach focused on the lower resilience of insectivorous cavity nesters to habitat alterations (Czeszczewik *et al*., 2014; Donald *et al*., 1998; Woodley *et al*., 2006). Both approaches were applied at every project site. At Chiarano-Sparvera, Mongiana and Tarvisio sites, similarity per area has been assessed using the Morisita index (Morisita, 1962) and species diversity indexes have been calculated to assess the effect of treatments on bird diversity (Shannon and Wiener, 1949; Simpson, 1949).

Results and Discussion

The presence of threatened and Birds Directive species decreased or did not changed after applied treatments (Table 1). Insectivorous cavity nesters response to treatments mirrored those of the whole bird community (Table 2). The analysis of similarity for Chiarano-Sparvera, Mongiana and Tarvisio sites showed no differences between communities before and after treatments (Morisita index for every paired comparison >0.9, P=1). Diversity indexes were similar before and after treatments; in Tarvisio diversity after thinning even increased (Figure 1).

Contrary to other, more intensive, harvesting practices and treatments (Czeszczewik *et al*., 2014; Woodley *et al*., 2006), our results indicate that the applied treatments may have not significantly affected bird communities, at least during the time of observations. The use of a different silvicultural measures may prove beneficial for different bird guilds, *e.g.* forest canopy specialists, ground nesters or insectivorous (King and DeGraaf, 2000). Our results also indicate that the guild made by the most forest-specialized birds can be negatively affected by applied treatments, since in three sites 2 species disappeared (Table 2). Disappearance of such species may be interpreted as an early warning of forest ecosystems deterioration, although it should be stressed that our results are referred to a limited period following treatments. We suppose that in the long time bird communities may 'react' to the alteration through a dynamic equilibrium. Eventual, negative, short-term effect may be concealed, at the community level, by an increase in number of open-habitat species or by the presence of larger forest patches around the study sites, supplementing further resources, buffering the negative effects of harvesting. Bird species richness is correlated with both larger trees and sparser tree distribution (Carrillo-Rubio *et al*., 2014). Applied treatments have had small effects on bird diversity likely because of their conservative character. The implementation of the applied innovative forestry practices at the Italian sites, can guarantee in the long period the opportunity for the forest bird community to recover from disturbance. Such practices need to be addressed locally; as a general approach we suggest retaining snags, stumps and deadwood (Bütler *et al*., 2004; Czeszczewik *et al*., 2014), creating a landscape mosaic with larger patches (Roberge *et al*., 2008), assuring the naturalness of the tree assemblage (Caprio *et al*., 2008; Gil-Tena *et al*., 2007), and preserving a reasonable number of 'large' and veteran trees whenever possible (Ellis and Betts, 2011). Forest management influences the structure and could benefit specific bird assemblages by sustaining forest multi-functionality. Although the choice of the bird assemblage is partly in the manager's hands, we noted and stressed that, among the insectivorous guild, there are more protected and specialist species.

The Slovenian experience

Study area and methods

At Slovenian sites, mainly composed of mixed silver fir and beech forests, the treatments consisted of: i) no harvesting; ii) 50% removal of the trees (living stock); and iii) and complete removal of all trees. Each treatment has been applied on randomly placed plots. Bird surveys were not accomplished according to a formal before-and-after applied measure scheme (*i.e.*, in the same plot before and after the harvesting took place), only after the treatments. Notwithstanding such a shortcoming, and because control plots (*i.e.,* un-harvested) were available for comparison, we were confident that our results could be at least roughly regarded as a fairly affordable proxy to a formal before-and-after sampling design. According to the adopted sampling protocol, 27 bounded points (radius 35 m) were surveyed within each of the three areas (Kočevski Rog, Snežnik and Trnovo). Sampling took place in April and May/June 2013 and each point has been surveyed twice for both aural and visual bird cues for 10 minutes.

Results and Discussion

In total 48 bird species were observed at the research plots in Slovenia. Thirty-two species were found in Kočevski Rog, 31 species in Snežnik and 37 species in Trnovo (Table 3). It was interesting to observe that in spite of intense or even complete wood extraction on some plots; some bird forest specialist species were still recorded. Three-toed woodpecker, Black woodpecker, Ural owl and Pygmy owl are all regarded as forest specialists, which are

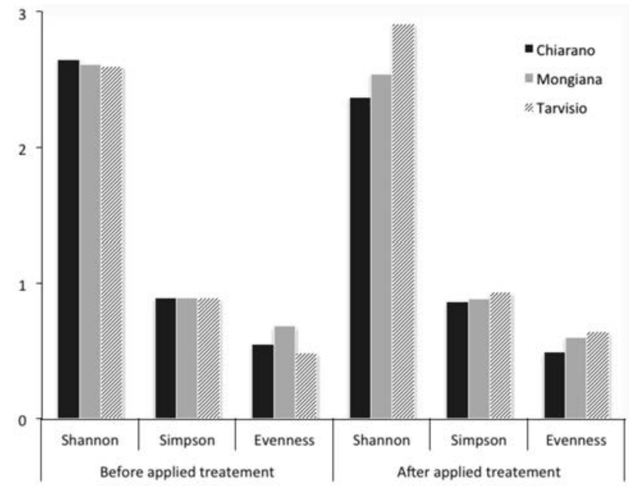

Figure 1. Diversity indexes computed at three ManFor sites before and after treatments. Index values showed no differences after treatments.

Table 1. Number of species listed in the Italian IUCN Red List or in the EU Bird Directive detected before and after the ManFor treatments.

Site	Before	After
Italian Red List		
Cansiglio	1	1
Chiarano	3	1
Lorenzago	1	1
Mongiana	0	1
Pennataro	1	1
Tarvisio	1	1
Birds Directive		
Cansiglio	1	0
Chiarano	1	1
Lorenzago	4	4
Mongiana	1	0
Pennataro	0	0
Tarvisio	2	1

Table 2. Number of species included in the insectivorous cavity nester guild detected before and after the ManFor treatments.

Site	Before	After
Cansiglio	10	10
Chiarano	13	12
Lorenzago	11	11
Mongiana	11	10
Pennataro	11	11
Tarvisio	12	11

Table 3. Number of bird species on three Slovenian research sites. The number of species is presented for both the control and treatment plots, according to the intensity of the applied silvicultural measures (50% or 100% removal). The number of species for each site represents all detected species on the sites, also independently from point count sampling.

	Number of species			
Research site	Control	50%	100%	Whole site
Kočevski Rog	9	9	4	32
Snežnik	11	12	2	31
Trnovo	14	10	5	37

affected by habitat loss (Rueda *et al*., 2013). The species' composition was as expected in a managed forest. Results suggest a certain adaptability (in terms of resistance or resilience) to disturbances by those species, which were still present notwithstanding the year before sampling heavy forestry operations were going on and in some plots there was a substantial or complete removal of the trees. Forest areas surrounding the experimental plots were left untouched which may be alternative reason for the presence of bird specialist species; such a spatial arrangement of harvested *vs*. unharvested sites could have acted as a habitat buffer to mitigate, at least for a short time, the effects of harvesting.

On Slovenian sites a strong decline in the abundance and number of bird species comparing control plots and plots with complete removal of trees was evident. There was also a strong difference in the species occurring according to different cutting intensities. For Kočevski Rog, 9 species were observed on the control plots and four species observed on plots with the 100% removal. On Snežnik, 11 species were observed on the control plot, and only two species on plots with the 100% removal. In Trnovo 14 species were found on the control plots. On plots with 100% removal only five bird species found. Presence of canopy species (e.g., Firecrest, Goldcrest and tits), dead wood dependent species (e.g., great spotted woodpecker) and forest dependent species (e.g., Ural owl) has not been evidenced completely open areas. Some species, known to use open areas, like the wren and the robin, were observed in the area. On plots with 50% cutting intensity, the bird species composition was similar to the unmanaged (control) plots.

Our results show that the applied treatments at research sites in Slovenia affect the diversity of bird species. In open areas with 100% intensity removal, the number of species declines dramatically and almost no open-area bird species replace the forest dwelling ones. We hypothesize that the spatial scale of the treatments was too small to inhabit open habitat species on research sites.

References

Balestrieri R, Basile M, Posillico M, Altea T, De Cinti B, Matteucci G, 2015. A guild-based approach to assessing the influence of beech forest structure on bird communities. Forest Ecol. Manag. 356:216-223.

Bütler R, Angelstam P, Ekelund P, Schlaepfer R, 2004. Dead wood threshold values for the three-toed woodpecker presence in boreal and sub-Alpine forest. Biol. Conserv. 119:305-318.

Caprio E, Ellena I, Rolando A, 2008. Assessing habitat/landscape predictors of bird diversity in managed deciduous forests: a seasonal and guild-based approach. Biodivers. Conserv. 18:1287-1303.

Carrillo-Rubio E, Kéry M, Morreale SJ, Sullivan PJ, Gardner B, Cooch EG, Lassoie JP, 2014. Use of multispecies occupancy models to evaluate the response of bird communities to forest degradation associated with logging. Conserv. Biol. 28:1034-1044.

Czeszczewik D, Zub K, Stanski T, Sahel M, Kapusta A, Walankiewicz W, 2014. Effects of forest management on bird assemblages in the Bialowieza Forest, Poland. iForest 8:377-385.

Donald PF, Fuller RJ, Evans AD, Gough SJ, 1998. Effects of forest management and grazing on breeding bird communities in plantations of broadleaved and coniferous trees in western England. Biol. Conserv. 85:183-197.

Ellis TM, Betts MG, 2011. Bird abundance and diversity across a hardwood gradient within early seral plantation forest. Forest Ecol. Manag. 261:1372-1381.

Gil-Tena A, Saura S, Brotons L, 2007. Effects of forest composition and structure on bird species richness in a Mediterranean context : implications for forest ecosystem management. Forest Ecol. Manag. 242:470-476.

King DI, DeGraaf RM, 2000. Bird species diversity and nesting success in mature, clearcut and shelterwood forest in northern New Hampshire, USA. Forest Ecol. Manag. 129:227-235.

Morisita M, 1962. Iδ-Index, a measure of dispersion of individuals. Res Popul Ecol (Kyoto) 4:1-7.

Newton I. 1994. The role of nest sites in limiting the numbers of hole-nesting birds: a review. Biol. Conserv. 70:265-276.

Peronace V, Cecere JG, Gustin M, Rondinini C, 2012. Lista rossa 2011 degli uccelli nidificanti in Italia. Avocetta 36:11-58.

Roberge J, Angelstam P, Villard M-A, 2008. Specialised woodpeckers and naturalness in hemiboreal forests - Deriving quantitative targets for conservation planning. Biol. Conserv. 141: 997-1012.

Rueda M, Hawkins BA, Morales-Castilla I, Vidanes RM, Ferrero M, Rodriguez MA, 2013. Does fragmentation increase extinction thresholds? A European-wide test with seven forest birds. Glob. Ecol. Biogeogr. 22:1282-1292.

Shannon CE, Wiener W, 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, USA.

Simpson EH, 1949. Measurement of diversity. Nature 163:688.

Verner J, 1984. The guild concept applied to management of bird populations. Environ. Manage. 8:1-13.

Woodley SJ, Johnson G, Freedman B, Kirk DA, 2006. Effects of timber harvesting and plantation development on cavity-nesting birds in New Brunswick. Can Field-Nat. 120:198-306.

Did ManFor C.BD forest treatments influence diversity and composition of local flora?

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Slovenian research sites

Experimental design

Three test sites within Dinaric fir-beech forests in Slovenia [Kočevski Rog (KR), Snežnik (S) and Trnovo (T)] have been selected (Kutnar *et al*., 2015). These forests thrive on high altitude karst areas with diverse soil and climate conditions, which are highly favourable for the growth of forests as there is plenty of rainfall and high air humidity. Such forests grow at an altitude of 700 to 1200 m asl in a diverse land configuration. Different processes, such as silver fir decline and uneven-aged forest management in the previous 40 years have created a great variability of forest structures (Kobal and Hladnik, 2009).

On each test site, an area of karst depressions (sinkholes) was preselected. Nine were randomly selected for each test site, and the circular plots of 0.4 ha were set at the bottom of each (27 plots in total).

To test the effects of forest management, three different silvicultural measures were applied on selected plots in 2012. On one third of all plots (3 per each site), all trees (100% of growing stock) were cut on 0.4 hectares. On one third of all plots, 50% of the growing stock was evenly harvested over selected plots. Immediately after tree logging on two thirds of plots, the logs, and thick branches were pulled out from logging sites and skidded to a landing. On the last third of selected plots, no logging was implemented, and plots were considered as control.

Vegetation assessment

Plant species diversity was studied in the central part of the 0.4 ha plots at the bottom of sinkholes (Kutnar *et al*., 2015). On 400 m^2 of the circular plots, the cover estimation of vertical vegetation-layers and plant species diversity was performed according to the modified ICP-Forests protocol (Canullo *et al*., 2011). Furthermore, the percentage cover of each vegetation layer, the share of bare soil, the surface rocks and cover of deadwood were estimated. All vascular plant species were recorded in three vertical layers (herb, shrub, and tree layer) separately. A separate record was made for each species in the different vertical layer. The estimation of plant species cover was done using a modified Barkman's method (Barkman *et al*., 1964). Nomenclature of species names followed Mala Flora Slovenije (Martinčič *et al*., 2007) and Flora Europaea (Tutin *et al*., 1964-1980, 1993).

The plant species diversity was assessed before and two years after applied measures.

Data analysis

The cover of herb layer, species richness (N), and the Shannon diversity index (H´) were calculated for plot and site levels. These parameters have been determined before and two years after the implementation of silvicultural measures.

The following measures of diversity were investigated:

1) Species richness (N) refers to number of species within given plot.

2) Shannon diversity index (H´) is a measure that describes the structural composition of communities (Pielou, 1975):

$$H' = -\sum_{(i=1)}^{R} p_I \ln p^i$$

where p_i is relative frequency of species in a record.

The differences between treatments in herb cover, species number, and Shannon index were tested using one-way ANOVA followed by Tukey *post-hoc* tests at significance level 0.05 after data was tested for normality and homogeneity of variances. The main compositional and diversity gradients of study sites and plots were extracted by detrended correspondence analysis (DCA) (Hill and Gauch, 1980; McCune and Grace, 2002) using PC-ORD 6.0 Package (McCune and Mefford, 2011). DCA is an eigenvector ordination technique based on correspondence analysis (CA or RA). In this study, DCA ordinates both study plots/sites and plant species simultaneously, and are geared to ecological-diversity data sets (the eigenvalues are related to diversity and structural parameters in this case). Based on plant species composition before and after logging, plots from three sites are plotted in a DCA ordination space. Differences among plots and sites were indicated graphically.

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Key words: plant diversity, species richness, plant life-form, forest management, stand gap, Dinaric fir-beech forest, mountain beech forest, Natura 2000, Slovenia, Italy.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Results

Forests stands on all three study sites are dominated by European beech (*Fagus sylvatica*), European silver fir (*Abies alba*) and Norway spruce (*Picea abies*). Some other tree species, mostly found in understory layers include sycamore maple (*Acer pseudoplatanus*), wych elm (*Ulmus glabra*), common ash (*Fraxinus excelsior*), rowan (*Sorbus aucuparia*), small-leaved and large-leaved lindens (*Tilia cordata*, *T. platyphyllos*), manna ash (*Fraxinus ornus*), whitebeam (*Sorbus aria*), Norway and Bosnian maples (*Acer platanoides*, *A. obtusatum*), and common aspen (*Populus tremula*) (Kutnar *et al*., 2015).

Before applied silvicultural measures, a total of 151 plant species on all 27 plots of 400 m^2 were recorded. Two years after the implementation of measures, 250 plant species were determined in total. Due to change of ecological conditions or successional and seasonal dynamic, six species from the first assessment were not confirmed again. A total of 105 new plant species appeared on all plots; most of them were early successional species and non-typical forest plants. The majority of these species appeared in the forest gaps created by high intensity logging measures.

Before the logging, the mean number of species per plots was 48.8; and varied between 29 and 68 per plot, and the value of the Shannon diversity index H' was between 1.23 and 3.32 (mean: 2.41). After the logging, the mean species number per plots was 70.4, and varied between 41 and 106 per plot. The value of the Shannon diversity index H' after the logging was between 2.04 and 3.81 (mean: 3.07).

Before logging on the selected sites, the tree canopy was dense, and forest stands were closed; the mean value of visually estimated cover of the tree layer was 95.4%. After the logging, light conditions at the bottom of forest stands were significantly different than before. Two years after the applied silvicultural measures, the cover of the tree layer was only 48.0%, and the tree cover in control plots remained almost the same as at the beginning of the experiment.

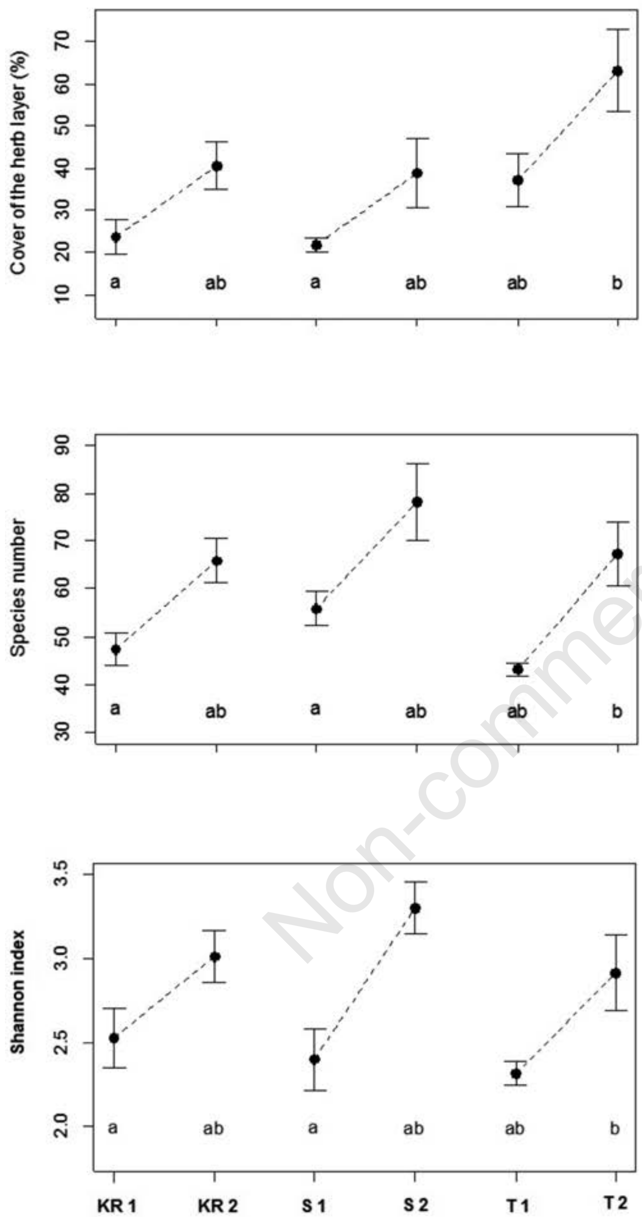

Figure 1. Mean cover of herb layer, species number and Shannon index on plots of three sites [Kočevski Rog (KR), Snežnik (S) and Trnovo (T)]. A comparison before (1) and after (2) logging is presented. The error bars represent standard errors of the mean. The letters denote homogeneous groups of treatments at a 0.05 significance level; means with the same letter are not significantly different from each other. Significant increases of average herb layer cover, plant species number and Shannon diversity index after logging were recorded at all three sites.

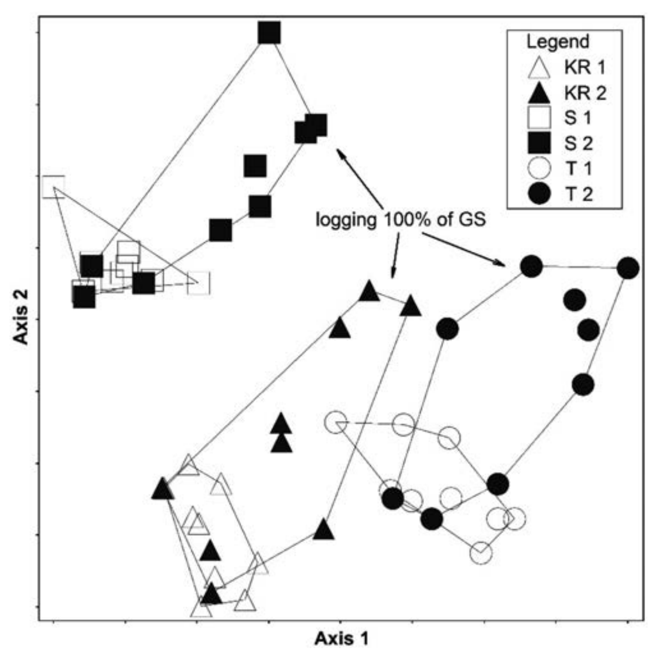

Figure 2. DCA ordination of three sites [Kočevski Rog (KR), Snežnik (S) and Trnovo (T)]before and after logging, based on species composition (presence/absence). The hollow symbols indicate the plots before (in 2012), and full symbols indicate the plots after the logging (in 2014), respectively.

The change of light conditions in forest stands resulted in the development of an herb layer, including herb species, graminoids, and saplings of different woody plants. Before logging, the herb layer cover varied between 21.7% in Snežnik site and 37.2% in Trnovo site (Figure 1). Two years after logging, a significant increase of herb layer cover was recorded, varying between 38.9% at the Snežnik site and as high as 63.1% at the Trnovo site.

Before logging, the highest mean species number was recorded at the Snežnik site (55.8 species); and the lowest number of 43.1 species at the Trnovo site (Figure 1). Significant increases in the number of plant species after logging were recorded at all three sites. The mean species number per plot was the highest at the Snežnik site (78.1 species) and the lowest at the Kočevski Rog site (65.9 species). However, the highest relative change in mean species number was established at the Trnovo site, where the number of species rose by 56%. The relative changes of species number at the other two sites were 39% (Kočevski Rog) and 40% (Snežnik).

Before logging, the mean Shannon diversity index varied between 2.31 (Trnovo site) and 2.53 (Kočevski Rog). After logging, the mean Shannon diversity index increased by 19% at the Kočevski Rog, 38% at the Snežnik site and 26% at the Trnovo site. It varied between 2.91 (Trnovo) and 3.30 (Snežnik) (Figure 1).

Based on plant species composition before and after logging, 27 study plots from three test sites are plotted in the DCA ordination space in Figure 2. Significant differences in species composition among three sites at the beginning of the experiment have been observed. The three groups of plots from different study sites indicating the state before logging are well separated in ordination space. The magnitude between control plots and plots with logging of 100% of growing stock may be observed.

Discussion

Three test sites were selected in Slovenia within the Dinaric fir-beech forests (association *Omphalodo-Fagetum* s. lat.) belonging to the Natura 2000 habitat type of 91K0 - Illyrian *Fagus sylvatica* forests (*Aremonio-Fagion*). Regardless of the fact that all test sites were selected and studied within the same forest and habitat type, the reactions of plant species on implementation of silvicultural measures were site specific (Kutnar *et al*., 2015). The implementation of different silvicultural measures caused different magnitudes of plant species turnover. With higher intensity of logging, from control without logging-to-logging 50% of growing stock, and to logging 100% of growing stock, the species turnover increased. The total number of plant species before the implementation of the silvicultural measures was 151, and more than 100 new plant species, mostly early successional species and non-forest plants appeared in the forest gaps created by high intensity logging measures. More open conditions, such as those created by gap formation, *e.g*., 100% growing stock logging in our study, result in higher variability in the extremes of ambient air and soil temperatures (Heithecker and Halpern, 2006), thus benefiting species that can tolerate such extremes. It is likely that such conditions would change over time as over-story canopies close and shrub layer species recover from logging operations. Thus, the impacts of thinning and gap formation on understory species groups will likely decrease over time, even though long-term impacts have been documented (Bailey *et al*., 1998; Lindh and Muir, 2004). To preserve the spatial heterogeneity of the wider area, new openings in the forest stand should be made in several year intervals.

In addition to the increased plant diversity and changed functional composition of the vegetation, other benefits of gaps created by logging could be expected. Managing of forests may improve food availability for wildlife and insect pollinators. Lower overstory densities, thinnings and gap creation are associated with the diversification of ecosystem functions and services, specifically the provision of food and habitat for wildlife, as evidenced by a higher cover of flowering, fleshy fruit and more palatable plant species (Neill and Puettmann, 2013). Species-rich forest gaps in Dinaric fir-beech forests have high feeding potential for larger herbivores and, consequently, they may reduce the harmful effect of the browsing of young trees in the nearby forest stands (Klopčič *et al*., 2010). It is expected that increased plant diversity also promotes diversity of other organisms, such as insects and other pollinators (Neill and Puettmann, 2013). Management actions that create such mosaic forest structures also improve habitat suitability for many bird species, including the endangered capercaillie (Graf *et al*., 2007). However, the size and position of gaps in Dinaric fir-beech forests should be carefully adjusted to sensitive karst terrain (Čater *et al*., 2014) and to climate change predictions (Kutnar and Kobler, 2011; Kutnar and Kobler, 2014), especially in the southern exposed slopes, in order not to jeopardize forest regeneration and soil productivity (Kutnar *et al*., 2015). The short-term effects of forest management on forest biodiversity is the first step in the long-term development of forest stands, and for this reason the use of more sustainable forest management options is heavily reliant on the profound understanding of interactions between management methods and the forest vegetation (Durak, 2012).

Appropriate forest management in Natura 2000 forests may contribute to very different biodiversity issues, but, in the context of particular habitat types, the key biodiversity factors and indicators of conservation status need to be defined first. However, it is commonly known that a high level of plant species diversity itself is one of the significant factors of favourable conservation status of forest habitats. It is even more important if forest management functions as a factor of enhancement of biodiversity in a wider sense and contributes to biodiversity conservation (Kutnar *et al*., 2015).

Italian research sites

Sampling method

To evaluate understory flora and vegetation response to silvicultural practices vegetation samples has been carried out. The percentage cover for each layer of forest structure (tree, shrub and herbaceous layer), a list of vascular flora and percentage cover for each species through a visual estimate has been recorded within plots of 400 m^2 of square plot, positioned on the same units where structural and deadwood measurements were realized, for a total of 140 plot. Aspect, slope, rockiness, stoniness and bedrock were also recorded. Moreover in the same plots, phytosociological relevés (Braun Blanquet, 1928, 1932; Tüxen, 1937; Westhoff and Van der Maarel, 1973; Géhu and Rivas-Martinez, 1981) have been carried out in order to define quantitatively vegetation types, to detect correlations between the vegetation communities and the environmental factors and to identify Habitat Natura 2000 (phytosociological syntaxonomy has been recognized as a basic reference for all of European member states).

Data analysis

Species of vascular flora were defined following Pignatti (1982) and the nomenclature according to Conti *et al*. (2005).

The vascular plant species list and relative percentage cover registered in each plot has been structured in a matrix associating to each inventoried species biological (Raunkiaer, 1934) and chorological (Pignatti, 1982) information.

Five life-form macro-categories were considered: Chamephytes (Ch), Geophytes (G), Hemicryptophytes, Phanerophytes (Ph) and Terophytes (T). Regarding Chorological types following macro-categories were analyzed Endemic, Steno-Mediterranean, Euri-Mediterranean, Montic Mediterranean, Eurasian, Atlantic, Orophyte, Boreal, and Cosmopolitan.

Chorological and life forms spectra, cover of herbaceous layer, species richness and Shannon diversity index (H') were calculated for every plot and site levels before and after management practices.

Indicators were calculated for groups of similar plots in each test sites, with the assumption that forest management treatments are a grouping factor.

Structural descriptors:

1) Cover of shrub and herbaceous forest layer;
2) Number of species recorded for each Life form group
3) Total cover for each Life form group, and
4) Frequency of all species occurring in each plot sites for each chorological type.

Biogeographical descriptor:

1) Number of species inventoried for each chorological type
2) Total cover for each chorological type, and
3) Frequency of all species occurring in each plot sites for each chorological type.

Biodiversity descriptors:

1) Species richness (N) refers to number of species within every plot.
2) Shannon diversity index (H′) is a measure that describes the structural composition of communities (Pielou, 1975):

$$H' = -\sum_{(i=1)}^{R} p_I \ln p^i$$

where p_i is relative frequency of species in a record.

The differences before and after treatments and among different treatments in shrub and herbaceous layer, Life forms and chorological spectra, species number and Shannon index were tested using SPSS (Statistical Package for Social Science) applying Student *t*-test, at significance level 0.05 (Table 1).

Results

Results of analysis carried out highlighted slight changes of understory flora indicators, except for biogeographical descriptor, for which insignificant alterations have been observed. Probably the driving forces of this category of descriptor are not due to different forest management applied, but to environmental factors.

Significant changes regards structural descriptors especially in total cover for each Life form group (Figure 3).

Cover's increase of Hemicryptophytes and Terophytes seems to be related to forest practices, with a significance of P=0.05.

Species richness (Figure 4) and species cover (Figure 5) are affected by silvicultural treatments, as highlighted from the Student *t*-test (Tables 2 and 3).

Discussion

Significant changes on understory flora and vegetation after silvicultural treatments has been recorded in investigated sites; in particular cover species increases in all different forest treatments. Although not in all the sites a common trend was observed about other structure descriptors and biodiversity indicators. The response of plant species to different forest treatments are quietly site specific and depends on forest types. Moreover, even if silvi-

Table 1. Results of the Student *t*-test on life forms cover before and after silvicultural treatments.

Thesis	Life forms	Ch	G	H	P	T
Innovative	-	-	*	-	*	
Traditional	-	-	-	-	-	
No Practice	-	-	-	-	-	

*P<0.05.

Table 2. Results of the Student *t*-test species richness before and after silvicultural treatments.

Thesis	Number of species
Innovative	*
Traditional	-
No practice	-

*P<0.05.

Table 3. Results of the Student *t*-test on species cover before and after silvicultural treatments

Thesis	Cover
Innovative	*
Traditional	**
No practice	-

*P<0.05, **P<0.05.

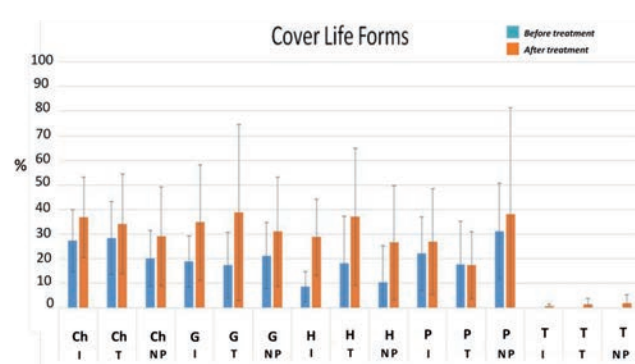

Figure 3. Cover of Life forms recorded before and after silvicultural treatments in Mongiana test site. Ch, Chamephytes; G, Geophytes; H, Hemicryptophytes; P, Phanerophytes; T, Terophytes; I, innovative treatment; T, traditional treatment; NP, no practices.

cultural treatments' design is different, they do not strictly affect understory vegetation; gaps created by low logging have simulated circumscribed natural disturbances, such as the fall of old tree. In that situation understory plant species are tolerant and so they overcome this short-term effect. Forest treatments applied to test sites demonstrate to be sustainable, especially for diagnostic species of Habitat Natura 2000.

In Italy, there are other LIFE projects which aim to promote the long-term conservation of particular forest community, such as beech forest belonging to habitats 9210* and 9220*. The importance to ensure the conservation of the species, which characterize these habitats, is due to their sensitivity to climate change and global warming and inappropriate management actions. LIFE+ Fagus, LIFE+ Faggete del Taburno, LIFE RESILFOR1 intend to improve ecosystems conservation status focusing on regeneration of silver fir, yew and holly and on enhancement of diversity levels for the focus taxa.

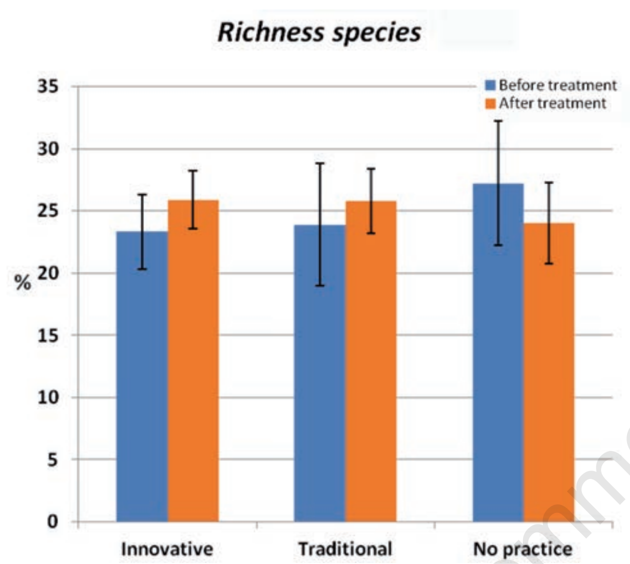

Figure 4. Species richness before and after silvicultural treatments in different management practices, Cansiglio sites.

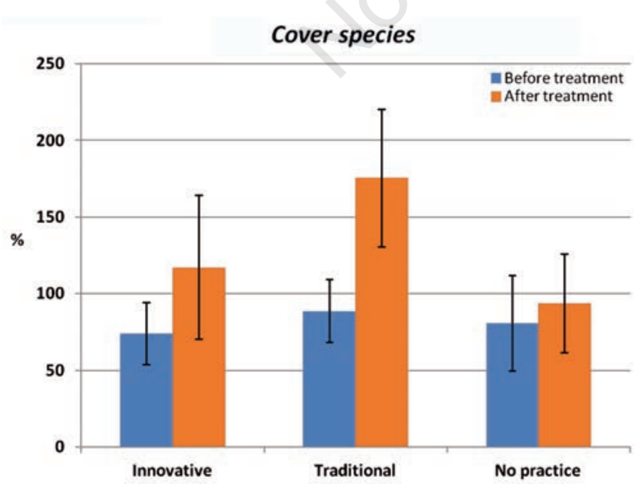

Figure 5. Cover Species cover before and after: ante and post silvicultural treatments in different thesis in management practices, Cansiglio test sites.

References

Barkman JJ, Doing H, Segal S, 1964. Kritische Bemerkungen und Vorschläge zur quantitativen Vegetationsanalyse. Acta Bot. Neerl. 13:394-419.

Bailey JD, Mayrsohn C, Doescher PS, St. Pierre E, Tappeiner JC, 1998. Understory vegetation in old and young Douglas-fir forests of western Oregon. Forest Ecol. Manag. 112:289-302.

Braun-Blanquet J, 1928. Pflanzensoziologie. Springer Verlag, Vienna.

Braun-Blanquet J, 1932. The study of plant communities. Plant sociology. McGraw-Hill Book Company, New York.

Canullo, R., Starlinger, F., Granke, O., Fischer, R., Aamlid, D., Neville, P., 2011. Assessment of ground vegetation. Manual Part VII-SP1. In: ICP Forests. Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE ICP Forests Programme Co-ordinating Centre, Hamburg. Available from: http://www.icp-forests.org/pdf/FINAL_GV.pdf

Čater M, Diaci J, Roženbergar D, 2014. Gap size and position influence variable response of Fagus sylvatica L. and Abies alba Mill. Forest Ecol. Manag. 325:128-135.

Conti F, Abbate G, Alessandrini A, Blasi C, 2005. An annotated checklist of the Italian vascular flora. Ministero dell'Ambiente e della Tutela del Territorio, Direzione per la Conservazione della Natura, Dipartimento di Biologia Vegetale, Università degli Studi di Roma "La Sapienza", Palombi Editori.

Durak T, 2012. Changes in diversity of the mountain beech forest herb layer as a function of the forest management method. Forest Ecol. Manag. 276:154-164.

Géhu J-H, Rivas-Martinez S, 1981. Notion fondamentales de Phytosociologie. Berichte der Internationalen vereinigung fur vegetation skunde "Syntaxonomie". Ed. Cramer, Vaduz.

Graf RF, Bollmann K, Bugmann H, Suter W, 2007. Forest and landscape structure as predictors of capercaillie occurrence. J. Wildl. Manage. 71:356-365.

Heithecker TD, Halpern CB, 2006. Variation in microclimate associated with dispersed-retention harvests in coniferous forests of western Washington. Forest Ecol. Manag. 226:60-71.

Klopčič M, Jerina K, Boncina A, 2010. Long-term changes of structure and tree species composition in Dinaric uneven-aged forests: are red deer an important factor? Eur. J. For. Res. 129:277-288.

Kobal M, Hladnik D, 2009. Stand diversity in the Dinaric fir-beech forests. Zbornik gozdarstva in lesarstva 90:25-42.

Kutnar L, Kobler A. 2011. Prediction of forest vegetation shift due to different climate-change scenarios in Slovenia. Šumarski list 135:113-126.

Kutnar L Kobler A, 2014. Possible impacts of global warming on forest tree species composition in Slovenia. Adv. GeoEcol. 43:221-230.

Kutnar L, Eler K, Marinšek A, 2015. Effects of different silvicultural measures on plant diversity - the case of the Illyrian Fagus sylvatica habitat type (Natura 2000). iForest doi: 10.3832/ifor1587-008.

Lindh B, Muir P, 2004. Understory vegetation in young Douglas-fir forests: does thinning help restore old-growth composition? Forest Ecol. Manag. 192:285-296.

Martinčič A, Wraber T, Jogan N, Podobnik A, Turk B, Vreš B, 2007. Mala flora Slovenije. Tehniška založba Slovenije, Ljubljana.

Neill AR, Puettmann KJ, 2013. Managing for adaptive capacity: thinning improves food availability for wildlife and insect pollinators under climate change conditions. Can. J. Forest Res. 43:428-440.

Pielou EC, 1975. Ecological diversity. Wiley, New York.

Pignatti S, 1982. Flora d'Italia. Vol. I, II, III. EdAgricole.

Raunkiaer C, 1934. Life forms and terrestrial plant geography. Oxford Clarendon Press.

Tutin TG, Burges NA, Chater AO, Edmondson JR, Heywood VH, Moore DM, Valentine DH, Walters SM, Webb DA, 1993. Flora Europaea, vol 1. Cambridge University Press, Cambridge.

Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA, 1964-1980. Flora Europaea, vol .2-5. Cambridge University Press, Cambridge.

Tüxen R, 1937. Assoziationskomplexe. Ber. Internat. Symp.Veg. Rinteln 1977, Cramer Verl. Vaduz.

Westhoff V, Van Der Maarel E, 1973. The Braun-Blanquet approach. In: R.H. Whittaker (ed.) Ordination and classification of communities. Handbook of vegetation science. Junk, The Hague, pp. 619-726.

Did ManFor C.BD forest treatments influence carbon stock and sequestration?

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Effect of management on carbon stock and sequestration

Forests are a key component of the global carbon cycle. It has been estimated that of the 480 Gt of carbon emitted by anthropogenic activities (fossil fuel and land-use change related emissions) since the start of industrial revolution, 166 GtC (35%) have been absorbed by forest ecosystems, 124 GtC by oceans (25%), while 190 GtC (40%) remained in the atmosphere, causing the relevant increase of CO_2 concentrations that is the main driver of climate change (House *et al*., 2002). In this respect, the role of managed forests is crucial as several studies attributed to the forests of the Northern hemisphere, a large part of which is managed, a prominent role in the carbon cycle of the last 20 to 30 years (Schimel *et al.*, 2001). The C cycle begins with the process of CO_2 assimilation by plants that determines the delivery of assimilates to the plant internal store, which may then be used for growth, reserve or defense. In trees, growth adds biomass as foliage, wood and roots. The annual cycle of plant part losses, arising in the form of the litterfall derived from above- and below-ground parts, migrates carbon to the soil and feeds back to the heterotrophs of the ecosystem which use the energy stored in the organic matter and recycle nutrients as a major resource for further plant growth (Schulze, 2000).

Methods

In both countries assessment procedures have been carried out on ManForC.BD representatives sampling plots. Basing measurements on a classic forest inventory approach (structure, stocks, increment) and biomass assessment on allometric equations are collected in all sites. Tree diameters at man breast height (DBH), of all plot trees, have been measured and these data, together with tree heights, have been used to assess the total arboreal biomass (carbon stock ~0.5 biomass).

Concerning leaves and fruits annual production, the litter funnel trap method has been used at plot level in three test sites in Slovenia and in beech stands in Italy (Cansiglio, Chiarano and Mongiana sites).

Soil carbon pool was estimated using a systematic sampling in each sub-plot. A quite different approach has been used. In Italy, undisturbed soil cores has been collected down to 40 cm or more (where possible), sampling mineral soil by pedological horizon depth. Sampling size has been of three core for each sub-plot at sites where treatments will be replicated (3 treatments, 3 plot per treatment, a total of 27 sub-plots and 81 soil samples).

On the same point, soil litter has been collected by a 20×20 cm metal frame.

In each Slovenian subplot, at three sites (1 m far from subplot centre, according to azimuths of 0, 120 and 240) soil sampling was performed. Mineral soil was sampled by fixed depths (0-10 cm, 10-20 cm, 20-40 cm, 40-60 cm, 60-80 cm), until reaching parent material. Soil litter was collected on square area 25 × 25 cm (area = 625 cm^2) and sampled material from all three points were put together (composite samples).

The humus forms, more recently used as significant indicators of soil organic carbon (SOC) storage (De Vos *et al*., 2015) and coinciding with the sequence of organic (OL, OF, OH, H) and underlying organo-mineral horizons (A, AE, Aa) (Zanella *et al*., 2011) was collecetd in the italian beech stands of Cansiglio, Chiarano and Mongiana sites. Sampling size has been of three core for each plot at sites where treatments will be replicated (3 treatments, 3 plot per treatment, a total of 27 topsoil samples). Soil, humus form and litter sampling was repeated in all sites after silvicultural operations, so near as possible to previous sampling holes.

In each plot, deadwood was assessed within one plot of 13 meters of radius concentric within the plot established for structural measurements. Coarse woody debris were measured when more than half base of their thicker end lied within the plot. A threshold height of 1.3 m was used to distinguish stumps (less than 1.3 m) from snags (higher than 1.3 m). Decay level classification of each deadwood piece was carried out visually by the system proposed by Hunter (1990).

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Key words: carbon stock, forest management, soil respiration, wood products.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Result and lesson from ManForC.BD sites

The first and very visible effect of forest management is a decrement of aboveground biomass.

In Italian site, the mean amounts of carbon removed by harvesting operations in innovative and traditional options were 47±13 and 34±13 $MgCha^{-1}$, respectively. The management effects on biomass of the innovative and traditional approach were not different, the amount of carbon stored in stems and branches decreased of 33±9 % and 26±7 %, respectively.

In the Slovenian sites, the cutting percentage were constant 50% and 100% of living above ground biomass, and the mean amount of carbon removed by harvesting operations was 114 $MgCha^{-1}$.

In the Italian sites, carbon stored in deadwood increased of 4.91 and 4.13 $MgCha^{-1}$ in innovative and traditional management, gaining of 202% and 194%, respectively. In all the innovative management options dead downed woods and girdled trees (future snags) were created.

In the Slovenian sites deadwood carbon pool increased of 588% in the plot where half of living biomass was cut and 1154% where all the trees were cut. After harvesting operations, the amount of carbon stored in deadwood increased of 26 and 54 $MgCha^{-1}$, respectively.

Along the north-south transect of the Italian peninsula the lowest values of Soil Organic Carbon (SOC) are in the northernmost site of Cansiglio where the average value is 65±15 $MgCha^{1}$. In Chiarano and Mongiana values are higher: the average content of SOC, indicates similar values in the two sites 93±8 and 94± 9 MgC ha^{-1}, respectively.

In Italian sites the innovative and traditional forest management did not create any significant variation in soil carbon pools. These results suggest first at all the low impact of forest operations upon the soil. Overall to discuss results we have to consider that the changes in soil are very slowly processes with a larger temporal scale, because different input of deadwood, litter aboveground or roots biomass could produce changes in the soil carbon pool in the next years. In fact the effect of different treatments has involved most superficial horizons (OF, OH) of humus form, with a trend from less active forms to other more active, showing a different storage of SOC in topsoil profile, in Cansiglio and Mongiana sites.

In Italian sites Innovative and traditional management options reduced the forest carbon stock of 33 and 41 MgCha1, respectively. In the Slovenian sites the reduction of carbon stock was 67 and 143 MgCha1 for 50% and 100% biomass cutting, respectively (Figure 1).

Effect of management on soil CO_2 emission

Carbon dioxide is produced in soils by roots and soil organism and, to a small extent, by chemical oxidation of carbon-containing materials. CO_2 is released from soils in the process variably referred to as soil respiration. The rate at which CO_2 moves from soil to the atmosphere is controlled by the rate of CO_2 production in the soil, the strength of the CO_2 concentration gradient between the soil and the atmosphere, and the properties such as soil pore size, air temperature, and wind that influence the movement of CO_2 through and out of the soil (Raich and Schlesinger, 1992).

Forest management could influence environmental characteristics that are involved in soil respiration (Tedeschi, 2003; Ma *et al.*, 2004).

Methods

In Chiarano, every 15-20 days the measurements has been performed by an IRGA (infra-red gas analyser) technology instrument commercialized as EGM-4 Environmental Gas Analyzer for CO_2, equipped with a soil respiration chamber (SRC1, PPSystems) and a soil temperature sensor. Measurement was carried out overlapping the soil chamber on a 15 cm diameter PVC collars, previously placed on the forest floor.

Three of the nine plots have been selected (one for each treatment). In each plot, measurements are performed in the three subplots, where 6 collars have been placed following the following criteria:

- a first one is randomly placed close to the sub-plot centre;
- a second one at three meters from the centre along the line of maximum slope;
- the other four are placed respectively at an increasing distance from the center, of 6, 9, 12, and 12 m with an angle of 90 degrees from each other starting from the second.

Such design describes a 'spiral arrangement' inscribed in a 13 m radius circle. In order to avoid measuring soil respiration too close to trees, the collars positioning occurs at a distance not less than one meter from the plants.

Soil flux measurement in Slovenia has been conducted by a slightly different method than in Italy. Manual measurement includes a LI-6400 console with battery pack, 6400-09 soil chamber and soil temperature probe that connects to the LI-6400 system, which allows for temperature measurements to be integrated into the data set.

CO_2 flux measurements require extensive sampling. Slovenian methodology includes three repetitive cycles on each point of the plot.

The Slovenian protocol foresees also the use of an automatic device (a prototype suitably adapted to the measurements requested for the Project purposes, see Ferlan, 2016).

Result and lesson from ManFor sites

In all sites soil temperature is the main driver of soil CO_2 efflux.

In Chiarano, the sensitivity of soil respiration (SR) to temperature (slope of regression lines) is greater in the plots where the traditional treatment occurred and in a plot without any silviculture operation, than in the plots where the innovative treatments have

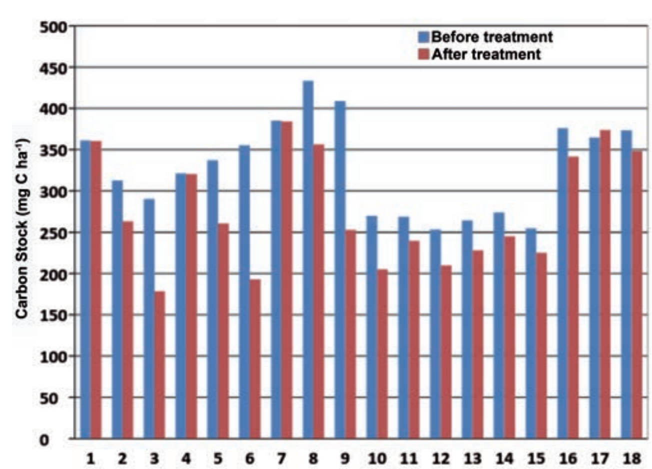

Figure 1. Carbon stock in six study sites. Blue, carbon stock before silvicultural treatments; red carbon stock after silvicultural treatments.

been performed (Figure 2).

A strong correlation between the basal area (the main index structure of forest stands) and the sensitivity of soil respiration to temperature was found in this site. After cutting, in the plot with highest basal area (Figure 3), proxy of root biomass, higher CO_2 effluxes were measured. These results suggest the importance of root respiration (autotrophic component) in this high elevation ecosystem.

The differences among the plot are reflected in the annual soil CO_2 effluxes to the atmosphere.

Analysing the whole growing season (from June 2013 to October 2013) we observed that the plot under traditional treatment lost a greater amount of carbon (576 gC m^{-2}) than Innovative40 (462 gC m^{-2}) and Innovative 80 (394 gC m^{-2}).

In Mongiana site soil respiration ranged from 0.13 μmol CO_2 m^{-2} s^{-1} of February to 2.65 μmol CO_2 m^{-2} s^{-1} of August. Also in this site soil temperature have a significant effect on soil respiration. Also in this site management options had a significant effect on CO_2 soil effluxes. Plots with innovative options showed higher annual mean respiration than traditional and no practice plots.

On Slovenian sites a significant relation between soil temperature and CO_2 soil efflux has been confirmed (Figure 4). Different relation was confirmed for plots with predominating beech (Figure 5).

Evident changes as the result of higher decomposition rates in beech-predominant stands have been evidenced after applied silvicultural measures, compared to silver fir or predominating spruce stands (Figure 5). Decrease in efflux rates during following period was similarly more pronounced in predominating beech stands. Absolute response values were higher on plots of Trnovo and smallest on Snežnik sites.

At the beginning of growing period changes were highly pronounced in beech forest stands, contributed to higher response in broadleaved species than in conifers (fir, spruce).

Level of SR in beech predominating stands was higher on all plots and increased even more after the applied silvicultural measures in September, compared to silver fir and spruce predominating stands.

Results confirm response differences connected with cutting intensity: highest change was measured on plots with 100% intensity and lowest on control plots. Differences between different sampling microsites (within each plot) are also connected with different temperature conditions (Figure 6).

Through experiences of ManFor sites it is possible to suggest that:

1. Carbon fluxes are different in regard to predominating tree species;
2. Soil temperature and forest structure affects soil respiration;
3. Intensity of silvicultural treatments affects release of below ground carbon;
4. Recovery to balanced stage/equilibrium is inversely proportional to silvicultural treatments intensity.

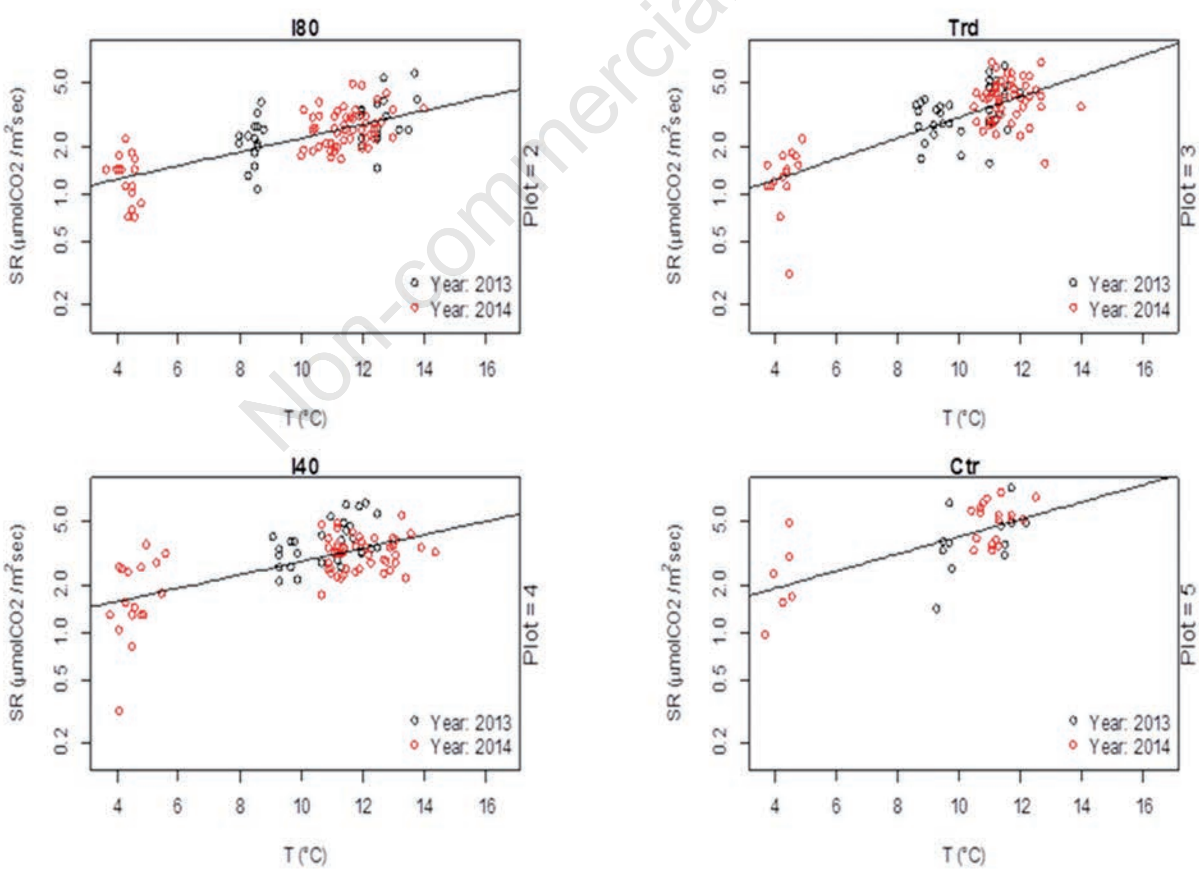

Figure 2. Response of respiration to temperature. The points in black represent the measures in 2013 while the points in red represent the measures in 2014. The vertical axis is a logarithmic scale. I80, innovative 80 management option; I40, innovative 40 management option; Trd, traditional management; Ctr, control without any management.

Effect of management on microclimatic parameters

Microclimate is the suite of climatic conditions measured in localized areas near the earth's surface. The importance of microclimate in influencing ecological processes such as plant regeneration and growth, soil respiration, nutrient cycling, and wildlife habitat selection has become an essential component of current ecological research (Davidson *et al*., 1998; Epron *et al*., 1999; Buchmann, 2000; Morén and Lindroth, 2000).

Natural modifications (windbreaks or the death of one or several trees) or artificial intervention by the forester (clearfelling, clearing, strip felling, shelterwood, seed felling, thinning) modify the microclimatic characteristics (Tedeschi, 2003; Katayama *et al*., 2009). The sensitivity of the microclimate to structural transformation (*e.g*., timber harvesting and the resultant stand-level changes in over-story height) offers strong potential for monitoring ecosystem at multiple spatial scales.

Methods

In Chiarano three permanent sensors (ECH2O-TE/EC-TM, Decagon Devices) were installed for measuring the temperature and humidity of soil and air.

Every sensor has a probe, place at a height of 1.80 m, for the measurement of temperature and relative humidity of the air and four probes for the measurement of temperature and humidity (Volumetric Water Content) of soil. Probes for the measurement of soil parameters are place at a depth of 5 and 10 cm (two at 5 cm and two at 10 cm).

In all Slovenian sites continuous measurements were performed on centre, north and south of each plot (27x3=81 measurements points).

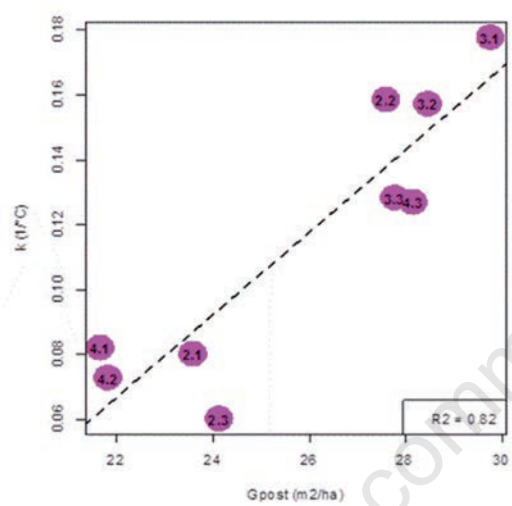

Figure 3. The relationship between the sensitivity of respiration to temperature (K) and the basal area after the silvicultural treatments (Gpost). Each point indicates a sub-plot (13 m radius). The dashed line represents the regression line (R2=0.82).

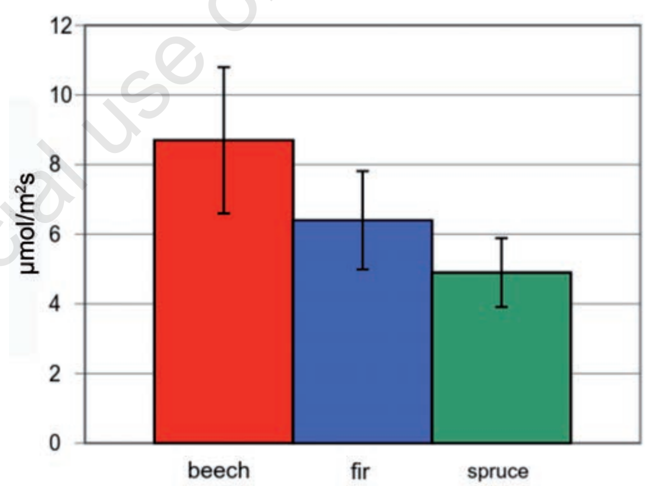

Figure 5. Average soil respiration rate according to predominating tree species.

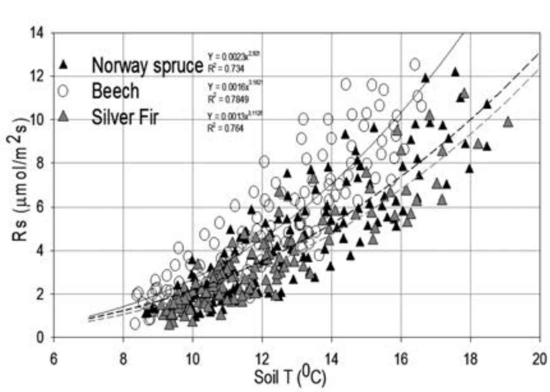

Figure 4. Relation between soil CO2 fluxes and soil temperature on Slovenian sites. Each points represent the mean of a sampling plot (Čater, 2015).

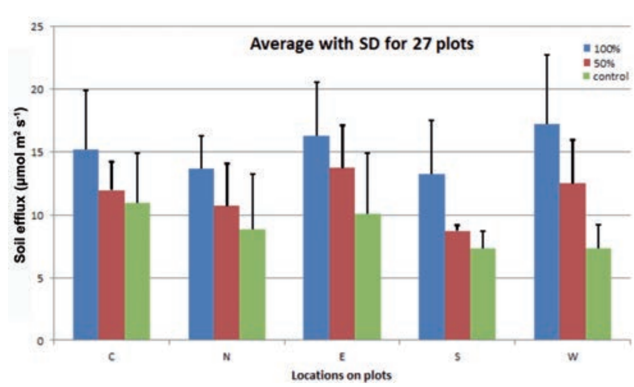

Figure 6. Average values of soil respiration, all 27 plots included.

Result and lesson from ManFor sites

In Slovenian sites a great effect of forest management on maximum temperature was found (Figure 7) differently to air humidity (Figure 8). In case of high temperature a difference of 6°C was observed between the plots where the total aboveground biomass was cut and the control ones.

In Chiarano the different management options do not have significant differences (Figure 9). Curves of temperature and humidity of the air measured in the traditional and innovative 80 are totally overlapped.

Data collected during the project shows that significant effect are evaluable only in case of drastic management options (cutting of 100% living biomass).

In Chiarano innovative ad traditional management options don't have any different effects on the microclimatic parameters.

Wood products and carbon cycling

Long term storage of carbon in products delays or reduces emissions. Use of wood products can also reduce emissions if they substitute for 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 accu-

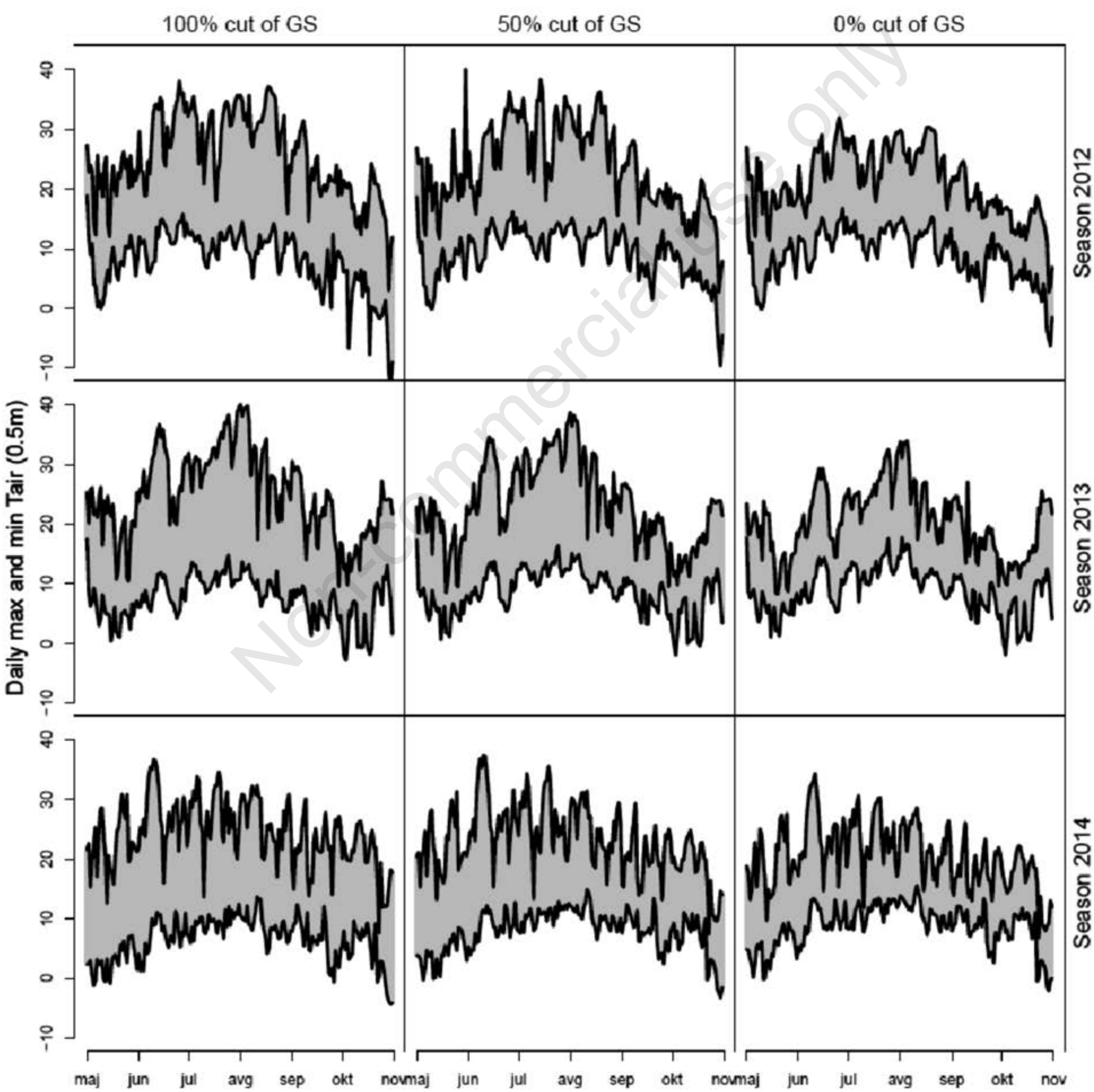

Figure 7. Average daily maximum and minimum temperatures measured in the Slovenian sites during 2012 and 2014 growing seasons.

mulation of carbon in products can be influenced by the mix of products and uses (USDA, 2011).

Consequently forest management plays a central role in providing good quality wood to the production chains, for this reason we compared the potential wood assortments obtainable by the different management options. Also the use of wood biomass for producing heat and energy has an impact on global carbon cycle. Since the burning of wood avoids the emissions of many possible fossil fuels, the avoided CO_2 emissions may be stated in terms of offsetting the burning of fossil fuels (USDA, 2011).

Methods

In the Italian beech forests we estimated the potential obtainable assortments from the different type of management, using a yield table that provide also the obtainable assortments. For each site we used the suitable fertility class comparing the site height and diameter with the values in the table (Castellani *et al*., 1972).

We considered 4 type of assortments: saw log (diameter >30 cm, length >4 m), yule log (diameter 15-30 cm), fuel wood (diameter 10-15 cm) and bundle (diameter <0 cm).

Result and lesson from ManFor sites

The quality of woody products is strongly dependent by the biomass before treatments (Figure 10). Inside the sites, the result of different management options is a different woody production. In the Italian beech forests of the project, the innovative management options could provide higher quality products (Figure 11). In mature forests (Cansiglio and Mongiana) the saw log amount represents 38% and 24% of the total woody products in innovative and in traditional options, respectively.

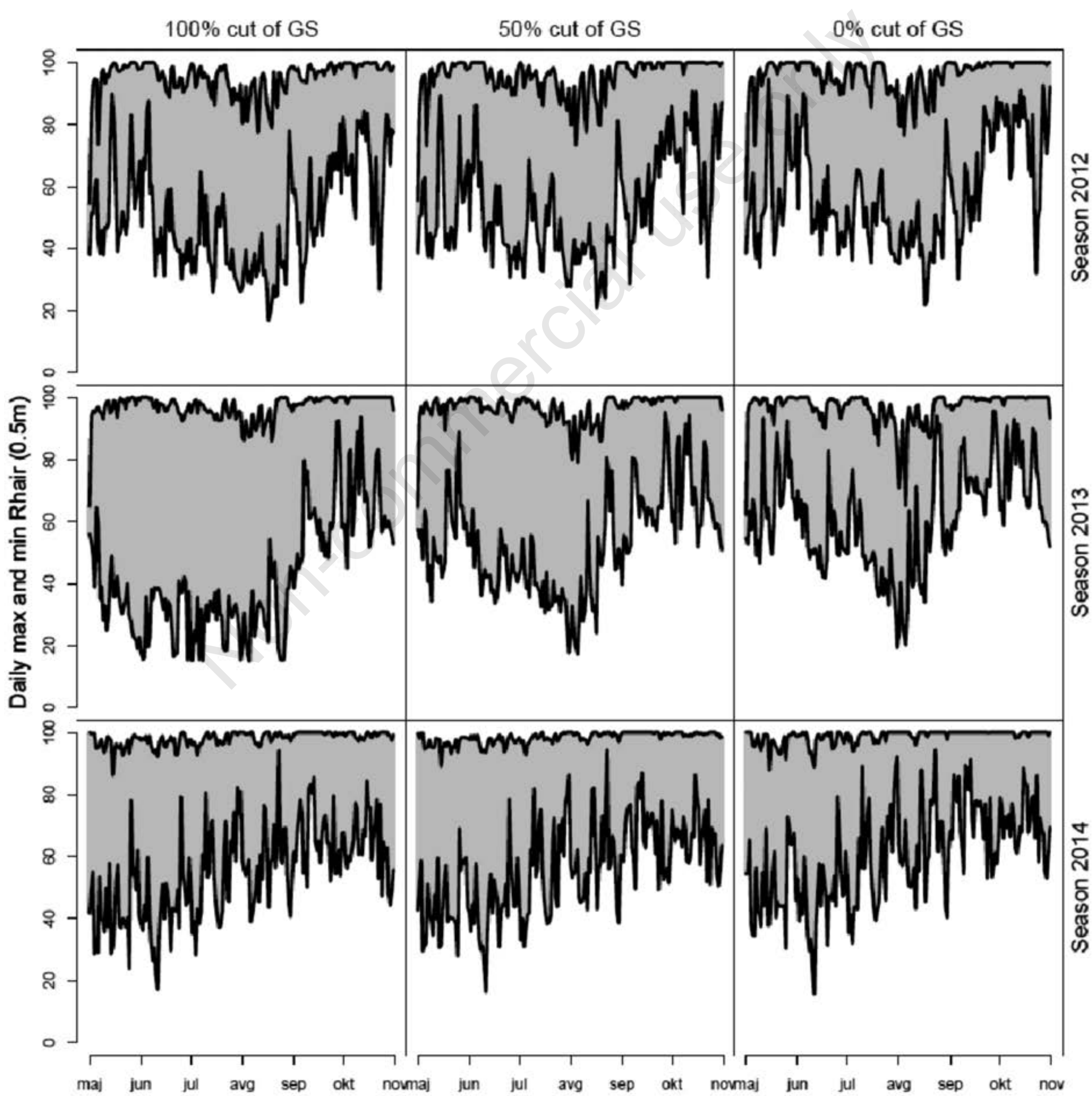

Figure 8. Average daily maximum and minimum air humidity measured in the Slovenian sites during 2012 and 2014 growing seasons.

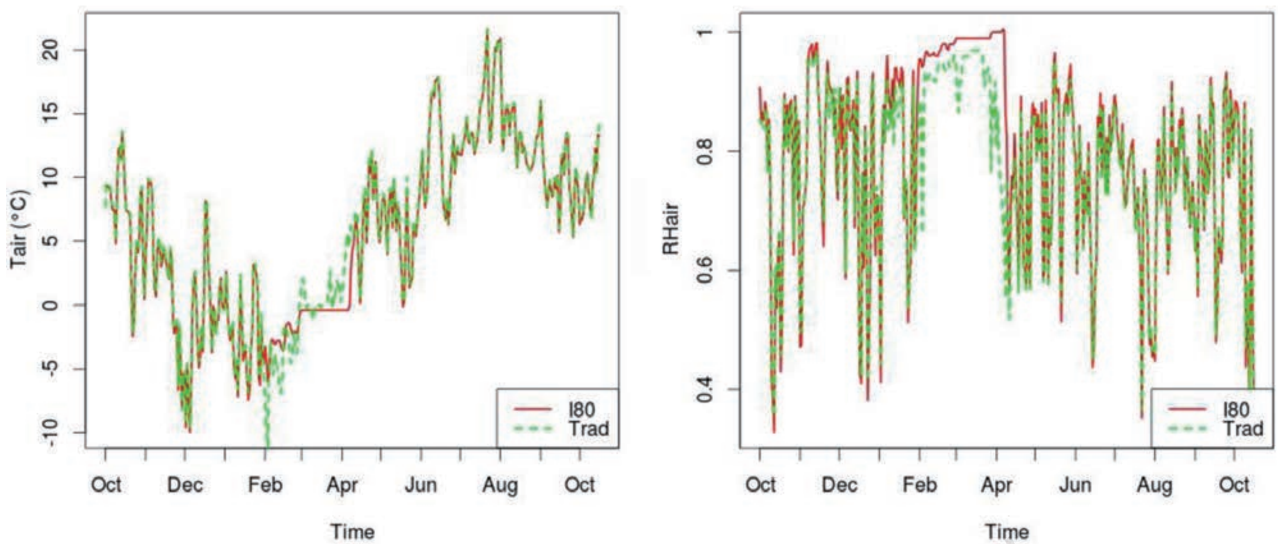

Figure 9. Average air temperature and humidity in Chiarano Forest; red, innovative 80 management option; green, traditional management.

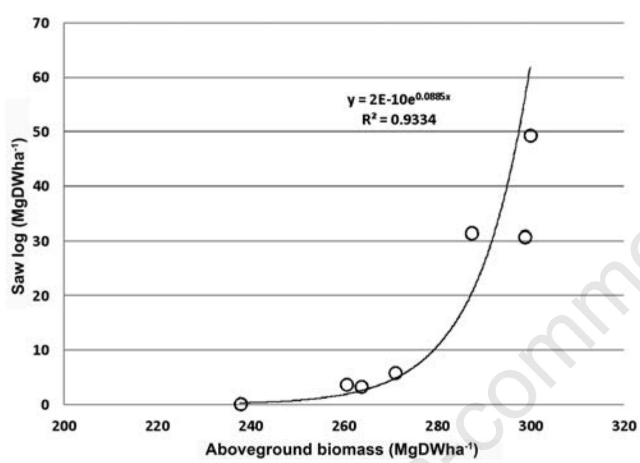

Figure 10. Relation between potential SAW LOG production and aboveground biomass before treatments. Each point represents a management option.

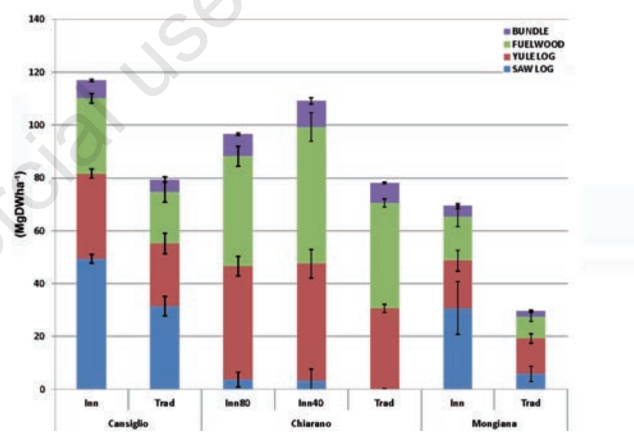

Figure 11. Potential woody products in each site *per* management options.

References

Buchmann N, 2000. Biotic and abiotic factors regulating soil respiration rates in Picea abies stands. Soil Biol. Biochem. 32:1625-1635.

Castellani C, 1972. Tavole stereometriche e alsometriche costruite per i boschi italiani. Annali Istituto Sperimentale Assestamento Forestale Apicoltura 2:89-90.

Čater M, 2015. Thinning effect on soil respiration in Silver fir, Beech and Spruce predominating adult forest stands. In: K. Houšková and J. Černý (eds.) Central European silviculture. Mendel university in Brno, pp. 154-163.

Davidson EA, Belk E, Boone RD, 1998. Soil water content and temperature as independent or confounded factors controlling soil respiration in a temperate mixed hardwood forest. Global Change Biol. 4:217-227.

Elliot WJ, Kimble JM, Heath LS, Birdsey RA, Lal R, 2003. Soil erosion in forest ecosystems and carbon dynamics. In: J.M. Kimble, R. Lal, R.A. Birdsey and L.S. Heath (eds.) The potential of US forest soils to sequester carbon and mitigate the greenhouse effect. CRC Press, Boca Raton, FL, USA, pp. 175-190.

Epron D, Farque L, Lucot E, Badot P-M, 1999. Soil CO2 efflux in a beech forest: dependence on soil temperature and soil water content. Ann. For. Sci. 56:221-226.

Ferlan M, 2016. Innovative system for measuring soil respiration. Ital. J. Agron. 11(s1):1-175.

House JI, Colin Prentice I, Le Quéré C, 2002. Maximum impacts of future reforestation or deforestation on atmospheric CO2. Glob. Change Biol. 8:1047-1052.

Hunter Jr ML, 1990. Wildlife, forests, and forestry. Principles of managing forests for biological diversity. Prentice Hall, Upper Saddle River, NJ, USA.

Johnson DW, Curtis PS, 2001. Effects of forest management on soil C and N storage: meta analysis. Forest Ecol. Manag. 140:227-238.

Kalbitz KS, Solinger S, Park JH, Michalzik B, Matzer E, 2000. Controls on the dynamics of dissolved organic matter in soils: a review. Soil Sci. Soc. 165:277-304.

Katayama A, Kume T, Komatsu H, Ohashi M, Nakagawa M, Yamashita M, Otsuki K, Suzukig M, Kumagai T, 2009. Effect of forest structure on the spatial variability in soil respiration in a Bornean tropical rainforest. Agr. Forest Meteorol. 149:1666-1673.

Ma S, Chen J, North M, Erickson HE, Bresee M, Moine JL, 2004. Short-term effects of experimental treatments on soil respiration in an old-growth, mixed-conifer forest. Environ. Manage. 34:S148-S159.

Morén AS, Lindroth A, 2000. CO2 exchange at the floor of a mixed boreal pine and spruce forest. Agr. Forest Meteorol. 101:1-14.

Raich JW, Schlesinger WH, 1992. The global carbon dioxide flux in soil respiration and its relationship to vegetation and climate. Tellus Ser. B 44:81-99.

Schimel DS, House JI, Hibbard KA, Bousquet P, Ciais P, Peylin P, Braswell BH, Apps MJ, Baker D, Bondeau A, Canadell J, Churkina G, Cramer W, Denning AS, Field CB, Friedlingstein P, Goodale C, Heimann M, Houghton RA, Melillo JM, Moore III B, Murdiyarso D, Noble I, Pacala SW, Prentice IC, Raupach MR, Rayner PJ, Scholes RJ, Steffen WL, Wirth C, 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. Nature 414:169-172.

Schulze ED, 2000. The carbon and nitrogen cycle of forest ecosystems. In: E.D. Schulze (ed.) Carbon and nitrogen cycling in European forest ecosystems. Springer, Germany, pp. 1-13.

Tedeschi V, 2003. Variabilità temporale e spaziale della respirazione del suolo in una cronosequenza di Quercus cerris L. dell'Italia centrale. Degree Diss. Università della Tuscia, Viterbo, Italy.

USDA, 2011 National report on sustainable forests-2010. United States Department of Agriculture, Washington, DC, USA.

Zanella A, Jabiol B, Ponge JF, Sartori G, De Waal R, Van Delft B, Englisch M, 2011. A European morpho-functional classification of humus forms. Geoderma 164:138-145.

Community analysis at medium scales: focus on Carabids

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Introduction

An investigation of carabid beetle communities of a managed spruce forest has been carried out in eastern Alps (Cadore, Veneto region, Italy) from May to September (2013). We positioned the pitfall traps across different sample units (i.e., forest stands), at an elevation between 800 and 1500 m asl, in order to collect carabid beetles. The study of the species composition and of the ecological structure of carabids assemblages allows to understand each structural parameters of communities and to analyse in detail how the ground beetle communities are influenced by the structure and the morphology of the forest and by the forest management. This type of information could be useful for understanding the impact of management activities in biological communities and for promoting good practice of sustainable forest management.

Response indicators

Species richness

We collected ground-beetles from Coleoptera order, in particular species belonging to Carabidae, often used in biodiversity assessment and conservation plans as they are easily captured, taxonomically well known, abundant, respond to changes in habitat structure and are sensitive to environmental variables (Brandmayr *et al.*, 2005). We measured the number of species present in the sample area. The number of sampled species (i.e., observed species richness) per sampling unit represents a basic characteristic of community and also basis for establishing further ecological models and conservation strategies (Gotelli and Colwell, 2001). Quantifying species richness defines differences between sites and addresses the saturation of local communities colonized from pools of sample area (Cornell, 1999). Number of total species estimated in the sample area using estimators' parameters (Chao, Jackknife and Bootstrap estimators) was also applied, where total species richness of the entire site was evaluated using a function based on individual species frequency in the sample sites (Colwell and Coddington, 1994). Estimates of total species richness may predict the size of the community in the sample area. We reported the result obtained with the first order Jackknife estimator because it is particularly effective in representing highly intensity sampled communities (Colwell and Coddington, 1994).

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Key words: Carabidae, community structure, community dynamics, Alpine fauna, pitfall traps.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Community diversity

Species diversity distribution in the sample area by computing species diversity indices was also evaluated, combining richness with relative abundance of species. The use of diversity indices (Shannon-Wiener, Simpson and InvSimpson indices) may measure level of species distribution heterogeneity present in the community of interest and the apportionment of species within the community (measure of evenness) (Frosini, 2004). Species richness, diversity indices and estimated richness parameters in the different sample sessions for each forest stand (i.e. sample unit) were provided to analyse Carabid beetle communities in details. Qualitative and quantitative ecological approach was used, to explain the variation in the structure of the species assemblages.

Indicator species

Indicator species for every sample unit and for the the habitat type were defined. We used Indicator species Analyses (IndVal) to explore the characteristic species of every forest typology, using the combination of species relative abundance and its relative frequency of occurrence in the various groups of samples (Dufrêne and Legendre, 1997). Statistical significance of the species indicator values was assessed using a randomisation procedure. Indicator species were defined as the most characteristic species of each taxonomic group, found preferably in a single group of habitat type and present in the majority of sites belonging to the same group (Dufrêne and Legendre, 1997).

Methods

Pitfall traps

Pitfall traps were used to collect ground-beetles species (Ward *et al.*, 2001); even if biased and inaccurate in estimating the absolute density, the method is useful in the monitoring and assessment of local population changes (Spence and Niemelä, 1994). Advantages are ease of their construction and deployment and their capacity for longer trapping periods. Traps consist of plastic cup filled of attractive liquid, placed in the ground. Traps were also protected by the transparent roof (Figure 1). With such approach, we caught beetle individuals with more efficiency and selectivity, providing protection from the rain and preventing the capture of small mammals.

Spatial design

Sampling was performed in South-eastern Alps, in the territory of Lorenzago di Cadore municipality (Belluno province, Veneto, Italy). Activities were carried out in the woodlands (1082 hectares) and in the main valleys (Val de Cridola, Val Frison, Val del Piova and Val Mauria), characterized by forests of Norway spruce and Silver fir with a minimum part of larch and beech. 92 pitfall traps were installed randomly and positioned across eleven sample forest stands, each with 28.16 ha of an average size (Figure 2) and elevation between 800 and 1500 m asl.

One of these stands corresponded to the ManFor Lorenzago site. The total number of pitfall traps, corresponding to eight traps per sample unit, represented the minimal unit to assure sufficient representativeness of the Carabidae local communities (Ward *et al*., 2001; Pearce *et al*., 2005; Baini *et al*., 2012). Traps were located more than 50 m apart and from the forest edge (Digweed *et al*., 1995; Magura *et al*., 2000; Baker and Barmuta, 2006). The potential of trap proximity, either in spatial autocorrelation of species assemblages (Spence and Niemelä, 1994), or in depletion of the local invertebrate fauna (Digweed *et al*., 1995; Ward *et al*., 2001), was considered in the design and interpretation of results.

Temporal sessions

Pitfall traps were active during May 17th - September 6th period in 2013. Before and after that time no ground beetle activity was evidenced. Traps were emptied and refilled every second week during sampling time. All beetles were removed from the traps and Carabidae identified to species level (Figure 3).

Observed response to forest management

Tempo-spatial changes in species richness

A total of 7420 individuals belonging to 22 different species of Carabidae were collected. Species have different distribution patterns, different temporal ranges of activity, food habits, and wings morphologies (Table 1). Species richness reached the maximum value in the third sample sessions (June/July), due to early-breeder species, followed by the decrease to the similar value as at the beginning during last session (September) because of late-breeder species. The highest values of total species richness were close to observed species richness (around 23 species). The values obtained by our sample gave an insight about the sample effort higher than 90% (calculated as ratio between expected and observed species richness in the entire study area), if we consider that estimated richness represent the total communities present in the sample area. The conclusion indicates that we have represented approximately the whole community present in the sample area by installing 92 traps. The highest values of estimated species richness occurred in the second sampling session (beginning of June), and gradually decreased afterwards.

Tempo-spatial changes in community diversity

High values of community diversity indices, due to high heterogeneity in the species distribution were obtained, particularly during the first half of the season. The maximum value of diversity was reached in the second, third, and fourth sampling session, indicating high heterogeneity of the species abundance, with a significant turnover in replacement of species, that are more active during the springtime period. After this period, the diversity gradually decreased until the end of the season (Figure 4).

Figure 1. The pitfall trap.

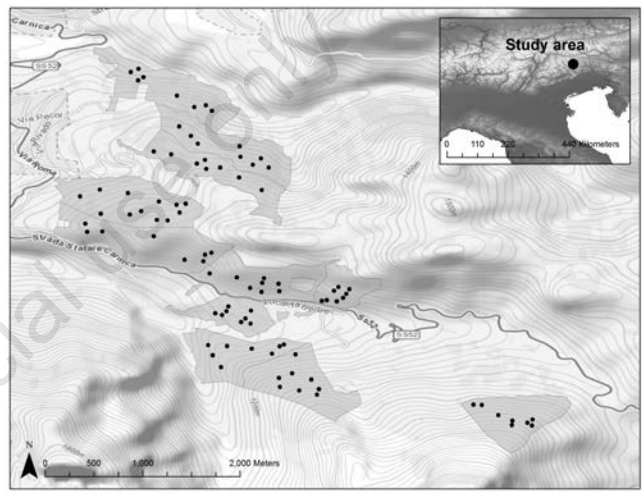

Figure 2. Sample units distribution in the municipality of Lorenzago di Cadore, district of Belluno, Veneto (IT). Black dots indicate trap positions. Sample units are delimited by grey lines.

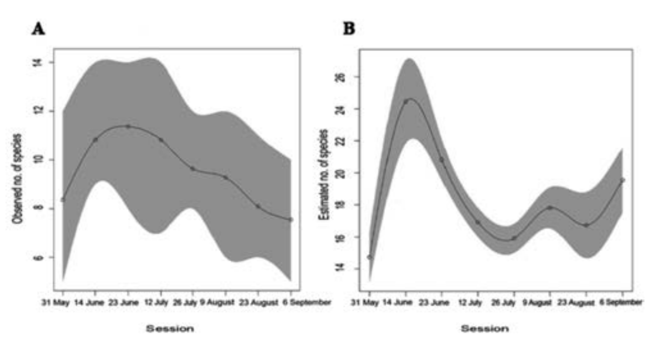

Figure 3. Temporal trend of species richness for ground beetles across the activity season. Sampling sessions span from mid-May to early-September. The lines represent the mean richness value. (A) The number of species is calculated as the average richness among all the considered forest stands. The grey band indicates the range of variation across stands. (B) The estimated species richness is the total number of species in an assemblage and is calculated estimating the number of undetected species in an assemblage (Jackknife estimator). The grey band indicate the standard error in the calculation.

Tempo-spatial changes in indicator values

Indicator species, as the most abundant and frequent in all sample units, were linked to specific stands characteristics; they were mainly specialized alpine forest species, influenced by forest habitat typology. Furthermore, stands characterized by critical environmental conditions, showed a high number of indicator species (stand M; Figure 5). In fact, stand M is characterized by critical environmental factors (temperature of -16°C and an altitude value around 1500 m) and some of the indicator species of this stand show a high degree of habitat specificity in order to survive (e.g., *Cychrus attenuatus, Pterostichus unctulatus, Abax parallelepipedus*). For example, in our study we considered the wing morphology as a specialisation character. We obtained a high number of brachypterous species of Carabidae (species lacking wings) that characterized stands with critical environmental conditions, showing a low dispersion power (In the stand M, all indicator species are brachypterous except *Leistus nitidus*).

Environmental correlates of beetles activity

In order to understand which environmental parameters influence the level of beetle activity, we performed Generalized Linear Models (GLM) on species abundances by using different variables related to forest structure, land morphology, and site climate as drivers. Overall, the parameters with a stronger effect on ground beetle communities are land orientation, minimum mean temperature, soil geology, and potential height (Figure 6).

Influence of forest structure, deadwood, and landscape on measured indicators

The surface-active carabid beetles are highly sensitive to habitat changes (Brandmayr *et al*., 2005). In our study, carabid beetles resulted particularly influenced by forest structure and morphology. More in detail, forest structure, sun exposition and soil type influenced indirectly carabid fauna by changing microclimate conditions and presence of prey. In fact, some species are specialized for a certain type of soils due to their prey. For example, *Cychrus attenuatus* and *C. angustatus* are linked to well-drained, low content of calcium carbonate and acid forest soils, while other species *(e.g. Molops piceus, Carabus creutzeri)* prefer soils characterized by a high content of clayey materials, rich in calcium carbonate, and lower acidity in order to find their prey. The presence of deadwood is another important characteristic. In fact, some carabid species (e.g. *Carabus creutzeri*) resulted particularly influenced by the presence of deadwood for specific reasons, such as the use of deadwood for hibernation (Lövei, 1996).

Finally, we obtained that the general seasonal activity of a Carabid beetles communities in alpine ecosystems begins immediately after snow melting for many species. Nevertheless, the

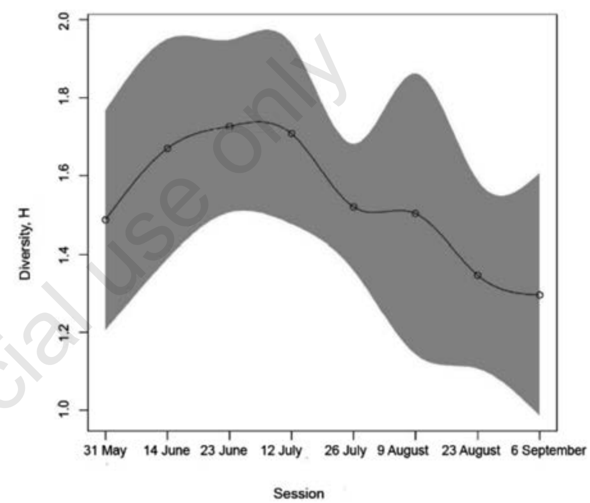

Figure 4. Temporal trend of species diversity for ground beetles across the activity season (Shannon-Wiener index). The species diversity of the Shannon-Wiener Index is calculated as the average diversity among all the considered forest stands. The grey band indicates the standard deviation across stands.

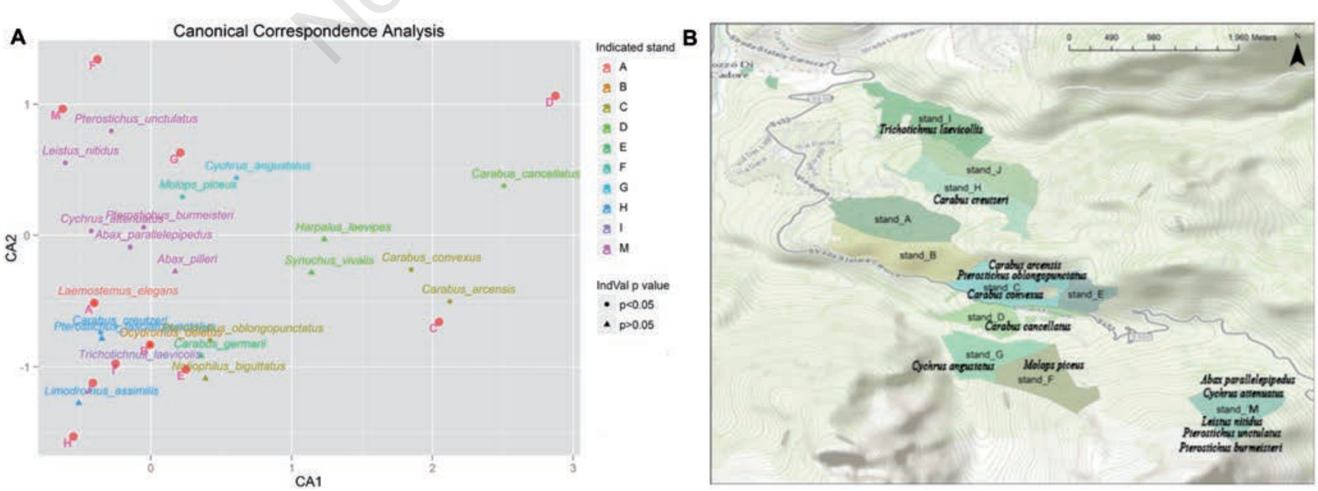

Figure 5. Canonical Correspondence Analysis (A) and indicator species for each forest stand (B).

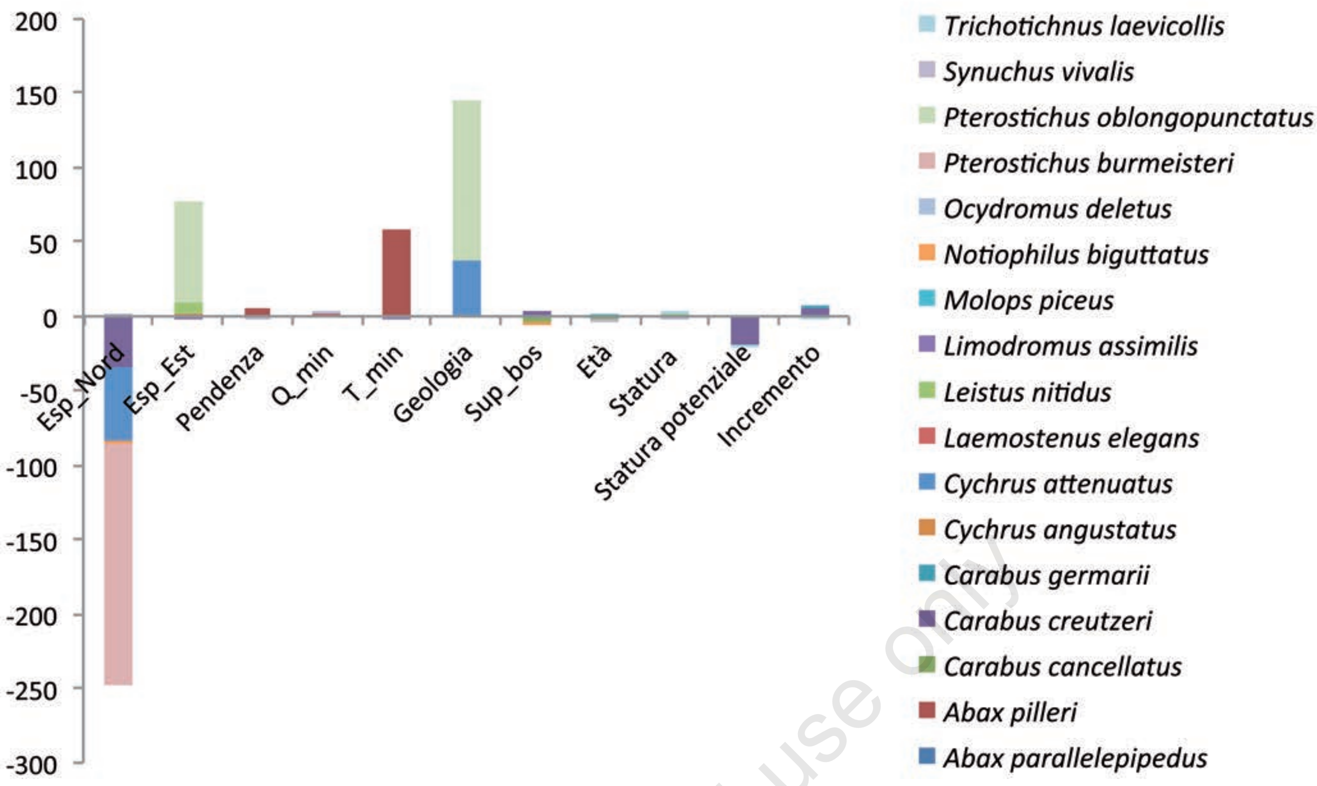

Figure 6. Relative importance of different parameters on ground beetles abundance.

Table 1. List of species (with subspecies) collected in the study area with indication of food adaptation, microhabitat and wing morphology.

Species	Food adaptation	Micro-habitat	Wing morphology
Carabus (Eucarabus) arcensis venetiatus Bernau, 1914	Oligophagous	Forest	Brachypterus
Carabus (Tachypus) cancellatus emarginatus Duftschmid, 1812	Polyphagous	Forest	Brachypterus
Carabus (Tomocarabus) convexus dilatatus Dejean, 1826	Polyphagous	Forest	Brachypterus
Carabus (Platycarabus) creutzeri creutzeri Fabricius, 1801	Oligophagous	Forest	Brachypterus
Carabus (Megodontus) germarii germarii Sturm, 1815	Oligophagous	Forest/Prairie	Brachypterus
Cychrus angustatus Hoppe & Hornschuch, 1825	Oligophagous	Forest	Brachypterus
Cychrus attenuatus attenuatus (Fabricius, 1792)	Oligophagous	Forest	Brachypterus
Leistus nitidus (Duftschmid, 1812)	Oligophagous	Forest	Macropterus
Notiophilus biguttatus (Fabricius, 1779)	Oligophagous	Forest	Macropterus
Ocydromus deletus deletus (Audinet-Serville, 1821)	Polyphagous	Forest/Prairie	Macropterus
Pterostichus (Bothriopterus) oblongopunctatus (Fabricius, 1787)	Polyphagous	Forest	Macropterus
Pterostichus (Haptoderus) unctulatus (Duftschmid, 1812)	Polyphagous	Forest	Brachypterus
Pterostichus (Cheporus) burmeisteri burmeisteri Heer, 1838	Polyphagous	Forest	Brachypterus
Pterostichus(Pterostichus) fasciatopunctatus (Creutzer, 1799)	Polyphagous	Forest	Brachypterus
Molops piceus austriacus Ganglbauer, 1889	Oligophagous	Forest	Brachypterus
Abax (Abax) parallelepipedus inferior (Seidlitz, 1887)	Oligophagous	Forest	Brachypterus
Abax (Abax) pilleri Csiki, 1916	Oligophagous	Forest	Brachypterus
Harpalus laevipes Zetterstedt, 1828	Polyphagous	Forest/Prairie	Macropterus
Trichotichnus (Trichotichnus) laevicollis (Duftschmid, 1812)	Polyphagous	Forest/Prairie	Macropterus
*Synuchus vivalis vivalis (*Illiger, 1798)	Polyphagous	Forest/Prairie	Macropterus
Laemostenus (Actenipus) elegans (Dejean, 1828)	Oligophagous	Forest	Brachypterus
Lymodromus assimilis (Paykull, 1790)	Polyphagous	Forest/Prairie	Macropterus

observed species richness values show in the central part of the sample, later in the season, a higher number of species having its activity peak (late-breeder species). Each period, between May and September, has therefore its specific assemblage of species and, consequently, its relative importance for that species. In fact, the entire good season should be considered a sensitive period for Carabidae diversity, and during this period particular care should be paid in carrying out activities with a high potential impact in forest habitats.

References

Baini F, Pitzalis M, Taiti S, Vigna Taglianti A, Zapparoli M, Bologna MA, 2012. Effects of reforestation with Quercus species on selected arthropod assemblages (Isopoda Oniscidea, Chilopoda, Coleoptera Carabidae) in a Mediterranean area. Forest Ecol. Manag. 286:183-191.

Baker CS, Barmuta AL, 2006. Evaluating spatial autocorrelation and depletion in pitfall-trap studies of environmental gradients. J. Insect Conserv. 10:269-276.

Brandmayr P, Zetto T, Pizzolotto R, 2005. Coleoptera Carabidae for the environmental assessment and for the conservation of biodiversity. Operative Manual N.34. APAT.

Cornell HV, 1999. Unsaturation and regional influences on species richness in ecological communities: a review of the evidence. Ecoscience 6:303-315.

Colwell, R.K., Coddington, J.A., 1994. Estimating terrestrial biodiversity through extrapolation. Philos. T. R. Soc. B 345:101-118.

Digweed SC, Currie CR, Cárcamo HA, Spence JR, 1995. Digging out the 'digging-in-effect' of pitfall traps: influences of depletion and disturbance on catches of ground beetles. (Coleoptera: Carabidae). Pedobiologia 39:561-576.

Dufrêne M, Legendre P, 1997. Species assemblage and indicator specie: the need for a flexible asymmetrical approach. Ecol. Monogr. 67:345-366.

Frosini BV, 2004. Descriptive measures of ecological diversity in environmetrics. In: J. Jureckova and A.H. El-Shaarawi (eds.) Encyclopedia of life support systems (EOLSS). Developed under the Auspices of UNESCO, EOLSS Publishers, Oxford, UK.

Gotelli N, Colwell RK, 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecol. Lett. 4:379-391.

Lovëi LG, 1996. Ecology and behaviour of Ground Beetles (Coleoptera: Carabidae). Ann. Rev. Entomol. 41:231-256.

Magura T, Tóthmérész B, Bordán Z, 2000. Effects of nature management practice on carabid assemblages (Coleoptera: Carabidae) in a non-native plantation. Biol. Conserv. 93:95-102.

Pearce JL, Schuurman D, Barber KN, Larrivée M, Venier LA, McKee J, McKenney D, 2005. Pitfall trap designs to maximize invertebrate captures and minimize captures of non target vertebrates. Can. Entomol. 137:233-250.

Spence JR, Niemelä JK, 1994. Sampling carabid beetle assemblages with pitfall traps: the madness in the method. Can. Entomol. 126:881-894.

Ward DF, New TR, Yen AL, 2001. Effects of pitfall trap spacing on the abundance, richness and composition of invertebrate catches. J. Insect Conserv. 5:47-53.

Forest management and amphibians: focus on the genus *Salamandrina*

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Introduction

Our aim was to investigate if and how some features of trees affect the occurrence of salamanders, using occupancy level (MacKenzie *et al.*, 2002) as a proxy of tree suitability. The Spectacled salamanders belonging to the genus *Salamandrina* are two Italian endemic species, occurring in hilly and mountain forested areas, as well as in Mediterranean maquis (Angelini *et al.*, 2007). *Salamandrina perspicillata* (Savi, 1821; Figure 1) occurs in Northern and Central Apennines while *S. terdigitata* (Bonnaterre, 1789) occurs in southern Italy (Romano et al., 2009). The spectacled salamanders (both under the name of *S. terdigitata* because their split is relatively recent: Mattoccia *et al.*, 2005, Nascetti *et al.*, 2005) are included in the annex II and IV of the Habitats Directive. Terrestrial activity of a population of *Salamandrina perspicillata* was studied in the ManFor site Pennataro and Montedimezzo (Central Italy), a mixed deciduous forest dominated by beech, situated at about 900 m asl, to highlight some ecological traits of this salamander and the implication for conservation during forest management.

Trees as shelters: suitability of different trees to offer shelter for *Salamandrina*

Amphibians are the most abundant class among vertebrates in many forest ecosystems (deMaynadier and Hunter, 1995). Both completely terrestrial and semi-aquatic amphibians need suitable terrestrial shelters for preserving them from hostile environmental conditions (Rittenhouse *et al.*, 2008). The role of trees in providing shelter sites for leaf-litter amphibians is well known since almost 40 years (Voris, 1977; Jaeger, 1980; Seebacher and Alford, 2002) as tree holes and buttresses are often used as preferred refuges. The relationships between some trees features and occurrence of salamanders were investigated using occupancy level (MacKenzie *et al*., 2002) as a proxy of tree suitability. On the experimental hectare forest plot, all trees with diameter at breast height (DBH) above 10 cm were considered as a potential shelter site for salamanders. For all those trees, DBH, number of buttresses (BUT; *i.e*., tree roots that extend above ground as a plate like outgrowth of the trunk supporting the tree) and the number of ground level cavities (HOL; *i.e*., cavities created between stumps and soil in the vicinity of the buttresses loops) were recorded. Samplings were conducted six times from October to November 2013, during comparable weather conditions. Occurrence of salamanders was recorded for each tree. Data were analysed using the 'occupancy' approach (MacKenzie *et al*., 2005) to define the suitability of the trees. The sampling units, where the state variable have been measured, were the sites (*i.e.,* the trees) in which the species could occur or not. The occupancy approach allows to model the parameters of interest as function of different covariates (MacKenzie *et al*., 2005). Our modelling approach present two parameters of interest, hierarchically estimated: the probability of occupancy at a site (ψ) and the probability of detection (p), dependent on the presence of an individual at a site (MacKenzie *et al*., 2003). Tree covariates were used to model the occupancy, while the detectability was modelled as time dependent (*i.e*., it could change among occasions). All possible combination of models with covariates were implemented, then, model selection proceeded through Akaike Information Criterion (AIC) ranking (Akaike, 1973), taking into account that models with a ΔAIC >2 do not have the same empirical support, showing substantial differences (Burnham and Anderson, 2002). In addition, AIC weight (AICw) was calculated to estimate the importance of every covariates in explaining salamanders' occupancy (Burnham and Anderson, 2002).

Average DBH of selected trees was 28.30±13.74 cm (mean ± s.d.), BUT = 3.89±2.36 and HOL= 2.42±2.20. We observed salamanders on 168 trees out of 384 (Figure 2), resulting in a naïve occupancy of 0.44.

Among the sixteen candidate models, those allowing for a change in detectability among surveys had the best empirical support. Regarding the site covariates, three models were better supported (with AIC score <2): ψ~DBH (ΔAIC = 0; AICw = 0.41), ψ~DBH+HOL (ΔAIC = 0.85; AICw = 0.27), ψ~DBH+BUT (ΔAIC = 1.56; AICw = 0.19). Estimate of proportion of area occupied (PAO), i.e. the estimate of the trees occupied, resulted in 0.70 ($CI_{95\%}$ = 0.46 - 1). Each covariate showed a positive correlation with the occupancy estimation.

The importance of high quality forest habitat for biodiversity conservation is well known. Many studies have emphasized the role of forest canopy in protecting amphibian from dehydration

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Key words: Amphibians, distribution, migration, occupancy, salamanders, shelters, forest management.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

(Rothermel and Semlitsch, 2002). Alteration of those habitats, *e.g.*, clearcutting, may have strong negative effects, such as reduction both in abundance and in dispersal capability of individuals (Patrick *et al*., 2006). Recent research efforts have focused at the stand level, describing the trend of abundance or occupancy as the stand characteristics changed (*e.g.*, stand-age or amount of coarse woody debris - Patrick *et al*., 2006; McIntyre *et al*., 2012). In contrast, our research focused at smaller extent, investigating single tree features to provide fine-grained proxies of tree suitability as shelter by means of occupancy level.

The results showed that ground level holes and buttresses are essential in providing shelter sites for spectacled salamanders. Both features are correlated with tree diameter, therefore trees with bigger diameter are expected to have more holes and buttresses than smaller trees. Tree size is usually related to tree age. Retention of bigger/older trees provides better shelter for salamanders, and trees with higher number of buttresses and holes should be preserved.

The evidence that amphibians often use trees as shelter sites is an information available only for tropical environments (Voris, 1977). Our research results highlighted importance of trees in the temperate zone environment. The detection of which tree features play an important role in maximising the suitability of a tree to serve as shelter for salamanders have clear consequences to combine forest management and biodiversity conservation

Terrestrial seasonal movements of *Salamandrina*: implication for forest harvesting

Among the main negative consequences of logging on amphibian and reptile populations is a high risk of crushing (Penman *et al*., 2005). Harvesting directly affects amphibians, reptiles and other small terrestrial vertebrates through operations which may be responsible for more than half of the deaths in a given population (Penman *et al*., 2005; Escobar *et al*., 2015).

Most of European amphibians have two distinct life stages: an aquatic egg-larval stage and a terrestrial stage after metamorpho-

Figure 1. The spectacled salamander *Salamandrina perspicillata*, endemic to the Apennines and living in forests and scrubs

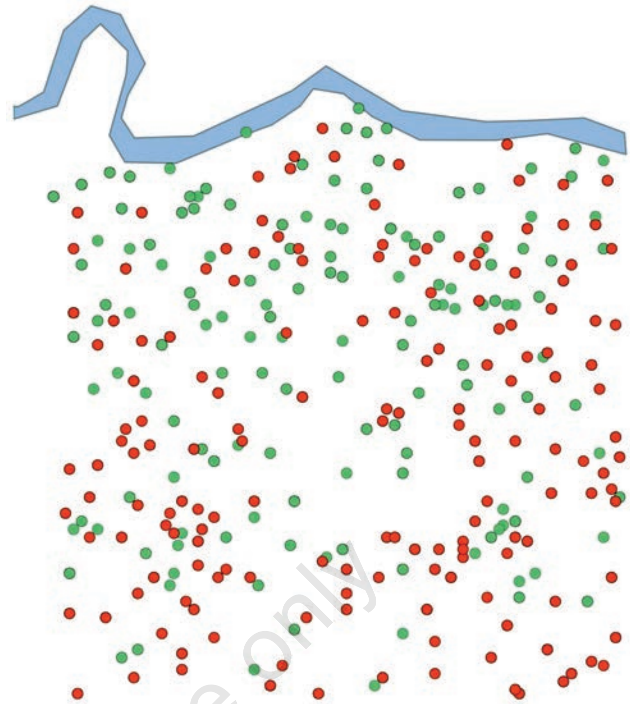

Figure 2. Study plot (one hectare) near a stream which is a breeding site of *Salamandrina perspicillata*. Circles show the position of each of the 384 trees with DBH >10 cm. Red circles are the trees used as shelter by salamanders in autumn 2013.

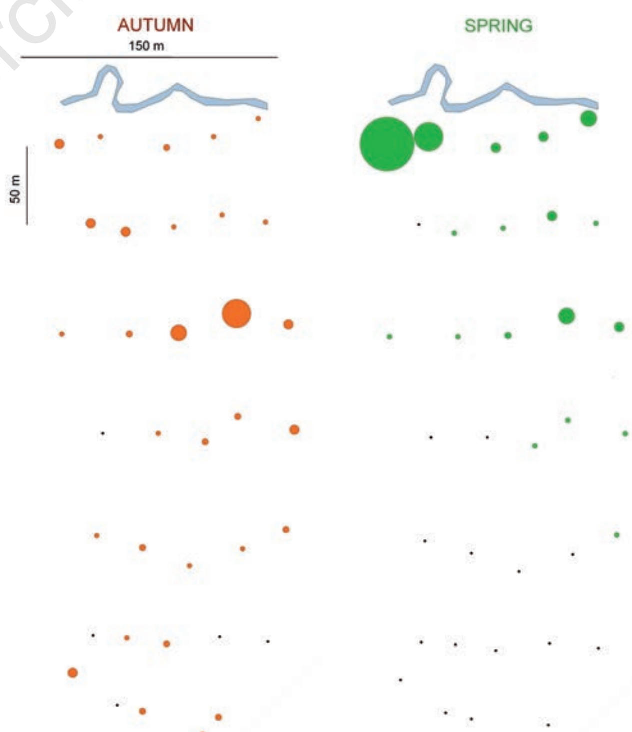

Figure 3. Density of salamanders in spring (green) and autumn (orange) as recorded at different distances from the breeding site (a stream). Circles show the plot (100 sq m) location. Circle size is proportional to the density of salamander in the whole sampling season, which ranges from smallest ones to largest one. Density categories are: 0 salamander/m2; 0.01-0.02; 0.03-0.05; 0.6-0.10; 0.11-0.15; 0.16-0.20; 0.21-0.28; 0.30-0.40; >0.40) (density >0.16/m2).

sis. Adults return to the aquatic breeding sites many times during their life for reproduction. The management of aquatic habitat only is not enough to preserve amphibian biodiversity. During the end of the twentieth century, terrestrial habitats surrounding breeding pools were considered as priority areas for the maintenance of the juvenile and adult populations in American countries (Welsch *et al*., 1995; Semlitsch, 1998). Information about the required size of these buffer areas is very heterogeneous, varying from a minimum if 15 m around pools (New Hampshire Division of Forests *et al*., 1997) to a larger buffer distance of approx. 120 m (Calhoun and deMaynadier, 2002).

Terrestrial distribution pattern of *Salamandrina perspicillata* was studied in spring and autumn, when salamanders are more active. The distribution around the breeding stream during the reproductive time (spring) and after post breeding migration toward terrestrial shelters (autumn) was studied. The study was performed on a plot of about one hectare, on a northeast-facing slope, with dominant beech, where salamanders occur in higher density.

Seven parallel transects 150 m long and 50 apart, with the breeding stream were identified, covering a total distance of approximately 300 m from the stream. On each transect salamanders were counted 6 times both in spring and autumn, in five square plots of 100 square meters. Plots on the same transect were placed every 30 m.

A total of 161 and 290 salamanders were found in spring and in autumn, respectively. Overall mean density of salamander per plot (0.9 and 0.75 in autumn and spring, respectively) did not vary significantly between the two seasons (Wilcoxon test for paired data, W = 318, p = 0.08). The salamanders distribution in the studied area greatly differed between autumn and spring, as can be seen in Figures 3 and 4).

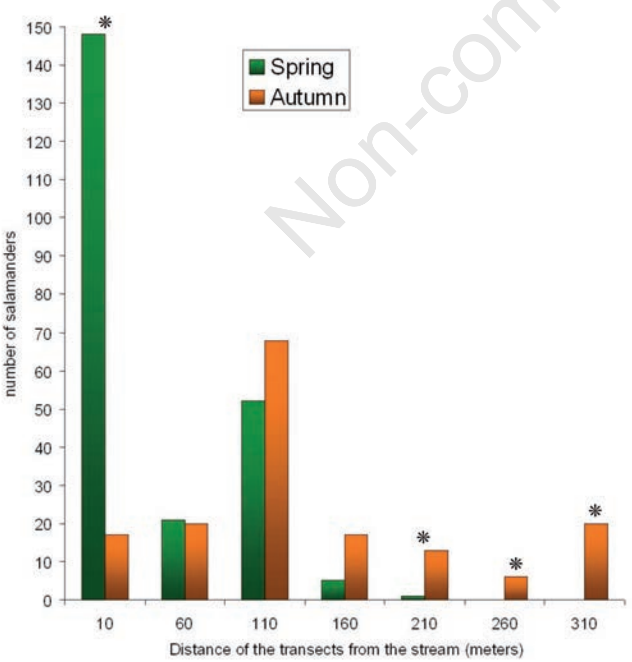

Figure 4. Seasonal average appearance of salamanders per transect in forest environment at different distance from the breeding site. Asterisks show significant differences between seasons on each transect (Wilcoxon test, paired data).

Comparisons for paired data using Wilcoxon test between number of salamanders on the same transect during two seasons (Figure 4) showed differences between the transect closest to the stream (about 10 meters from the stream), where salamanders were significantly more abundant in spring than in autumn, and the three furthest transects *(i.e*., from about 200 meters up to about 300 m), where salamanders were significantly more abundant in autumn than in spring. Correlation between distance from the stream and number of salamanders was highly significant in spring (Spearman correlation, r = -0.95; p = 0.004) but not in the autumn (r = -0.28; p = 0.544).

Results obtained in field experiment show, that in autumn salamanders were largely widespread in the forest (at least up to 300 m from the stream) while in spring they occurred at high density only near the breeding site, and their occurrence rapidly decreasing after about 100 m from the stream.

Understanding the movement of animals is critical to many aspects of management and conservation. For amphibians with a biphasic life cycle, movements around breeding sites are crucial for populations reproduction and their survival (Semlitsch and Bodie, 2003; Semlitsch, 2008). The magnitude of migration from and toward aquatic breeding site is taxon and environment specific. As a general rule, frogs and toads exhibit higher migration capability (about 200-370 m from their breeding sites as minimum and maximum mean respectively) compared to salamanders and newts (140-290 m; Semlitsch and Bodie, 2003).

References

Angelini C, Vanni S, Vignoli L, 2007. Salamandrina perspicillata. In: B. Lanza, F. Andreone, M.A. Bologna, C. Corti and E. Razzetti (eds) Fauna d'Italia, vol. XLII. Amphibia. Ed. Calderini, Bologna, pp. 228-237.

Akaike H, 1973. Information theory and an extension of the maximum likelihood principle. pp. 267-281 in Proc. II Int. Symp. on Information Theory. Akademiai Kidao, Budapest, Hungary.

Burnham KP, Anderson DR, 2002. Model selection and multimodal inference, 2nd ed. Springer-Verlag, New York.

Calhoun AJK, deMaynadier PG, 2002. Forestry habitat management guidelines for vernal pool wildlife in Maine. A cooperative publication of the University of Maine, Maine Department of Inland Fisheries and Wildlife, Maine Audubon, and Maine Department of Conservation, Orono.

deMaynadier PG, Hunter ML Jr, 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environ. Rev. 3:230-261.

Escobar MAH, Uribe SV, Chiappe R, Estades CF, 2015. Effect of clearcutting operations on the survival rate of a small mammal. PLoS ONE 10: e0118883.

Jaeger RG, 1980.: Microhabitat of a terrestrial forest salamander. Copeia 1980:265-268.

MacKenzie DI, Nichols JD, Lachman GB, Droege S, Royle JA, Langtimm A, 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

MacKenzie DI, Nichols JD, Hines JE, Knutson MG, Franklin AB, 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

MacKenzie DI, Nichols JD, Sutton N, Kawanishi K, Bailey LL, 2005. Improving inferences in population studies of rare

species that are detected imperfectly. Ecology 86:1101-1113.
Mattoccia M, Romano A, Sbordoni V, 2005. Mitochondrial DNA sequence analysis of the spectacled salamander, Salamandrina terdigitata (Urodela: Salamandridae), supports the existence of two distinct species. Zootaxa 995:1-19.
McIntyre AP, Jones JE, Lund EM, Waterstrat FT, Giovanini JN, Duke SD, Hayes MP, Quinn T, Kroll AJ, 2012. Empirical and simulation evaluations of an abundance estimator using unmarked individuals of cryptic forest-dwelling taxa. Forest Ecol. Manag. 286:129-136.
Nascetti G, Zangari F, Canestrelli D, 2005. The spectacled salamanders, Salamandrina terdigitata (Lacépède, 1788) and S. perspicillata (Savi, 1821): genetic differentiation and evolutionary history. Rend. Lincei 16:159-169.
New Hampshire Division of Forests and Lands, New Hampshire Department of Resources and Economic Development, Society for the Protection of New Hampshire Forests, 1997. Good forestry in the granite state: recommended voluntary forest management practices for New Hampshire. Society for the protection of New Hampshire forests.
Patrick DA, Hunter ML Jr, Calhoun AJK, 2006. Effects of experimental forestry treatments on a Maine amphibian community. Forest Ecol. Manag. 234:323-332.
Penman TD, Mahony MJ, Lemckert FL, 2005. Soil disturbance in integrated logging operations and the potential impacts on a fossorial Australian frog. Appl. Herpetol. 2:415-424.
Rittenhouse TAG, Harper EB, Rehard LR, Semlitsch RD, 2008. The role of microhabitats in the desiccation and survival of anurans in recently harvested oak-hickory forest. Copeia 2008:807-814.
Romano A, Mattoccia M, Marta S, Bogaérts S, Pasmans F, Sbordoni V, 2009. Distribution and morphological characterization of the endemic Italian salamanders Salamandrina persipicillata (Savi, 1821) and S. terdigitata (Bonnaterre, 1789) (Caudata: Salamandridae). Ital. J. Zool. 76:422-432.
Rothermel BB, Semlitsch RD, 2002. An experimental investigation of landscape resistance of forest versus old-field habitats to emigrating juvenile amphibians. Conserv. Biol. 16:1324-1332.
Seebacher F, Alford RA, 2002. Shelter microhabitats determine body temperature and dehydration rates of a terrestrial amphibian (Bufo marinus). J. Herpetol. 36:69-75.
Semlitsch RD, 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conserv. Biol. 12:1113-1119.
Semlitsch RD, 2008. Differentiating migration and dispersal processes for pond-breeding amphibians. J. Wildlife Manage. 72:260-267.
Semlitsch RD, Bodie JR, 2003. Biological criteria for buffer zones around wetlands and riparian habitats. Conserv. Biol. 17:1219-1228.
Voris HK, 1977. Comparison of herpetofaunal diversity in tree buttresses of evergreen tropical forests. Herpetologica 33:375-380.
Welsch DJ, Smart DL, Boyer JN, Minkin P, Smith HC, McCandless TL, 1995. Forested wetlands: functions, benefits and the use of Best Management Practices. USDA Forest Service NAPR- 01-95.

Îlots de senescence in the ManFor C.BD sites

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The ÎdS development in the European context

Ever since the European conference in Lisbon on the protection of European forests (1998), the importance of deadwood preservation for ecosystem conservation represents a well-established concept. The conservation of the species that depend on deadwood (*i.e.*, saproxylic; Speight, 1989) in productive forests is achieved through two approaches, complementary to natural reserves: the set aside of small forest patches and the preservation of habitat trees, which work as stepping-stones to increase the connectivity of a forest landscape (Lachat and Bütler, 2007). The creation of small forest reserves has been experimented in different countries: in France and Swiss as *îlots de senescence*[1] or senescence islands, and in northern Europe as 'woodland key habitats'.

The first woodland key habitat (WKH) definition was coined in Sweden in 1990 (Norén *et al*., 2002) as an environment, a habitat patch, where saproxylic species (often red-listed) could be expected. Afterwards, more emphasis has been given to forest structure and history (Timonen *et al*., 2010). The main idea behind WKHs is rather common in northern European countries (*e.g.*, Sweden, Finland, Norway, Latvia, Estonia and Lithuania): to conserve biodiversity in productive forests by preserving small habitat patches (0.7 to 4.6 ha) for maintaining landscape-level biodiversity.

Aging islands (ÎdV) and senescence islands (ÎdS) were established mainly in public forests, for the first time on the initiative of the Office National des Forêts (ONF) for what concerns France, and in several Swiss Cantons at federal level (*e.g.*, Argovie, Berne, Fribourg e Vaud).

The French Office National des Forêts (ONF, 2009a, 2009b) and the Forest Vocabulary (Bastien and Gauberville, 2011) provide the following general definitions:

Îlot de sénescence (ÎdS): small forest stand left free to evolve and where no harvest activities take place, preserved until its physical termination, thus until tree collapse (physical utilization). The ÎdS are preferably composed by trees of reduced economic value that show important biological features (hollows, deadwood, *etc*.).

Îlot de vieillissement (ÎdV): small forest stand that has gone beyond the optimum yield, and that benefits from a prolonged sylvigenic cycle. Forest management can take place inside the ÎdV, to ensure that the trees retain their productive function. Trees are thus harvest before their market price falls.

Îlot de vieux bois (ÎdVB): island of senescent deadwood, term used to refer to both ÎdS and ÎdV.

The ÎdS, compared to the ephemeral ÎdV, represents the most effective conservation strategy. Actually, the temporary nature of ÎdV may be detrimental, transforming them in an ecological trap. Furthermore, the ONF definition of ÎdS (ONF, 2009a, 2009b) presents perilous ambiguities since its preservation is guaranteed only until its 'physical collapse'. In fact, for an ÎdS to be assimilated to a strict nature reserve it should be exonerated from any management intervention.

ÎdS and ÎdV were conceived in and put into practice in Switzerland as part of a federal program of collaboration among the Cantons: between 2008 and 2011, 918 ha of 'îlots de senescence' were established mainly in Vaud, Fribourg, Berne and Argovie. For what concerns France, the majority of them were implemented by the ONF and are nowadays widespread in many regions, such as Rhône-Alpes, Savoie, Ile-de-Franc, Parc national des Cévennes, *etc*. The ONF has established the target of managing the 3% of the forest areas as 'vieux bois' (old wood) by 2030, and the 1% of them should be allocated to ÎdS (Rouveyrol, 2009). Scientific publications on the 'Îlots' are rather scarce, while there are reports on their application and a copious grey literature is available on the web (Vallauri, pers. comm., 2015).

ÎdS implementation costs

The creation of ÎdS by private owners may be compromised by the lack of a suitable economic support, and by the responsibilities associated with security issues (Rouveyrol, 2009). The report by Arnaudet and Bastianelli (2013) demonstrated that the implementation of ÎdS and ÎdV by private owners depends on the availability of economic contributions and on effective divulgation. In

[1] This term, and the corresponding acronym, has not been translated intentionally, as it has been created and developed in a Francophone context.

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Key words: conservation, deadwood, forest biodiversity, saproxylic.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

France, deadwood preservation for biodiversity has been dealt, acknowledging public and owners, considering it as a public issue, with the development of specific programs such as RESINE (Deuffic and Bouget, 2011).

The ONF definition of ÎdS (ONF, 2009a, b) lays itself to two interpretations, which overlap on the economic estimate of their cost. The fundamental difference among the two views is on the final destiny of the area assigned to the ÎdS: if after tree collapse it should return to traditional silviculture (thus falling in the ÎdV definition) or kept as a strict forest reserve, where all management activities are excluded for indefinite time. In this latter case, Biache (2009) bases the economic estimate on the opportunity cost, derived from the benefits lost indefinitely keeping the ÎdS instead of managing it. The value of an ÎdS, ÎdS network or retained tree network depends on a fundamental concept of forestry economics: the realization principle, financial process that establishes the current value of a capital according to the formula: $V_{current} = V_{future}/(1+r)^n$ (r, actualization rate; n, number of years) (Biache, 2009; Chevalier *et al*., 2009), keeping the ÎdS instead of managing it. The value of an ÎdS, could be estimated with the theoretical method based on the unit value, where the ÎdS cost equals the net potential profits after the ÎdS creation, actualised to the date *a* and brought to infinite duration (Biache and Rouveyrol, 2011). For the year *a*, the forest unit value would be:

$$\hat{I}dScost = \frac{\sum_{i=a}^{n}(R_i - D_i) \times (1+r)^{n+a-i} + \sum_{i=0}^{a-1}(R_i - D_i) \times (1+r)^{a-1}}{(1+r)^n - 1}$$

where R_i and D_i respectively represent the income and expenses for the year *i*, and *r* the actualization rate. There are a few practical applications of the estimate of the economic costs of an ÎdS, as lost profit for the owner (Biache, 2009; Chevalier *et al*., 2009; Biache and Rouveyrol, 2011). The obtained figures are very diverse, depending on the actualisation rate, fertility class, forest species, *etc*. In a study carried in French state property, a cost of 8750 €/ha and an actualisation rate of 1.76% were estimated by Biache and Rouveyrol (2011). In Switzerland, compensations for private owners are available, as an all-in refund of 1600-2400 €/ha for 50 year commitments, and approximately of a half for 25 year commitments. In France, private owners of forests in the Natura 2000 network can benefit from compensations for the ÎdS actualisation and habitat-tree retention. The payout for retaining 30 trees in 0.5 ha, with at least 10 trees bearing microhabitats or species included in the Annex II of the Habitat Directive can reach 2000 €/ha (Arnaudet and Bastianelli, 2013). This latter compensation is designed for ÎdVs. The criteria to benefit from the Natura 2000 payouts are described in specific manuals (*e.g.*, DREAL PACA, 2013). To the ÎdS cost estimation, a part from their role for biodiversity conservation, there are multiple added values that should be considered, such as the recreational, aesthetic, spiritual components, non-forest utilities which should be taken into account (Chevalier *et al*., 2009).

The ÎdS for forest biodiversity conservation and other functions

The importance of landscape connectivity for the conservation of invertebrates has been included in the Pan-European Biodiversity and Landscape Diversity Strategy (Haslett, 2007). The expansion of protected areas is often limited by the scarcity of economic resources and competing goals, thus the integration of micro-reserves in production and protection forests (Kraus and Krumm, 2013) represents a cost-effective intervention (Mason and Zapponi, 2015). ÎdS are ultimately old-growth forests that, according to Peterken's definition (1996), 'identify both managed and unmanaged woods in Europe and apply generally to stands with more than 200 years growth'. The ecosystem services provided by the old-growth forests (Wirth *et al*., 2009) may be of spiritual and/or aesthetic nature, but also many other services such as the provision of genetic resources, non-timber products, and habitat for wildlife (hunting and ecotourism), the sequestration of carbon, the prevention of floods and erosion. Old-growth forests remove carbon dioxide from the atmosphere, storing it in living and dead woody tissues and slowly decomposing organic matter in litter and soil (Luyssaert *et al*., 2008). Old-growth attributes are of crucial importance for biodiversity conservation, notably for saproxylic taxa and, more generally, for forest specialists (Paillet *et al*., 2015)

Deadwood management and its acceptance

The amount of dead wood found in managed and unmanaged forests varies and depends on the time of last disturbance, the amount of input (mortality) at the time of the disturbance, natural mortality rates, decay rate, and management (Köhl *et al*., 2008; Mason, 2004). The effectiveness of the amount of dead wood preserved by the ÎdSs and by other retained structures requires the development of an ad hoc assessment systems and modeling tools based on sound science *i.e.*, including the monitoring of the constant and negative exponential decay rates, the average annual transfer into and out of dead wood stock (IPCC, 2003).

The retention of deadwood and veteran trees has historically been perceived as a dangerous negligence. Deadwood was traditionally removed to reduce fire risk and ease planting, and to limit the spreading of pests that might attack living trees. However, the attitude of managers towards this critical resource for biodiversity is changing, recognising that rather than being a threat, it plays a key role for ecosystem functionality (Swanson and Chapin, 2009). Jonsson and Siitonen (2012), to plead for deadwood conservation, underline that pest outbreaks are caused by three main factors: i) the introduction of tree species outside their optimal climatic conditions (*e.g. Ips typographus* in spruce lowland forests); ii) exceptional disturbance events; and iii) the introduction of alien pest species (*e.g.*, *Bursaphelenchus xylophilus* in Iberian pine forests). Thus sanitary felling and deadwood removal from the ground represent neither a panacea nor a guarantee against pest outbreaks. Considering fire risk, the optimum amount of CWD could be established balancing ecological benefit and excessive fire hazard (Brown *et al*., 2003). Size and decay class should be taken into account, when establishing deadwood volumes to be retained, tacknowledging that smaller deadwood may contribute more to fire intensity than to habitat value (Knapp, 2015). The preservation of senescent and dead trees has been discarded also because it poses safety risks associated with branch felling. To evaluate the opportunity of retaining this structures, a Site Risk Assessment should be performed, to detect any hazards posed by particular trees (Blakesley and Buckley, 2010). Furthermore, the retention of these elements should be avoided close to public roads, footpaths and recreational areas. If a tree of high value, for conservation or amenity, represents a risk to people, it can be kept at a distance diverging access routes or facilities, placing warning and explanatory signs (Lonsdale, 2000). Davies *et al*. (2000) offer a detailed account of how legal safety responsibilities can be fulfilled to achieve the conservation of veteran trees. In a few Italian public forests, a security protocol has been applied to visually monitor trees with the potential risk of falling. These trees are generally retained at a distance from paths that equals at least their height (Campanaro *et al*., 2007; Mason, 2004).

The ÎdS and forest certification (PEFC, FSC)

The most spread forest certification system are the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification schemes (PEFC), both based on the forester commitment to comply with principles and criteria that ensure forest sustainable management. Nevertheless, ÎdS are not yet included in either certification system (Rouveyrol, 2009).

The Swedish Forestry Act requires the after harvest retention of a number of trees equal to the 2-10% of the total timber value (FAO, 2010).

General guidelines

The concepts and definitions of the WKH and of the Îlots from France, Switzerland and Italy, can be summarized as follows:

- they represent small areas of mature forest (microreserves), left free to evolve for a definite (ÎdV) or indefinite amount of time (ÎdS and WKH);
- WKH and French ÎdS generally do not take into account the connectivity. Conversely, in Switzerland ÎdS were designed as part of a network of habitat trees and large natural reserves (Lachat and Bütler, 2007). For example, in the State forest of Ramboillet ÎdS forest connectivity is based on the river and streams networks (Temoin, 2009).

The criteria for the design of the microreserves in Cansiglio and Pennataro for the ManFor C.BD project are based on the ONF (2009) concepts, adding an active management component. Where the stands present a high structural and compositional homogeneity, such as for the Cansiglio experimental site, it could be advisable to apply active restoration techniques, to avoid a prolonged biostatic phase and the risk of local extinctions (Bouget *et al*., 2014). The accelerated senescence of an ÎdS (pre-senescence treatment; Speight, 1989) can be achieved girdling or cutting the youngest trees in order to increase deadwood availability and favour the growth of the trees with the highest diameter, more likely to develop microhabitats. This further development modifies the ÎdS definition.

Thus, ÎdS are areas with a surface ranging between 0.5 and 20 ha, set aside for indefinite aging, where if the initial condition require it, specific interventions are carried out to maximize structural and individual biodiversity, ensuring the continuity of habitat-trees in both space and time.

The Life ManFor C.BD Project experience

Pro ÎdS silvicultural interventions aim at the coexistence of different development stages: from open areas (where initial stages of forest succession could start) to mature/old trees with microhabitats. The tree spatial distribution can be focused on target single trees or small groups, according to the ecology of the considered tree species. The final goal is to increase, in time, the availability of microhabitats, both quantitatively and qualitatively.

Deadwood dynamism plays an essential role: from standing deadwood (snag, girdled trees) to laying deadwood completely decayed, a complete succession will take place, where every stage will be characterized by microhabitats with specific physical and chemical, and their associated biodiversity (Gosselin *et al*., 2006; Schiegg Pasinelli and Sutter, 2000). It is clear that such a way of preserving each decomposition stage guarantees a 'temporal continuum' in the forest ecosystem (Dodelin *et al*., 2004; Gosselin *et al*., 2006).

Protocol for the realisation of the ÎdS in the ManFor C.BD project

I. Assessment of forest composition and structure;
II. Establish management goals, which may include:
  a. Preserve and increase openness to favour forest renewal;
  b. Thinning around the selected MHTs and FHTs, to remove competitors;
III. Identify (considering the diameter at breast height (DBH) distribution, structure and microhabitat presence):
  a. Mature Habitat Trees (MHT): selected because of their habitus, qualitative and quantitative presence of microhabitat. They will become veteran trees, increasing microhabitat availability in the short and medium-term and deadwood in the long-term;
  b. Future Habitat Trees (FHT): trees that have a suitable structure to replace the present HT in the future;
  c. Deadwood elements: will contribute to the 'deadwood compartment' (*sensu* Bormann and Likens, 1994): either as standing dead trees (snags and girdled trees) or as downed trees;
  d. Non-target trees: irrelevant for what concerns the silvicultural treatment. Trees that do not have the MHT or FHT key features, they would be left free to evolve and their management will be established the next felling;
  e. Canopy openness, for natural seed regeneration
IV. Plant selection criteria, applied to single trees or small groups of 2-3 trees, considering the following criteria:
  a. DBH (diameter at breast height);
  b. Microhabitat presence;
  c. Tree habitus (crown insertion height, crown radium, crown deadwood presence, *etc.*);
  d. Spatial distribution, ensuring at 20 m between the target trees;
V. Tree marking operation, see Figure 1.

In the ÎdS areas, the data have been collected through three circular survey plots (measurement of DBH and heights) of 20 m (Cansiglio) and 13 m (Pennataro) radius. For each site, the results presented in the Tables 1-6 are the average of the three survey plots with their standard deviations (SD). Volume data is obtained applying INFC (National Forest Inventory and Carbon Sinks) formulas (Tabacchi *et al.,* 2011).

Application of the protocol to the ManFor C.BD sites

Cansiglio Forest

The designed area lies in a beech (*Fagus sylvatica* L.) high forest compartment aged from 120 to 145 years. The average basal area is 39 m^2 ha^{-1} and the mean DBH is 41.5 cm. The current status of the forest is the result of a long history of forest management: moderate thinnings (from below or mixed) repeated every 20 years, and regeneration by group shelterwood system.

During the tree marking operation pro ÎdS, mature habitat trees (MHT) and the future habitat trees (FHT) have been identified. A 20 meters distance among trees has been established, taking into account groups or couple of trees with microhabitats occurrence. Subsequently a thinning has been performed: competitor trees have been girdled or cut and left on site. Dominant trees were cut in order to favour the maturation of MHT the FHT development. Afterwards, the remnant trees (about the 50% of the competitors) will be girdled, in two or three seasons, to ensure the continuous availability of deadwood.

Besides, open areas have been promoted and preserved in order to stimulate seed regeneration, and to favour the early stages of forest succession.

In terms of basal area, the silvicultural treatment brought a decrease of the 27% (Table 3). Therefore, the treatment 'pro ÎdS' is comparable to the thinning traditionally performed in the Cansiglio beech high forest (Di Salvatore *et al*., 2016). Furthermore, the silvicultural treatment 'pro ÎdS' increased of 42 m^3 ha^{-1} the volume of laying deadwood released, and of 40 m^3 ha^{-1} of standing deadwood.

Pennataro Forest

The designed area lies in a Turkey oak (*Quercus cerris* L.) forest with other complementary broadleaves, such as maples (*Acer* sp.) and hornbeam (*Carpinus betulus* L.). The prevalent age is 60-70 years, but there are also several individuals of Turkey oak with an estimated age between 130-140 years, originated as a result of a clear-cut with reserves made at the end of 1800. The average basal area is 37 m^2 ha^{-1} and the DBH average 27 cm.

During the tree marking operation 'pro ÎdS', mature habitat trees (MHT) and the future habitat trees (FHT) have been identified. MHT's competitors have been cut and left on the ground, to increase the amount of deadwood present in the forest. Instead, FHT's competitors have been girdled. For several years they will stimulate the growth of seedlings for potential replacements of MHT, and will also provide a stock of deadwood. Since the mini-

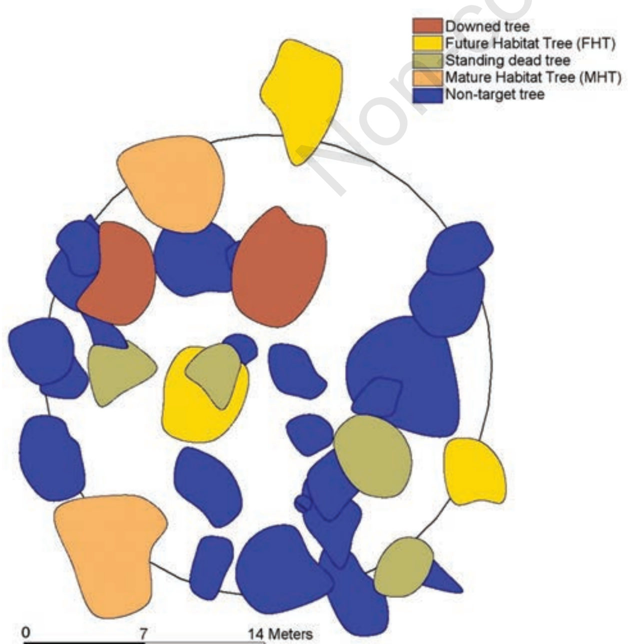

Figure 1. Tree marking operation for the Pennataro sampling plot.

Table 1. Cansiglio ÎdS. Average values of the survey plot main parameters, before and after the silvicultural treatment.

	Before thinning	After thinning
Tree density (n ha^{-1})	292±68	210±24
Basal area (m^2 ha^{-1})	39.1±6.8	28.6±2.1
Standing volume (m^3 ha^{-1})	547.9±92.0	401.0±29.2
Stem phytomass (Mg^3 ha-1)	349.3±58.6	255.6±18.6
Small branch phytomass (Mg^3 ha^{-1})	72.8±12.3	53.3±3.9
Stump phytomass (Mg^3 ha^{-1})	11.0±1.8	8.0±0.6 (live); 3.0±0.5 (dead)
Total aboveground phytomass (Mg^3 ha^{-1})	433.1±72.8	316.9±23.0
Mean DBH (cm)	41.5±1.4	41.8±1.3
Mean height (m)	26.1±0.3	26.8±0.2
Dominant trees DBH (cm)	49.2±1.2	48.3±0.8
Dominant trees height (m)	28.8±1.7	29.5±0.5

Table 2. Cansiglio ÎdS. General effect of the selvicultural treatment on the deadwood volume, considering standing dead trees and downed trees.

	Standing dead trees	Downed trees	Total
Tree density n ha^{-1}	40±21	42±23	82±44
Basal area (m^2 ha^{-1})	5.4±2.8	5.0±2.3	10.4±5.1
Standing volume (m^3 ha^{-1})	77.1±39.9	69.8±30.7	147.0±70.1
Stem phytomass (Mg^3 ha^{-1})	49.2±25.4	44.5±19.6	93.7±44.7
Small branchphytomass (Mg^3 ha^{-1})	10.2±5.3	9.3±4.1	19.5±9.3
Stump phytomass (Mg^3 ha^{-1})	1.5±0.8	1.4±0.6	2.9±1.4
Total aboveground phytomass (Mg3 ha^{-1})	60.9±31.5	55.2±24.3	116.1±55.4
Mean DBH (cm)	41.7±1.2	39.8±3.3	40.8±1.9
Mean height (m)	26.1±0.3	25.7±0.8	25.9±0.4

Table 3. Cansiglio ÎdS. Intensity of the selvicultural treatment, expressed in percentage values.

	Tree density (%)	BA (%)	Standing volume (%)
Standing dead trees	13	14	14
Downed trees	15	13	13
Total	28	27	27

mum suggested DBH for girdling is 25 cm (Cavalli and Donini, 2003), competitors with smaller diameters became downed trees.

In terms of basal area the treatment pro ÎdS brought a decrease of the 25%, and then it is comparable, from this point of view, to the traditional thinning performed in Molise's Turkey oak forests treated by shelterwood system (Cantiani *et al.*, 2010).

The silvicultural treatment pro ÎdS increased laying deadwood to a total of 70 m^3 ha^{-1} and standing deadwood to 40 m^3 ha^{-1} (Table 5).

As stated before, the first goal of an ÎdS is to reach as soon as possible a higher level of biodiversity by speeding up the natural effects of forest successions and of the associated deadwood decay processes. Both the demonstration sites show that it is crucial to analyse of the initial structure of the forest in order to predict the effects of the pro ÎdS silvicultural treatment and its future structure. Knowing the structure, it will be possible to define a management plan focused on old-growth forests characteristics. The duration of the felling cycle will be set according to specific tree species' ecological characteristics.

Table 4. Pennataro ÎdS. Average values of the survey plot main parameters, before and after the silvicultural treatment.

	Before thinning	After thinning
Tree density (n ha^{-1})	656±83	495±73
Basal area (m^2 ha^{-1})	36.7±4.3	26.7±3.1
Standing volume (m^3 ha^{-1})	411.4±61.7	298.2±42.8
Stem phytomass (Mg^3 ha^{-1})	272.8±40.6	197.3±27.9
Small branch phytomass (Mg3 ha^{-1})	51.5±7.6	37.6±5.3
Stump phytomass (Mg^3 ha^{-1})	7.3±1.1	5.3±1.1 (live); 2±0.4 (dead)
Total aboveground phytomass (Mg^3 ha^{-1})	331.7±49.3	240.2±33.9
Mean DBH (cm)	27.0±2.5	26.3±2.1
Mean height (m)	22.0±0.9	21.8±0.7
Dominant trees DBH (cm)	43.9±4.4	46.0±5.6
Dominant trees height (m)	25.4±1.1	27.0±1.3

Table 5. Pennataro ÎdS. General effect of the selvicultural treatment on the deadwood volume, considering standing dead trees and downed trees.

	Standing dead trees	Downed trees	Total
Tree density n ha^{-1}	48±30	113±47	161±38
Basal area (m^2 ha^{-1})	3.7±2.8	6.3±1.5	10.0±2.3
Standing volume (m^3 ha^{-1})	44.0±35.7	69.2±16.7	113.2±30.6
Stem phytomass (Mg^3 ha^{-1})	29.4±23.7	46.1±11.2	75.5±20.5
Small branch phytomass (Mg^3 ha^{-1})	5.4±4.4	8.6±1.9	13.9±3.7
Stump phytomass (Mg^3 ha^{-1})	0.8±0.6	1.2±0.3	2.0±0.5
Total aboveground phytomass (Mg^3 ha^{-1})	35.5±28.7	56.0±13.4	91.4±24.7
Mean DBH (cm)	30.6±1.5	28.2±3.9	29.4±2.0
Mean height (m)	23.2±0.4	22.3±1.3	22.7±0.7

Table 6. Pennataro ÎdS. Intensity of the selvicultural treatment, expressed in percentage values.

	Tree density (%)	BA (%)	Standing volume (%)
Standing dead trees	7	10	11
Downed trees	17	17	17
Total	24	27	28

References

Bastien Y, Gauberville C, 2011. Vocabulaire forestier. Écologie, gestion et conservation des espaces boisés. AgroParisTech, CNPF/IDF, Office National de Forêts.

Biache C, 2009. Comment indemniser les pratiques de mantien de stades de développement matures er teminaux du cycle sylvicole? AgroParisTech. Office National de Forêts.

Biache C, Rouveyrol P, 2011. Mise en place d'un îlot de sénescence: enquête sur des préconisations possibles et estimation du coût. Rev. For. Fran. 63:45-56.

Blakesley D, Buckley P, 2010. Managing your woodland for wildlife. Pisces Publications, Newbury, UK.

Bormann FH, Likens GE, 1994. Pattern and process in a forested ecosystem. Springer, New York.

Bouget C, Parmain G, Gilg O, Noblecourt T, Nusillard B, Paillet Y, Pernot C, Larrieu L, Gosselin F, 2014. Does a set-aside conservation strategy help the restoration of old-growth forest attributes and recolonization by saproxylic beetles ? Anim. Conserv. 17:342-353.

Brown JK, Reinhardt ED, Kramer KA, 2003. Coarse woody debris: managing benefits and fire hazard in the recovering forest. General Technical Report RMRS GTR-105. USDA Forest Service, Rocky Mountain Research Station, Ogden, USA.

Campanaro A, Hardersen S, Mason F, 2007. Piano di gestione della Riserva Naturale Statale e Sito Natura 2000 "Bosco della Fontana". Cierre Ed., Verona.

Cantiani P, Ferretti F, Pelleri F, Sansone D, Tagliente G, 2010. Le fustaie di cerro del Molise. Analisi del trattamento del passato per le attuali scelte selvicolturali. Ann. Centro Ric. Selv. 36:25-36.

Cavalli R, Donini F, 2003. Possible management actions to increase the amount of dead and marcescent wood. In: R. Cavalli and F. Mason (eds.) Techniques for re-establishment of dead wood for saproxylic fauna conservation. LIFE Nature Project NAT/IT/99/6245 "Bosco Della Fontana" (Mantova, Italy). Arcari Ed., Mantova, pp. 31-56.

Chevalier, H, Gosselin M, Costa S, Paillet Y, Bruciamacchie M, 2009. Évaluation économique de pratiques favorables à la biodiversité saproxylique: intérêts et limites. RDV techniques n° 25-26. Office National de Forêts.

Davies C, Fay N, Mynors C, 2000. Veteran trees: a guide to risk and responsibility. English Nature, Peterborough.

Deuffic P, Bouget C, 2011. Making biodiversity a public problem. The case of dead wood in forests. Revue SET 3:132-138.

Di Salvatore U, Tonti D, Bascietto M, Chiavetta U, Cantiani P, Fabbio G, Becagli C, Bertini G, Sansone D, Skudnik M, Kobal M, Kutnar L, Kobler A, Ferreira A, Kovač M, Simončič P, Ferretti F, 2016. ManFor C.BD sites and the drivers of forest functions. Ital. J. Agron. 11(s1):1-175.

Dodelin B, Andre J, Wlerick L, Lemperiere G, 2004. Le bois mort en forêt de montagne (Alpes françaises). Rev. For. Fran. 56:507-518.

FAO, 2010. Global forest resources assessment 2010. Main report. FAO Publ., Roma.
Gosselin M, Valadon A, Bergès L, Dumas Y, Gosselin F, Baltzinger C, Archuax F, 2006. Prise en compte de la biodiversité dans la gestion forestière: état des connaissances et recommandations. Cemagref, Nogent-sur-Vernisson.
Haslett JR, 2007. European strategy for the conservation of invertebrates. Convention on the conservation of European Wildlife and Natural Habitats (Bern Convention), Nature and environment, No. 145. Council of Europe Publishing.
Jonsson BG, Siitonen J, 2012. Dead wood and sustainable forest management. In: J. Stokland, J. Sittonen and B. Jonsson (eds.), Biodiversity in dead wood. Cambridge University Press, Cambridge, pp. 302-337.
Knapp EE, 2015. Long-term dead wood changes in a Sierra Nevada mixed conifer forest: Habitat and fire hazard implications. Forest Ecol. Manag. 339:87-95.
Köhl M, Stümer W, Kenter B, Riedel T, 2008. Effect of the estimation of forest management and decay of dead woody material on the reliability of carbon stock and carbon stock changes - A simulation study. Forest Ecol. Manag. 256: 229-236.
Kraus D, Krumm F, 2013. Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute, Freiburg.
Lachat T, Bütler R, 2007. Gestion des vieux arbres et du bois mort: Îlots de sénescence, arbres-habitat et métapopulations saproxyliques. Mandat de l'Office fédéral de l'environnement, OFEV, WSL, Lausanne.
Lonsdale D, 2000. Hazards from trees: a general guide. Forestry Commission, Edinburgh.
Luyssaert S, Schulze E-D, Börner A, Knohl A, Hessenmöller D, Law BE, Ciais P, Grace J, 2008. Old-growth forests as global carbon sinks. Nature 455:213-215.
Mason F, 2004. Dinamica di una foresta della Pianura Padana. Bosco della Fontana. Primo contributo, monitoraggio 1995. Seconda edizione con linee di gestione forestale. Arcari Ed., Mantova.
Mason F, Zapponi L, 2015. The forest biodiversity artery: towards forest management for saproxylic conservation. iForest doi:10.3832ifor1657-008
ONF, 2009a. Instruction n. INS-09-T-71 relative aux Îlot de vieux bois. Office National des Forêts.
ONF, 2009b. Note de service n. NDS-09-T-310 relative aux Ilots de vieux bois. Office National des Forêts.
Paillet Y, Pernot C, Boulanger V, Debaive N, Fuhr M, Gilg O, Gosselin F, 2015. Quantifying the recovery of old-growth attributes in forest reserves: a first reference for France. Forest Ecol. Manag. 346:51-64.
Peterken GF, 1996. Natural woodland: ecology and conservation in northern temperate regions. Cambridge University Press, Cambridge.
Rouveyrol P, 2009. Caractérisation d'un îlot idéal de vieux arbres en forêt de montagne. Etat des connaissances et synthèse pour la réalisation d'un guide de gestion. Mémoire de fin d'études. AgroParisTech. Office National de Forêts.
Schiegg Pasinelli K, Sutter W, 2000. Le bois mort - un habitat. Not. Prat. 33. Swiss Federal Institute for Forest, Snow and Landscape Research, Birmensdorf.
Speight MCD, 1989. Saproxylic invertebrates and their conservation. Council of Europe, Strasbourg.
Swanson FJ, Chapin FSI, 2009. Forest systems: living with long-term change. In: F.S.I. Chapin, F.S. Kofinas and C. Folke (eds.) Principles of ecosystem stewardship. Relience-based natural resource management in a changing world. Springer, New York, pp. 149-170.
Tabacchi G, Di Cosmo L, Gasparini P, Morelli S, 2011. Stima del volume e della fitomassa delle principali specie forestali italiane. Equazioni di previsione, tavole del volume e tavole della fitomassa arborea epigea. Consiglio per la Ricerca e la sperimentazione in Agricoltura, Unità di Ricerca per il Monitoraggio e la Pianificazione Forestale, Trento.
Temoin J, 2009. Creation d'îlots de vieux bois en forêt domaniale de Rambouillet. Office National de Forêts. Agence interdépartementale de Versailles UT de Rambouillet.
Timonen J, Siitonen J, Gustafsson L, Kotiaho JS, Stokland JN, Sverdrup-Thygeson A, Mönkkönen M, 2010. Woodland key habitats in northern Europe: concepts, inventory and protection. Scand. J. For. Res. 25:309-324.
Wirth C, Messier C, Bergeron Y, Frank D, Fankhänel A, 2009. Old-growth forest definitions: a pragmatic view. In: C. Wirth, G. Gleixner and M. Heimann (eds.), Old-growth forests. Springer Berlin, pp. 11-33.

From forest stand to forest landscape: the spatial distribution of forest treatments in the landscape of ManFor Italian sites

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Introduction

Fragmentation of forest habitats is among several factors caused by the consequence of forest management, depending on type of silvicultural system and besides, the spatial scale in which the phenomena is studied (Frate *et al*., 2016).

At the Italian sites of the LIFE+ ManFor C.BD, different criteria (not managed, traditional and innovative forest management) were applied on small areas of about 3 hectares within forest management areas (FMAs) of about 30 hectares. Both criteria involve the application of 'selection cutting' (single tree selection, group selection or a combination of both).

The main aim of 'traditional' forest management criteria is the reduction of competition and optimization growing space distribution for the most appropriate tree species within the forest population. With 'innovative' approach the aim was to increase structural diversity within forest stands (Di Salvatore *et al*., 2016b).

Harvesting in the dominant tree canopy layer causes small openings or larger gaps and consequently causes discontinuity of the continuous canopy cover. In addition, gaps change microclimatic conditions at the local scale, various response of the tree species involved and also changes in the spatial pattern of forest habitats.

To understand the influence of the forestry practices applied in the ManFor C.BD (Di Salvatore *et al*., 2016b) on the forest landscape spatial pattern, for each Italian site the forest treatments were simulated within equal-area landscape frames of 10 km^2. The area of landscape frame was chosen according to the size of a generic fauna species home range and on the basis of the remote sensing data availability. Landscape frames were spatially defined from the geographic centroid of each FMA (Figure 1).

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Key words: forest landscape, morphlogical spatial pattern analysis, GUIDOS, forest treatments.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Methods

Treatments were simulated by HARVEST 6.1 (Gustafson, 1999). It is a spatially explicit and rule-based stochastic model which simulates the timber management of forested landscapes by applying silvicultural techniques to maps of forest mosaics and operates on a grid-cell (raster) representation of the landscape.

The forest spatial pattern after timber harvesting is simulated in 'neutral' (random) landscape (Gustafson and Loehle, 2006), an ideal solution to overcome problems related to initial conditions of forest stands (that can to reflect past management actions of the various owners) (Gustafson and Loehle, 2006). Neutral model landscapes use algorithms to produce patterns that are neutral relative to all spatial processes except the ones being experimentally manipulated (Gardner *et al*., 1987; Gustafson and Parker, 1992), generating neutral stand maps that are independent of past management.

The forest landscape mosaic of Italian sites (10 km^2 size areas) was represented by a 5 m x 5 m grid-cell size. The simulation of harvest activity by HARVEST required a set of four input maps: forest age map (Age), forest type map (FT), management area map (MA), and a forest stand identification number (ID) map (Figure 2). The simulation provided scenario maps of the different forest management options (not managed, traditional and innovative scenarios). For each option ten simulation replicates were generated. The forest landscape spatial pattern of each resulting scenario was classified and mapped by the Mathematical Morphological Spatial Pattern Analysis (MSPA) based on the freeware GUIDOS (Graphical User Interface for the Detection of Objects and Shapes) software (developed by the JRC-IES and available at URL: http://forest.jrc.ec.europa.eu/download/software/guidos), on binary forest/non forest maps.

The GUIDOS application (according to a specific user defined depth-of-edge) allows an automated classification per pixel and description of the geometry, pattern and connectivity of the forest landscape. The forest spatial pattern is classified into seven main classes:

- **Core** pixels are defined as forest pixels whose distance to the non-forested areas is greater than the defined edge width. All other forest pixels not corresponding to the core (habitat) areas are assigned to one of the six following remaining pattern classes.
- **Edge** (external perimeter of core patch);
- **Perforation** (perimeter of perforation in core patch);
- **Bridge** and **loop** (when same core) connectors between cores;
- **Branches** (pixels that do not belong to any of the previously defined categories. They emanate from boundaries as edge or perforation);
- **Islet/fleck** (isolated non-core forest patches).

The choice of the depth-of-edge clearly influence the classification results. For more details on the use of MSPA and GUIDOS application please see the specific bibliography (Vogt *et al*., 2006; Estreguil *et al*., 2007; Vogt, 2009).

Honnay *et al.* (2002) suggest a distance of 20-25 m from the external forest border as maximum permeability capability of invasive species to permeate in the interior temperate forests.

Beyond this distance local ecological conditions are maintained and do not cause the 'edge effect' for interior vegetation species. For the MSPA within the 10 km^2 landscape areas at Italian research sites, a 25 m edge width was defined.

The MSPA classification can be conducted with 4- or 8-neighbourhood rule. For Italian sites, the 8- neighbourhood rule was used i.e. two pixels of the same class belong to the same landscape element if they share either one of their sides or vertices.

As indicators of levels of changes in the forest spatial pattern and connectivity, the amount of 'core' and 'bridges' (connection elements) between the different forest management options (not managed, traditional and innovative) were used.

Modelling the forest treatments

Treatments were simulated within 'stands' (from stand ID map) and on the 100% of available amount of FMA (from MA map). In the model this map remained constant throughout the simulation period. Treatments were simulated as applied in the period of one year without successional processes. Forests were considered even aged and in proper age for harvesting (from the Age map). The 'protective forest areas' (if present and identified by the forest management plan of the site) and forest types different from that considered in the simulation (from FT map) were assumed as not managed forests. The forest thinnings were assumed as applied to dominant canopy trees. The age of harvested areas was reset at 1 year and for the spatial pattern analysis considered as gaps. The harvesting of a single tree was assumed to cause gap within the forest canopy of a minimum 25 m^2 (according to the landscape cell-size 5 m x 5 m). The harvesting simulation of more than one single tree or trees with a crowns size bigger than 25 m^2 were simulated by the aggregation of more pixels. The algorithm of simulation randomly chooses stands inside a forest management and then harvests small openings within those stands.

The percentage of simulated gaps within canopy gaps was related to the mean crown size collected in the field and to the plot size (1256.64 m^2). The percentage differed between sites and forest management approaches.

The HARVEST simulator assumes that the likelihood of harvest of a stand (ID) within given forest type (FT) and management area (MA) is solely related to the age (Age) of the stand, although it is known, that also other conditions influence the harvesting decisions in field. Simulator randomly selects suitable stands from the ones that meet the age criteria and eventually adjacency constraints

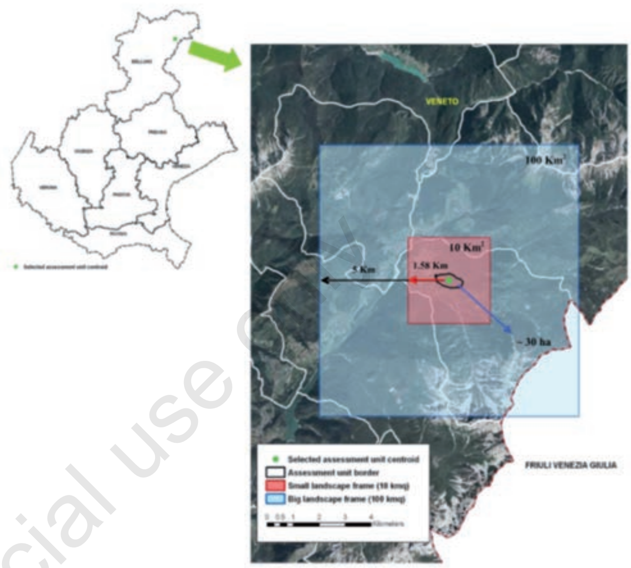

Figure 1. Example of the spatial definition of landscape investigation within the ManFor C.BD project (Site 3: Lorenzago di Cadore, Italy). From the geographic centroid of the forest management areas (for each site along the Italian transect) two portions of landscape were drawn. Within larger area of 100 km^2 (light blue in picture) the landscape characteristics were analysed, which also included smaller area of 10 km^2 (light red in picture) for the detailed analysis, where forest treatments were spatially distributed by the simulation model.

Table 1. Summarization example of parameters used by HARVEST 6.1 simulator for the Cansiglio site.

	Traditional	Innovative
Dispersion method: Group selection	Group selection randomly chooses stands and then harvests small openings within those stands	
Proportion to cut in stands	0.17 (%)	0.33 (%)
Revisit interval (yrs)	20	20
Management area ID	1 (Beech forest managed, not protective forest and coniferous forests)	1 (Beech forest managed, not protective forest and coniferous forests)
Forest type value	1 (Beech forest)	1 (Beech forest)
Average harvesting size	0.0025	0.05
Standard deviation	0.0025	0.0025
Minimum harvesting size	0.0025	0.0025
Maximum harvesting size	0.0075	0.0075
Minimum age allowed for the harvesting	80	80
Minimum time since the last harvest	20	20
Percent to cut (>0.1)	100	100
Green up interval (yrs)	20	20
Buffer distance	100	100

and over a time period of a decade or more, mimics the pattern found in managed forests (Gustafson and Crow, 1999).

An example of the simulation parameters used by HARVEST is shown in Table 1. Parameters refer to the simulation of treatments applied at the Cansiglio site.

Figure 3 shows schemes of resulting forest pattern at stand level within plots (1256.64 m^2). The Figure 4 shows an example of the modelled treatments scenarios for Cansiglio site, classified by GUIDOS. An example of comparison between resulting classes from the MSPA for the three treatments scenarios for the Cansiglio site is presented in Table 2, which shows the innovative approach creating bigger fragmentation in regard to the traditional approach,

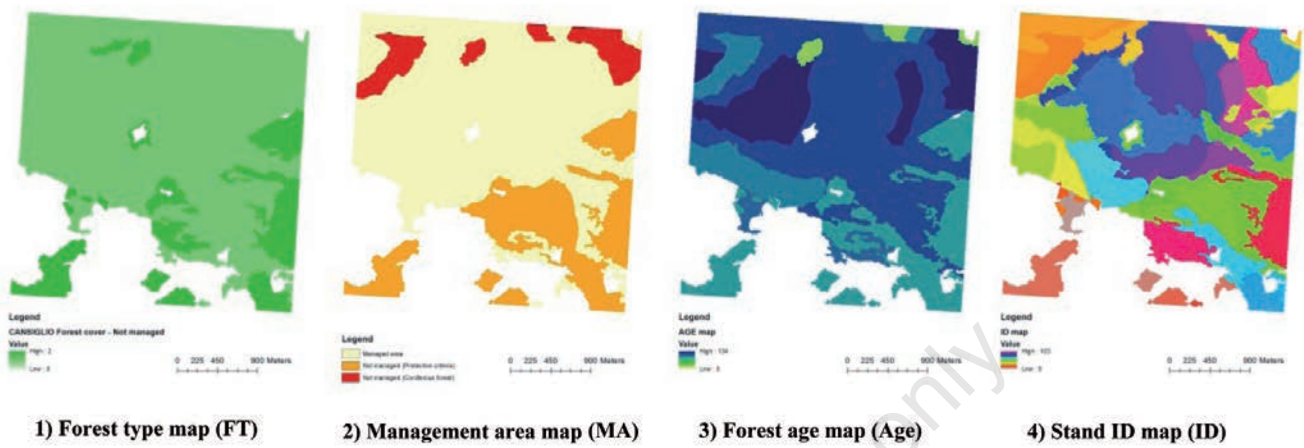

Figure 2. Example of input maps (Site 1: Cansiglio) for the simulation. 1) FT: derived by the classification of multispectral RapidEye imagery. This map is used by HARVEST to apply harvest rules to the correct forest type. 2) MA: defined from the forest management plans, used to apply the specified harvesting strategy to the correct management area. 3) Age: map containing cells whose values represent the age (in years) of the forest in each cell. It is used to determine if cells meet the age constraints for harvesting. Information on forest age were obtained by the forest management plans, when available. 4) ID: map of stand ID numbers, where each stand ID value is a unique integer <64,535. This map is used to track harvesting activity in stands.

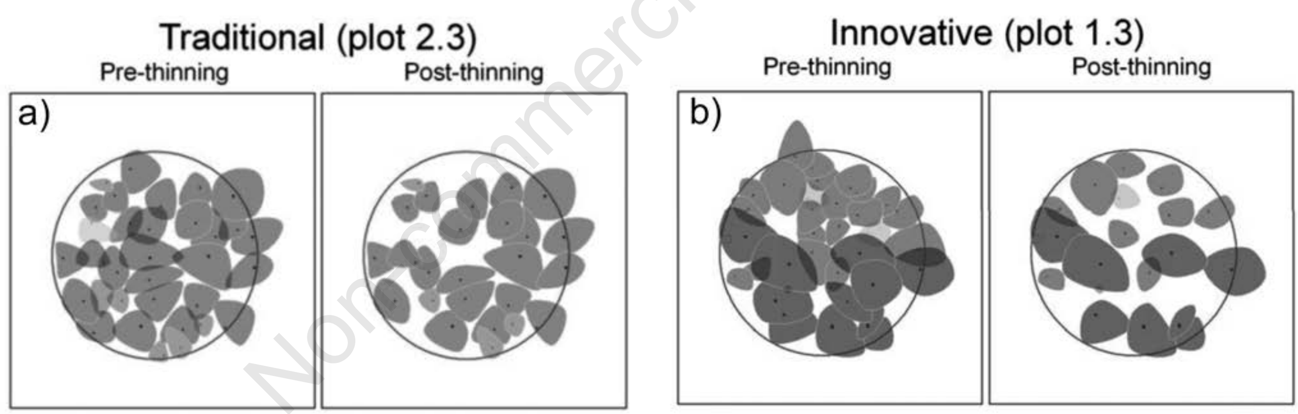

Figure 3. The resulting forest-stand pattern following the two forest management criteria applied in two plots within Cansiglio site (for more details on the applied criteria: Di Salvatore et al., 2016a). It is possible to note the higher density of gaps / openings after applied thinning within innovative approach in regard to the traditional way.

Table 2. An example of the MSPA developed by GUIDOS for the Cansiglio site.

	Not harvested		Traditional		Innovative	
	ha	%	ha	%	ha	%
Branch	47.10	0.41	1.50	0.15	1.90	0.19
Edge	28.63	2.86	16.63	1.66	16.54	1.65
Perforation	4.54	0.45	0	0	0	0
Islet	0	0	0	0	0.17	0.02
Core	760.94	76.09	196.37	19.54	192.76	19.28
Bridge	1.12	0.11	485.89	48.59	419.21	41.92
Loop	1.71	0.17	10.21	1.02	3.70	0.37
Non forest/holes	197.75	19.77	288.18	28.82	364.51	36.45

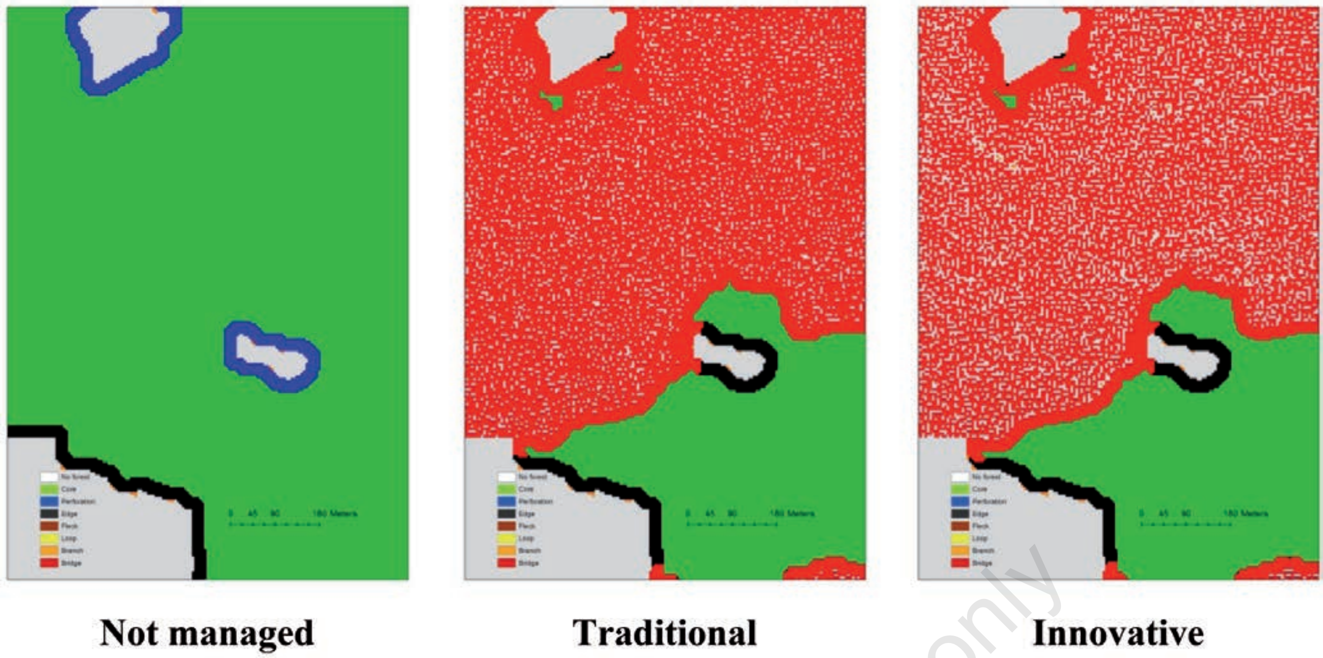

Figure 4. Details of forest spatial patterns resulting maps classified by GuidosToolbox for different scenarios: an example for Cansiglio site. Green, core areas; red, bridges; black, edge areas; blue, perforations; grey, non forested area.

as shown by the decreasing amount of core areas (192.76 ha), compared to the not managed scenario (760.94 ha). In both simulated treatments (innovative and traditional), the increasing of bridge class was confirmed as the result of a more fragmented core area (traditionally: 485.89 ha; innovative: 419.21 ha).

The fragmentation of core areas due to the harvesting activities is a temporary phenomena that will persist for the period of the natural processes of forest restoration. As showed for the Cansiglio site, results of simulation may be in agreement with the ‘innovative’ approach, aiming to create more species diversity in the forest patches. Such phenomena was explained with the intermediate disturbance hypothesis (Connel, 1978), assuming maximum values of floristic richness in moderately disturbed environment. Forest treatments produce new forest edges where new colonization of species are possible and influence the overall values of floristic species (Frate *et al*., 2011) due to the creation of new climatic conditions (Forman, 1995; Lovejoy *et al*., 1986; Kapos, 1989; Laurance *et al*., 1998; Farina, 2001).

References

Di Salvatore U, Cantiani P, Ferretti F, 2016a. From sectorial-optimum to multipurpose silviculture. How to compromise. Ital. J. Agron. 11(s1):1-175.

Di Salvatore U, Tonti D, Bascietto M, Chiavetta U, Cantiani P, Fabbio G, Becagli C, Bertini G, Sansone D, Skudnik M, Kobal M, Kutnar L, Kobler A, Ferreira A, Kovač M, Simončič P, Ferretti F, 2016b. ManFor C.BD sites and the drivers of forest functions. Ital. J. Agron. 11(s1):1-175.

Connell JH, 1978. Diversity in tropical rain forest and coral reefs. Science 199:1302-1310.

Estreguil C, Vogt P, Ostapowicz K, 2007. Implementation of the MCPFE Indicator on landscape level forest spatial pattern for Europe. p. 163 in Proc. ForestSAT Conf., Montpellier, France. Available from: http://forestsat.teledetection.fr/

Farina A, 2001. Ecologia del paesaggio, principi, metodi e applicazioni. UTET, Torino, Italy.

Forman RT, 1995. Land mosaics: the ecology of landscape and regions. Cambridge University Press, New York, USA.

Frate L, Carranza ML, Paura B, Di Biasi N, 2011. Analisi della diversità floristica dei boschi lungo un gradiente di frammentazione: un caso studio nelle faggete dell’Appennino molisano. Forest@ 8:137-148.

Frate L, Carranza ML, Tonti D, Ferreira A, Marchetti M, 2016. Landscape as a driver of forest functions. Ital. J. Agron. 11(s1):1-175.

Gustafson EJ, 1999. HARVEST: A timber harvest allocation model for simulating management alternatives. In: J. Klopatek and R.H. Gardner (eds.) Landscape ecological analysis: issues and applications. Springerg, New York, pp. 109-124.

Gustafson EJ, 2007. Relative influence of the components of timber harvest strategies on landscape pattern. For Sci. 53:556-561.

Gustafson EJ, Crow TR, 1999. HARVEST: linking timber harvesting strategies to landscape patterns. In: D.J. Mladenoff and W.L. Baker (eds.) Spatial modelling of forest landscapes: approaches and application. Cambridge Univeristy Press, Cambridge, UK, pp. 309-332.

Gustafson EJ, Loehle C, 2006. Effects of parcelization and land divestiture on forest sustainability in industrial forest landscapes. Forest Ecol. Manag. 236:305-314.

Gustafson EJ, Parker GR, 1992. Relationship between landcover proportion and indices of landscape spatial pattern. Landscape Ecol. 7:101-110.

Honnay O, Verheyen K, Hermy M, 2002. Permeability of ancient forest edges for weedy plant species invasion. Forest Ecol.

Manag. 161:109-122.
Kapos V, 1989. Effects of isolation on the water status of forest patches in the Brazilian Amazon. J. Trop. Ecol. 5:173-185.
Laurance WF, Ferreira LV, Rankin-De-Merona JM, Laurance SG, 1998. Rain forest fragmentation and the dynamics of Amazonian tree communities. Ecology 79:2032-2040.
Lovejoy TE, Bierregaard ROJR Rylands AB, Malcolm JR, Quintela CE, Harper LH, Brown KS Jr, Powell AH, Powel, GVN, Schubart HOR, Hays M, 1986. Edge and other effects of isolation on Amazon forest fragments. In: M. Soulé (ed.) Conservation biology: the science of scarcity and diversity. Sinauer Associates Inc, Sunderland, MA, USA, pp. 257-285.
Vogt P, 2009. MSPA-Guidos: innovative methods in landscape pattern analysis. Page 42 Proc. Latin American IALE 2009, Sao Paulo, Brazil.
Vogt P, Riitters KH, Estreguil C, Kozak J, Wade TG, Wickham JD, 2006. Mapping spatial patterns with morphological image processing. Landscape Ecol. 22:171-177.

Forest fragmentation at forest stand level at three test sites in Slovenia

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High-resolution 3-D remote sensing was used to determine change in forest stand fragmentation for the three Slovenian test sites before and after applied silvicultural measures. A multi-temporal aerial lidar scanning campaign was performed over the Slovenian test sites. The 3-D lidar data were first processed into intermediate products, the 1-meter resolution raster maps, relating to the gradients of bare ground relief, vegetation height, and canopy cover percentage. These maps were then the basis for further detailed identification of gaps in canopy cover reflecting the continuity of canopy cover. The first phase was computing the digital elevation model (DEM) showing the bare ground relief using the REIN algorithm (Kobler *et al*., 2007). In the next stage this enabled determination of height above bare ground of each lidar point in the point cloud, which was necessary to compute all the further raster layers. The criterion "Continuity of forest canopy cover" corresponds to the change indicator Spatial pattern of gaps in the forest stand canopy, related to the MCPFE indicators 3.1 Increment and fellings, 4.2 Regeneration and 4.7 Landscape pattern (MCPFE 2015). The discontinuities (gaps) in forest canopy reaching to the ground are the centres of forest rejuvenation. Their areal percentage and spatial juxtaposition is an important indicator of forest stand developmental and ecological status. The indicator is gleaned from the lidar based high-resolution digital canopy model (DCM), depicting the vegetation heights, estimated from lidar point cloud with known relative heights above bare ground. DCM vegetation heights were computed in a rectangular grid with the horizontal resolution of 1m x 1m. All types of lidar returns were taken into account (first, last, only, intermediate). For each return its height above the bare ground was computed using bilinear interpolation from the neighbouring DEM grid points. The highest lidar return within each grid cell was considered as the vegetation height for this grid cell. The gaps in forest stand canopy have been identified from DCM as those areas where vegetation heights do not exceed 1 m, i.e. discontinuities or gaps in the forest canopy cover. In addition, the depth of the internal forest environment was computed as distance (proximity) to the nearest gap in forest stand canopy. The results for the 70 ha Kočevski Rog test site (as an example of the 3 test sites in Slovenia, where lidar-based criteria were tryed) are shown in the figures below. Visual comparison of the before and after treatment DCM maps (Figure 1) clearly show the spatial pattern of the treatments. The mean forest canopy height in the Kočevski Rog test site decreased from 25.3 m to 22.7 m, for pre-treatment and post-treatment period, respectively. A more detailed analysis is given in Figure 2, where the pre- and post-treatment distributions of the forest vegetation heights at the site are compared. After treatment the forest heights below 10 m show a dramatic increase in area. The DCMs in Figure 1 are the intermediate products used as the basis for forest gap / forest fragmentation mapping and analysis in the following figures. Figure 3 shows the change of spatial pattern of gaps in the forest stand canopy and the change in the depth of the internal forest environment due to the treatments. The mean distance to forest gap in the Kočevski Rog test site decreased from 13.6 m to 9.6 m, for pre-treatment and post-treatment period, respectively, which indicates a considerable change in microclimate and growing conditions. This is more clearly seen from the chart in Figure 4 which indicates an increase in areas closer than 10 meters to forest edge and a corresponding general decrease in areas further from the forest edge. A less scattered spatial pattern of treatments might have a less pronounced effect on the internal forest environment. Another aspect of forest fragmentation due to treatments is the mean forest gap area at the test site, which increased from 7.9 m^2 to 33.4 m^2, before and after the treatment, respectively. Figure 5 shows both an increase in the number of gaps, as well as an increase in the size of the gaps. All the demonstrated forest stand lidar-based criteria, show different aspects of sylvicultural treatment effects at the forest stand scale. This has important implications since in Slovenia a country wide lidar dataset has meanwhile became available and these finding will have practical implications for forest management in Slovenia in general and for sylvicultural intervention in particular. Specifically, it was shown: 1) The average forest stand height change can be estimated from multitemporal lidar data, thus quantifying the intensity of cutting in a forest stand. This feature can be put to use in forest inspection where exceeding allowed cut or even illegal cuts can be identified accurately, reliably, and on large areas. If a model-based link between average stand height and stand age is established, then the balance of age classes on large areas can be reliably determined. The inappropriate balance of age classes in Slovenia has been suggested as a long term problem of Slovenian forests (Kovač 2014, Kovač *et al.* 2016). 2) The depth of internal forest environment has been shown to influence forest rejuvenation and the species mix of the rejuvenated forest stand, but also species-specific habitat suitability and several forest- and ecosystem services (Hladnik 2005, Rugani *et al*. 2013). This criterion is depending not only on the area of cut forest but also in the spatial pattern of cuts. The former can be gleaned from the forest gap area (number and size of forest gaps), easily derived from the DCM, while the latter can be quantified from the dedicated map of the distances to the nearest gap.

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Key words: lidar, forest, forest fragmentation, sylviculture.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

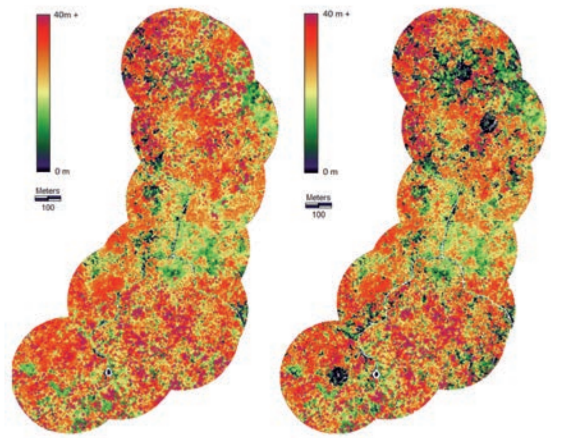

Figure 1. The digital canopy model DCM (*i.e.*, forest vegetation heights) for the Kočevski Rog test site. Situation before (left) and after applied measure (right). The DCM horizontal resolution is 1 m. The DCM is the intermediate product used as the basis for forest gap / forest fragmentation mapping and analysis.

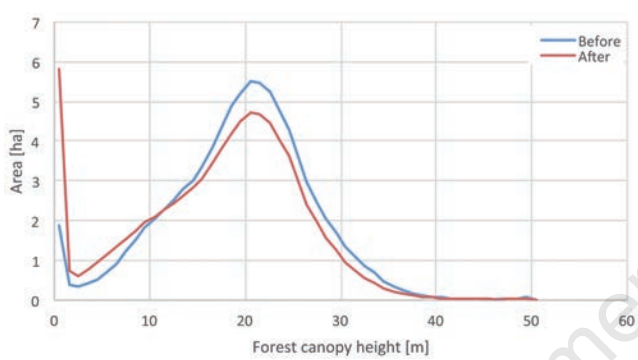

Figure 2. The comparison of forest vegetation heights distributions at the Kočevski Rog test site before and after applied measures. The chart corresponds to the maps in Figure 1.

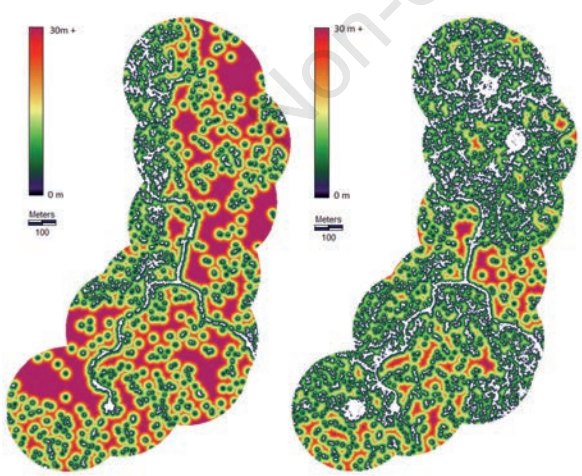

Figure 3. Kočevski Rog test site - the spatial pattern of gaps (white areas) in the forest stand canopy and the depth of the internal forest environment (as distance to the nearest gap in forest stand canopy, shown with the colour scale). Conditions before (left) and after applied measures (right). The gaps in forest stand canopy have been identified from DCM as the areas where vegetation heights do not exceed 1 m. The map horizontal resolution is 1 m.

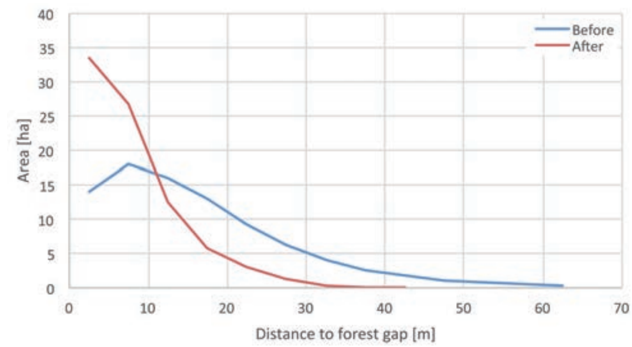

Figure 4. The change in the distances to the nearest gap in forest stand canopy before and after applied measures. The chart corresponds to the maps in Figure 3.

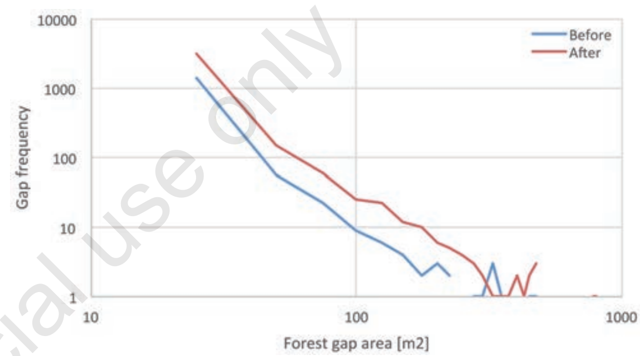

Figure 5. The change in the number and the size of forest gaps due to treatments.

References

Hladnik D, 2005. Spatial structure of disturbed landscapes in Slovenia. Ecol. Eng. 24:17-27.

Kobler A, Pfeifer N, Ogrinc P, Todorovski L, Oštir K, Džeroski S, 2007. Repetitive interpolation: a robust algorithm for DTM generation from aerial laser scanner data in forested terrain. Remote Sens. Environ. 108:9-23.

Kovač M, 2014. Stanje gozdov in gozdarstva v luči Resolucije nacionalnega gozdnega programa Gozdarski vestnik 72:59-75.

Kovač M, Kutnar L, Hladnik D, 2016. Assessing biodiversity and conservation status of the Natura 2000 forest habitat types: tools for designated forestlands stewardship. Forest Ecol. Manag. 359:256-267.

MCPFE, 2015. State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe, Madrid.

Rugani T, Diaci J, Hladnik D, 2013. Gap dynamics and structure of two old-growth beech forest remnants in Slovenia. PloS One 8:e52641.

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Comparing silvicultural treatments through a forest simulator

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Introduction

Growth models represent important tools for forest researchers and managers, particularly because of their ability in exploring management options and silvicultural alternatives. For example, foresters may wish to compare the long-term effect of two management strategies on both the forest and on future harvests. With a growth model, they can examine the forecasted outcomes of the two strategies and can make their decision objectively. The process of developing a growth model may also offer interesting new insights into stand dynamics.

The simplest growth models are the traditional yield tables. They predict stand development (e.g. growth of mean diameter) for a given 'reference stand'. Yield tables always refer to a given site condition, forest structure and management option. In practice, they are only used for even-aged, pure stands. However, with the shift toward all-aged and mixed species managed forests, new growth models are required to support sustainable management. An answer to this request is given by individual-based models that predict the development of all trees within a forest, where the level of resolution is the tree with its specific neighbouring competition. In principle, this allows to predict tree growth with the required flexibility regardless of species mixture, age distribution, spatial structure or management strategy.

The core of these models is a set of mathematical equations describing neighbouring competition, growth and mortality at the tree level and an algorithm that systematically applies these equations to all trees within a stand. In order to allow the required flexibility and reliability of these models, the core equations should be based on a high number of observations (at the tree level) covering all the situations to be modelled. For example, the model SILVA discussed in this chapter is based on about 155,000 tree observations (Pretzsch *et al*., 2002).

Several those models have been developed in the last decades. Among them, SILVA has a particularly attractive feature. Core equations and parameters describing the site effect on tree growth are separated from those describing the competition effect. This should allow an easier transferability of SILVA to forest stands, different from those used for model construction. In SILVA, a tree is described by the following key variables: tree species, tree position (*x, y*), diameter at breast height (*dbh*) and height (*h*). Then, based on allometric relationships, the three-dimensional crown shape is calculated. In turn, crown shape together with *dbh* and *h* are used to describe neighbouring competition. Finally, based on competition, tree growth and mortality are calculated for all trees every 5 years (time step). SILVA is parameterized for 5 species: Norway spruce, Silver fir, Scots pine, Common beech and Sessile oak (for details see Pretzsch *et al*., 2002).

In this article we discuss the applicability and use of SILVA on one forest site studied within the ManFor Project.

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Key words: Growth models, competition, forest management.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Preliminary settings

Before executing a simulation run, site conditions and a detailed description of the 'initial' forest must be specified. We now describe how we dealt with these two preliminary settings. In particular, note that evaluating the site-specific parameters is the first step for applying SILVA to Italian forests.

Site parameters

In SILVA, the site conditions are described by 9 environmental variables describing temperature, precipitation, soil type and atmosphere at the site. For most simulation purposes, the environmental conditions are kept constant, but they may also be altered during a simulation run if desired. After a complex procedure, these 9 variables are transformed into 4 site-specific parameters. Three of these parameters (A, k, p) describe the dominant height growth curve and the last parameter (*ESto*) acts as a modifier for diameter growth. The dominant height growth curve is as follows:

$$h_{100}(t) = A(1 - e^{-kt})^p$$

where h_{100} is the dominant height (i.e. the mean total height of the 100 largest trees per hectare) and t is the stand age. Then, the (species-specific) potential height growth curve is calculated as $hpot(t) = F_{species} h_{100}(t)$. Where $F_{species}$ is a species-specific coefficient (Pretzsch, 2009).

Since the procedure for transforming the 9 environmental variables into the A, k and p parameters is quite complex (Pretzsch, 2009), we decided to directly estimate the site-specific parameters by comparing simulations with measured data.

Here, we are interested in simulating the time evolution of a forest site in the Cansiglio region, which received three different silvicultural treatments within the ManFor Project. In order to estimate the relevant site parameters, we used growth data from the CONECOFOR project (Ferretti *et al.,* 2008) where a 0.25 ha stand in the Cansiglio forest has been monitored from 1996 to 2009. In SILVA the equation for diameter growth for the beech species can be summarized as Δdbh = ESto × f(dbh). This fact enabled us to easily estimate ESto. Then, in order to estimate the height growth curve, we used an equation based on the French National Inventory described by Seynave *et al.* (2008). In their equation two out of the three parameters are kept constant and only one parameter identifies the curve written above. We tried different values of this parameter to find the best fit between simulated and measured data (Figure 1).

Initial forest

Once the site parameters have been fixed, SILVA takes as input the initial position, diameter and height of all trees in the stand to be simulated and produces as output the final position, diameter and height of surviving trees after a desired time period (*e.g*., 100 years). Since this initial forest is rarely known with the required precision, SILVA provides a module that simulates the initial forest based on less detailed information, such as diameter distribution (Pretzsch, 1997). However, in this case, detailed measurements were taken in several small sampling areas and they were used to simulate a more realistic initial forest.

Specifically in the Cansiglio site, silvicultural treatments were applied to nine 3 ha areas (plots) each of which is described in detail by 3 circular sampling areas with radius 20 m (subplots). To use this information, we followed Pommerening and Stoyan (2008). They describe a method for simulating a map of trees within a large plot from nearest neighbour summary statistics (NNSS) sampled in small circular subplots. Very shortly, their algorithm goes as follows:

i) NNSS for the small subplots are calculated ($NNSS_{obs}$);
ii) the same NNSS are calculated for a simulated random forest within the large plot but outside the small subplots ($NNSS_{sim}$);
iii) one tree is randomly selected among the simulated ones and its position is randomly changed until the difference between $NNSS_{obs}$ and $NNSS_{sim}$ is small enough.

In the final forest map, trees outside the subplots are simulated, while tree inside the subplots are measured. Several choices for NNSS are possible. As the relative positions of trees with different size are important for correctly evaluating spatial competition, we used as NNSS the histograms of distance to the first nearest neighbour for two size classes. An example is given in Figure 2 (left panel). The yellow circles are the actual sampling areas, while trees outside the circles have been simulated, based on NNSS measured within the circles.

Results and discussion

After having determined the site-specific parameters, we compared the output from SILVA with measured data from yield tables and from the CONECOFOR data mentioned above. Unfortunately, it turned out that simply modifying site-specific parameters is not enough to apply SILVA to Italian sites. The main problem was the natural mortality. Mortality rates higher than expected were probably due to the individual height/diameter ratio, which is used as a mortality component in SILVA (Pretzsch *et al*., 2002). Presently, we have not enough data to correctly parameterize natural mortality. Therefore, we suppressed the natural mortality in the following simulations. This is acceptable only in case of short-term simulations and if silvicultural treatments are applied repeatedly.

In the Cansiglio site, three management options have been applied. They are called 'No practice', 'Traditional' (thinning from below; about 25% of basal area is removed) and 'Innovative' (selective thinning + thinning from below; about 40% of basal area is removed). Forest structure before and after the treatment have been simulated following criteria described by Söderbergh and Ledermann (2003). Each treatment was assigned to three plots. In particular, plot 4 received the innovative treatment. However, in order to compare treatments, we simulated the evolution of plot 4

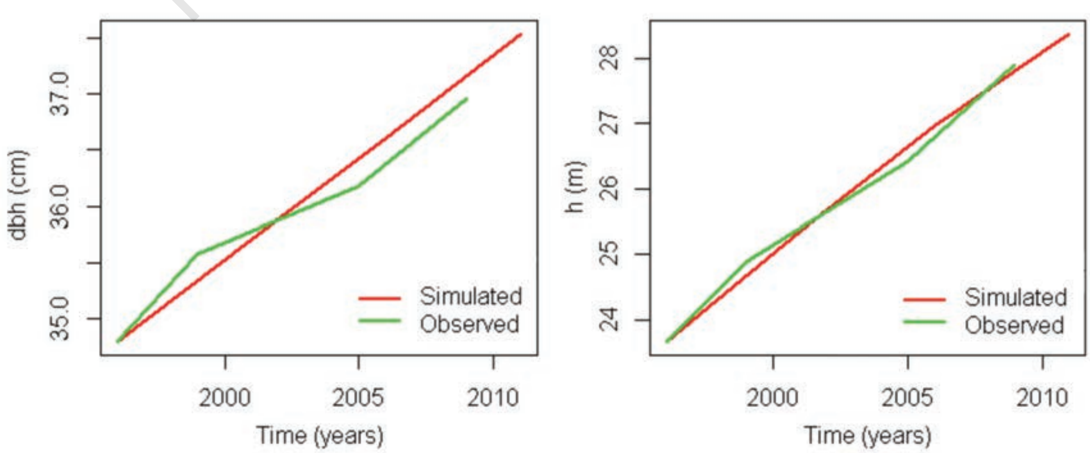

Figure 1. Mean diameter and mean height curves. Green line represent data measured in 1996, 1999, 2005, 2009. Red lines are the simulated data (natural mortality has been suppressed).

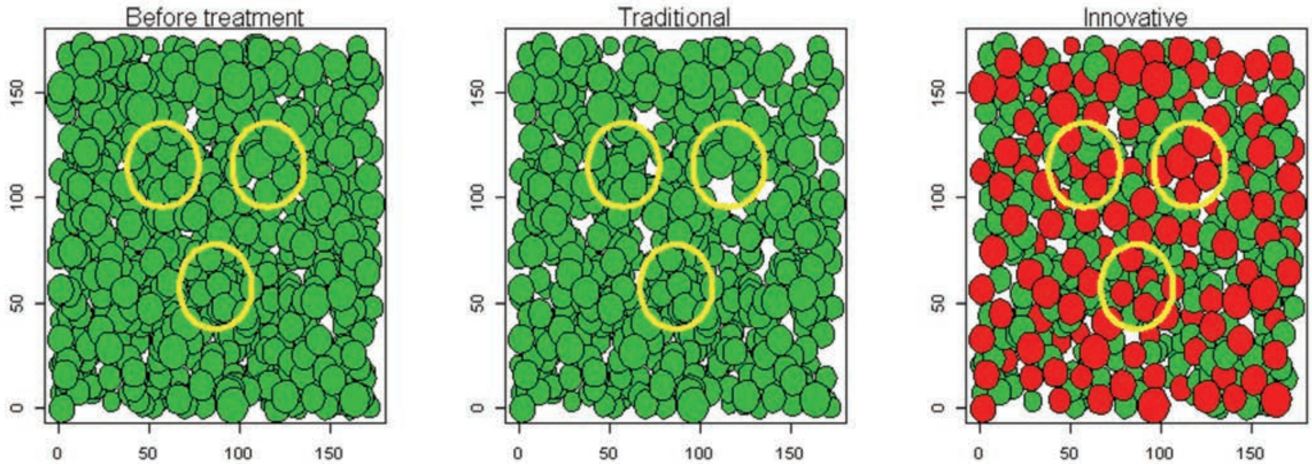

Figure 2. Simulation of plot 4 in the Cansiglio site before and after two alternative treatments. Size of circles is as large as crown diameter. Red trees are the selected crop trees in the innovative treatment. Yellow lines are the sampling areas.

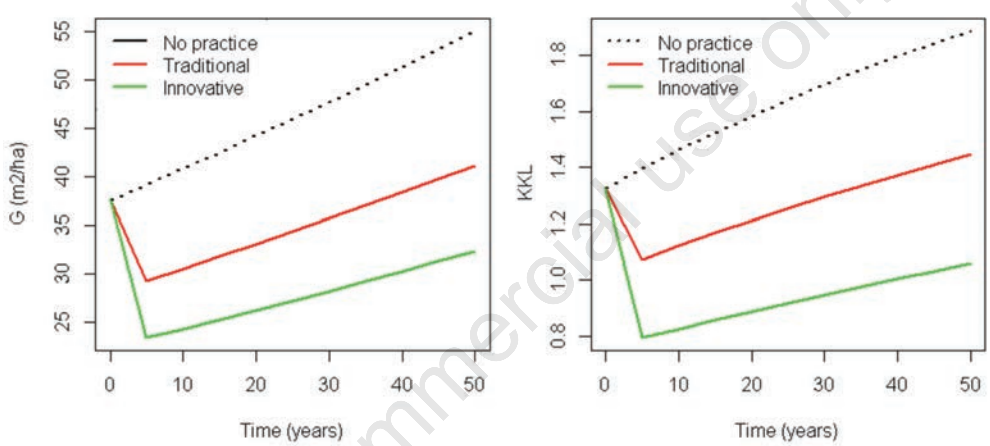

Figure 3. Simulated evolution of plot 4 in the Cansiglio site under three alternative treatments. Left: basal area. Right: the competition index KKL (see the text for details). Treatment is applied during the first time step (5 years).

under all treatments. First, the initial structure of plot 4 has been simulated as described above (Figure 2, left panel). Then, the selected treatment has been applied (Figure 2). Finally, forest evolution has been simulated with SILVA (the No practice treatments without natural mortality has been plotted for reference).

Some simulation results are presented in Figure 3. They are the evolution of basal area and of the average competition index during 50 years. KKL is a measure of the reduced light availability because of neighbouring competition (Pretzsch *et al*., 2002; Pretzsch, 2009). It usually ranges from zero for open grown trees to about 30 for highly suppressed trees. Values around unity are typical of co-dominance. From both panels the higher severity of the innovative treatment is clear. It is interesting to note that within the innovative treatment the competition index keeps low for a long period. In other words, this means that light availability is generally higher than in the other treatments. This could have important consequences for the forest habitat.

References

Ferretti M, Bussotti F, Fabbio G, Petriccione B, 2008. Ecological condition of selected forest ecosystem in Italy. Status and changes 1995 - 2005. Fourth report of the Task Force on Integrated and Combinated (I&C) evaluation of the CONECOFOR programme. Annali CRA - Centro di Ricerca per la Selvicoltura, Special Issue 34.

Pommerening A, Stoyan D, 2008. Reconstructing spatial tree point patterns from nearest neighbour summary statistics measured in small subwindows. Can. J. For. Res. 38:1110-1122.

Pretzsch H, 2009. Forest dynamics, growth and yield. From measurement to model. Springer-Verlag, Berlin.

Pretzsch H, Biber P, Dursky J, 2002. The single tree-based stand simulator SILVA: construction, application and evaluation. Forest Ecol. Manag. 162:3-21.

Seynave I, Gégout JC, Hervé JC, Dhote JF, 2008. Is the spatial distribution of European beech (Fagus sylvatica L.) limited by its potential height growth? J. Biogeogr. 35:1851-1862.

Innovative system for measuring soil respiration

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Introduction

Despite the widespread use of chambers for soil respiration (Rs) measurements, no standard is established with regard to the dimensions and type of chamber to perform these measurements.

The problem with non-steady state chambers is how to mark and prepare the measuring point for a campaign or continuous measurements. Very often different types of collars are used. Collars can be placed very carefully less than 1 cm deep in the soil with extreme care, so that no roots are cut. In this case, the collar is about 5 cm above ground. Over longer term, the soil inside the collar is exposed to different conditions: the collar can affect the wind speed above the ground and also the soil water content and temperature on the very first layer of the soil. Alternatively, the collars may be placed deeper into soil to cut the roots and prevent the measuring point to be overgrown with roots from aside. This changes the environment in the soil very much and affects the Rs flux (Kutsch *et al*., 2010). Measuring Rs with non-steady chamber technique has many sources of errors, such as using collars and preparing measuring point by removing live plants. The basic problem of measurements in natural ecosystems is heterogeneity which may be particularly well expressed in soil with the processes of Rs. For a better measurement of specific soil parameters it is not sufficient to perform multiple measurements at one point, so the parameters should rather be measured simultaneously at several points. These requirements make measurements more expensive, but they provide a better insight into the temporal and spatial dynamics of monitored parameters. Measurements made in closed dynamic chambers allow us to get the Rs value for shorter periods, e.g. hours. Some researchers made their own automatic systems for Rs measurements, tested them, and used them in their research. In all these systems, the chambers have to be installed on the measuring area and should allow the closing of chamber before measurement and its re-opening after it. They must be designed in a way that minimizes a long-term impact on the measuring point. The majority of researchers use a system, on which only the lid of the chamber is opened, and its perimeter stays at the measurement point (McGinn *et al*., 1998;Edwards and Riggs, 2003; Delle Vedove *et al*., 2007). To perform Rs measurement, all photosynthetically active biomass above ground has to be removed at the measuring point. Between 8% and 52% of total fixed CO_2 in assimilates during photosynthesis is respired by roots (Lambers *et al*., 1996;Atkin *et al*., 2000). Part of assimilates allocated in roots is used by organisms associated with plant roots in the rhizosphere. The release of exudates, secretions and root residues results in a much higher concentration of micro-organisms in the rhizosphere around the roots in comparison to the soil not directly influenced by the roots (Grayston *et al*., 1997). Therefore, removing live photosynthetic plants drastically changes the measuring point that is set for use for soil respiration measurements. If we cut the green part of the plant and leave the roots in the soil, we change the ratio of dead and live roots and therefore give more food to decompositors; consequently the Rs is overestimated. If we cut the green part of the plant and wait several months for roots to be decomposed, and measure Rs after that, there is a possibility that we would underestimate the Rs. If the measuring point would be large because of big chamber diameter, the roots from side will not overgrow the volume. Furthermore, when aboveground biomass is removed on a larger area, the microclimatic conditions above ground change, too. The measurement of the realistic Rs is not easy and we must take into account possible sources of errors due to the choice and management of measuring points. Apart from Rs measurements, it is necessary, especially in the more heterogeneous ecosystem, to perform measurements of soil moisture and soil temperature. Both parameters can, in some cases, explain 80% of the time variability cases of Rs (Tang *et al*., 2006). To carry out the measurements of soil moisture there are different implementations of sensors available, while for soil temperature measurements most commonly thermocouples are used. Measurements of soil processes in karst ecosystems are more important, since the influx of carbon from the karst ecosystem to the atmosphere could be significantly contributed to by geogenic CO_2 (suggested in studies by Emmerich, 2003; Kowalski *et al*., 2008; Inglima *et al*., 2009; Serrano-Ortiz *et al*., 2009, 2010). This makes CO_2 research in karst ecosystems even more complex and demanding. To eliminate or minimize described errors, a solution with a special chamber design must be found which will not seriously affect and change the environmental conditions around the measuring point and which would allow the measurement of Rs with minimum removal of living plants required. A system with the new chamber design must have the possibility to measure Rs with different chambers in case of soil heterogeneity.

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Key words: Soil respiration, CO_2 efflux, datalogger, multiplexing system, patent, infrared gas analyzer (IRGA).

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Chamber, datalogger and multiplexing system

Portable soil respiration systems such as LI-6400-09 do not allow a deeper insight into the temporal variability of Rs. For this, automated systems for measuring soil respiration are needed.

Drawback of existing systems is their very high price of approximately EUR 80.000,00. Another drawback may be the impact of mechanical parts of the automatic chamber into the measuring point. Collars that are inserted around the location and provide stability of the chamber can affect the measurement point and could have the effect on increasing temperature and/or soil moisture. In the Laboratory for Electronic Devices, which was established in 2009 at the Slovenian Forestry Institute, an automatic chamber with an improved mechanism for opening and closing was developed. The automatic soil respiration system includes automatic chamber(s) with electronics, central data storage electronic devices and infrared gas analyser LI-840.

The first step in the development of automatic soil respiration system was to construct the automatic chamber with electronics (Figure 1). As for all micrometeorological measurements also this instrument should not be too bulky. All known apparatus for capturing a gas flow (gas flux system chambers) have a big body with collar and the body has installed an electronic system with a closing and opening mechanism and they are usually too bulky for micrometeorological measurements. Such construction of the chamber have an impact on the measuring point and consequently to temperature and humidity of measuring point. Our aim was to move the part with electronic system and the opening and closing mechanism as far as possible from the measuring point to minimise the impact on it. Total height of the newly designed chamber is 100 cm and the lower part of the moving chamber is around 70 cm above the measuring point. To construct an apparatus for capturing a gas flow also on very heterogenic surfaces, an improvement was elaborated to minimize the chamber diameter. Chamber diameter is only 9 cm, which allows researchers to install it on stony and rocky surface.

For vertical moving of the chamber, a servo motor (GS-5515MG 15 kgcm^{-1}) was used. The motor was rebuilt to move either in clockwise or counter clockwise direction, continuously. Sensing the position of chamber is controlled by two magnetic switches, which are installed along the path of moving chamber. In addition, a test of the moving part of chamber was done. The electronic system in the chamber was programmed to move the chamber down and up continuously once per minute to test the servo motor performance. The test started on 25th of February 2011 and motor was found broken on 19th of April 2011. According to this, it could be concluded that the motor was reliably working for 51 days. That also means that motor made 73440 movements of chamber along the vertical axis. From the practical point of view the measurements of Rs once *per* hour could be performed continuously for more than 8 years. For the electronic system in the chamber a microcontroller ATmega8 (Atmel Corporation, San Jose, CA) was used. It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. Peripheral devices and components are connected to the microcontroller.

Each chamber can operate independently from other chambers and does not require a central data storage electronic device. The electronic system in the chamber can be broken down into four constituent parts: the start and stop control part (1), the measuring part (2), the chamber control part (3) and the data transmission part (4). The start and stop control part of the chamber electronic system is responsible for starting the measurement and for waking up the electronic system from power-down mode. For start-up of the system, an interrupt pin of microcontroller with pull up resistor was used. The trigger for starting the measurement is a signal going from 5V towards 0V. The signal can be sent by pushing the button or it could be generated in central data storage device or in the electronic system of the chamber. The measuring cycle lasts 3 minutes and after ending, the electronic system of the chamber sends a signal going from 5V towards 0V to trigger the next chamber if they are connected in series. After the measuring cycle, the chamber enters into power-down mode to lower the power consumption to 5 microamperes.

When the chamber electronic system wakes up, the measuring part of the circuit performs the measurements. The microcontroller of the chamber electronic system has a built-in 10-bit analog to digital converter (ADC converter). Therefore only a 100 mH inductor and a 100 nF capacitor must be applied to perform an accurate voltage reading. Due to this feature, there is no need to construct a peripheral analog to digital converter and fewer components are needed. The chamber electronic has two single ended channels for measuring voltages between 0 and 2500 mV. One channel is reserved for voltage reading from IRGA and another for any other sensor with output signal from 0 to 2500 mV can be used. Therefore only an accuracy test of voltage readings with chamber electronic was performed. For this purpose we used a laboratory voltage generator (Digimaster, DF1730SB5A) generating voltage in range from 0 to 2500mV. Voltage was measured with chamber electronic and simultaneously with a laboratory Digital Mutilmeter (M-3890D-USB, Metex Instruments, Seoul, Korea) connected to a PC for logging. Values were logged every second.

Linear regression between data from our system and Digital Mutilmeter was done (n=1548, R^2 = 0.998, slope=1.002, intercept=-0.188). From these results we can see that our system underestimates voltage by approximately 0.2 mV, which is for the equipment that can measure voltage from 0 to 2500 mV negligible. From simultaneous measurements accuracy of chamber electronic measurements was calculated and it was ±0.22% for testing range. For measuring temperature usually differential or single-ended voltage measurements and different types of sensors are used. Most frequently used are thermocouples or thermo-sensitive resistors with negative or positive temperature coefficients. There are also several types of integrated circuits, which can measure temperature and convert data to a digital signal. For chamber electronic factory calibrated temperature sensors DS18B20 (Maxim Integrated Products, Sunnyvale, CA) with ±0.5°C accuracy in the range between -10°C and +85°C were used. The sensors use 1-wire communication protocol (1-Wire is a registered trademark of Maxim Integrated Products, Inc). Despite manufacturer guarantee that sensors are calibrated, we performed a test with seven temperature sensors and classical meteorological thermometer (mercury thermometer). As a testing media, water with ice was used and

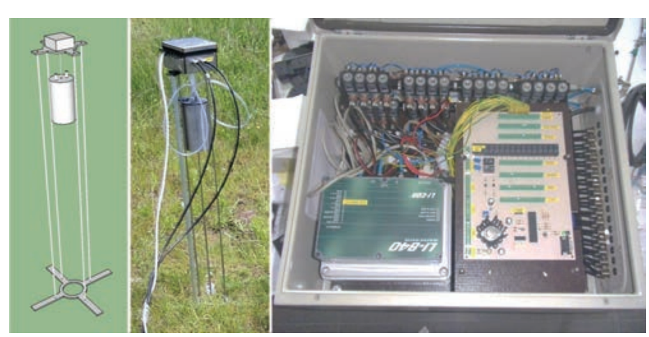

Figure 1. Automatic soil respiration system. Left, schematic view of automatic chamber design. Middle, automatic chamber installed on the field. Right, central data storage electronic with multiplexer containing 2x16 electromagnetic valves.

appropriate hand mixing was performed. Temperature ranged from 4 to 17°C and values were logged or manually read every 30 minutes. For each temperature sensor, linear regression with mercury thermometer measurements (n = 12) was made. From all parameters of linear regression (N = 7), we calculated means and standard deviations (R^2 = 0.997±0.001, slope = 0.975±0.023, intercept = 0.124±0.377). With these temperature sensors, the temperature is slightly underestimated compared with the mercury thermometer. From simultaneously measurements accuracy of chamber electronic measurements was calculated and it is ±1.1% for testing range. Each chamber has option to connect four temperature sensors and one frequency domain sensor EC-5 (Decagon Devices Inc., Pullman, WA) for measuring soil water content was used. For correct supply voltage of 2.5 V for the sensors, regulator LD1117 (SGS-THOMSON Microelectronics) was used. Sensor output ranges from 250 to 1000 mV at a 2.5 V supply voltage and supposed to be proportional to volumetric soil water content. IRGA is set up to output each second and ranged from 0 mV to 2500 mV. Single ended channel reserved for IRGA measuring voltage every second. After the measurements on single-ended channel and channels for temperature, the chamber control part of chamber electronic system starts to control the chamber measurement. The first step

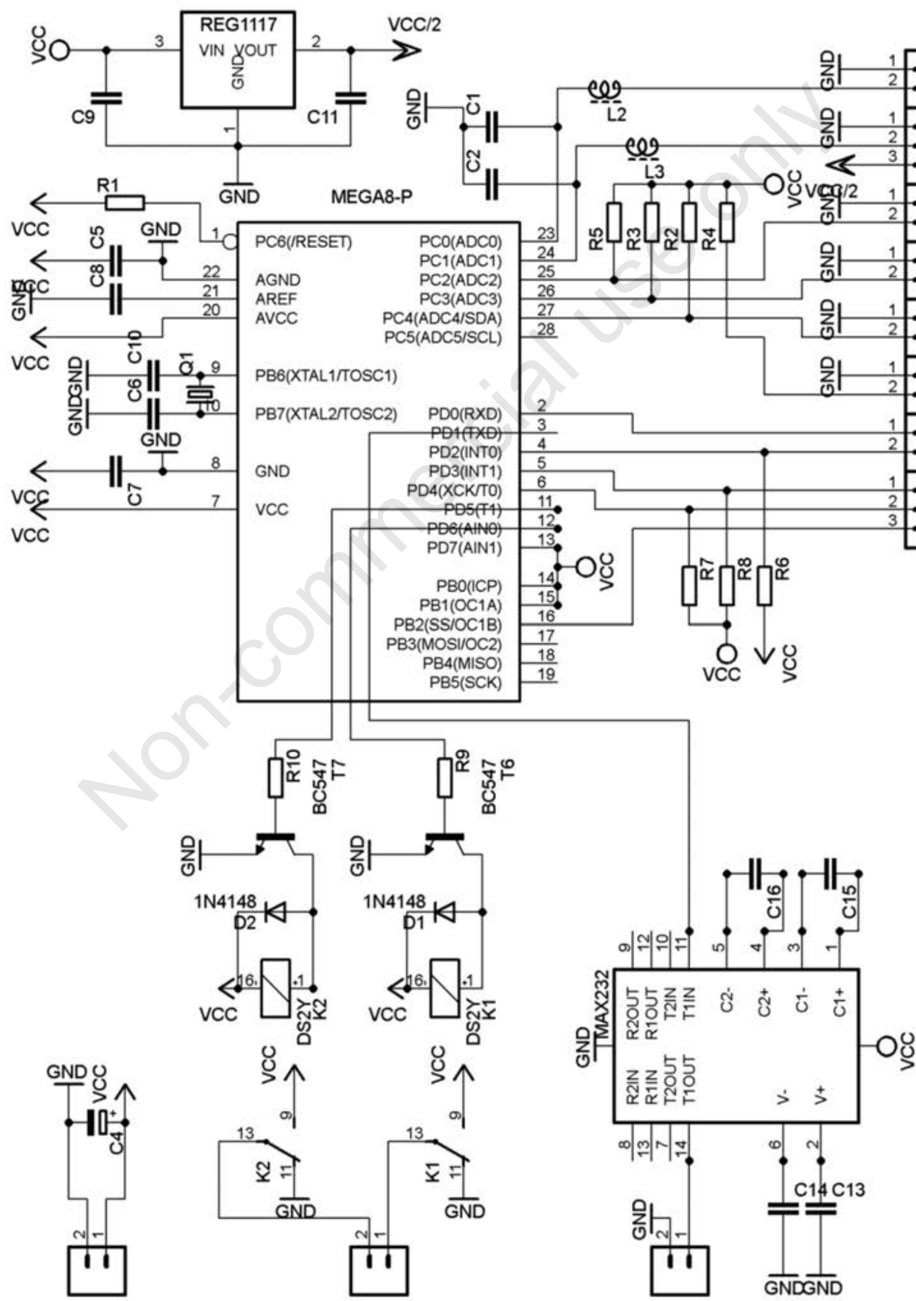

Figure 2. Electrical schematic of chamber electronic circuit board.

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is to trigger the multiplexer to switch the right valve if the chambers are connected in series. After this, it takes 30s to vent all the tubes between the IRGA and the chamber. The next step is to move the chamber down to the measuring point, wait for 160 s to finalize the measurement of CO_2 concentration, and move the chamber back up to open position. For moving the chamber up and down two magnetic switches and a motor, connected to two relays for clockwise and counter-clockwise movement are used.

The data from chamber electronic system to the central data storage or other media is transmitted via a serial interface (baud rate: 9600, Data bits: 8, Parity: none, Stop bits: 1, Handshaking: none). For this communication an integrated circuit MAX232 with capacitors was used. To establish serial communication with computer it would also be possible to use a serial to USB converter. Hyper Terminal (Windows) or any other free software for reading data from serial ports can be used. Every second chamber electronic system sends a line with comma separated data that includes chamber id, year, month, day, hour, minute, second, CO_2 concentration and five channels of temperature and voltage readings.

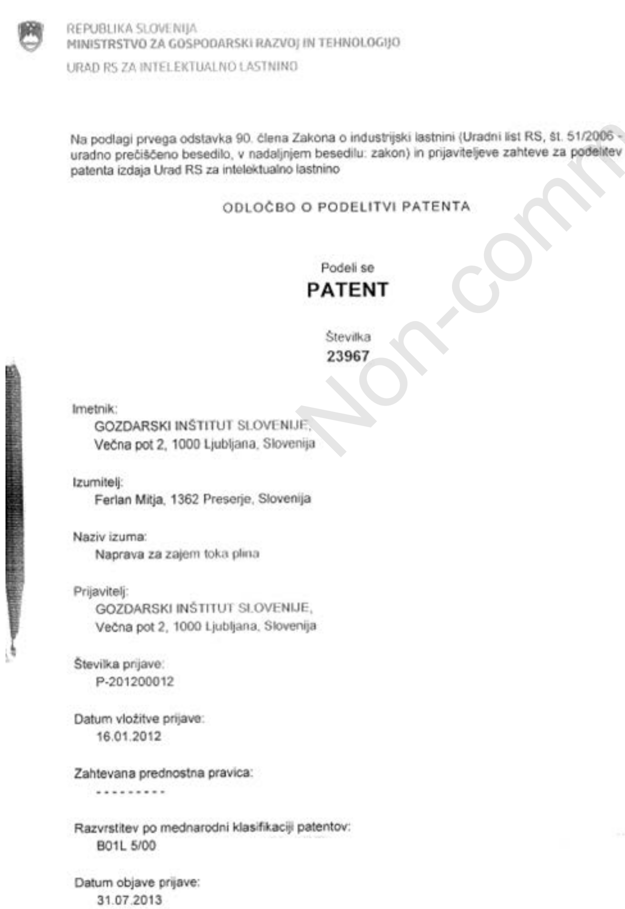
For the central data storage device a microcontroller ATmega32 (Atmel Corporation, San Jose, CA) was used. It is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. An interface for SD cards to store data and a multiplexer to switch data transmission relays and valves between chambers is connected to the microcontroller. The whole system was named Ukulele. The software for microcontrollers (chamber electronic and central data storage) was written in a BASIC-like language (BASCOM-AVR, MCS Electronics, Holland) for Microsoft Windows XP. The program was compiled in microcontroller assembly language and uploaded to the microcontroller using a programmer (PROGGY AVR, AX Elektronika, Slovenia) via AVR Studio 4 software (Atmel Corporation, San Jose, CA).

The electrical schematic of the circuit board was drawn (Figure 2) and the circuit board was made at the Laboratory for Electronic Devices at the Slovenian Forestry Institute. The schematic was transferred to the circuit board, which was drilled out on a small CNC machine in the same laboratory.

The developed automatic soil respiration system has closed dynamic chambers. CO_2 concentration in this type of chambers increases during the measurements and the change of CO_2 concentration during time is represented by the slope of the least squares regression line relating CO_2 concentration and time (), where *a* represents flux gradient d[CO_2]. Final Rs flux ($\mu molCO_2m^{-2}s^{-1}$) calculation is done using equation:

$$Rsoil = \frac{V}{A} \cdot \frac{d[CO_2]}{dt} \cdot \frac{P_0}{R{\cdot}(T_0+273.14)} \qquad \text{(eq. 1)}$$

where V and A represents volume and area of a chamber in m^2, respectively. P_0 and T_0 are air pressure and temperature at time zero. R is the universal gas constant (8.314 $Jmol^{-1}K^{-1}$).



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Na podlagi prvega odstavka 90. člena Zakona o industrijski lastnini (Uradni list RS, št. 51/2006 - uradno prečiščeno besedilo, v nadaljnjem besedilu: zakon) in prijaviteljeve zahteve za podelitev patenta izdaja Urad RS za intelektualno lastnino

ODLOČBO O PODELITVI PATENTA

Podeli se
PATENT

Številka
23967

Imetnik:
GOZDARSKI INŠTITUT SLOVENIJE,
Večna pot 2, 1000 Ljubljana, Slovenija

Izumitelj:
Ferlan Mitja, 1362 Preserje, Slovenija

Naziv izuma:
Naprava za zajem toka plina

Prijavitelj:
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Številka prijave:
P-201200012

Datum vložitve prijave:
16.01.2012

Zahtevana prednostna pravica:

Razvrstitev po mednarodni klasifikaciji patentov:
B01L 5/00

Datum objave prijave:
31.07.2013

Figure 3. Slovenian patent certificate.

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Acknowledgement of receipt

We hereby acknowledge receipt of your request for grant of a European patent as follows:

Submission number	1694887
Application number	EP12172542.8
File No. to be used for priority declarations	EP12172542
Date of receipt	19 June 2012
Your reference	P2120602
Applicant	Gozdarski institut Slovenije
Country	SI
Title	APPARATUS FOR CAPTURING A GAS FLOW

Figure 4. Application certificate for the European patent.

Patent

For the innovative measuring equipment for capturing a gas flow, Slovenian patent was accepted under number SI 23967 (Figure 3). We also applied for the European patent; the application is still in progress (Figure 4).

References

Atkin OK, Edwards EJ, Loveys BR, 2000. Response of root respiration to changes in temperature and its relevance to global warming. New Phytol. 147;141-154.

Delle Vedove G, Albert G, Zuliani M, Peressotti A, 2007. Automated monitoring of soil respiration: an improved automatic chamber system. Ital. J. Agron. 377-382.

Edwards NT, Riggs JS, 2003. Automated monitoring of soil respiration: a moving chamber design. Soil Sci. Soc. Am. J. 67: 1266-1271.

Emmerich WE, 2003. Carbon dioxide fluxes in a semiarid environment with high carbonate soils. Agr. Forest Meteorol. 116:91-102.

Grayston SJ, Vaughan D, Jones D, 1997. Rhizosphere carbon flow in trees, in comparison with annual plants: the importance of root exudation and its impact on microbial activity and nutrient availability. Appl. Soil Ecol. 5:29-56.

Inglima I, Alberti G, Bertolini T, Vaccari FP, Gioli B, Miglietta F, Cotrufo MF, Peressotti A, 2009. Precipitation pulses enhance respiration of Mediterranean ecosystems: the balance between organic and inorganic components of increased soil CO2 efflux. Global Change Biol. 15:1289-1301.

Kowalski AS, Serrano-Ortiz P, Janssens IA, Sanchez-Moraic S, Cuezva S, Domingo F, Were A, Alados-Arboledas L, 2008. Can flux tower research neglect geochemical CO2 exchange? Agr. Forest Meteorol. 148:1045-1054.

Kutsch WL, Bahn M, Heinemeyer A, 2010. Soil carbon dynamics. Cambridge University Press, New York.

Lambers H, Stulen I, vanderWerf A, 1996. Carbon use in root respiration as affected by elevated atmospheric O-2. Plant Soil 187:251-263.

McGinn SM, Akinremi OO, McLean HDJ, Ellert B, 1998. An automated chamber system for measuring soil respiration. Can. J. Soil Sci. 78:573-579.

Serrano-Ortiz P, Domingo F, Cazorla A, Were A, Cuezva S, Villagarcia L, Alados-Arboledas L, Kowalski AS, 2009. Interannual CO2 exchange of a sparse Mediterranean shrubland on a carbonaceous substrate. J. Geophys. Res. 114: G04015.

Serrano-Ortiz P, Roland M, Sanchez-Moral S, Janssens IA, Domingo F, Godderis Y, Kowalski AS, 2010. Hidden, abiotic CO2 flows and gaseous reservoirs in the terrestrial carbon cycle: review and perspectives. Agr. Forest Meteorol. 150:321-329.

Tang XL, Zhou GY, Liu SG, Zhang DQ, Liu SZ, Li J, Zhou CY, 2006. Dependence of soil respiration on soil temperature and soil moisture in successional forests in southern China. J. Integr. Plant Biol. 48:654-663.

Forest operations for implementing silvicultural treatments for multiple purposes

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Introduction

In silvicultural treatments, the methodologies of felling, processing and extraction have to be planned on a larger scale; they cannot be sporadic events, not connected to the social, environmental and economic contexts. The forest operations have to be planned during implementation and execution of the working phases.

Three harvesting methods are commonly used in forest operation: cut-to-length systems (CTL), tree length system (TLS) and whole-tree harvesting (WTH). In CTL, trees are felled and processed at the stump before extracted to landing (Maesano *et al.*, 2013; Spinelli *et al.*, 2010a). In TLS, trees are felled, de-limbed and topped at the stump before extracted to landing (Rushton *et al.*, 2003). In WTH, trees are felled and removed to a landing area where they are processed, thereby reducing potential fire severity more than other methods, which left slash within the stands (Marchi *et al.*, 2014; Picchio *et al.*, 2012a, 2012c). The main forest operations are felling and processing, bunching and extraction. Felling and processing can be efficiently carried out by chainsaw. The introduction of harvester and feller increased productivity and reduced costs of forest operation, especially in comparison with motor-manual (chainsaw) felling and processing on wide forest surfaces to cut (Wang *et al.*, 1998). The ground slope and roughness are the main limiting conditions for the introduction of these modern machineries.

Wood bunching and extraction could be performed mainly by skidding, forwarding or cable yarding, with different performances in terms of productivity. Extraction by skidder with winch is the most affordable in thinnings or similar silvicultural treatments due to the low effective costs and its flexibility. Traditionally, the cable of the winch is used in bunching logs or trees to skid trail (winching). In such way, only the limited part of the topsoil layer is damaged by skidder compression, while the rest remains unharmed (Ampoorter *et al.*, 2012). Today, skidder with grapple could be used on terrains with moderate slopes. To maximize the performances of skidding systems, a network of strategically planned forest trails is necessary to ensure a good productivity and minimize the impact on forest soil (Picchio *et al.*, 2011, 2012a, 2012b). The extraction by forwarder or by tractor and trailer is usually not recommended in the first thinning and in the selective thinning due to the considerable size and weight of these machines. In cable yarding, trees are removed by skyline cable system and can be processed at the stump or at the landing. Cable yarding is generally reserved for steep slopes, where the use of ground-based forest equipment is restricted.

The impacts on the environment, especially on soil and residual trees, is an important aspect to be considered in forest operation planning. The area affected by soil disturbance (compaction, rutting, soil mixing and displacement) may range between 10 and 70% of the total logged stand and the impact on the ecosystem can be substantial (Grigal, 2000; Frey *et al.*, 2009; Picchio *et al.*, 2012b). The damaged trees due to forest operations may range between 4-21% of the total post harvest stand (Picchio *et al.*, 2011; Spinelli *et al.*, 2010b; Vasiliauskas, 2001). Other impacts, directly linked to the logging operation should be assessed, because they contribute to the ecological footprint of a product or a production cycle. For example the energy input may range between 56 to 900 MJ m^{-3} (Picchio *et al.*, 2009; Balimunsi *et al.*, 2012; Maesano *et al.*, 2013; Vusic *et al.*, 2013), or CO_2 emissions may range between 1.3 to 7.2 kg m^{-3} (Valente *et al.*, 2011; Vusic *et al.*, 2013).

Planning, design and execution of forest operation in silvicultural treatments have to take into consideration also the potential impacts.

In four ManFor sites (Pian Cansiglio, Tarvisio, Chiarano e Mongiana) forest treatments were applied and studied. The planning of logging methodologies were not done on a large spatial and temporal scale. The single forest operation was planned only during implementation and execution of the work phases. To assess the impact on the environment on the basis of recent scientific publications (Parisi *et al.*, 2005; Marchi *et al.*, 2014; Visuc *et al.*, 2013), were analysed soil, top soil and air modification due to forest operations.

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Key words: Logging, GHG emissions, soil impact, QBS-ar, abovegraound damage.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Materials and methods

To assess the impact on the environment for the silvicultural treatments applied on some ManFor sites, pollutant emissions, some soil characteristics and post harvest stand situation were analysed.

The study of working time and productivities are the preliminary approach to the pollutant emissions evaluation. Working times were recorded for every single phase to evaluate efficiency of workers, by a chronometric table Minerva equipped with three centesimal chronometers. To calculate outputs on different plots, effective time and delays in the work routine up to 15 min (UT, unavoidable time and AT, avoidable time) were taken into consideration (Picchio *et al.*, 2009). Based on working times for volume, the productivity per worker for the different operations was calculated as an average gross productivity (PHS_{15} productivity) and average net productivity (PHS_0 productivity) (Savelli *et al.*, 2010).

Pollutant emissions due to the extraction operations at both sites were determined as described by Vusic *et al.* (2013). Emissions generated from the fuel were calculated as the sum of emissions produced by fuel combustion (Efc) and emissions produced during the fuel production, transport, and distribution (Efp). The emissions related to lubricant consumption were calculated as the sum of the emissions produced by both the production processes (Eop) and the reprocessing of used oils for the purposes of combustion (Eor). For the logging wound analysis (Picchio *et al.*, 2012a), measurements were performed on four plots per method, adjacent to the forest road and projected 90 m into the forest, (the average distance). Each plot was 40 m wide, for a unitary surface of 3600 m^2. Aboveground damage was determined by visual inspection on all standing trees. Once the wound was detected, the following data were recorded: tree diameter at breast height (DBH); hierarchical and geographical positions of the tree within the stand; location, size, and depth of the wound. These parameters were translated into numerical classes. Wound size and depth classes were multiplied to obtain a synthetic damage severity index. Wounds with an index larger than 6 were considered severe, and capable of affecting tree growth, quality and survival (Picchio *et al.*, 2011, 2012a; Tavankar *et al.*, 2015).

Impact on forest soil was studied as described by Marchi *et al.* (2014). For the study three transects for each harvested forest have been identified. Each transect was rectangular (width 2 m, length 50 m) and located parallel to the contour lines. In these transects we have measured and recorded the portions of damaged and undamaged soils by logging operations.

The impact on soil was assessed on twenty (20) randomly selected sampling plots (SP). On every plot, we measured bulk density, pH, organic matter content, penetration resistance, and shear strength. Each SP consisted of a circular area 12 m in diameter, where two different points (PO) were selected based on visual assessment (*e.g.* presence or absence of bent understory, crushed litter, ruts or soil mixing) to represent disturbed and undisturbed soil conditions, respectively. As a control, for the effect due to the silvicultural treatment, it was considered a forest area neighbouring, managed, but not impacted for more than 10 years, in this area 20 randomly selected SP have been identified. One measurement each PO for bulk density, pH, organic matter, and three measurements for penetration resistance and shear strength were performed. For the microarthropods extraction and QBS-ar index application, three soil cores 100 cm^2 and 10 cm deep were sampled in each soil typology. Microarthropods were extracted using a Berlese-Tüllgren funnel; the specimens were collected in a preserving solution and identified to different taxonomic levels (class for Myriapoda and order for Insecta, Chelicerata and Crustacea) using a stereo microscope. Soil quality was estimated with the QBS-ar index (Parisi *et al.*, 2005; Blasi *et al.*, 2013; Venanzi *et al.*, 2016).

Statistical analyses were carried out with the Statistica 7.1 (2007) Software. As a first step, data distribution was plotted and checked for normality (Lilliefors) and homogeneity of variance (Levene test). All the data points then underwent to t-test, ANOVA or MANOVA test, to test the effect of different treatments or were processed using the non parametric ANOVA the Kruskal-Wallis test.

Results

Tarvisio site

On the study area harvesting has been performed with high level of mechanization on the basis of Hippoliti classification (1997). The felling and processing operations were done by harvester, while bunching, extraction and transport operations by forwarder. Three silvicultural treatments were applied, one traditional and two innovative, working productivity analysis are shown in Table 1.

The pollutant emissions (Table 2) caused by fuel production process (Efp) were negligible in comparison with those caused by fuel combustion (Efc), with the exception of HC. The combustion process was responsible, on average, for 93.8% of CO_2, 97.8% of CO, 32.2% of HC, 97% of NOx, and 95.1% of PM emissions.

The smaller pollutant emission values were calculated for treatment 'Innovative 1', which allowed a reduction in GHG emissions than other two treatments, ranging from 3 to 5%. From the analysis of the damage to the trees released after the treatment we can observe that the traditional treatment had highest amount of damages (6%), followed by the 'innovative 1' (2%); no damage was found in the treatment 'innovative 2'.

Table 1. Logging operation productivities for the three applied treatments.

Operation	Parameter	Traditional treatment	Innovative treatment 1	Innovative treatment 2
Felling and processing	PHS_{15} (m^3/h)	20.6	21.5	19.0
	PHS_0 (m^3/h)	21.1	22.1	19.2
Bunching-extraction	PHS_{15} (m^3/h)	10.0	10.0	10.0
	PHS_0 (m^3/h)	10.9	10.5	10.9

Table 2. Logging operation GHG emissions, for the three applied treatments.

Treatment	CO_2 (g m^{-3})	CO (g m^{-3})	HC (g m^{-3})	NO_x (g m^{-3})	PM (g m^{-3})	CO_{2eq} (g m^{-3})
Traditional	13983	141	17	235	24	98100
Innovative 1	13464	135	15	228	21	94800
Innovative 2	13992	143	19	239	26	99100

On average, damaged trees by logging operations were classified as dominant in both traditional and innovative 1 treatment. Regarding the average location of the damage, two main situations have been observed: in case of the traditional treatment, the wound position on the ground level was on the collar, while in the treatment 'innovative 1', wound position on the ground level were on roots. Assessing the size of the wounds on trees, the middle classes appeared similar in both treatments and amounted to an average value found ranging between 50 - 200 cm^2. Depth of the wound on the released trees in both treatments (traditional and innovative 1) were profound, both affecting tree fibres.

Logging operations affected over 17±4% of the stand surface for the three treatments, with highest rate found for the 'innovative 1' (21%) and a minimal rate for the traditional (14%) treatment.

Soil bulk density, organic matter content and QBS-ar index were significantly affected by extractions in all three treatments (Figure 1). Resistance to penetration and shear strength, due to soil typology, were not possible to be sampled due to specific soil typology.

Cansiglio site

On the study area harvesting has been performed by an average level of mechanization (Hippoliti, 1997). The felling and processing operations were done by chainsaw, while bunching and extraction operations were done by wheeled tractor equipped by forest winch. The silvicultural treatments applied were two: traditional and innovative 1, working productivity analyses are shown in Table 3.

The pollutant emissions (Table 4) caused by the fuel production process (Efp) were negligible in comparison to those caused by fuel combustion (Efc), with the exception of HC. The combustion process was responsible, on average, for 93.8% of CO_2, 99.4% of CO, 33.6% of HC, 97.9% of NOx, and 100% of PM emissions.

The lower pollutant emission values were calculated for treatment 'Innovative 1', which allowed a reduction in GHG emissions of 6% compared to traditional one.

Traditional treatment had highest negative effect (67%), followed by the 'innovative 1' (64%).

On average, damaged trees by logging operations were dominant in the traditional treatment, and codominant in the 'Innovative 1' treatment. For both treatments wound position on the ground level were on the collar. Size of the wounds on trees in the middle classes was similar for both treatments, on average value between 10 to 50 cm^2. Depth of the wounds in both treatments (traditional and innovative 1) was light, affecting only the bark of the trees.

Logging operations affected over 39±4% of the stand surface in both treatments, with 42% in the 'innovative 1' and 35% in the traditional approach.

Soil bulk density, organic matter content, pH, QBS-ar index, penetrometric and shear resistance (Figure 2) were significantly affected by extraction in both treatments.

Mongiana site

On the study area harvesting has been performed by an average level of mechanization (Hippoliti, 1997). The felling and processing operations were done by chainsaw, while bunching and extraction operations were done by wheeled tractor. Two silvicultural treatments were applied, working productivity analysis are shown in Table 5.

Table 3. Logging operation productivities for the applied treatments.

Operation	Parameter	Traditional treatment	Innovative treatment 1
Felling and processing	PHS_{15} (m^3/h)	13.6	14.5
	PHS_0 (m^3/h)	17.4	18.7
Bunching-extraction	PHS_{15} (m^3/h)	3.1	4.8
	PHS_0 (m^3/h)	3.4	5.6

Table 4. Logging operation GHG emissions, for the applied treatments.

Treatment	CO_2 (g m^{-3})	CO (g m^{-3})	HC (g m^{-3})	NO_x (g m^{-3})	PM (g m^{-3})	CO_{2eq} (g m^{-3})
Traditional	8897	101	10	151	21	54000
Innovative 1	8545	95	10	142	19	51000

Table 5. Logging operation productivities.

Operation	Parameter	Traditional treatment	Innovative treatment 1
Felling and processing	PHS_{15} (m^3/h)	7.4	7.1
	PHS_0 (m^3/h)	8.6	8.2
Bunching-extraction	PHS_{15} (m^3/h)	3.7	5.4
	PHS_0 (m^3/h)	4.0	6.1

Table 6. Logging operation GHG emissions, for the two treatments applied.

Treatment	CO_2 (g m^{-3})	CO (g m^{-3})	HC (g m^{-3})	NO_x (g m^{-3})	PM (g m^{-3})	CO_{2eq} (g m^{-3})
Traditional	6857.2	150.8	15.1	225.7	31.0	75000
Innovative 1	7108.6	160.7	16.5	238.5	32.0	78000

The pollutant emissions (Table 6) from the fuel production (Efp) were negligible in comparison with those due to fuel combustion (Efc), with the exception of HC. The combustion process was responsible, on average, for 93.9% of CO_2, 99.3% of CO, 33.5% of HC, 97.7% of NOx, and 99.9% of PM emissions. The lower pollutant emission values were calculated for traditional treatment. This treatment has allowed a reduction in GHG emissions than the other treatment (4%).

Again, traditional treatment caused more damages (38%), than ‘innovative 1’ (20%). In traditional treatment average damaged trees were co-dominant and dominant in the ‘Innovative 1’ treatment. In both treatments wound position on the ground level was on the collar, while the size of the wounds on trees were of middle class, similar for both treatments and amounted in average between 10 to 50 cm^2. In both treatments damages found were light, affecting only the bark.

Logging operations affected over 34±11% of the stand surface, mostly the ‘innovative 1’ (45%) and least the traditional way (23%). Soil bulk density, organic matter content, pH, QBS-ar index, penetrometric and shear resistance (Figure 3) were significantly affected by extraction in both treatments.

Chiarano site

On the study area harvesting has been performed by a low level of mechanization (Hippoliti, 1997). The felling and processing operations were done by chainsaw, while bunching and extraction operations were done by animals (mules). Three silvicultural treatments were applied, one traditional and two innovative ones, working productivity analysis are shown in Table 7.

The pollutant emissions (Table 8) from the fuel production process (Efp) were negligible in comparison with those due to fuel combustion (Efc), with the exception of HC. The combustion process was responsible, on average, for 62% of CO_2, 99% of CO, 7% of HC, 96% of NOx, and 99.9% of PM emissions.

The lower pollutant emission values were in ‘Innovative 1’ treatment. This treatment has allowed a reduction in GHG emissions

Table 7. Logging operation productivities for applied treatments.

Operation	Parameter	Traditional treatment	Innovative treatment 1	Innovative treatment 2
Felling and processing	PHS_{15} (m^3/h)	2.2	2.3	2.3
	PHS_0 (m^3/h)	3.6	3.7	3.7
Bunching-extraction	PHS_{15} (m^3/h)	1.2	1.2	1.2
	PHS_0 (m^3/h)	1.3	1.5	1.5

Table 8. Logging operation GHG emissions, for the applied treatments.

Treatment	CO_2 (g m^{-3})	CO (g m^{-3})	HC (g m^{-3})	NO_x (g m^{-3})	PM (g m^{-3})	CO_{2eq} (g m^{-3})
Traditional	3172.3	18.3	9.5	33.3	4.2	13500
Innovative 1	3113.1	18.3	8.9	32.7	4.1	12900
Innovative 2	3122.2	18.4	8.9	32.8	4.1	13100

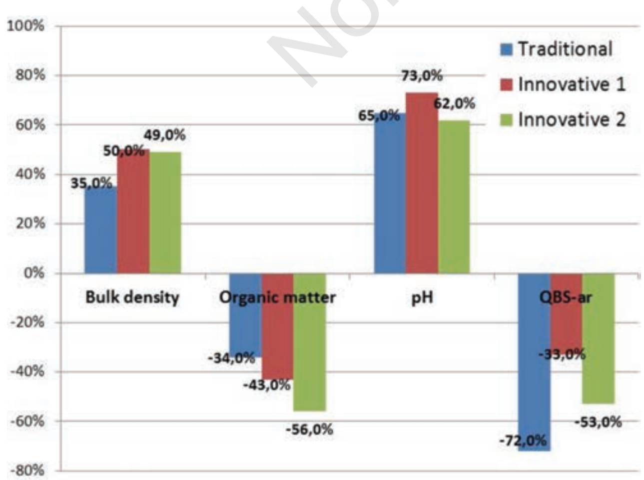

Figure 1. Tarvisio. Studied main soil characteristics, their percentage changes compared to the undisturbed soil, for the three treatments applied.

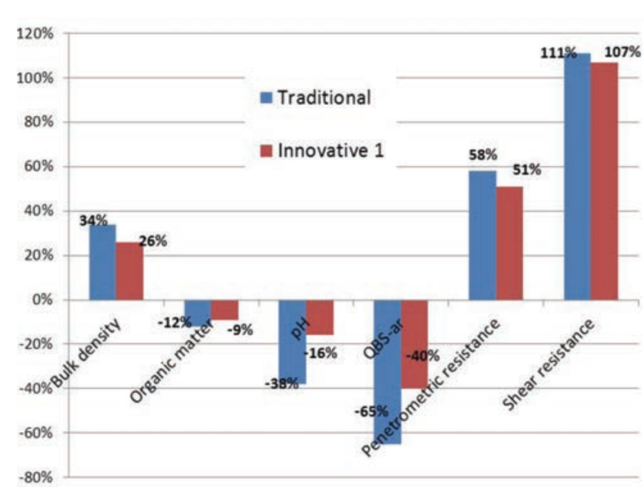

Figure 2. Cansiglio. Main values of soil studied characteristics, presented as the percentage changes compared to the undisturbed soil.

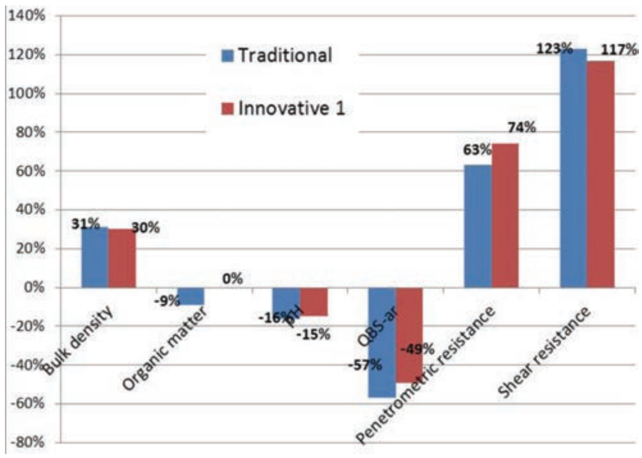

Figure 3. Mongiana. Main studied soil characteristics studied and percentage changes compared to the undisturbed soil.

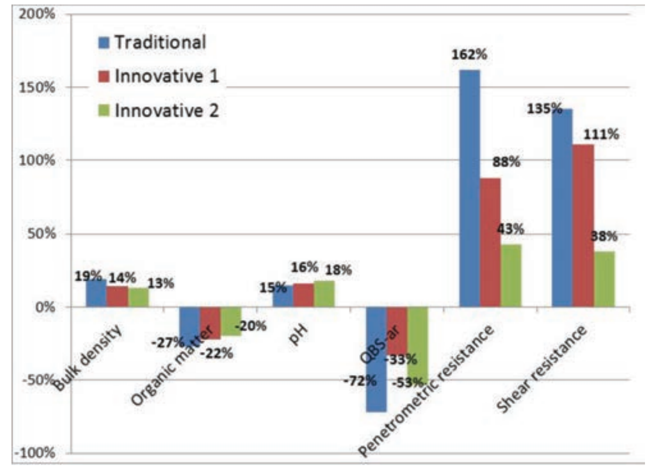

Figure 4. Chiarano. Main studied soil characteristics studied, percentage changes compared to the undisturbed soil.

Table 9. General qualitative assessment of the treatments applied on the four ManFor sites.

Treatment	Tarvisio			Cansiglio		Mongiana		Chiarano		
	T	I1	I2	T	I1	T	I1	T	I1	I2
Productivity	N	S	U	N	S	U	N	U	N	N
GHG emissions	U	N	U	N	S	U	U	N	S	N
Trees wound	U	U	S	U	U	U	S	U	U	U
% of disturbed soil	S	N	S	N	U	N	U	S	N	U
Bulk density variation	N	U	U	N	S	N	N	N	S	S
Organic matter variation	S	N	U	N	S	N	S	N	N	N
pH variation	N	U	S	U	N	N	N	N	N	N
QBS-ar variation	U	S	N	U	N	U	N	U	S	N
Penetrometric resistance	-	-	-	N	N	N	N	U	U	N
Shear resistance	-	-	-	U	U	U	U	U	U	N

S, suitable; U, unsuitable; N, neutral.

than the other treatment ranging between 1-2%.

Highest negative damage impact was evidenced in 'Innovative 2' treatment (56%), followed by the 'Innovative 1' (50%) and then the traditional one (44%).

Damaged trees by logging operations were classified as codominant in the traditional and 'Innovative 2' treatments, and dominant in the 'Innovative 1' treatment. In traditional and 'Innovative 2' treatments, the wound position on the ground was on the collar, while in case of the 'innovative 1' treatment it was on roots. For traditional and 'Innovative 1' treatments wounds were in size of middle class between 50 to 200 cm^2 and for the 'Innovative 2' treatment amounted between 10 to 50 cm^2. The depth of the wounds in all treatments was middle, affecting the phloem of the trees. Logging operations affected over 18±4% of the stand surface in all three treatments, mostly in the 'Innovative 2' (22%) and least in the traditional (14%) treatment.

Soil bulk density, organic matter content, pH, QBS-ar index, penetrometric and shear resistance (Figure 4) were significantly affected by extraction in all the treatments.

Conclusions

To comprehensively assess the potential and the sustainability of different systems, equal weight was given to the studied variables and presented in a table. For every variable were reported in Table 9 the main results, expressed as suitable, unsuitable and neutral referred to a sustainable system of reduced impact logging. From the data analysis it is possible to note as the different silvicultural treatments applied had impacted differently on the 4 sites studied, although at least one of the innovative treatments had provided the best result. Considering the different mechanization levels employed, on average, the less impactful results are by average and low levels of mechanization. However the high mechanization level employed in Tarvisio site has not led to significant differences. Overall it is evident that the combination of planning and technical management of interventions leading to fit the reduced impact logging purpose.

References

Ampoorter E, Schrijver A, Nevel L, Hermy M, Verheyen K, 2012. Impact of mechanized harvesting on compaction of sandy and clayey forest soils: results of a meta-analysis. Ann. Forest Sci. 69:533-542.

Balimunsi H, Grigolato S, Picchio R, Nyombi K, Cavalli R, 2012. Productivity and energy balance of motor manual harvesting in Uganda; For. Stud. China 14:276-282.

Blasi S, Menta C, Balducci L, Delia Conti F, Petrini E, Piovesan G, 2013. Soil microarthropod communities from Mediterranean forest ecosystems in Central Italy under different disturbances. Environ. Monit. Assess. 185:1637-1655.

Hippoliti G, 1997. Appunti di meccanizzazione forestale. Studio Editoriale Fiorentino, Firenze 318 pp.

Maesano M, Picchio R, Lo Monaco A, Neri F, Lasserre B, Marchetti M, 2013. Productivity and energy consumption in logging operation in a Cameroonian tropical forest. Ecol. Eng. 57:149-153.

Marchi E, Picchio R, Spinelli R, Verani S, Venanzi R, Certini G, 2014. Environmental impact assessment of different logging methods in pine forests thinning. Ecol. Eng. 70:429-436.

Parisi V, Cristina M, Gardi C, Jacomini C, Mozzanica E, 2005. Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy. Agric. Ecosyst. Environ. 105:323-333.

Picchio R, Maesano M, Savelli S, Marchi E, 2009. Productivity and Energy balance in conversion of a Quercus cerris L. coppice stand into high forest in Central Italy. Croat. J. For. Eng. 30:15-26.

Picchio R, Neri F, Maesano M, Savelli S, Sirna A, Blasi S, Baldini S, Marchi E, 2011. Growth effects of thinning damage in a Corsican pine (Pinus Laricio Poiret) stand in Central Italy. Forest Ecol. Manage 262:237-243.

Picchio R, Magagnotti N. Sirna A, Spinelli R, 2012a. Improved winching technique to reduce logging damage. Ecol. Eng. 47:83-86.

Picchio R, Neri F, Petrini E, Verani S, Marchi E, Certini G., 2012b. Machinery-induced soil compaction in thinning two pine stands in central Italy. Forest Ecol. Manag. 285:38-43.

Picchio R, Sirna A, Sperandio G, Spina R, Verani S, 2012c. Mechanized harvesting of eucalypt coppice for biomass production using high mechanization level. Croat. J. Forest Eng. 33:15-24.

Rushton T, Brown S, McGrath T, 2003. Impact of tree length versus short - wood harvesting systems on natural regeneration. Forest Research Report 70, Department of Natural Resources, Halifax, Nova Scotia.

Savelli S, Cavalli R, Baldini S, Picchio R, 2010. Small scale mechanization of thinning in artificial coniferous plantation. Croat. J. Forest Eng. 1:11-21.

Spinelli R, Magagnotti N, Picchi G, 2010a. Deploying mechanized cut-to-length tecnology in Italy: fleet size, annual usage and costs. Int. J. Forest Eng. 21:23-31.

Spinelli R, Magagnotti N, Nati C, 2010b. Benchmarking the impact of traditional small-scale logging systems used in Mediterranean forestry. Forest Ecol. Manag. 260:1997-2001.

Tavankar F, Bonyad A, Marchi E, Venanz, R, Picchio R, 2015. Effect of logging wounds on diameter growth of beech (Fagus orientalis Lipsky) trees following selection cutting in Caspian forests of Iran. New Zeal. J. For Sci. 45:19.

Valente C, Spinelli R, Hillring BG, 2011. LCA of environmental and socio-economic impacts related to wood energy production in the alpine conditions: Valle di Fiemme (Italy). J. Clean. Prod. 19:1931-1938.

Vasiliauskas R, 2001. Damage to trees due to forestry operation and its pathological significance in temperate forests: a literature review. Forestry 74:319-336.

Venanzi R, Picchio R, Piovesan G, 2016. Silvicultural and logging impact on soil characteristics in Chestnut(Castanea sativa Mill.) Mediterranean coppice. Ecol. Eng. 96: 82-89.

Vusic D, Šušnjar M, Marchi E, Spina R, Zečić T, Picchio R, 2013. Skidding operations in thinning and shelterwood cut of mixed stands - Work productivity, energy inputs and emissions. Ecol. Eng. 61:216-223.

Wang J, Greene WD, Stokes BJ, 1998. Stand, harvest, and equipment interactions in simulated harvesting prescriptions. Forest Prod. Soc. 48:81-85.

Informing people about forest management and field operations

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Forests are an important part of European environment and economy. When well managed, they provide a number of ecosystem services, e.g. clean air and water, wildlife habitats, beautiful scenery, places for recreation and over 5000 wood or non-wood products (MCPFE, 2015). Wood products also play an important role in terms of greenhouse effect mitigation since they store carbon (Penman *et al*., 2003). Wood requires less energy to be extracted, processed and transported than other materials (UNECE) and represents a source of clean energy.

Forestry today is considered more and more marginal, as the focus of modern society in many cases aims towards short-term benefits. The pressures of demands are increasing and without proper tools the basic principles are neglected. Demonstrating the importance and raising general awareness may be achieved only by didactic examples from the praxis.

LIFE+ projects give much importance to the demonstration and dissemination of the achieved results, including publications of manuals, CDs, scientific and popular articles and other editorial products, as we will see later. In the ManFor C.BD project, the first decisive step in communication was to 'talk' with local communities and to provide the right messages to residents and visitors of the test areas - an operation (always needed when it comes to forestry issues), that made smooth flow of the project.

Harvesting operations in managed forests are often perceived by general public as damage to the forest or even as destruction, especially if new methodologies and criteria are introduced. Therefore it is important to communicate to different target groups to dispel the skepticism and communicate promptly through institutional meetings, workshops, meetings with the press, popular articles on newspapers and magazines, with key concepts:

- thinnings are a phase of sustainable forest management, essential for the health and stability of the forests;
- harvesting is one of the essential phases of the forest management cycle, that maintains ecological and economical stability;
- proposed approaches aim to harmonize socio - environmental functions with the productive use of forest resources to benefit local communities. Public would understand and adopt these messages and become a participant, rather than opponent of the process.

The communicating parties should accept and focus on simplicity, the most important principle of communication: a simple, clear and well-explained approach provides the message to everyone, including children.

In case of thinnings, basic concepts have often been misunderstood by non-professionals, and sometimes even by experts from other branches of natural sciences. To maintain clarity we should avoid technical terms and describe them as 'periodical interventions of cutting, that foresters use to adjust the wood density and preserve structure stabile'. Actions are planned by people who are able to interpret the various dynamics of the forests and are provided by experienced personnel.

The communication within the ManFor project also aimed to clarify mistaken assumption, that reintroduction of historically managed forests to natural evolution processes may not involve some short term (unpleasant) consequences, that provide balance and benefits both to the forest stability and society over longer time periods. If such measures would not be taken, short-term benefits would outbalance the long-term forest stability.

We must provide information for the people and whole communities that managed forests require human interventions, apart from old growth reserves, that provide continuous evolution cycle without human interactions. Indeed, if we enjoy today such healthy woods, it is because of the secular, sustainable management approach adopted in the past. Interruption and abandoning such approach would in most cases consequently lead to regression processes, before evident, gradual rehabilitation. Delaying of planned interventions and measures could also inhibit regeneration and close to nature forest processes, that would be hard or even impossible to reach after missed windows of opportunities.

If processes in forests are balanced and tuned, they do not stretch in the contrasts and are in accordance also with other landscape elements.

In view of mitigation of the greenhouse effect and conservation of biodiversity one of the main project objectives was the effective demonstration of multifunctional forest management, in which the key elements are the ability of the forest for CO_2 atmospheric carbon storage, biodiversity management, timber production, *etc*. and then dissemination of results and examples of good practices along other, also different levels. From the technical-scientific to the political decision and the general public message: the entire population, adults and children, as users of the forest and sedentary citizens, scholars and graduate students and by people with different level of qualifications.

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Key words:Communication, dissemination, learning program, seminar, workshops, newsletter, website, media.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

The ManFor C.BD experience has once again highlighted, importance of building an effective communication plan. The bases, in the project, are formed by the local communities from various sites where the project was developed. The population also expects a dialogue with experts and staff who work in nearby field. Through careful work of communication, it is possible to gain the consideration and trust of both involved parties.

What are the most effective means of communication? The ManFor experience shows that the 'dissemination' of the project reaches a significant target, when it varies and is based on different platforms. Not only of sectorial and general publications and, much essential (because exceptionally followed), the worldwide web, but also on various other, sometimes unconventional communication channels.

Under 'dissemination', educational paths were established in stages on every project site. The ManFor C. BD. is accompanied by the 'Life' brand, an EU instrument that is used to finance demonstration projects: we wanted to leave a legacy to the local community and all forest visitors of the test areas, the trails in the woods in which it is explained what is being done, and how, at that particular point.

In nine sites (Tarvisio, Cansiglio, Lorenzago di Cadore, Chiarano, Mongiana, Pennataro, Trnovo, Kočevski Rog, Snežnik), these demonstration routes (Figure 1), trails of forest management, these exceptional instruments of communication 'for all', may now be visited in the forests and will remain there after official conclusion of the ManFor C.BD project, scheduled for spring 2016 (Čater *et al*., 2014a, 2014b, 2014c).

The stages vary from four to six and through illustrative panels explain the key principles of forestry and the development of the European project ManFor C.BD By following the marked path explained on the panels, one can 'touch' the practical implementation of the theories tested by the project in the real forest environment. The panels would help to understand the differences between the traditional and the innovative management approaches of the forest, explain how carbon is quantified, which selected animal indicator species of biodiversity are monitored, and which appropriate management indicators are measured, always using the simple language.

The installation of each path has been accompanied by the official inauguration, an event aimed at involving local authorities and media attention.

A 'Collaborative learning program' for forest practitioners was elaborated in cooperation between Slovenian Forestry Institute and Slovenian Forest service to promote and incorporate new findings into forestry praxis. A visualization tool (software) of forest stands and indicators has also been developed between both Slovenian institutions and University of Ljubljana based on field data from demonstration areas and tested by forest practitioners in field; the tool helps to select appropriate thinning intensity by taking into account timber production, biodiversity and carbon sequestration indicators (Figure 2).

Another example of 'unconventional communication' developed within the project ManFor C.BD is the realization, in collaboration with the State Forestry Corps, an original and courageous editorial initiative, a storybook set in the Cansiglio forest, written and conceived by Paola Favero, commander of the Forest Service of Vittorio Veneto, in collaboration with Bruno de Cinti, technical manager of the Project, and the artist-climber Mauro Lampo, the 'father' of Giauli (Figure 3).

Just the Giauli, creatures half a gnome and a half tree, are the protagonists of the book, which combines science and fantasy and is titled 'The guardians of nature' (Favero *et al*., 2014). The stated

Figure 1. Notice board at Snežnik (left) and Cansiglio sites (right). Courtesy: M. Čater and B. De Cinti.

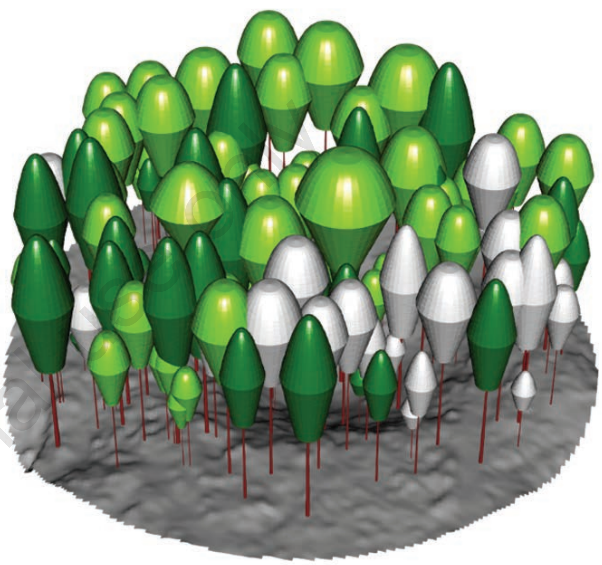

Figure 2. A software visualization tool of forest stands and indicators.

Figure 3. Fairy tale cover 'I custodi della natura'.

objective of the publication is to awake the sense of man's responsibility for the environment, but also to spread the concepts of forestry, carbon sinks, biodiversity. The book has been printed and distributed (for free) as part of Project ManFor C. BD and it is clearly intended for children, in the belief that they can learn more easily the issues described and, why not, also be messengers for the most distracted adults.

Biodiversity conservation, carbon sequestration and wood production objectives were introduced on periodical seminars for teachers in Slovenian kindergartens and schools along with several workshops for children. Events were organized in order to learn and raise awareness on the topics, related to forest ecosystems and natural processes in the forests.

Among other publishing tools that cannot be missed - as seen before - the telematics ones. Since its very beginning, the Project LIFE+ ManFor C.BD had its website (at www.manfor.eu) which has been repeatedly redesigned during the five year period and is regularly updated with news, reports and results.

The site represents a valuable showcase about the project activities that provide clear message to the public. On the home page, there is what may be called the ID of ManFor C.BD Data related to the views of ManFor website, press releases at the end of the project made by website editors, are really astonishing: about 200.000 views in two years, with particular focus during special events, as the inaugurations of Dem paths or for Annual Meetings.

Even more dynamic and easier to create and manage than the website, is the Facebook page of the Project. Social networks became fundamental to keep attention high for every activity, even the scientific one. This section is less concentrated on the theoretic-scientific news spread and more concentrated on news. You can consider it as an agenda of the Project activities.

'Best forest owner award for 2015' with Slovenian Forest Service has been organized at Snežnik demonstration site in Slovenia, where project objectives and results were presented with big interest to the forest owners, forestry practitioners, representatives of Ministry of Agriculture, Forestry and Food and also media.

Another popular tool that has accompanied the project ManFor C.BD from its beginning and has excellent impact results, is the digital newsletter. We published two country-specific periodical newsletters: 'ManFor Novice' and 'ManFor Magazine' (Figure 5), two online magazines that have been regularly realized to provide updated information of the work progress, images, comments and interviews to ManFor team of researchers (to study a forestry issue) or other targeted communities that work in the environmental sector (and have direct link with ManFor activities) (Kutnar, 2013; 2014a, 2014b; Kutnar and Vilhar, 2015; Recanatesi *et al*., 2014, 2015).

The first number of the newsletter, published in 2013, was opened by an exclusive interview to the then Environment Minister Andrea Orlando, who spoke of the importance of forests in terms of the green economy and biodiversity. To achieve (and maintain) such target which includes the institutions, partner organizations and all structures surrounding the project, ManFor Magazine has proved very effective. A similar web magazine has been published in Slovenia: all publications, Italian and Slovenian, in addition to being sent to a selected mailing list, have the advantage of being able to be placed and made available for downloading on the ManFor web site, thus giving a double opportunity of communication.

In spite of worldwide web's significant opportunities, one also should not forget the power of 'traditional' media: printed paper, television and radio broadcasts. To show a message during a show of the most visited channels becomes today more and more important. Within ManFor C.BD, coordinators participated in some shows of the main Italian tv (*Rai*), during main and most reliable private daily news bulletin (*Sky Tg24*), and in several national newspapers: *La Repubblica*, *Corriere della Sera*, *Il Messaggero*, *il Tempo*, just to name a few, and in several local newspapers. Scientific topics are becoming more and more actual in the daily news spread (based on Ansa data), in particular those targeting climate change, biodiversity or ecology. In such context, the timing and the message context have to be well prepared, so the possibilities to be published are bigger. The request to take part in a daily show at Sky Tg24, just to make an example, has been forwarded for March 21st, International Day of Forests. To talk about new ways of woods handling, on that day, immediately looked very

Figure 4. Network of Forest Kindergartens and Schools of Slovenia in Kočevski Rog demo-area (left) and primary school students learning and raising awareness on the topics. Courtesy: M. Rupel.

Figure 5. Slovenian and Italian periodical newsletters.

proper to the Editors of Sky Tg24. As well as the concept of carbon absorption from the atmosphere made by forests becomes more and more important every time you talk about greenhouse effect, or climate that keeps on changing. Constantly reading the newspapers, always being informed about not only on the development of the scientific project, but also on the most discussed topics in the world surrounding us, are the essential duties of the communicator. Media are his goals and allies.

We don't have to forget that researchers are, in many cases, the ones who offer a service to newspapers (and not the other), and the community in general. When dealing with environment, forests, biodiversity, as for the group of researchers of the project LIFE + ManFor C.BD, it is essential to send messages and show directions so the relations between man and environment progress in more and more sustainable direction. In such way the benefits for the people and society are obtained and also the key elements of natural heritage are preserved.

References

Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P, Skudnik M, 2014a. Večnamensko gospodarjenje z gozdom : ogljik, biotska raznovrstnost in socio-ekonomske koristi Kočevje. Ljubljana: Slovenian Forestry Institute, 2 panels.

Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P, Skudnik M, 2014b. Večnamensko gospodarjenje z gozdom : ogljik, biotska raznovrstnost in socio-ekonomske koristi Snežnik. Ljubljana: Slovenian Forestry Institute, 2 panels.

Čater M, de Groot M, Ferlan M, Kobler A, Kutnar L, Simončič P, Skudnik M, 2014c Večnamensko gospodarjenje z gozdom : ogljik, biotska raznovrstnost in socio-ekonomske koristi Trnovo. Ljubljana: Slovenian Forestry Institute, 2 panels.

De Cinti B, Fabbio G, Ferretti F, Cantiani P, Di Salvatore U, Bascietto M, Bombi P, D'Andrea E, Lombardi F, Mason F, Zapponi L, Matteucci G, 2014. Progetto LIFE + ManFor C.BD: Un'esperienza per valorizzare tutte le funzioni del bosco. Sherwood 206:29-32

Favero P, Lampo M, De Cinti B, 2014. I custodi della natura. Edizioni Filò, Belluno.

Kutnar L, 2013. ManFor novice: številka/issue 1, ManFor C.BD LIFE09ENV/IT/000078 projekt - Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi. Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.

Kutnar L, 2014a. ManFor novice: številka/issue 2, ManFor C.BD LIFE09ENV/IT/000078 projekt - Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi. Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.

Kutnar L, 2014b. ManFor novice: številka/issue 3, ManFor C.BD LIFE09ENV/IT/000078 projekt Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi. Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.

Kutnar L, Vilhar U, 2015. ManFor novice: številka/issue 4, ManFor C.BD LIFE09ENV/IT/000078 Večnamensko gospodarjenje z gozdom: ogljik, biotska raznovrstnost in socio-ekonomske koristi. Ljubljana: Silva Slovenica, Gozdarski inštitut Slovenije.

MCPFE, 2015. Full State of Europe's Forests 2015 Report. FOREST EUROPE, UNECE, EFI and FAO.

Penman J, Gytarsky M, Hiraishi T, Krug T, Kruger D, Pipatti R, Buendia L, Miwa K, Ngara T, Kiyoto T, Fabian W EDS. 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry Institute for Global Environmental Strategies (IGES) for the Intergovernmental Panel on Climate Change, IPCC National Greenhouse Gas Inventories Programme, Hayama, Kanagawa

Recanatesi M, De Cinti B, Matteucci G, 2014. Manfor Magazine. ManFor C.BD LIFE09ENV/IT/000078 project - Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing.

Recanatesi M, De Cinti B, Matteucci G, 2015. Manfor Magazine. ManFor C.BD LIFE09ENV/IT/000078 project - Managing forests for multiple purposes: carbon, biodiversity and socio-economic wellbeing.

How results from test area can be suggested as 'good practice'

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Introduction

This section can be considered as the core of the project results and as an important output of its overall activities, being ManFor CBD a demonstrative project.

Some of the suggestions enclosed in the chapter are derived from data produced during the project activities. Other suggestions come from observations made by the project experts during the planning and the execution of practical activities as the tree marking, the harvesting, the pre and post harvesting surveys, *etc.* (Balestrieri *et al.*, 2016; Basile *et al.*, 2016; Bombi and Gnetti, 2016; Chiavetta *et al.*, 2016; Costa *et al.*, 2016; D'Andrea *et al.*, 2016; Di Salvatore *et al.*, 2016; Fabbio *et al.*, 2016; Frate D'Andrea *et al.*, 2016; Giancola *et al.*, 2016; Lombardi and Mali, 2016; D'Andrea *et al.*, 2016; Mason *et al.*, 2016; Picchio *et al.*, 2016; Romano *et al.*, 2016a, 2016b; Tonti and Marchetti, 2016; Zapponi *et al.*, 2016)

Part of the suggestions provided in this section have also been gained during the dissemination activities that have allowed the project experts to meet many people connected to the forests in various forms and at different levels, collecting several opinions and points of view.

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Key words: best practices, silviculture, biodiversity conservation, Slovenia, Italy, *Fagus sylvatica*, *Quercus cerris*, *Picea abies*, *Abies alba*, *Larix decidua*, mixed forests.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Choosing a silvicultural treatment - from problem statement to management solutions

Choosing a 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. Each time, a silviculturist will need to answer to these three questions, adopting the following reasoning framework (Figure 1).

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), the application of the chosen silvicultural treatment should consider a series of good forestry practices. The aim of this section is to provide a list of best and effective practices to achieve goals related to forest health and vitality, silviculture, timber production, biodiversity conservation, recreation and other social aspects to forest owners, foresters, public entities and others involved in forest management and silvicultural operations.

The suggestions, derived from project ManFor C.BD activities, are divided into two parts: considering silviculture and biodiversity conservation.

Best practices pro - silviculture

Selective thinning

The treatment consists of the preliminary choice of a predefined number of well-shaped phenotypes per hectare (candidate trees) and cutting of all surrounding competitors in order to promote the future growth ability of selected trees at crown, stem and root level.

The management objective is to provide a sufficient number of good-quality dominant trees for the subsequent selection process. A defined number of frame trees is then identified and promoted through thinning from above in the actual selection phase. After a number of interventions, these trees will form the dominant part of the stand. In the release phase, management focuses on creating and maintaining free growth conditions for the crowns of the frame trees in order to guarantee persistent high increment in volume and value (Schädelin, 1934).

The conditions of the forest stand should be such as to respond to the chosen intervention.

Every time, the number of candidate trees should be define according to the local conditions (climate, soil, orography and aspect) and forest structure stage. Then, referring again to the local conditions, the amount of neighbouring competitors of crown to thin must be defined. The choices should be done considering the main goal, *i.e.* maintenance of forest health and vitality, and considering that the thinning should be intense enough to trigger other processes such as crowns gaps.

Main operations of selective thinning:

i) define the number per hectare of candidate trees and their spatial distribution (average distance between candidate trees)
ii) select candidate trees that give the best guarantee of stability and vitality: stem form (height/diameter at breast height ratio – *htot/dbh*) and crown development (relative crown length *cl/htot*) are the relevant attributes. A *htot/dbh ratio* of 80 (or 0.8, depending on the measurement unit used for calculation) is often quoted as a critical threshold between stable and unstable trees. Open-grown trees typically have htot/dbh ratios below 50 (0.5) (Burschel and Huss, 1997); open-grown trees where the crown reaches down to the ground will show a c/h ratio of 1, and a value of ~0.5 is commonly considered to be the stability threshold (Schütz, 2001). A couples of neighbouring trees could be selected as candidates too.
iii) identify 'competitors trees' and 'indifferent trees';
iv) localized thinning (dominant layer): remove competitors around candidates (more light and space) ;
v) leave standing indifferent trees, especially if their cut only represents a financial cost;
vi) release intercropping trees or removed only along hauling courses. In such a way, the overall stand structure moves both at stem and at crown level. The high tree density of intercropped stand would promote regular mortality and deadwood enrichment, where the establishments of further habitats and related niches would be favoured;
vii) identify permanently the candidates trees, both for the control and for the subsequent silvicultural interventions.

Selective thinning increases:

- mechanical stability of the standing trees and forest stability in general;
- economic value of the products (leads to a more valuable timber assortments);
- structural diversity of forest.

Shape, size and distribution of canopy gaps is also different between the selective and other thinning. The remaining standing crop is fully maintained and will produce differentiation in crown layer, stem distribution and size.

Selective thinning are recommended as the primary method to develop and manage quality hardwood stands for the production of high value sawtimber and veneer logs.

Crown thinning

Identification of a not-fixed number of scattered, well-shaped trees (usually in the predominant-dominant social classes) and of crown thinning of neighboring competitors in order to promote the future growth ability 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.

Crown thinning, or thinning from above, involves removal of trees from the dominant and codominant crown classes in order to favor the best trees of those same crown classes. Large intermediates that interfere with crop trees can also be removed. The method stimulates the growth of selected, preferred trees (quality) without sacrificing the production of quantity.

To optimize growth, the remaining stand should also be thinned. Release the best dominant and codominant trees by removing high risk, low vigor competitors.

To be most effective, crown thinning requires considerable skill in tree selection and density management. The timing and intensity of thinning are important in managing stem form and natural pruning.

Main operations of selective thinning:

i) identify best dominant and codominant trees that give the best guarantee of stability and vitality: stem form (height/diameter at breast height ratio – htot/dbh) and crown development (relative crown length cl/htot) are the relevant attributes: a htot/dbh ratio of 80 (or 0.8, depending on the measurement unit used for calculation) is often quoted as a critical threshold between stable and unstable trees. Open-grown trees typically have htot/dbh ratios below 50 (0.5) (Burschel and Huss, 1997); open-grown trees where the crown reaches down to the ground will show a c/h ratio of 1, and a value of ~0.5 is commonly considered to be the stability threshold (Schütz, 2001);

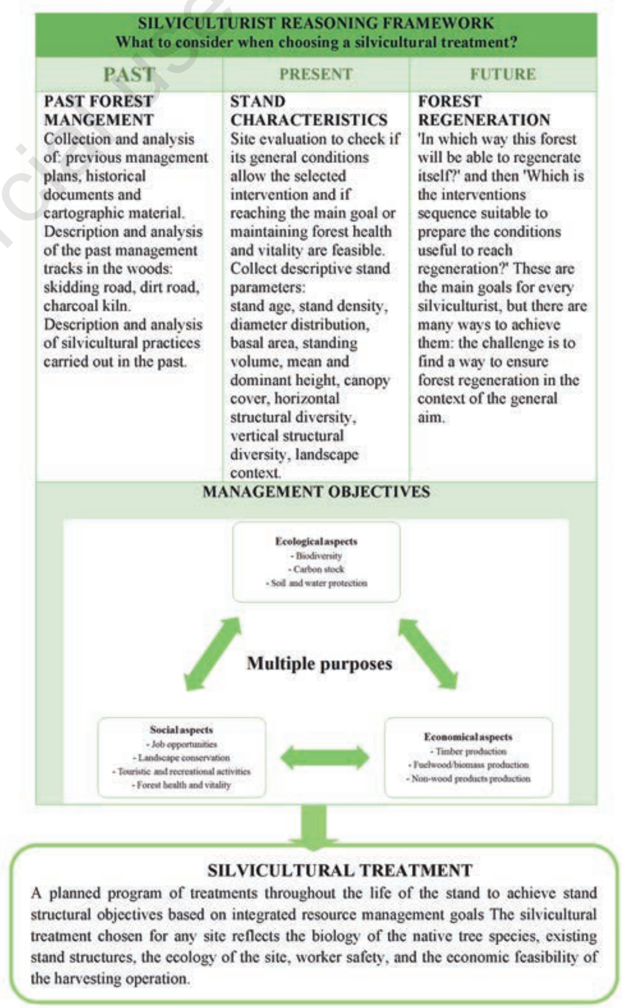

Figure 1. The silviculturist reasoning framework, showing the different factors involved in the process.

ii) identify ‘competitor trees’ and ‘indifferent trees’;
iii) remove competitor trees (more light and space) ;
iv) leave standing indifferent trees, especially if their cut only represents a financial cost;
v) release intercropping trees or removed only along hauling courses. In such a way, the overall stand structure moves both at stem and at crown level. The high tree density of intercropped stand would promote regular mortality and deadwood enrichment, where the establishments of further habitats and related niches would be favoured;
vi) in the case of mixed forests, it is important to choose which specie (or species) silvicultural practises has to favour.

In the case of mature forests, crown thinning should be preferred to selective thinning because of minor stability issues that could be take place in the first years after interventions (Piussi and Alberti, 2015).

Light thinning

The mixed, uneven-aged coniferous forests, such as the case of Lorenzago, need a special care. The contemporary harvesting of a few mature trees and thinning of intermediate-sized trees, all of them being arranged into small groups, allow a minimum degree of mechanized harvesting. Such demonstrative/innovative practice have been also implemented opening strips of clear-cutting 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 thinning’ are NW-SE oriented along the direction of maximum slope in order to ensure the maximum lighting. Broadleaved trees and young regeneration on the strips are being released. Cutting as usual get strips connected. Beech regeneration (eradicated in the past because not valuable as compared with fir and spruce timber), is always favored to enhance tree specific diversity.

Select the best sites where the stripes can be opened considering the presence of seed trees and orographic conditions (NW-SE oriented stripes).

Define the stripes width and length: 1½ top height long (for Lorenzago 60 m) and ½ top height wide (for Lorenzago 20 m).

In addition to stripes implementation, define the intensity of the contemporary harvesting of a few mature trees and the thinning of intermediate-sized trees both of them arranged per small groups.

Forest harvest

In silvicultural treatments, felling, processing and extraction have to be planned on a larger scale; they should not be sporadic events, not connected to the social, environmental and economic contexts. The forest operations have to be planned during implementation and execution of the working phases.

Felling and processing by chainsaw and skidding-winching extraction is the methodology suitable for a lot of these silvicultural treatments. To maximize the performances and minimize the impacts this methodology needs an appropriate logging system, in this case ‘cut to length’ or ‘tree length’ system.

The application of an high mechanization level, for example harvester and forwarder, in some cases is possible, but it needs more attention. Machines appropriate to the tree dimensions and to the level of tree density. Put slashes and brushwoods on the tracks to minimize the soil impacts due to compaction.

Bunching and extraction by mules or horses is possible only for very low harvesting intensity and only for firewood production. The impacts due to this methodology are close to the other methodologies, but the performances are drastically low.

For a sustainable forest management appropriate training of technicians and operators is necessary, to maximize the performances and minimize the impacts of the new forest technologies.

Best practices pro – biodiversity conservation

Landscape

In general terms, forest fragmentation is negative for biodiversity conservation. Nevertheless, when species typical of forest

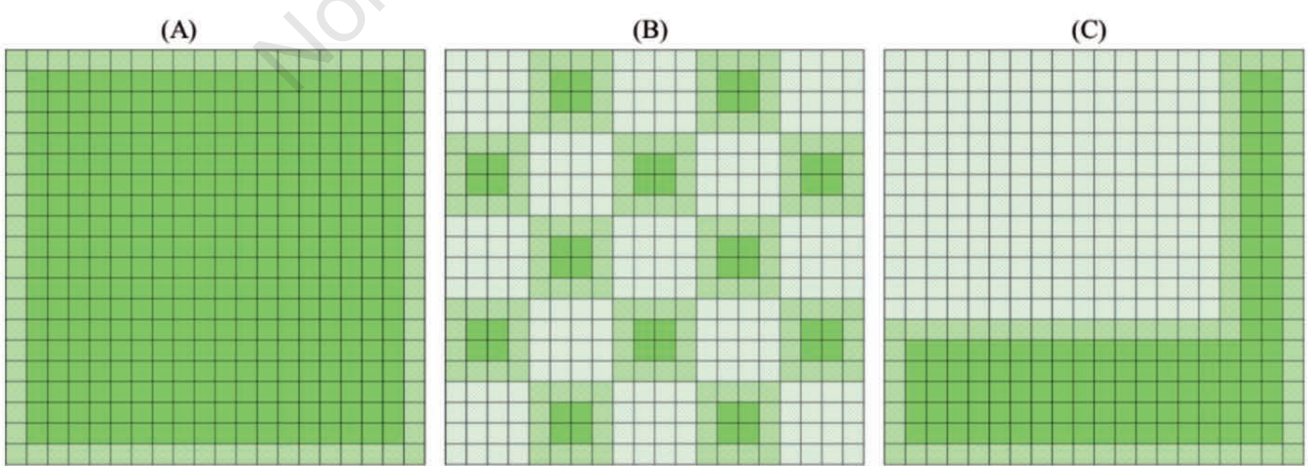

Figure 2. Patterns of timber harvesting of the 50% of existing forests according with two spatial models: (B) check-board model and (C) aggregated model. (A) represents uncut forests. Dark green represents interior conditions whereas light green indicates edge conditions. Aqua green represents the harvested areas. Each cell is 0.01 ha in size of the total 4 ha area. (Modified from Franklin and Forman. Landscape Ecology 1987; 1:5-18).

edges deserve particular measures for ensuring their conservation (*e.g.*, rare species), increasing the ratio between forest edge and interior can be helpful. The adopted silvicultural system significantly affects the spatial pattern and structure of forests and also the balance between edge and interior areas. For instance, a check-board setting, characterized by several small-dispersed cutting-units, always creates a more fragmented pattern than using large clumped cutting units. Yet, the check-board model generates longer edges and reduces the extent of interior habitats (Figure 2B). Conversely, by adopting aggregated cutting units, more forest interior are retained (Figure 2C).

Conserve forest water bodies (*e.g.*, streams, cattle ponds) and riparian habitats to support the diversity of birds, bats and amphibians. Small ponds and rivers in forests are typically insect-rich habitats and offer further foraging opportunities. Corridors along streams are used as foraging sites and for dispersal by several animal species.

Ensure forest connectivity: while planning forest practices and patches utilizations, it will be crucial to avoid creating isolated stands; hedgerows and tree-lines connecting forests or areas of woodland could also be beneficial. Networks of trees, particularly those following historic boundaries and natural features such as streams, with a rich variety of tree and shrub species, should be preserved. Such areas are often where ancient trees of great values as habitat are found.

The preservation of large patches of unmanaged forest on a regional scale represents the first step to preserve forest bat populations. The release of small groups of potentially suitable trees (such as trees with roosting cavities), or even single ones widespread inside the woodland, would permit colonization and movement of bats across the whole forest patch and improve the connection of optimal reproduction areas.

Increase forest continuity to allow insects' metapopulation dynamics. Favour forest landscape heterogeneity to guarantee spatial and temporal resource availability. A diversified forest management strategy allowing the co-occurrence of forest patches with different forest structures (*sensu lato*) and different management goals, could help favouring the coexistence of viable bird populations as well, supporting species with contrasting or dissimilar habitat preferences.

Forest structure

Support the achievement of older stand ages, maintaining the status of 'health and vitality' both at individual and stand level, to ensure current sequestration ability and higher growing stocks.

Higher tree species diversity equals insect diversity: since broadleaf species tend to sustain more complex communities, privilege mixed species stands. Broadleaf species tend to offer a higher abundance and diversity of microhabitats, thus this applies to other forest species as well (*e.g.*, bats). In case of supplying implantation, prefer native tree species.

For insect communities, to increase the availability of blossoms, a network of forest gaps, used as stepping stones and corridors would be preferable. Forest layers sustain different species, therefore, the maintenance of a complex forest structure (herbaceous, shrub and canopy) is recommended.

Maintaining cattle grazing and browsing inside clearings creates a variable semi-open forest, which is a good foraging habitat for bats.

Seedling establishment may be favoured by creating small and irregular gaps and by successive extension of gaps along the sun-exposed gap edge. Circular gaps with diameters greater than stand height contribute to increased ground vegetation coverage and hinder tree regeneration. Irregular gap shapes of small sizes should be created to provide as many of optimal micro-sites as possible or the gaps should be expanded accordingly while accounting for the specific micro-relief (*e.g.* avoiding larger canopy gaps on steep south-facing slopes).

Where low strata could be an obstacle to regenerate main species (*i.e.* hornbeam could obstacle Turkey oak regeneration), the low strata stumps are treated by releasing the dominated shoot, while monocormic individuals would not be harvested to avoid a new growth from the stump.

Deadwood and senescent and veteran trees

Increase the mortality of dominated or defective trees to promote the establishment of snags and lying deadwood, at present understocked. Forest management should focus not only on the spatial availability of deadwood, but also on its temporal continuity.

For deadwood to accomplish its role of structural legacy, a complete range of typologies and decay stages should be available. Compensate the time-lag of deadwood natural restoration actively increasing deadwood volumes, taking into account values relevant to the considered structure. The minimum total volume required to preserve biodiversity in productive forests could be based on thresholds values statistically derived from literature. To sustain saproxylic species diversity, we experimented the artificial increase of deadwood in the plots where the innovative criteria were implemented, calibrating this intervention as the 5% of the standing volume after harvest. This approach allowed the increase and diversification of deadwood in the shorter term, releasing standing and downed trees, and reaching a final volume of at least 10 m^3/ha.

Planning and establish senescent islands (îlots de sénescence): areas of a few hectares where trees are left to an indefinite ageing, up to their death and decay. In these areas the availability of deadwood and senescent trees rich in microhabitats is higher compared to the rest of the stand. Structural diversity may be increased with specific artificial interventions, in order to reach deadwood volumes of at least 30 m^3h^{-1}, girdling a part of the living stems to create standing dead trees, or leaving whole felled trees on the ground. Pro îlot de sénescence silvicultural treatments aim at the coexistence of different development stages : from open areas (where initial stages of forest succession could start) to senescent trees with microhabitats. The tree spatial distribution can be focused on single target trees or small groups, according to the ecology of the considered tree species. The final goal is to increase, in time, the availability of microhabitats and deadwood, both quantitatively and qualitatively, preserving each decomposition stage to guarantee a "temporal continuum" in the forest ecosystem.

Preserve and increase roosting opportunities for bats, conserving standing dead trees, decaying and big trees with cavities. Snags, used for roosting by barbastelle bat as well as other strictly related forest bats species, may be created by girdling, injecting or inoculating large stems inside managed woodlands. Where habitat trees are absent or scarce is suggested the adoption of artificial roosts sites as the bat box.

In order to support biodiversity, release living or dead trees that provide ecological niches (microhabitats) such as cavities, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot. Standing and fallen dead wood, hollow trees, old groves and special rare tree species should be left in quantities and distribution necessary to safeguard biological diversity. Preserve veteran senescent trees that have developed microhabitats and allow their replacement.

Deadwood retention in harvested forest has a positive effect on Amphibian populations as well, and its mitigating effect is more important in the first years after cut when few shelters are available due to biomass removal.

Cavities, created by both the natural detachment of dead branches and by cavity excavators, like woodpeckers are the principal nest site of many birds, some of which are obliged cavity nesters: thus trees bearing these structures should be retained.

Girdle or cut some selected trees (and left on the ground) in order to increase deadwood availability and favour the growth of the trees with the highest diameter, more likely to develop microhabitats.

Forest harvest

Trees with bigger diameter are expected to have more holes and buttresses than smaller trees. Consequently, retention of bigger/older trees is a good forestry practice and, among large trees, those with higher number of buttresses and holes should be preferred and preserved.

Even if timber harvesting reduces the abundance of salamanders, this negative effect may be mitigated concentrating high-intensity timber harvesting in small sized areas.

Prefer harvesting and logging techniques with a reduced impact. The disturbance of species included inside the Annex IV of EC/92/43 Habitats Directive, is prohibited even outside Special Areas of Conservation (SACs). Hence, forestry plans should be scheduled taking in consideration the potential and real impact on species' activity.

Logging that leaves undisturbed patches among harvested gaps is preferable for cavity nester to a more uniform, although less intense, forest cutting.

At a stand scale it is important to consider the status of the occurring species (at a local or country level, and also independently from Birds directive) to prioritize among forest management choices.

Carbon sequestration and carbon stock

Increment of the vertical structural diversity to improve the photosynthesis, that means a higher carbon uptake from atmosphere. Production of good quality wood (partially related to the 1st point) for making durable products for competing materials having a larger atmospheric CO_2 footprint. Residues management and deadwood release, which can improve the C/N ratio in the soil and release nutrients in the middle and long terms.

Organization of harvesting operations to reduce mixing and movement of organic material/litter layer with mineral part of soil, soil erosion and leaching of dissolved organic carbon nitrogen.

Information for managers of large forest areas

Stakeholders involvement

The population expects a dialogue with those who work in its territory. Through careful work of communication, it is possible to meet this need, gaining the consideration and trust of the people.

When it comes to forestry issues, always talk with local communities and to get the right messages to residents and visitors of the test areas.

To be effective, communication of a scientific project, especially if linked to forest management and the innovative concept of 'multifunctionality' of forests, must use a language 'to everyone', which captures the attention but above all that can be understood.

The researchers, in many cases, offer a service to newspapers (and not the other), and the community.

Effective communication tools

- Educational courses in stages from implanting in the woods, on each site
- Web site
- Newsletter
- Meeting and congress
- Social network
- Publishing products
- Media relations and press office

References

Balestrieri R, Basile M, de Groot M, Flajšman K, Posillico M, 2016. Did ManFor C.BD forest treatments influence diversity and composition of the bird community? Ital. J. Agron. 11(s1):1-175.

Basile M, Balestrieri R, de Groot M, Flajšman K, Posillico M, 2016. Conservation of birds as a function of forestry, Ital. J. Agron. 11(s1):1-175.

Bombi P, Gnetti V, Muzzini V, D'Andrea E, 2016. Community analysis at medium scales, focus on Carabids. Ital. J. Agron. 11(s1):1-175.

Bončina A, 2011. History, current status and future prospects of uneven-aged forest management in the Dinaric region: an overview. Forestry 84:467-478.

Burschel B, Huss J, 1997. Grundriß des Waldbaus. Parey Buchverlag, Berlin.

Chiavetta U, Skudnik M, Becagli C, Bertini G, Ferretti F, Cantiani P, Di Salvatore U, Fabbio G, 2016. Diversity of structure through silviculture. Ital. J. Agron. 11(s1):1-175.

Costa A, Posillico M, Basile M, Romano A, 2016. Conservation of herpetofauna as a function of forestry. Ital. J. Agron. D'Andrea E, Micali M, Sicuriello F, Cammarano M, Giovannozzi Sermanni A, Ferlan M, Skudnik M, Mali B, Čater M, Simončič P, Rezaie N, Mazzenga F, Magnani E, Bertolotto P, De Cinti B, Levanic T, Marinsek A, Kobal M, Ricca N, Coletta V, Conforti M, Pellicone G, Veltri A, Froio R, Buttafuoco G, Matteucci G, 2016. Did ManFor C.BD forest treatments influence Carbon Stock and sequestration. Ital. J. Agron. 11(s1):1-175.

Di Salvatore U, Tonti D, Bascietto M, Chiavetta U, Cantiani P, Fabbio G, Becagli C, Bertini G, Sansone D, Skudnik M, Kobal M, Kutnar L, Kobler A, Ferreira A, Kovač M, Simončič P, Ferretti F, 2016. ManFor C.BD sites and the drivers of forest functions. Ital. J. Agron. 11(s1):1-175.

Fabbio G, Kovač M, Planinšek S, Skudnik M, Cantiani P, Ferretti F, Di Salvatore U, Bertini G, Becagli C, 2016. Wood production. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services? Ital. J. Agron. 11(s1):1-175.

Frate L, Carranza ML, Tonti D, Ferreira A, Marchetti M, 2016. Landscape as a driver of forest functions. Ital. J. Agron. 11(s1)1-175.

Garcıa-Fernandez C, Ruiz-Perez M, Wunder S, 2008. Is multiple-use forest management widely implementable in the tropics?

Forest Ecol. Manag. 256:1468-1476.

Kutnar L, Giancola C, Marinšek A, Eler K, 2016. Did ManFor C.BD forest treatments influence diversity and composition of local flora? Ital. J. Agron. 11(s1):1-175.

Lombardi F, Mali B, 2016. Deadwood as a driver of forest functions. Ital. J. Agron. 11(s1):1-175.

Mason F, Di Salvatore U, Zapponi L, Cantiani P, De Cinti B, Ferretti F, 2016. Îlots de senescence in the ManFor C.BD sites. Ital. J. Agron. 11(s1):1-175.

Mlinšek D, 1972. Ein Beitrag zur Entdeckung der Postojna Kontrollmethode in Slowenien. Forstwissenschaf. Centralb. 4:291-296.

Leibundgut H, 1984. Die Waldpflege. Paul Haupt, Bern.

Picchio R, Spina R, Calienno L, Venanzi R, Lo Monaco A, 2016. Forest operations for implementing silvicultural treatments for multiple purposes. Ital. J. Agron. 11(s1):1-175.

Piussi P, Alberti G, 2015. Selvicoltura generale. Boschi, società e tecniche colturali. Compagnia delle foreste, Arezzo.

Romano A, Costa A, Posillico M, Basile M, 2016a. Forest management and amphibians: focus on genus Salamandrina. Ital. J. Agron. 11(s1):1-175.

Romano A, Posillico M, Basile M, Costa A, 2016b. Did ManFor C.BD forest treatments influence species biodiversity of amphibians and reptiles? Ital. J. Agron. 11(s1):1-175.

Schädelin W, 1934. Die Durchforstung als Auslese- und Veredelungsbetrieb höchste Wertleistung. Bern and Leipzig.

Tabbush P, 2004. Public money for public good? Public participation in forest planning. Forestry 77: 45-156.

Tonti D, Marchetti M, 2016. From forest stand to forest landscape: the spatial distribution of forest treatments in the landscape of ManFor Italian sites. Ital. J. Agron. 11(s1):1-175.

Wyder J, 2001. Multifunctionality in the Alps: challenges and the potential for conflict over development. Mount. Res. Dev. 21:327-330.

Zapponi L, de Groot M, Badano D, Birtele D, Corezzola S, Jurc M, Meterc G, 2016. Did ManFor C.BD forest treatments influence diversity and composition of Invertebrate communities? Ital. J. Agron. 11(s1):1-175.

Exportability of options and results to other forests

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Introduction

The aim of paper is to provide an overview of options and results and how these can be scaled up and transferred to other forests. The adaptability of implementations tested, is also discussed.

ManFor C.BD suggests the opportunity of managing forests formerly devoted mainly to wood production balancing different goals such as:

i) the productive functions;
ii) the maintenance or development of the inherent carbon sequestration and stock ability (i.e, the mitigation function);
iii) the maintenance and development of structural, compositional and functional biodiversity at the different operational scales.

All of this, can be defined as a multi-purpose management, *i.e.*, a conceptual framework not based on forest uses, but on the goals to be achieved. These are being identified first, then suited practices are being designed and implemented at the purpose. The method wants to:

i) get a multifunctional role from a former prevailing function;
ii) achieve this in an adaptive way, *i.e.*, have the chance to test, monitor and adjust the initial choices over time;
iii) compare customary management techniques with the new-established practices to verify the degree of fulfilment of awaited function(s).

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Key words: silviculture, multi-purpose management, thinning, biodiversity conservation, Italy, Slovenia.

Italian Journal of Agronomy 2016; 11(s1):1-175
This study was supported by the project LIFE+ ManFor C.BD (LIFE09 ENV/IT/000078)

Each country concerned, Italy and Slovenia, besides the common forest types included in the trials, has got an own background as for management heritage and practices of forestry. Within the common ManFor C.BD framework, each of them has tackled complementary questions. Basically, the Italian approach handled the question of tending fellings (intermediate thinnings) in evenaged forests and of the recovery of selection cutting in an unevenaged Alpine forest. Slovenian implementation focused on the regeneration cutting techniques to match the further step of the forest cultivation cycle. Both of them have to be read as a suite of approaches across the stand life-span within the common working hypothesis.

The Italian contribution originates from the evidence that most of public forests, formerly devoted to wood production following certified management plans (*i.e.*, managed according to a prevailing function at the scale of forest compartment), are nowadays much more extensively managed or somehow in 'a post-cultivation phase'. Reasons why are the diffuse perception of the emerging functions concerning - especially - public forests. These issues range from a generalized protection purpose, to the aesthetical and recreational values, up to carbon sequestration (mitigation) in the view of climate change. All of this implies, first, the elongation of former rotations still established in accordance with the maximum volume production. The evidence of this pattern is on the ground and many forests are nowadays experiencing the elongation of customary stand permanence time (rotation length). In addition, we witness the suspension or slowdown of the practice of silviculture because any wood harvesting (intermediate or final) clashes with the conservative aptitude prevailing at the political and technical decision-making levels. All of this, is spite of the relatively uniform stand structures established by the wood-oriented goal ruling previous management and of silviculture applied over the past decades across the same forests. The prominent concept of the 'large scale segregation', *i.e.* pursuing a prevailing function only, *e.g.* production or protection over full compartments, does not allow any scaling down as in the 'small scale segregation', where a prevailing role is distributed over different forest patches in a way that the full cover is managed in accordance with a multi-purpose goal.

In this context, the main driver of trials at Italian sites was the maintenance of forest 'health and vitality' as the basic attribute to implement, over the following stand life-span, the manifold awaited functions.

At the meantime, the innovative criteria applied were designed under the common goal of reducing current evenness outcome of past management, mostly devoted to produce stems sized alike at the final harvesting under regular stand structures. This applies to the evenaged stands, i.e six out of the seven case-studies. In the unevenaged forest of Lorenzago, an already established canonical model well-fitting the multifunctional purpose, the choice was made to restore suited condition to maintain the unevenaged structure in terms of type, size and arrangement of cuttings, taking into account also the potential mixture with the broadleaved spp. already present within the standing structure.

Another common goal of all the practices designed and implemented within ManFor C.BD was the preventive accurate estimate of their technical and economical feasibility in each physical, structural and management context. This point was believed to be the first condition for testing, monitoring and getting transferable results.

Under this assumption, the mechanization of thinning practices (felling-harvesting-forwarding) has been implemented as for the pre-commercial thinnings (the case of Tarvisio), whilst the more suited hauling systems have been selected in advance at each site, proposed and shared with the local technical staff and responsible.

Technical feasibility of the proposed silvicultural approaches

All the silvicultural options tested are described in the textbooks and in literature, even when they are innovative to the routine of forestry practice into the forest types and contexts examined. The reader can easily find out their technical descriptions into Kovac and Fabbio, 2016. The heritage management systems and practices into wood-oriented production forests and Fabbio *et al.*, 2016. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services?

Benefits arising from the approach are in principle synthesizable under the following points:

- Practices implemented give the right input to move the uniform stand structure in the evenaged stands by the crown thinning or the selective thinning methods. Practices implemented will allow the further differentiation of individual crowns, a well-constructed canopy texture, a more effective occupancy of growing space within the crown layer, the temporary change of the interception ability;
- Opening of gaps modifies locally inner site conditions in terms of incoming light and rainfall to the soil, air temperature, soil microbiological activity, soil respiration, etc., creating conditions suited to new habitats and related ecological niches, these including also non-wood productions;
- A better crown to stem ratio will promote growth pattern and carbon sequestration in the short to medium run and the 'health and vitality' of trees over longer life-spans;
- Tree growth and related carbon storage in the living biomass and in the soil will enhanced by the reduced competitive pressure;
- Attention to the successful natural regeneration and the tending of the other, even if complementary, tree species will promote patches and level of compositional diversity;
- Higher structural heterogeneity is basic to a better occupancy of growing space and to the functioning of trees as well as of the other living communities in the whole forest system;
- Parallel implementation of customary practices and of the no-intervention thesis (where this condition is in progress) is a sound benchmark to the options tested;
- Adaptive nature of criteria established within the project needs the careful monitoring and the adjustment and tuning of each step in the follow-up, when needed. It implies an effective management and a considerable change in the customary standards ruling so far public forests.
- Theory of the 'small scale segregation' intermediate to the theories of 'large-scale segregation' and 'equal priorities' (*i.e.* presence of multiple uses at the same time on the same forest area) seems to fit at best the goals of the work implemented within ManFor C.BD.
- To sustain saproxylic species diversity, associated to the innovative criteria, we experimented the artificial increase of deadwood, calibrating this intervention as the 10% of the standing volume after harvest. This intervention allowed the increase and diversification of deadwood in the shorter term, releasing stand-

Table 1. Slovenian results: pros and cons.

PROS
Rise of public awareness, increase of interest in wider share of population
Increased yields taking into account the specifics of local sites
In situ insight into natural processes and their effects
Comparison between before and after measure effect of different parameters
Spatial-temporal comparison of effects on stand and landscape level
Public acknowledgement of benefits from professional approach (planning, measures, long term benefits)
Sustainability of presented research results on a local scale
Less is more - explanation
Constant verification of adaptation processes in changing environment
CONS
Drawing and generalizing conclusions out of ecological scope
Spreading site-specific responses from local to regional or broader level
Site degradation
Predomination of short term- over long term-benefits solutions to achieve current (short-term goals)
Research conclusions not reaching operative forestry
Loss of identity and standards (EU, regional level) of forestry sector, consequences at national and local level

ing and downed trees.
- Conservation of saproxylic species was supported by the creation of senescent islands (Mason *et al*., 2016), where structural diversity, deadwood and microhabitat availability was maximized with specific artificial interventions.

The Slovenian contribution (Table 1) originates from the evidence that in the changing and unstable environment it is essential to adapt all management activities in such way, that production and continuous forest cover remain stable as they provide all further ecological and social benefits. Only the stable structure with adaptive silvicultural system (to environmental and site conditions) would ensure further stability and would optimize (not maximize) our long term outputs.

The knowledge and culture in forest management requires close to nature approach. Crucial is the role of silviculture that respects nature potential of the forest sites, represented by the regeneration processes and tending. By tending we understand all measures, aiming towards balanced growth of trees and stands that management goal is optimized in best possible way (Leibundgut, 1984). Growth processes in forests are managed by light, affecting the between and within species competition. Supporting the quality with tending young stands and later with thinning, the share of quality assortments is increased and quality of future and emerging stands is improved both in biological and mechanical way to assure optimal sustainability.

General aims/guidelines:

- Preservation of site fertility and productivity;
- Tending of young and tending selection (thinning) of adult stands;
- Principle of individuality;
- Focus on the function carriers - the selected individuals;
- Natural regeneration;
- Continuous forest cover;
- Tuned silvicultural planning;
- Mimicking natural processes;
- Sustainability on smallest area with consideration of economic and nature motifs;
- Preservation of stabile stand structure;
- Succession development after silvicultural measures of bigger intensities on different locations and sites (according to predominant tree species);
- Evidence and observation of competitive strength of different (predominating) tree species.

If most of abovementioned items could be accomplished, all questions regarding biodiversity and carbon stock etc. would be encompassed and automatically provided by regular management praxis on all (different) levels.

Correct and well-tuned spatial-temporal measures may vary among different silvicultural systems. Most of Dinaric fir-beech forests were gradually transformed from old-growth conditions and have never experienced clear cut silvicultural systems and extensive planting (Bončina, 2011), where selection system and irregular shelterwood (femel) system within the compass of close-to-nature silviculture were predominantly applied. They were managed with continuous cover silvicultural systems, especially with single-tree selection systems, irregular shelterwood or their combination (Mlinšek, 1972; Bončina, 2011).

Close to nature silvicultural systems

The *selection system*, developed as the main alternative to the clear-cutting system has a long tradition in Slovenia, Switzerland, and France and is also called the plenter system or plentering (Schütz, 2001). Selection stands are characterized by stand structure and tree growth patterns, where trees of different sizes (height and diameter at breast height - dbh) and ages grow together in areas smaller than 0.1 ha. Understory trees recruit to the upperstory when light conditions are favourable (Schütz, 2001).

If trees are grouped in larger cohorts, we define it as types of *irregular shelterwood systems* (Matthews, 1999; Raymond *et al*., 2009). Patch sizes vary from a few hundred square meters to a few hectares, with often indistinctive edges and dynamic horizontal structure, because of silvicultural measures, tree growth, regeneration and natural disturbances. To optimize the potential of different stand patches and to take into consideration the variety of stand dynamics, a *freestyle silviculture* was introduced by Mlinšek (1968), where combination of elements of different silvicultural systems are adapted to the structural and developmental characteristics of the forest stand and to site conditions at the micro-spatial scale. In such way, a suitable treatment (*e.g.* thinning or selection cutting) or a combination of treatments (*e.g.* gap creation with additional planting) was to be determined on every microsite and location.

References

Bončina A, 2011. History, current status and future prospects of uneven-aged forest management in the Dinaric region: an overview. Forestry 84:467-478.

Fabbio G, Kovac M, Planisek S, Cantiani P, Ferretti F, Di Salvatore U, Bertini G, Becagli C, 2016. Optimizing forest management regimes to get best possible outcomes: compromise or best-fitting choice for one or more ecosystem services? Ital. J. Agron. 11(s1):1-175.

Mason F, Di Salvatore U, Zapponi L, Cantiani P, De Cinti B, Ferretti F, 2016. Ilots de Senescence in the ManFor C.BD sites. Ital. J. Agron. 11(s1):1-175.

Matthews JD, 1999. Silvicultural systems. Oxford University Press, New York.

Mlinšek D, 1972. Ein Beitrag zur Entdeckung der Postojna Kontrollmethode in Slowenien. Forstwissenschaft. Centralb. 4:291-296.

Mlinšek D, 1968. Sproščena tehnika gojenja gozdov na osnovi nege. Poslovno združenje gozdnogospodarskih organizacij, Ljubljana.

Kovac M, Fabbio G, 2016. The heritage management systems and practices into woodoriented production forests. Ital. J. Agron. 11(s1):1-175.

Leibundgut H, 1984. Die Waldpflege. Paul Haupt, Bern,Stuttgart.

Raymond P, Bedard, S, Roy V, Larouche C, Tremblay S, 2009. The irregular shelterwood system: review, classification, and potential application to forests affected by partial disturbances. J. Forest 107:405-413.

Schütz J-P, 2001. Der Plenterwald und weitere Formen strukturierter und gemischter Wälder. Parey, Berlin.

Errata Corrige. De Cinti *et al.*, (Eds). From the experience of LIFE+ ManFor C.BD to the Manual of Best Practices in Sustainable Forest Management

Page viii, the correct "Acknowledgements" are:
It was possible to write this volume thanks to many people that contributed in different ways to the project activities. We want to acknowledge in particular: Daraio A., Franzè G., Gallè G., Angilletta C., Costa C., Dilena C., Barsottini P., Favero P., Dorigo E., Bortoluzzi L., Azzalini S., Torrini L., Gallipò G., De Vincenzi D., Terlicher P., Vedovato A., Dilena F., Altea T., Bottacci A., Panella M., La Civita F., Salvidio S., Gobbo G., Nicolao B., De Martini E., Consalvo M., Sammarone L. Many other people were involved in the project and we want to show our thankfulness to all of them.

Page viii, "focus on the genus Salamandrina" should be "focus on the genus *Salamandrina*"

Page 1, in "From the experience of LIFE+ ManFor C.BD to the Manual of Best Practices in Sustainable Forest Management" for the author Primož Simončič, the correct affiliation is:
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Page 5, in "Italian and Slovenian forest governances within the International context", for the author Marko Kovač, the correct affiliation is:
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Page 14, in "Landscape as a driver of forest functions", for the author Andreja Ferreira the correct affiliation is:
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Page 18, in "Diversity of structure through silviculture", for the author Mitja Skudnik, the correct affiliation is:
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Page 23, in "Deadwood as a driver of forest functions" for the author Boštjan Mali, the correct affiliation is:
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Page 24, in "Deadwood as a driver of forest functions", "values of 2÷30%; in the range of 14÷222 m^3 ha^{-1}" should be: "values of 2-30%; in the range of 14-222 m^3 ha^{-1}"

Page 27, in "Wood production. Hereditary management systems and practices in wood-production forests", for the author Marko Kovač, the correct affiliation is:
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Page 28, in "Wood production. Hereditary management systems and practices in wood-production forests" the right Table 1 is:

Silvicultural type	Clearcutting	Clearcutting	Shelterwood	Shelterwood	Irregular shelterwood	Irregular shelterwood	Irregular shelterwood	Selection	Selection
Specific name	Clearcutting	Clearcutting with reserves	Uniform shelterwood	Group-shelterwood	Expanding-gap Bayerischer Femelschlag	Continuous cover Badischer, Schweizerischer Femelschlag	Extended; Delayed regeneration	Group selection	Single-tree selection
Age arrangement	Even-aged/ whole stand	Even-aged/ whole stand	Even-aged/ whole stand	Even-aged/ whole patch	Uneven-aged/ gap, group of trees	Uneven-aged/ parts of a stand, gaps	Uneven-aged/ parts of a stand	Uneven-aged/ even-aged only in groups of trees	Uneven-aged
Regeneration origin	Artificial	Artificial, natural	Artificial, natural, combined	Artificial, natural, combined	Natural	Natural	Natural	Natural	Natural
Regeneration pattern	Concentrated, large foci	Concentrated, large foci	Concentrated, large foci	Concentrated, large foci in patches	Concentrated and irregular foci	Irregular foci, continuous recruitment	Concentrated, large foci	Irregular, continuous recruitment	Irregular, continuous recruitment
Harvesting intensity	Strips, tracts, whole stand	Strips, tracts, whole stand	Tracts, parts of a stand	Seed-cut, final cut of a patch	Single trees, group of trees in a gap	Single tree, group of trees	Single tree, group of trees, tracts	Tree groups, single trees	Single trees
Final cut	Yes	Yes	Yes	Yes	Optional	No	Optional	No	No
Horizontal structure	Single cohort	Single cohort	Two cohorts, single cohort after final harvest	Two cohorts, single cohort after final harvest	Irregular, mosaic of cohorts	Irregular, mix of cohorts and trees	Two cohorts	Irregular, mix of cohorts and trees	Irregular, mix of trees of different DBH
Vertical layer	Regular, one layer	Regular, one layer	Regular, one layer	Regular at patch scale	Regular at gap scale	Irregular	Regular at group or strip scale	Regular at group scale	Irregular

Page 56, in “Improving carbon sequestration and stocking as a function of forestry”, for the authors Boštjan Mali and Mitja Skudnik, the correct affiliation is:
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