SelPiBio Life

SELECTIVE THINNING

Increasing mechanical stability and biodiversity in black pine plantations

SelPiBioLife technical handbook

LIFE13 BIO/IT/000282
Prodotto realizzato con il contributo dello strumento finanziario LIFE dell'UE

SELECTIVE THINNING

Increasing mechanical stability and biodiversity in black pine plantations

SelPiBioLife technical handbook

SELECTIVE THINNING
Increasing mechanical stability and biodiversity in black pine plantations
SelPiBioLife technical handbook

Pubblication from SelPiBioLife Project [LIFE13 BIO/IT/000282]

Edited by
Paolo Cantiani

Authors
Gianni Bettini, Elisa Bianchetto, Fabrizio Butti, Paolo Cantiani, Carolina Chiellini, Isabella De Meo, Giada d'Errico, Arturo Fabiani, Lorenzo Gardin, Anna Graziani, Silvia Landi, Maurizio Marchi, Giuseppe Mazza, Stefano Mocali, Piergiuseppe Montini, Manuela Plutino, Pio Federico Roversi, Elena Salerni, Stefano Samaden, Isaac Sanz Canencia, Giulia Torrini

Editorial coordination
Silvia Bruschini - Compagnia delle Foreste S.r.l.

Publisher
Compagnia delle Foreste S.r.l.
Via Pietro Aretino 8, 52100 Arezzo
Tel. 0575.323504 / Fax 0575.370846
Email posta@compagniadelleforeste.it
www.compagniadelleforeste.it

Photographs
Archivio fotografico Compagnia delle Foreste

Traslation
Chapters 1; 2; 3; 5; 6; 7 by Valentina Giulietti
Chapter 4 by Authors

Project coordinator

Partner

ISBN 978-88-98850-26-6

Published in October 2016

INDEX

1

SelPiBioLife
The project

Paolo Cantiani

The main goal of the SelPiBioLife project is to demonstrate how an innovative silvicultural treatment applied to pine forests of *Pinus nigra* J.F. Arnold could increases biodiversity of the various soil components (flora, fungi, bacteria, mesofauna, nematods). In particular, we evaluated the effects on the forest functionality (both productive and protective) and soil biodiversity of selective thinning, compared with customary thinning (thinning from below) and with no treatment areas of young forest. Despite its effectiveness has been demonstrated on incremental effects and stability of artificial black pine stands, this silvicultural treatment is not commonly applied in the Apennines pine forests. With this project, therefore, we want to show that this management technique, by changing both the horizontal and vertical forest structure and then the canopy coverage, changes the light, water and temperature regimes at the soil level. Consequently, it contributes at increasing the establishment of herbaceous-shrub vegetation (the plant biodiversity), the mycological and microbiological diversity and the creation of additional habitat, ecological niches and nutrient sources (plant-insect-predator food chains), easing the enhancement of biodiversity and overall functionality of the ecosystem.

Among the objectives of the project there are also activities aimed at disseminating the results through seminars, training courses, workshops and in-field visits, public awareness finalized at demonstrating that this innovative silvicultural treatment, even if it need a prior process for determine which plants have to be cut ("tree marking"), is easy to apply and reproducible in a variety of contexts.

In particular, the project will produce the following results:

- analysis of the relationship *forest structure/floristic biodiversity* (i.e after-treatment forest structural indexes vs. floristic biodiversity indexes);
- analysis of the relationship *forest structure/mycological biodiversity* (i.e after-treatment forest structural indexes vs. mycological biodiversity indexes);
- analysis of the relationship *forest structure/mesofauna biodiversity*;
- analysis of the relationship *forest structure/soil microbial communities biodiversity*;
- multiple correlations between soil biodiversity components analyzed;
- relationship between forest treatment and wood production (indexes of improved

economic value of the forest as a function of applied treatments);

- relationship between forest treatment and forest stability (analysis of forest mechanical stability indexes as a function of applied treatments).

EXPERIMENTAL PROTOCOL

The experimental protocol of SelPiBioLife project defines, in both the territories under study, namely Unione dei Comuni del Pratomagno (hereinafter called Pratomagno-Figure 1.1) and Unione dei Comuni Amiata Val d'Orcia (hereinafter called Amiata-Figure 1.2), 9 treatment-areas, each one of 1 ha surface. The forest treatments we considered are:

- control (no thinning);
- customary thinning (thinning from below of moderate intensity);
- selective thinning.

The monitoring design involved the drawing lots of treatment thesis for each monitoring area: 3 repetitions for each thesis.
In each of the 9 treatment areas were placed, with random criterion, 3 circular-plot of variable surface from 10 m radius for the biodiversity analysis to 13 m radius for the dendrometric and structural analyses. The dendrometric and structural parameters were detected using FieldMap®.
The dendrometric variables, inserted in the database produced by the Project, are as follows:

- tree identification number;
- species;
- diameter at 1.30 m height (above 5 cm threshold);
- total height;
- height at the maximum crown diameter
- height at the crown base (from the ground);
- social-rank classification in three classes (dominant - co-dominant - subdominant);
- plant health classification in three classes (live-dead-break off);
- number of living whorls along the stem;
- polar coordinates (azimuth in sexagesimal degree to the North and distance in meters) of stem position relative to the plot center;
- polar coordinates (azimuth in sexagesimal degree to the North and distance in meters) of crown projection in 8 points, relative to the plot centre.

After the georeferencing data with GIS we calculated the degree of canopy closure and crown coverage before and after thinning together with a series of competition and distribution indexes. These latter measured the effect of selective thinning compared with customary thinning and with control area (no thinning). For the demonstration and dissemination of thinning methods, for each pilot area two theses of treatment were repeated on a total of 6 ha (three per treatment) in an area border on monitoring area. Border on thinning plots were released two areas of about 1/4 of hectare where, for demonstration purposes, and were made only the tree marking.

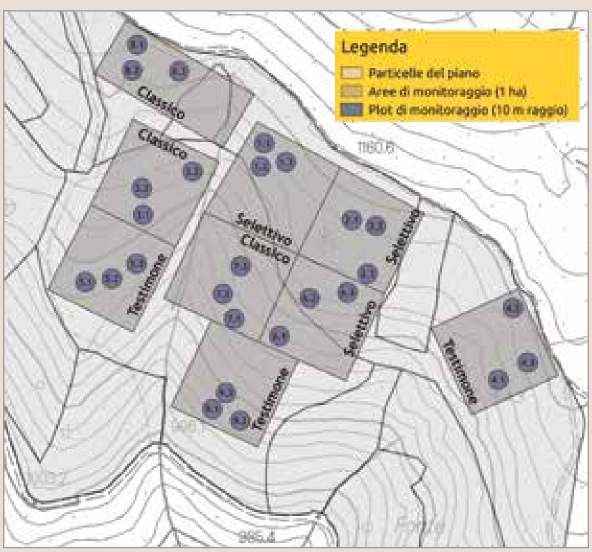


Figure 1.1 - Location of treatment areas and monitoring plots in "Unione dei Comuni del Pratomagno

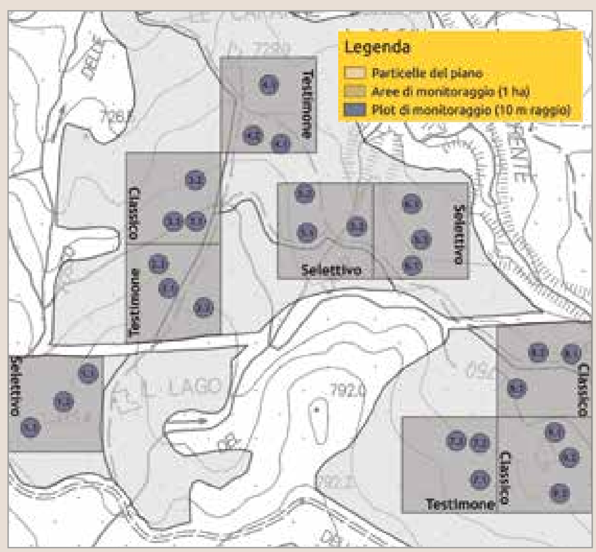


Figure 1.2 - Location of treatment areas and monitoring plots in "Unione dei Comuni Amiata Val d'Orcia".

2

ESTABLISHING BLACK PINE FORESTS IN APENNINES

Paolo Cantiani, Maurizio Marchi, Manuela Plutino

The task of reforestation in Italy began in 1880 in ex-Austrian regions. Early in '900, the black pine reforestation were widespread in almost all Italy regions. Chronological evolution in terms of the involved district's percentage is as follows (from Gambi 1983):

- before 1922 (7%);
- between 1922 and 1942 (18%);
- between 1942 and 1952 (7%);
- between 1952 and 1962 (37%);
- between 1962 and 1972 (31%).

The first reforestations were made, mostly in pure stands, possibly in association with sycamore maple. Among the high number of available species and proveniences, the sub-specie *Pinus austriaca* (Höss) was used more commonly on calcareous soils and *Pinus calabrica* Delam. (laricio pine) original from *Calabria* was preferred on acid soils. The latter provenience proved to be very effective over time for rooting, efficient use of water and resistance to plant diseases.

Customary treatment included: cleaning in early developmental stages, thinning in more mature stages, a rotation of about 90 years with clear-cutting and postponed artificial regeneration with native species preferably when the pine forest had played its restoration role (Pavari 1961).

Forest plantation management was initially entrusted to the State through the implementation of the so-called "Legge della Montagna" (LN n. 991 of July 25, 1952). The purchase process and managerial transfer was very quick as the attention of populations towards the mountain economy was lacking.

The pine trees plantation was usually performed at high densities to ensure the forest coverage in a short period of time (De Philippis 1958). In Apennines the planting density was 2,500 plants per hectare on average in regular planting patterns, varying according to the site characteristics. In public pine forests the stand tending at pole stage and young high forest stage is often limited to pruning for fire prevention and removal of subdominant trees (definitely not affecting the competition dynamics) (Cantiani *et al.* 2005).

The first thinning, when actually carried out, have generally been delayed compared to the cultivation module expected; it's quite unusual that the first intermediate cutting has been performed in stands younger than 30-35 years. In private pine forests thinning is almost totally neglected. The reasons of this behavior is due to both the low economic value of the assortments from young stand and the management instability after the change of ownership from State to Regions, in terms of competence and management agencies.

The primary objective of reforestation was the protection with canopy of low-fertility and unproductive soil as a result of intense exploitation. The black pine represented a pioneer solution for his adaptability to harsh environments.

2.1 SILVICULTURAL CRITERIA in pine stands

Most of the pine forests (especially those with *laricio* pine) have shown that it can carry out positively to wood production function, except those planted on low-fertility soils. According to Bernetti (2015), instead of the customary silvicultural treatment (clear-cutting with postponed artificial regeneration), today the following criteria are preferred:

1) Criteria of "nature-based" inspiration (*especially for public-owned pine forests with a non-economic management*):

This section covers all those stands that are released to a spontaneous evolution of the vegetation (Nocentini 1995). In this case the choice involves a of very long succession period, according to the pine longevity of in excellent climatic and edaphic conditions. The understory of the pine forest will be likely subject to several "waves" of subsequent regeneration, as long as the upper canopy layer of pine stand comes into senescence crisis (Bernetti 2015, Del Favero 2010).

To speed up this process a high intensity thinning can be performed until end felling like clear cut on small area, with release of reserves for landscaped and seed purpose. Mercurio (2010) defines the clear cut in favour of natural regeneration "final felling" in pine forest proposing also, based on past experiences on natural pine forests of Calabrian *laricio* pine, to cut on small patches to make succession easier.

A possible alternative to the final felling of the pine forest is represented by clear cut on small areas or canopy gaps (Mercurio 2010) and the subsequent re-planting of native species. A possible variant of this option is to perform native species plantation in pine stand's open-canopied in early stages. The goal of these teratments is to establish, in young or juvenile stands, areas with natural succession to encourage and direct the future seed trees quantity. This technique can be mostly taken in public lands characterized by large areas of reforestation, high structural, evolutionary and specific monotony and generally characterized by a lack of potentially disseminating native species (Plutino *et al*. 2009).

2) Business inspired criteria (mostly for private pine forests):

The general policy is to apply a treatment providing the pine natural regeneration, so that the species may be termed "naturalized". Among possible hypothesis the most known and applied are:

- treatment with gaps cutting ("skimmer") as used in the Calabrian pine stands, stip cutting, shelterwood system (Cantiani 2012) etc. In such a way the pine regeneration will benefit of superficial tillage (Del Favero 2010, Bernetti 1995). Examples of natural regeneration of black pine post fire can be locally found in Apennines (Picture 2.2) and this may suggest a possible combination of clear cut with reserves and controlled fire;
- the clear cut on a few hectares area with planting of fast-growing conifers resulting in an economic benefit (such as the Douglas fir). Because of its cost and impact on the territory this treatment is recommended for small areas of silicate and deep soils, i.e. where site fertility is already higher than with seedlings rotation and plantation.

Young high forest of black pine never thinned. The density is still that of plantation. The stand would positively react to a late first thinning, otherwise it would activate an high mortality for competition and the overall stability of the stand would be compromised.

The black pine shows natural regeneration after fire. The photo refers to the pine forest of Comano (MS) in nearly a decade by a fire.

2.2 INTERMEDIATE CUTTING

Piussi and Alberti (2015) define intermediate cuts in the one-storey forests "felling made before the deadline expected for the regeneration cutting". "The main objectives of the intermediate cuts are to increase the mechanical and biological individual and overall stability" but rather to create optimal microclimate and soil conditions for seedling establishment at the time of regeneration cut. We summarize below the benefits of intermediate cuts on artificial single canopy stands:

- increased growth and improved plants shape, as it increases radiation at crown level acting on their growth. This stimulates additional growth of stems diameter;
- improved soil water conditions (decreases the probability of a vegetation inactivity during the summer period and therefore increases the time available for the active vegetation);
- increased space for roots growth and the potential for nutrients to be absorbed;
- improved mechanical stability of the stand: increased height/DBH ratio (slenderness coefficient) due to the higher stem growth in radial direction compared at that longitudinal.

The early intermediate (cleaning) are generally "pre-commercial" operations, in other words whose product is not a desirable assortment for the market due to the small size and poor quality (grain, diameter increment, etc). Generally these felling are carried out in stands with good quality wood species and are intended to:

- increase the overall mechanical stability of the stand:
- regulate the mixing species;
- increase production value by the action of education and selection of the selected trees.

2.2.1 Thinning

Thinning are intermediate cuts in even-aged stands carried out from the pole stage.

They are classified by

- type: defines the social position of thinned plants;
- grade: defines the percentage of the wood biomass removed;

- starting age;
- thinning frequency.

The classic treatment of black pine forests contemplates thinning, in a production cycle of 90 years, from below, moderate, with early starting and 10-15 years frequency (Bernetti 2000).

Outcome form an economic point of view

Apart from the pre-commercial intermediate cuts (cleaning in thicket and thinning in pole stage), that have stumpage value for the most negative, with thinning in high forests in good to excellent conditions of site fertility and favourable for wood extraction, economically positive results can be achieved. With free selective thinning it is possible to adjust the species mixture in the pine forests mixed with other species and appreciate the value of valuable broadleaved that might be present in the stand.

Effects on mechanical stability and forest protection level

Thinning actually stimulating growth of dominant or particularly vigorous trees (super-thinning, free thinning such as thinning *fotoincrementali* (Piussi and Alberti 2015)) and thinning “after selection of final stand” (Pretch 2009) act on the stability of dominant storey or the fraction of selected plants.

These type of thinning determine the reduction of slenderness ratio, increasing depth and eccentricity of the crown of selected trees and then the stand overall. The period immediately following the treatment, due to the increase of “coarseness” of canopy condition and consequently of wind turbulence event, is the most critical for the stand stability (Piussi and Alberti 2015). For this reason, in case of free selective thinning, it is important that the choice of trees (or clusters) selected will be particularly careful and select trees with high mechanical stability phenotypes.

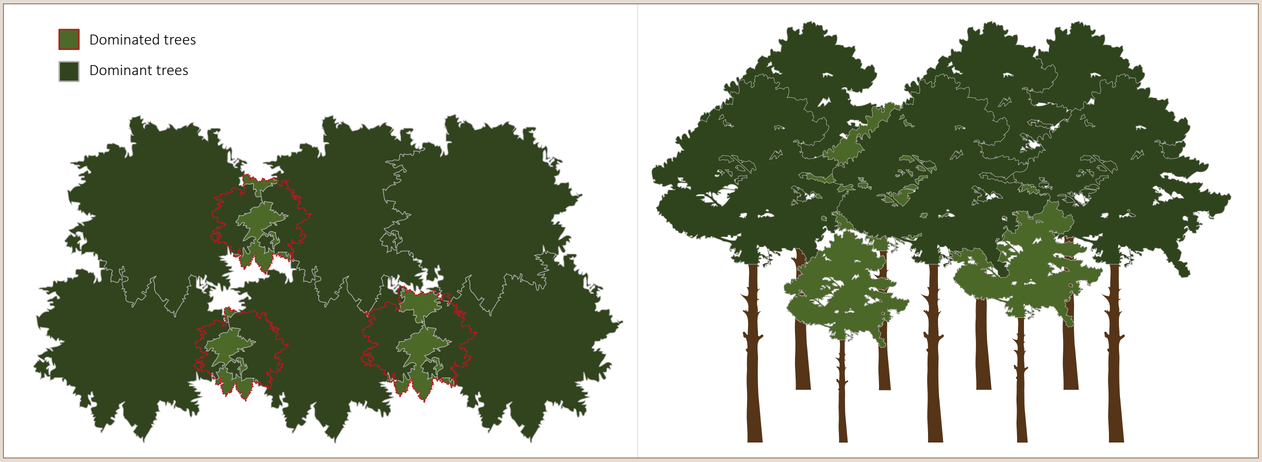
Effects on biodiversity

The active selection in thinning phase allows to give value to possible tree mixture.

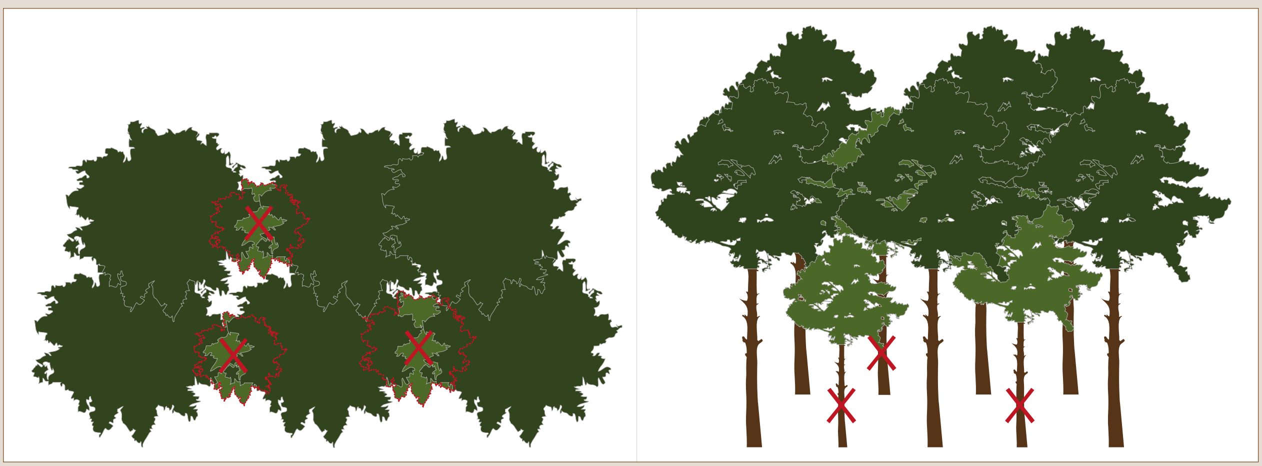
The free thinning contribute to increase the patches of light in an irregular manner on the ground. The alternation of covered-uncovered of canopy condition determines an increase in the diversity of the undergrowth flora and mycological flora making shade-tolerant and light-demanding species can coexist (Cantiani *et al*. 2015).

Young high forest of black pine never thinned. The competition between trees cause a limited crowns expansion.

THINNING FROM BELOW IN A YOUNG EVEN-AGED HIGH FOREST



Structure of the forest before treatment.



Selection of trees to be removed.

Structure of the forest after treatment. No significant effect on canopy cover.

The absence of thinning makes the high conifers forests of artificial origin very unstable and sensitive to wind fall-down risk.

Bibliography

Bernetti G., 1995 - **Selvicoltura speciale.** Unione Tipografico-Editrice Torinese.

Bernetti G., 2000 - **Problemi e prospettive della selvicoltura nell'Appennino Centro Settentrionale.** Atti del Secondo Congresso Nazionale di Selvicoltura, Venezia 24-27 giugno 1998, 2:79-119.

Bernetti G., 2015 - **Le piante del bosco. Forme, vita e gestione.** Compagnia delle Foreste. pp. 350.

Cantiani P., 2012 - **Pinete di pino nero in Toscana. Note sul trattamento in ordine alle normative vigenti**. Sherwood - Foreste ed Alberi Oggi 18.184 (2012): 15-20.

Cantiani P., Iorio G., Pelleri F., - 2005. **Effetti di diradamenti in soprassuoli di pino nero (Pettenaio, Perugia).** Forest@-Journal of Silviculture and Forest Ecology, 2(2), 207.

Cantiani P., Meo I., Becagli I., Bianchetto E., Cazau C., Mocali S., Salerni E., 2015 - **Effects oh thinnings on plants and fungi biodiversity in a *pinus nigra* plantation: a case study in central Italy.** Forestry Ideas, vol. 21, n. 2

De Philippis A., 1958 - **Lezioni di Selvicoltura Speciale.** Firenze, p. 130-131.

Del Favero R., 2010 - **I boschi delle regioni dell'Italia centrale. Tipologia, funzionamento, selvicoltura.** Cleup. 425 pp.

Gambi 1983 - **Il pino nero, pianta della bonifica montana.** Annali Istituto Sperimentale per la Selvicoltura, 14: 3-46.

Mercurio R., 2010 - **Restauro della foresta mediterranea.** Clueb. 368 pp.

Nocentini S., 1995 - **La rinaturalizzazione dei rimboschimenti. Una prova su pino nero e laricio nel complesso di Monte Morello (Firenze).** L'Italia Forestale e Montana, 4: 425-435.

Pavari A., 1961 - **I rimboschimenti nella catena appenninica. Atti del Congresso Nazionale sui rimboschimenti e sulla ricostituzione dei boschi degradati.** Accademia Italiana di Scienze Forestali. Firenze.

Piussi P., Alberti G., 2015 - **Selvicoltura generale-Boschi, società e tecniche colturali.** Scienze Forestali e Ambientali. Compagnia delle Foreste. 434 pp.

Plutino M., Piovosi M., Cantiani P., 2009 - **Rinaturalizzazione dei rimboschimenti di pino nero. Prove di impianto di potenziali nuclei di disseminazione di rovere in Pratomagno (Arezzo).** Sherwood - Foreste ed Alberi Oggi 150 (2009): 9-14.

Pretzsch H., 2009 - **Forest dynamics, growth, and yield.** Springer Berlin Heidelberg. pp. 664.

3

SELECTIVE THINNING
IN THE SelPiBioLife PROJECT

Paolo Cantiani, Maurizio Marchi

A free thinning regime with positive selection.

The thinning were define “free” when do not provide a specific class of plants to harvest and focus rather on the specific characteristics and phenology of those to be left. This kind of thinning aims at enhancing an average number of trees with good potential development.

Due to the primarily protective function of the black pine Apennines forests, the trees “selection” will be made on those trees that provide the greatest degree of mechanical stability, even if, generally, the pines with a good degree of stability are also those of great productive potential.

This kind of treatment will be henceforth called “**selective thinning**”, though we are aware that in literature, this term is used specifically for selective thinning of Schaedelin (perfected by Leibundgut in 1946), which means a form of free thinning linked to nature-based forestry, with precise codified rules (Piussi and Alberti 2015). Similarly, the term “candidate” will be adopted for the selected vigorous trees to be enhanced with treatments.

The selective thinning adopted by the SelPiBio project acts with a first treatment in a young high forest (age 30-40 years) not thinned or at least submitted to low-intensity thinning from below. The reference structure is the currently most represented by artificial black pine stands in the Apennines.

3.1 BACKGROUND: IS THINNING FROM below useful to black pines forests functionality?

Thinning from below results in periodic removal of stand trees with low development. The degree of thinning is the discriminating factor if the treatment affect only the dominated layer (low thinning from below) or if it goes even in the dominant layer and, limited to crooked trees, also in the overstorey (moderate and heavy thinning from below).

The Apennine regional forest laws often regulate the incidence of treatment based on thinning yield percentages on the trees number. Consequently, especially in the early treatment this translates into felling of only dominated layer.

The absence of thinning results in a low individual stability of trees (high slenderness coefficient)

An analysis performed on 88 experimental stands, of different ages, in Tuscany in permanent protocols followed by CREA SEL (comparable for fertility and initial planting density) suggests **that the relationship between the dominant and the dominated layer remains essentially constant over the developmental stages of pole/young high forest/mature high forest untreated**. In these developmental stages the number of dominated pine is 25.7% (± 5.8%) in percentage of the total number of trees. Then the first thinning, affecting approximately 30% of the number of trees, do not affect the overstorey. Figure 3.1 shows the density trend in function of mean diameter (of mean basal area) in pine forests untreated. At increasing of diameter value a decrease in the number of trees has been observed.

The yield model for the black pine and *laricio* pine forests in Tuscany (Bernetti *et al.* 1969) evidenced a close relationship between mean diameter and age in untreated stands. The analysis of 33 permanent plots, in CREA SEL experimental stands, have confirmed the yield model of 1969.

Appling the linear function of Figure 3.2, has been calculated the self-thinning rate as a function of age for Tuscan pine forests.

Assuming a constant planting density (average 2,500 trees per hectare), from 30 to 45 years of age in particular, has been observed an average pine trees mortality of about 35% (in absolute terms around 550 trees per hectare) (Figure 3.3).

A thinning from below of 30 years old plantations, carried out in accordance with ordinary regional laws, should remove only the fraction of trees that would die in the next decade and a half for self-thinning. In other words the treatment would not lead to any positive effect on competition of the pine trees belonging to the dominant layer representing main candidates to give the woody product at the end of production cycle and the stand fraction of greater potential stability.

Recent studies have shown that **the dominant fraction of pine forest is that *sensitive* to thinning** (Cantiani and Piovosi 2009, Bianchi *et al.* 2010). Essentially, treatments that not concerning the dominant stand layer do not affect the growth and stability of pine forests. The unperturbed coverage of the overstorey canopy does not change significantly the soil irradiation and therefore has no impact on the dynamics of flora, other biotic components of soil. Conversely, **selective thinning from above produces a significant positive change of all the stand characteristics**. A thinning with cultivation purpose (increasing stability

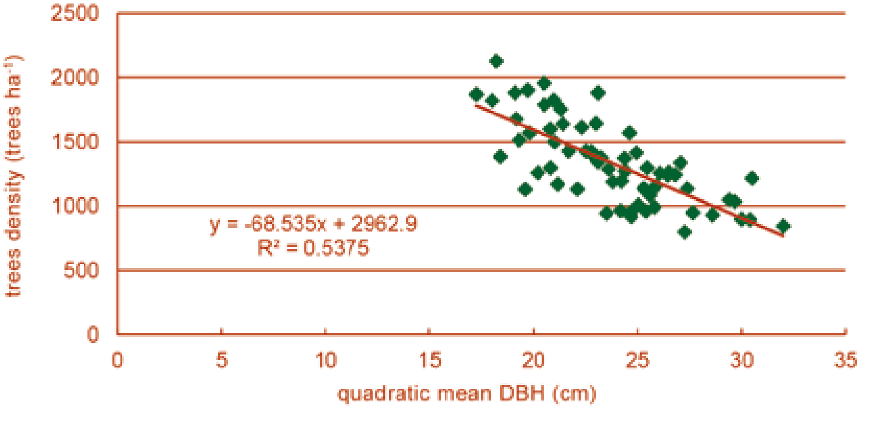


Figure 3.1 - Density on the basis of diameter of mean basal area.

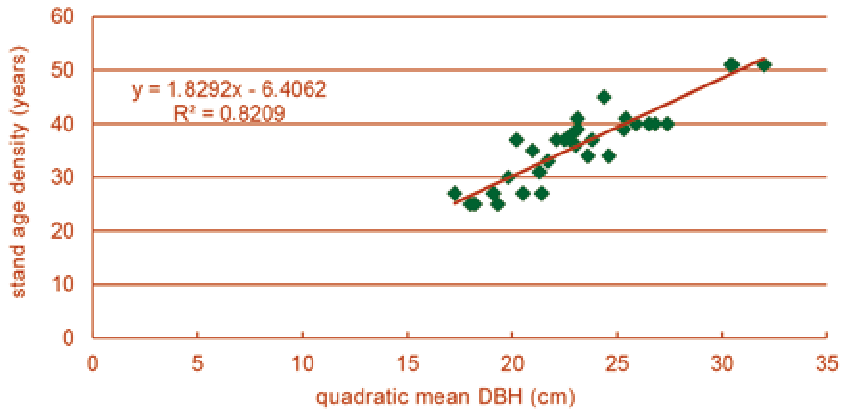


Figure 3.2 - Stand age on the basis of diameter of mean basal area (data from 33 experimental stands untreated).

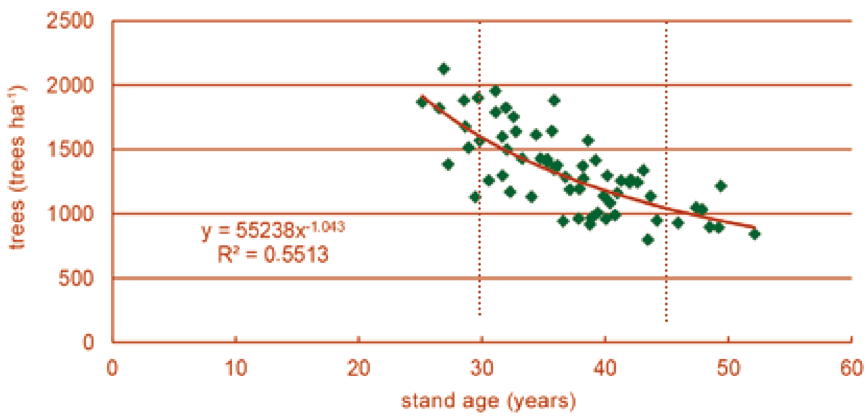


Figure 3.3 - Density on the basis of stand age (data from 66 experimental stands untreated).

and growth rates) could therefore ignore the dominated trees when they do not have a economic target destination, for example production of biomass for wood chips (CANTIANI 2012).

3.2 THE PROPOSED THINNING SYSTEM of SelPiBioLife

The proposed method is based on experimental evaluations and has the characteristic of being **easily feasible and reproducible**.

As mentioned above it is a thinning system "selective" that aim to increase the overall functionality of pine forests, with particular regard to the hydrogeological protection.

The method is valid for stands from medium to good vegetative vigour, with regular density and free from pathological evidences.

Adult black pine high forest. The absence of thinning operations resulted in a high mortality for competition

Thinning objective

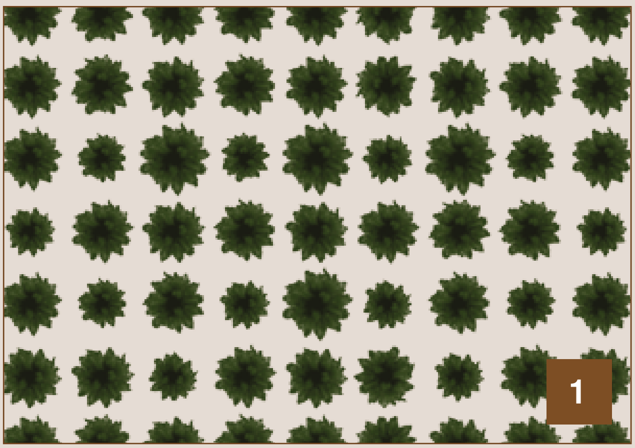
The proposed thinning system aims at optimizing the stand characteristics towards the overall mechanical stability (protective function), tree growth capability (production function) of structural differentiation (enhancement of biodiversity function).

From a structural point of view the treatment aims at increasing the structural diversity both horizontal (opening of micro gaps around the candidate trees) or vertical (breaking the monotony of canopy layer). The structure variation will affect the microclimate at soil level in terms of light and water, increasing the environmental diversity and thus the biotic diversity (shrub and herbaceous flora, mycological component, meso-and micro-fauna, component of bacteria in soil).

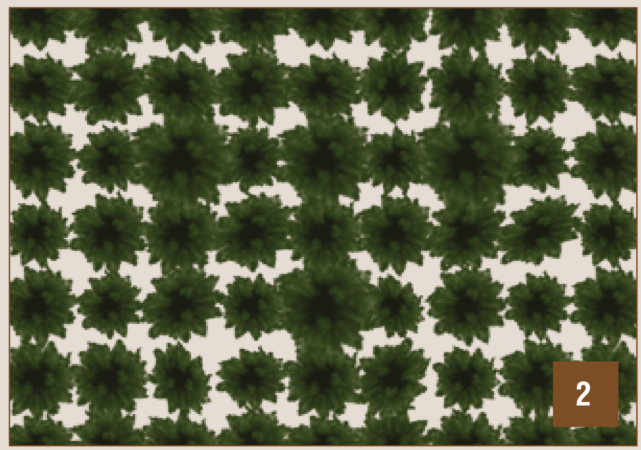
The first tree marking of selective thinning will produce:

- positive selection of the trees candidate to constitute the stand at the end of the rotation period

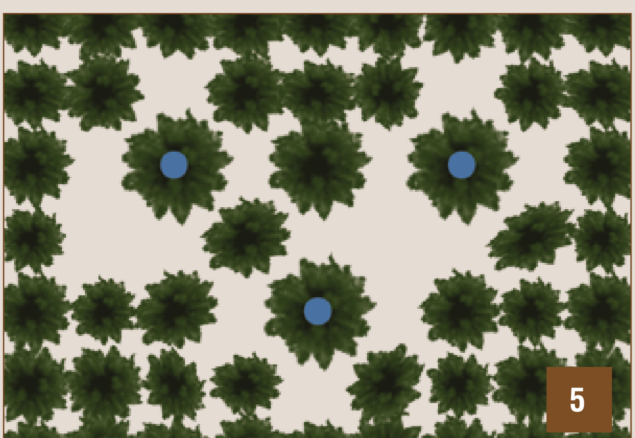
SELECTIVE THINNING PROPOSAL OF SelPiBioLife PROJECT



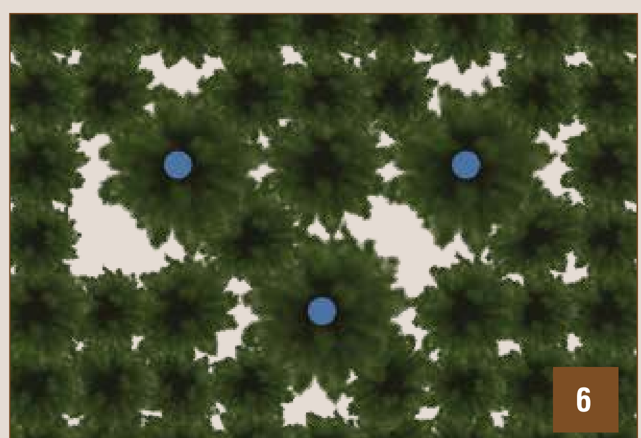
Young artificial pine forest in which the tree crowns are not in contact yet.



Stage which trees come into competition, the crowns are in contact: it's time to make thinning.



Situation after selective thinning.



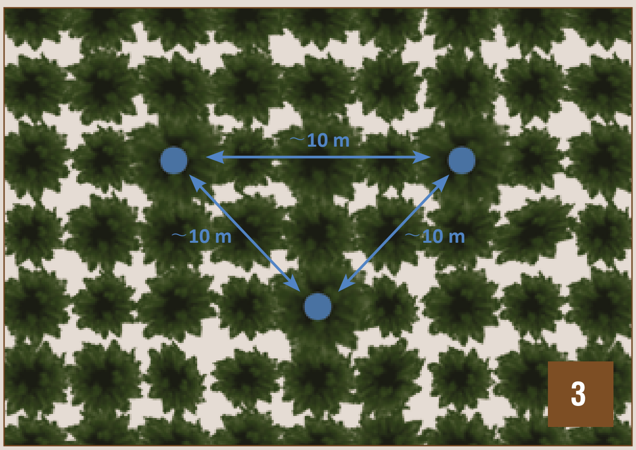
Trees, both the candidate than those of margin, are taking advantage of the spaces created by thinning.

- making candidate trees free from their direct competitors, i.e. all the trees that limit the full crown growth of the candidate tree.

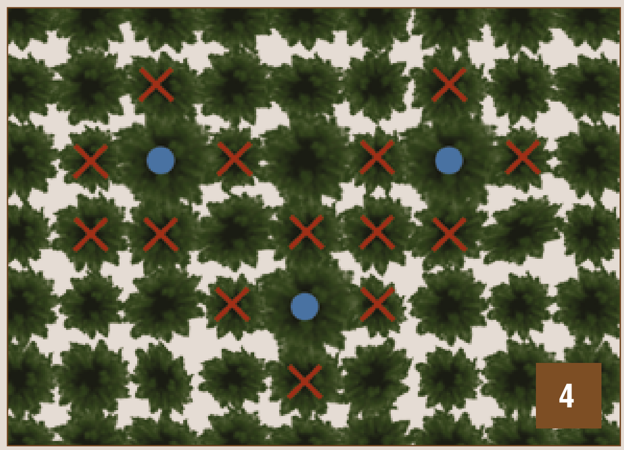
3.3 SELECTION OF CANDIDATE TREES

Density and localization of trees to be selected

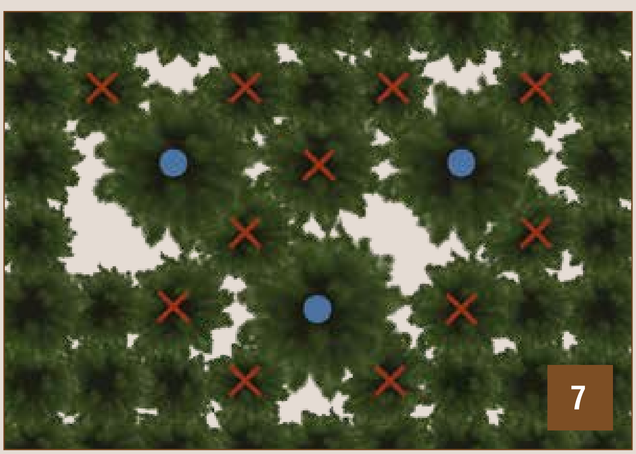
The selection of trees to be enhanced in coniferous forests is hardly feasible in the early development stages because of insufficient social and phenotypic differentiation of arboreal plants, which is more evident during the young high-forest stage. The recent trend of *laricio* pine forests silviculture in Spain has recognized this need, suggesting (in a customary thinning system) the first two intermediate cutting in juvenile stage as mechanical or from below thinning, then, around 30 years old, operate a thinning with selection of final crop trees (SERRADA *et al*. 2008).



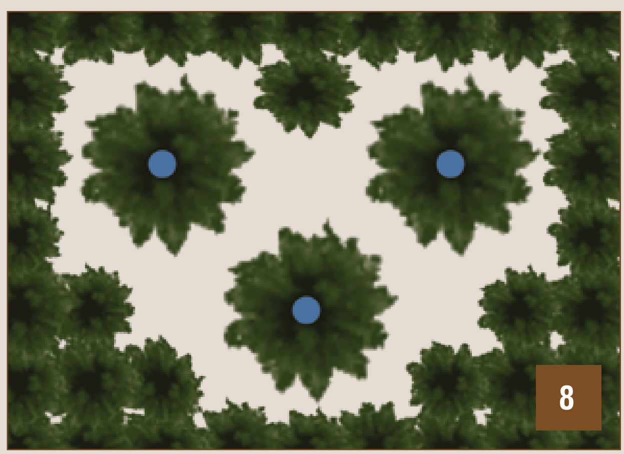
Selection of candidate trees (see section 3.3.1). With a density in pine forests of 100 candidate trees per hectare, the average distance is about 10 m.



Selection of direct competitors, from dominant candidate trees.



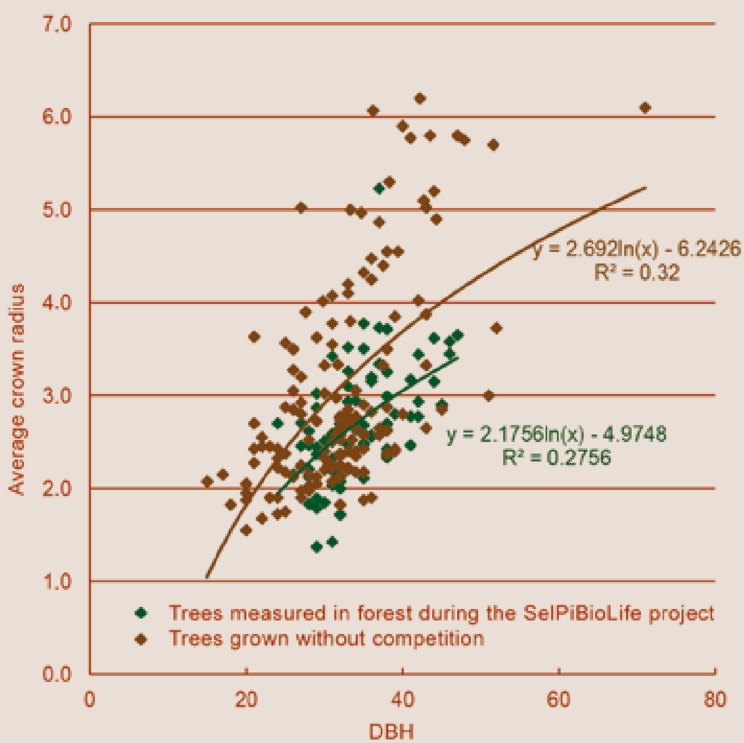
It's time for a new thinning with direct competitor removal.



Situation after the selective thinning.

With the **first selective treatment** in the development stages of pole/young high forest, was operate the **trees candidate selection**, whether or not the stand has the planting density or previous interventions from below has been realized. The average number of trees candidate should be around at 100 trees per hectare. The density of **100 trees per hectare** (10 meters, average distance between trees) comes from the analysis of crown development patterns of black pine in the absence of lateral competition (Bernetti *et al.* 1969, Cantiani and Piovosi 2009) and by experimental data taken ad hoc. This number represents the optimum average density of pine forest at 100 years old. In order to make the treatment simple and easily reproducible, we suggest to spatially locate candidate trees according to a regular design. It is recommended to mark them with a team of two operators. Starting from the lower elevation of the treated area and proceeding for contour lines on elevation above, once the candidate have been chosen and marked with a strip of paint, an operator stays next to it, while the second moves to the second candidate. This makes possible to evaluate briefly the distance between candidate trees (around 10 m). Repeat the operation to the contour lines above, the paint stripes placed on candidate tree will support for proper regular space between the candidate trees disposal. The regularity of spatially location is obviously not a strict rule. The 100 trees per hectare are an indicative number, as well as the distance of 10 metres between a candidate tree and the other must be considered an average distance. The operator must consider from time to time to change the rule for

POTENTIAL AVERAGE DENSITY OF A PINE FOREST 100-YEAR OLD



A model of potential crown development at 100 years has been created.
For the evaluation of the relationship between diameter and crown radius of free growth in adjacent areas to the project areas, were measured the crown radii of 150 trees grown isolated (unpublished data). The Figure shows the development of average crown radius according to diameter candidate trees in the project SelPiBio and those theoretical if tree were grown isolated.
This trend was approximated to a logarithmic regression line. Assuming an increment on candidate trees of the Project less than those given in yield table of black pine (given the delay in first thinning than the theoretical model) we should have in 100 years a canopy cover area (suppose square-shaped) of 9,615 m^2, which is the maximum possible use of space available (96.2% of the surface).

Figure 3.4 - Trend of average crown radius of trees grown isolated and in forest on the basis of diameter (DBH).

the absence of candidate trees from the theoretical distance, or for local site emergencies (rocky soil, landslides, etc.)

3.3.1 Characteristics of candidate trees

For a correct choice of candidate trees it should be evaluated:

- the specific composition;
- the vigour;
- the degree of mechanical stability;
- the mechanical and/or pathological damage;
- the stability groups

Specific composition

Within the choice of candidate trees we have an opportunity to address the stand from a specific composition point of view. It is a management choice, closely dependent on the stand characteristics. The black pine forests of the Apennines, in fact, have often some degree of species mixture, due to localized planting of different species from pine at reforestation time(frequently sycamore and silver fire at higher elevations or Turkey oak, holm oak, cypress or other conifers at lower elevations) or for the persistence of the degraded forest before planting (often chestnut or oak trees).

The choice to select other species than the pine must be cautious and be limited to those trees that can guarantee with their vigour a good reaction to the treatment. When there are sporadic trees species with high commercial (especially valuable sporadic species) or ecological (any habitat trees) value, will be a good practice choice them as candidate.


In selective thinning of black pine forests is important the choice of candidate trees.
The choice should be based on phenotype as a function of mechanical stability and vigour.

Vigour

The candidate trees must belong to the stand dominant layer (and therefore must have diameters and heights above average stand parameters). Will be selected the dominant trees that have vegetated for a long time above crowns of close trees.

It is important that candidate trees have a crown as dense as possible.

Mechanical stability

Due to the predominantly protective function of black pine forests in the Apennines, the evaluation of this parameter is the most important.

The choice to use this thinning type is closely dependent on the presence in the stand of a sufficient number of trees with good individual stability to select as candidate trees. If the number of trees with good individual stability in the forest is low the stand will be treated with other type of thinning. Candidate tree should have:

- a low slenderness coefficient (less than 90);
- a high crown depth;
- the crown as symmetrical as possible;
- the crown as ample as possible.

Mechanical and/or pathological damage

The candidate trees must be free from mechanical damage (break off or forked crown, lightning damage to the stem, ungulate damage, etc.) and pathological damage (evidence of fungal bodies or insect attacks).

Stability groups

It's possible to select small groups, two or more trees, when it is considered that they represent a group of mutual stability, consisting in dominant trees with crowns overlapping. Such groups of trees will be treated as a single candidate tree and then, as such, will follow the thinning rules.

3.4 MAKING CANDIDATE TREES FREE FROM their competitors

After selecting the candidate trees, next step is to rid out their crown from near competitors. The competitor trees are those that hinder the natural development of candidate trees' crown directly. It would then enough to get the candidate trees free from dominant and co-dominant trees (located in overstorey) that are in direct competition with them. To ensure a greater effectiveness of this procedure with increasing of stand structural differentiation and contribute to increase micro-climatic changes on the ground (light and water)

PARAMETERS OF MECHANICAL STABILITY OF FOREST STANDS
Proposal of a speedy method for the determination of mechanical stability of black pines

The most common morphometric parameters of single tree stability proposed by scientific literature are:
the **slenderness coefficient** => Htot/DBH, called HD in the following
the **relative depth** of the crown => (Htot-Hins)/Htot
the crown **projection** => as a projection of the crown on the ground (m^2)
the crown **eccentricity** => major crown radius/ minor crown radius.
The slenderness coefficient, between these parameters, is the only one which is based on **thresholds values** experimentally measured. They discriminate between mechanical stability and instability of a single tree. For this reason it is the most adopted parameter. For the black pine forests the value 90HD is a prudent value and can be considered the threshold limit set for black pine stands in developmental stages of young high forest/high forest (Cantiani and Chiavetta 2015, Cantiani *et al.* 2015). A speedy method to visually evaluate the stability degree of Apennine pines lies on counting the living whorls along the stem (LWN-living whorls number). Experiments have shown that black pines with a number of living whorls greater than 16 (Figure 3.5) have a slenderness coefficient sufficiently low to be mechanically stable (Cantiani and Chiavetta 2015).
Of course, during the evaluation of the tree quality, the operator, in addition of living whorls count, will also take in account other morphological and functional aspects, such as the crown shape, any stem bifurcation, pathological or mechanical damage, etc. These aspects can suggest to classify the tree as "unstable" even if it has a large number of living whorls. Evaluation of stability needs be carefully prepared, including considerations independent from counts of living whorls, in particular site conditions, such as areas with rocky cliff or with surface soils, where root's anchoring on the ground has to be evaluated.

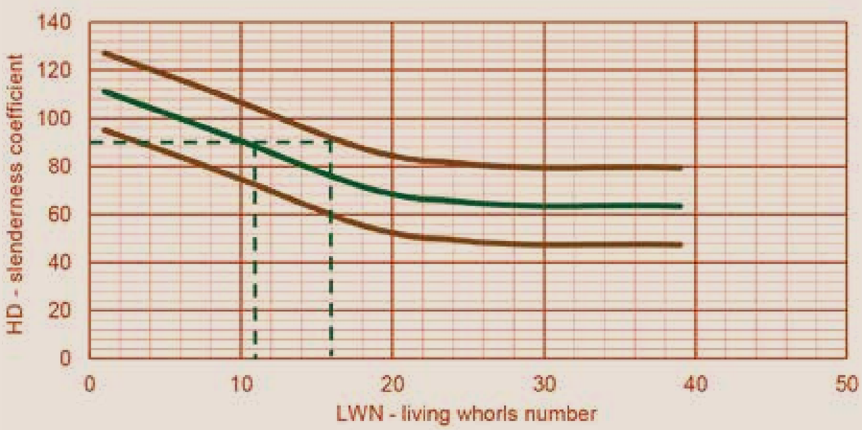


Figure 3.5 - Graphic representation of model (green line) and error (brown lines). The threshold values of LWN (conservative and non-conservative) are shown with dotted lines.

and encourage biodiversity at ground level, it is recommended to harvest even the dominated trees near the candidate tree.

The harvest of competitor trees is intended to release all candidate trees' crown creating discontinuity between the whole maximum crown width of each candidate tree and crown of its potential future competitor trees.

The forest stand fraction not directly affected to selective thinning can be treated alternately with two modality:

- to leave untouched all this stand fraction;
- to achieve moderate thinning from below.

Both modalities preserve the thinning efficacy from a technical point of view. It is, in fact, a harvest of a portion of dominated trees, which will not influence competitive relationships of dominant layer. However the choice of leave untouched all the stand fraction helps to more differentiate the structure (coexistence of dense stand areas and micro gap in canopy cover).

Treatments frequency

Later thinning will be repeated when the candidate trees' crown will come in contact with their direct competitors.

The time between a treatment and the next one (treatments frequency) depends on several factors:

The selective thinning determines the rid of candidate trees' crown. All direct competitor trees are removed.

The tree marking in selective thinning involves the following steps:
A) identification of candidate trees (tree with blue ring);
B) identification of direct competitor (trees with red cross);
C) localized thinning in support of candidate trees.
The aim of thinning is to leave free space to the crowns of candidate trees. A new thinning should be made at the time when the candidate trees will have the canopy overlapping with that of competitor trees.

- the first selective thinning intensity. The time between a treatment and the next one is directly related to the intensity of first treatment (and therefore the distance between the crowns created after thinning);
- the stand development stage. The most reactive capability of trees growth in juvenile stages suggests an higher frequency among treatments if the first selective thinning was performed during pole stage/young high forest;
- the site fertility (correlation inverse between degree of fertility and treatments frequency).

Thinning procedures after the first selective treatment

Thinning after the first treatment conceptually follow those already seen for the first treatment.

Key point is always to act in order to rid the candidate trees' crown of near competitors for light with the first thinning.

Operatively, candidate trees, will be recognized from their ring around the stem, made with indelible paint at the stage of first selective marking. In the case of tree mortality, or damage, among the candidate trees they can be (if necessary) replace with another adjacent vigour tree.

3.5 DISCUSSION

In our opinion, the silvicultural method proposed shows the following strengths:

- it is designed starting from the analysis of the current structure of artificial black pine forests in Apennines (mostly young high forest whose density depends on self-thinning);
- it is a thinning system of simple application and easily reproducible;
- it is a method rather flexible, even with the necessary stiffness of application for certain parameters (limit of a maximum candidate trees number and, above all, the importance of selecting good candidate with good physical and biological characteristics);
- it is a method that facilitate evaluation check of treatments (the indelible marking of candidate trees guarantees ex post monitoring on the goodness of the selection made);
- it stimulates the short-term increase of stand mechanical stability;
- it ensures a higher yield in terms of timber harvested, both in terms of quality of the assortments obtained;
- it increases diversity of horizontal and vertical structures at stands level;
- it increases diversity of microenvironments and therefore biological diversity at ground level;
- it makes more flexible the choice of the various management options for the regeneration/succession of pine forests.

In this treatment type cannot be elude marking phase, for which it is assumed a sufficient technical preparation. However, many previous experience of method dissemination to technical operators encourage us about its effective replication.

The technical time for the selective thinning do not affected stretches than those required to customary marking from below. If you decide to leave untouched the stand fraction, not subordinate to selective treatment, the time for candidate trees selection marking is compensated by the absence of marking in the other stand fraction.

The harvest of competitor trees requires greater technical expertise by operators, compared to thinning from below, because:

- the harvested trees are larger, on average, than those cut with thinning from below;

- It is necessary to prevent crown damage to candidate trees during the felling of competitors.

The average distance of 10 metres between the candidate trees is generally enough to avoid obstruction during logs extraction; only locally the regular candidate trees distribution on the ground would necessitate to arrange extraction racks not perfectly straight.

The micro gaps, i.e. spaces open at the canopy level, determines a variability of the microclimate at ground level with benefits for biodiversity.

Bibliography

Bernetti G., Cantiani M., Hellrigl B., 1969 - **Ricerche alsometriche e dendrometriche sulle pinete di pino nero e laricio della Toscana.** L'Italia Forestale e Montana, 1: 10-41.

Bianchi L., Paci M., Bresciani A., 2010 - **Effetti del diradamento in parcelle sperimentali di pino nero in Casentino (AR): risultati a otto anni dall'intervento.** Forest@ 7: 73-83.

Cantiani P., 2012 - **Pinete di pino nero in Toscana. Note sul trattamento in ordine alle normative vigenti.** Sherwood n. 184: 15-19.

Cantiani P., Piovosi M., 2009 - **La gestione dei rimboschimenti di pino nero appenninici. I diradamenti nella strategia di rinaturalizzazione.** Annali CRA-SEL, 35:35-42.

Cantiani P., Chiavetta U., 2015 - **Estimating the mechanical stability of Pinus nigra Arn. using an alternative approach across several plantations in central Italy.** iForest (early view): e1-e7 ***www.sisef.it/iforest/contents/?id=ifor1300007***

Cantiani P, Chiavetta U., Marchi M., 2015 - **Valutazione in bosco della stabilità di piante di pino nero. Il metodo speditivo della conta dei palchi vivi.** Sherwood 215: 5 - 8.

Piussi P., Alberti G., 2015 - **Selvicoltura generale-Boschi, società e tecniche colturali.** Scienze Forestali e Ambientali. Compagnia delle Foreste. 434 pp.

Serrada R., Montero G., Reque J.A., 2008 - **Compendio de Selvicultura Aplicada en España.** Publisher: Mº Educación y Ciencia / Fund. Conde del Valle Salazar, 1178 pp,

4

STUDIES OF THE EFFECTS OF THINNING ON UNDERGROWTH AND SOIL

Forest planning has historically focused on timber production, but globalization of the wood market and the concerns related to the protection of ecosystems have increased the importance of other organisms present in the forest (Bonet *et al*. 2010). That is why today we look for forest management tools designed to safeguard and implement not only the wood production, as a resource to be exploited, but also the presence of all the other organisms.

The direct economic benefits of some forest stands like those of *Pinus nigra* J.F. Arnold is scarce for the low value of the productions obtained, so that the active management of these formations is generally episodic and limited mainly to site with good accessibility, where costs for silviculture are reduced and where it is possible to adopt a higher degree of mechanization. On the other hand the pine forests provide quite well the optimal protective action for which they were established. But the strong public investment for their plantation and maintenance can be vanished by the absence or incorrect execution of tending operations. The project, in this context, aims at preserving and increasing, through a new silvicultural approach, forest biodiversity in artificial stands of black pine.

In particular, it evaluates the effect of using selective thinning in place of standard options (thinning from below) and no treatment on pine stands in their juvenile stage.

Here is shown how this management technique, by changing horizontally and vertically the structural diversity of forest stand, determines a different regime of light, water and temperature at ground level, enhances biodiversity and overall functionality of the ecosystem (thereby increasing economic, touristic and hydrogeological protection value). The following chapter will briefly describe the methods of survey and measure, to demonstrate the positive impact of the proposed treatment on biodiversity and soil quality.

4.1 EFFECT OF THINNING ON FLORISTIC DIVERSITY

Elisa Bianchetto, Isaac Sanz Canencia

Differents criteria are available to assess diversity of a plant community.

The assessment of the number of species in a community represents the species Richness, while the distribution of the individual among occurring species of the community represents the Eveness. Biodiversity of a community is not only determined by the number of species, but also by their distribution. It could happen that a community with a greater number of species but with only 2 or 3 dominant species presents a reduced biodiversity is less biodiverse than a community with a lower number of species with a more uniform distribution.

Which are the factors determining variations in species composition of a plant community?

An undisturbed forest stand follows the mechanisms and the rhythms of the natural evolution, which affects species composition and spatial structure of the vegetation. The acceleration of the processes of change in forest stands could be determined both by natural phenomena, such as climatic events, fires, phytosanitary problems, and by anthropic ones, such as forest management, like silvicultural treatments, harvesting and so on.

These phenomena could induce the reduction of the forest cover and different processes influencing vegetation may occur. These processes could be natural vegetation successions or variations in the species composition of the forest understory. The variations of the plant communities can affect or number or kind of the community's species. In fact herbaceous species typical of other habitats can spread, particularly coming from open areas of non-forest habitats.

Cephalanthera damasonium (Mill.) orchid is common in pine stands

Thinning of forest stands can result in the reduction of the forest cover and, consequently, in the change of the environmental conditions. In particular light quantity, temperature and soil moisture are affected (Mattioli *et al.* 2008).

The effects on soil and forest biodiversity components of two different methods of thinning are compared in the Project. With thinning the areas interested by the harvesting operations are characterized by different environmental conditions of lights, temperature and soil moisture, according to the type of intervention.

After thinning an increase of the floristic diversity is expected, due to the higher quantity of light that reaches the soil, thus fostering the spread of heliophilous species and in general of species typical of non-forest habitats (Baragatti *et al*. 2004, Riondato *et al.* 2005). The forest cover is determinant for the persistence of these species. In fact, the clearings created at time of thinning tend to be reduced by increase of forest cover in the years after the intervention.

In literature there are studies reporting the effect of the thinning on the increase of the species of the understorey and their persistence in the time. These studies give information on the possibility of planning the silvicultural treatments according not only with the production targets but also with ecological aspects related to biodiversity (Carey 2003).

METHOD

In each study area 27 permanent plots with a radius of 10 m were identified for the three treatments (selective, traditional, control). In each plot, floristic diversity is sampled every year during spring and summer when vegetation is flowering and species identification is easier.

Data collection: phytosociological method (Braun Blanquet 1932)
Description of the vegetation cover:
- Estimation at soil level of the percentage of the projected cover of the total vegetation;
- Estimation at soil level of the percentage of the projected cover of the woody component;
- Estimation at soil level of the percentage of the projected cover of the herbaceous component.

Afterwards, according to the Braun Blanquet method, in each plot the floristic list of the species is made and a value of cover is assigned to each species through a visual estimation.

Advantages
- Rapidity of the technique;
- Simplicity of the procedure.

Disadvantages
- Risk of subjectivity due to visual estimation;

After data collection and elaboration, the vegetation is characterized and biodiversity indices calculated. In this way the variations of vegetation composition after thinning will be assessed.

Bibliography

Baragatti E., Frati L., Chiarucci A., 2004 - **Cambiamenti nella diversità della vegetazione in seguito a diversi tipi di matricinatura in boschi di cerro.** Annali Istituto Sperimentale per la Selvicoltura. n. 33, 39-50.

Braun-Blanquet J., 1932 - **Plant Sociology: The Study of Plant Communities (English translation).** McGraw Hill, New York.

Carey A.B., 2003 - **Biocomplexity and restoration of biodiversity in temperate coniferous forest: inducing spatial heterogeneity with variable-density thinning.** Forestry, Vol. 76, No. 2, 2003, 127-136.

Mattioli W., Pinelli A., Filibeck G., Portoghesi L., Scoppola A., Corona P., 2008 - **Relazioni tra gestione selvicolturale, tipo forestale e diversità floristica in cedui castanili.** Forest@ n. 5, 136-150.

Riondato R., Colpi C., Del Favero R., 2005 - **Indicatori di biodiversità in ostrio-querceti cedui di diversa età sui Colli Euganei (PD).** L'Italia Forestale e Montana 65 (4), 405-427.

4.2 EFFECTS OF THINNIG ON FUNGAL DIVERSITY

Elena Salerni

4.2.1 Macrofungal communities

Macrofungi have spore-bearing structures: mushrooms, brackets, puffballs, false-truffles, cup fungi, etc. and are large enough to be seen with the naked eye (> 1 mm) and to be picked up by hand (Arnolds 1981, Chang and Miles 1992, Mueller *et al*. 2007).

Most terrestrial macrofungi are saprobes. Saprotrophic mushrooms play an important role in the cycling of carbon and other elements through the breakdown of lignocellulosic plant residues and animal dung, whereas mycorrhizal mushrooms are involved in symbiotic associations with plant roots. Fungi fruiting on woody substrata are usually either saprobes or plant pathogens (Mueller *et al*. 2007, Savoie and Largeteau 2011).

The importance of forests management for mushroom production, the so called myco-silviculture, is increasing in Europe (Bonet *et al.* 2010, Egli *et al*. 2010, Garcia-Barreda and Reyna 2012, 2013, Martinez De Aragón *et al.* 2012, Pilz *et al.* 2006, Rineau *et al.* 2010, Salerni and Perini 2004, 2010, Smit *et al.* 2003, Wang and Hall 2004).

Our results support the hypothesis that fruit body production might be coupled with the physiological status of the associated tree. This means that after thinning treatments, strongly growing trees with a high photosynthetic capacity tend to produce more ectomycorrhizal fruit bodies and simultaneously also the fruit body production of not-mycorrhizal species increase.

Mycocoenological analyses: harvest of all fruit bodies visible to naked eye (> 1 mm).

Species divisions for biomass calculation.

METHOD

According to the method described in Arnolds (1981), mycocoenological observations before and after the silvicultural treatments were made to characterize the macrofungal community. In autumn, when climatic conditions are generally optimal for fungal fruiting in our areas, periodic excursions were organized and all epigeous fruit bodies were registered and counted in 54 plot (27 in Pratomagno area and 27 in Amiata area). Species identification was performed with the usual morphological techniques and employing general analytic keys and monographs. At each sampling for each species fresh and dry weight was also detected in order to have the fungal biomass.

Finally following information will be obtained:

- specific composition;
- number of species;
- abundance (number of fruit bodies);
- trophic group;
- fresh and dry weight;
- biodiversity indices.

Bibliography

Arnolds E., 1981 - **Ecology and coenology of macrofungi in grassland and moist heathland in Drenthe, the Netherlands.** In vol. 83 of Biblioteca Mycologica 407 pp.

Bonet J.A., Palahi M., Colinas C., Pukkala T., Fischer C.R., Miina J., Martinez de Aragón, 2010 - **Modelling the production and species richness of wild mushrooms in pine forests of the Central Pyrenees in northeastern Spain.** Can. J. For. Res. 40: 347-356.

Chang S.T., Miles P.G., 1992 - **Mushroom biology, a new discipline.** Mycologist 6:64-65.

Egli S., Ayer F., Peter M., Eilmann B., Rigling A., 2010 - **Is forests mushroom productivity driven by tree growth? Results from a thinning experiment.** Ann For Sci 67:509p1-509p9.

Garcia-Barreda S., Reyna S., 2012 - **Below-ground ectomycorrhizal community in natural *Tuber melamosporum* truffle grounds and dynamics after canopy opening.** Mycorrhiza, 22: 361-369.

Garcia-Barreda S., Reyna S., 2013 - **Response of *Tuber melanosporum* fruiting to canopy opening in a Pinus-Quercus forest.** Ecological Engineering, 53: 54-60.

Martinez de Aragón J., Fischer C., Bonet A.J., Olivera A., Oliach D., Colinas C., 2012 - **Economically profitable post fire restoration with black truffle (*Tuber melanosporum*) producing plantations.** New Forest, 43: 615-630.

Mueller G.M., Schmit J.P., Leacock P.R., Buyck B., Cifuentes J., Desjardin D.E., Halling R.E., Hjortstam K., Iturriaga T., Larsson K.-H., Lodge D.J., May T.W., Minter D., Rajchenberg M., Redhead S.A., Ryvarden L., Trappe J.M., Watling R., Wu Q., 2007 - **Global diversity and distribution of macrofungi.** Biodivers. Conserv.. 16: 37-48.

Pilz D., Molina R., Mayo J., 2006 - **Effects of thinning young forests on chanterelle mushroom production.** J Forest 104:9-14.

Rineau F., Maurice J.P., Nys C., Voiry H., Garbaye J., 2010 - **Forest liming durably impact the communities of ectomycorrhizas and fungal epigeous fruiting bodies.** Ann For Sci 67:110.

Salerni E., Perini C., 2004 - **Experimental study for increasing productivity of *Boletus edulis* s.l. in Italy.** For Ecol Manag. 201:161-170.

Salerni E., Perini C., 2010 - **Macrofungal communities in Italian fir woods - short-term effects of silviculture and its implications for conservation.** Cryptogamie, Mycologie 31(3):251-283.

Savoie J.M., Largeteau M.L., 2011 - **Production of edible mushrooms in forests: trends in development of a mycosilviculture.** Appl. Microbiol. Biotechnol., 89: 971-979.

Smit E., Veenman C., Baar J., 2003 - **Molecular analysis of ectomycorrhizal basidiomycete communities in a *Pinus sylvestris* L. stand reveals long-term increased diversity after removal of litter and humus layers.** FEMS Microbiol Ecol 45:49-57.

Wang Y., Hall I.R., 2004 - **Edible ectomycorrhizal mushrooms: challenges and achievements.** Can J Bot 82:1063-1073.

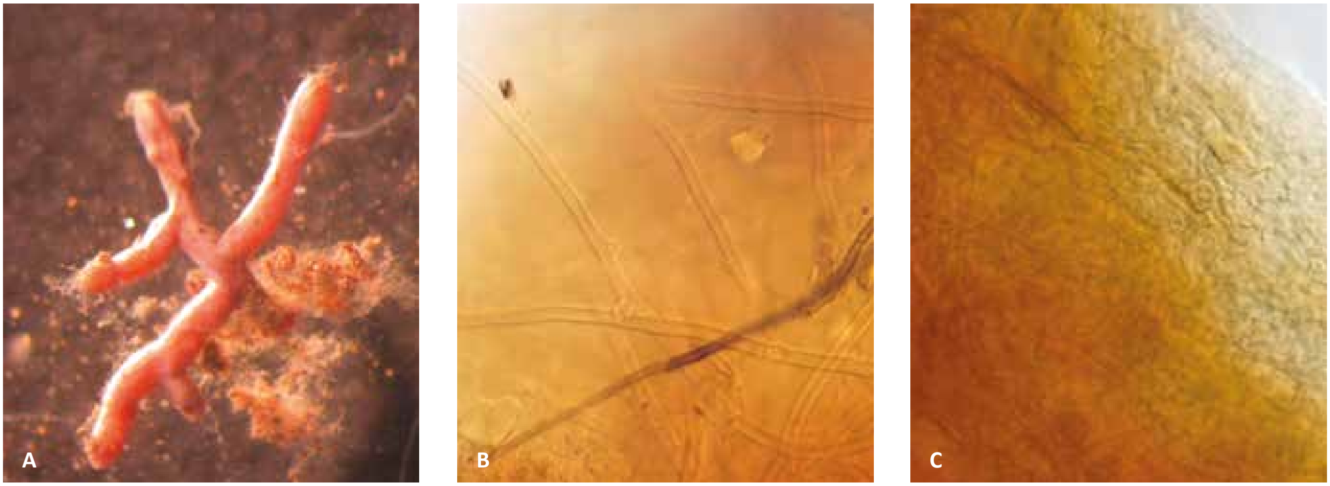
4.2.2 Ectomycorrhizal communities

About 6,000 and 25,000 fungal and plant species respectively are able to form ectomycorrhiza (ECM) and dominate all forest habitats (Brundrett 2009, Rinaldi *et al*. 2008). In a single forest, several ECM fungal species are present, many of which share the same plant, and even the same root.

Among these fungi a relationship of mutual competition is established to reach first young roots and the "winner" is the one that best adapts to particular soil conditions. Temporal changes of some biotic and abiotic variables can cause changes in species composition and therefor ECM communities are extremely dynamic. An underground network exists, partially still mysterious, that allows a kind of communication and transfer of energy and nutrients. This allows the appearance of fruit bodies of the ECM involved (Rayner 1998) …

The knowledge of fungal community is the first step to understand the relationship between plants and fungi and the effect of various variables that influence it.

mycorrhizal root tips sampling (ECM).



Inocybe pseudorubens: (A) Stereo microscope view of ECM. (B) Optical microscope view of hyphae. (C) Optical microscope view of mantle.

METHOD

Soil cores of 30 cm in length and 6 cm in diameter were collected in 54 plot (27 in Pratomagno area and 27 in Amiata area) before and after the silvicultural treatments. Anatomical structures of the mantles, external elements (hyphae, rhizomorphs, and cystidia), and longitudinal and cross-sections of each morphotype were examined under a stereo microscope (x12) and described according to Agerer (1991, 1987-2008).
ECM tips of each morphotype were counted and morphotypes were molecularly identified using a direct PCR approach as described by Iotti and Zambonelli (2006).

From the data elaboration will be obtained:

- Morphotype differentiation
- specific composition;
- abundance of each species (i)

$$i=(x_i/n)*100,$$

n= number of mycorrhizae or clones

x_i= number of mycorrhizae/clone of species (i)

- biodiversity indices.

Bibliography

Agerer R., 1987-2002 - **Colour Atlas of Ectomycorrhizas.** Einhorn-Verlag, Schwäbisch Gmünd.

Agerer R., 1991 - **Characterization of ectomycorrhiza.** In: Norris J.R., Read DJ, Varma A (eds.), Techniques for the study of mycorrhiza. Methods in microbiology, vol 23. Academic Press, London, pp. 25-73.

Brundrett M.C., 2009 - **Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis.** Plant and Soil, 320:37-77.

Iotti M., Zambonelli A., 2006 - **A quick and precise technique for identifying ectomycorrhizas by PCR.** Mycological Research 110: 60-65.

Rayner A.D.M., 1998 - **Fountains of the forest - The interconnectedness between trees and fungi.** Mycological Research, 102:1441-1449.

Rinaldi A. C., Comandini O., Kuyper T.W., 2008 - **Ectomycorrhizal fungal diversity: separating the whet from chaff.** Fungal Diversity, 33:1-45.

4.3 EFFECT OF THINNING ON MACROFAUNA'S DIVERSITY

Gianni Bettini

To international level, the Carabids are considered an important group of bioindicators very reliable and also they constitutes an index that allows to assess the health of the environment. The beetles Carabidae are widely used for the evaluation and monitoring of environmental changes in relation to changes occurring in habitats and landscapes.

In Italy there are 1,300 species of Coleoptera Carabidae which are not homogeneously distributed in different biomes that compose the Biosphere and in particular of the plant cover of the country.

The Beetles Carabidae are epigeal geophilic Insects whose spatial distribution and whose morphological and ecological characters (eg. : the wing morphology, diet and body length) are strongly influenced by physical and chemical parameters (eg .: temperature, humidity, pH, metal concentration), this fact makes them indicators of the effects of environmental changes (eg. soil heating, management and pollution) on soils and types of humus. The decline of that Carabid's biodiversity has had in the last century in Europe and the role which these beetles have as predators and preys of many vertebrates, prioritizes the knowledge of their spatial distribution in relation to human activities.

It is now established that the wings of the Carabid have the tendency to be reduced and to become rudimentary in stable environments, infact the carabidocenosi respond to growing of the environmental instability by increasing the percentage of Macropterous and Pteridimorphic species with larger wings and higher dispersive power. The largest number of Micropterous and forestry species are present in mature sites with tall trees which have not undergone coppicing for several years .

Stages of preparation of pitfall traps in the areas of study of the Project LIFE. In particular the detail of the trap.

The predatory and large species with short wings, are related to more mature stages of the vegetation and soil, which are less perturbed and present the most trophic availability. In the more disturbed habitats appear a large number of species with generalist diet, fully developed wings and reduced body size.

For this reason it was decided to select these indicators for biodiversity soil monitoring before and after the silvicultural treatment in the Project SelPiBioLife.

Surveying in the field and analysis of the carabidofauna diversity began in June 2015, and has consisted in setting up 108 falls pit traps (54 traps for each plot in two areas: Pratomagno and Amiata). In Mediterranean environments the sampling period could last all year, but the activity of ground beetles is still concentrated in the spring or autumn, so we repeated the samples in June and October in the two areas. The pit falls have been placed near the center of the sampling units.

During the project, biological forms of the species were analyzed because this fact shows us the way to feed is in relationship with the favorite habitat (mature woodland, open environment).

The community of Coletteri Carabid was analyzed on the relationship between species “non fliers” and species capable of flying (Macropterous + Pteridimorphic) because this type of evaluation allows us to understand the variation of leakage power along the most important ecological gradients of study’s area.


A


B


C

A) *Percus passerinii*, italian endemism of the central-northern Apennine, mountainous and forestry specie, micropterous.
B) *Nebria tibialis subcontracta* Apennine endemic specie, micropterous.
C) *Abax parallelepipedus* (= *ater*) Element forestry micropterous.

METHOD

The methodology involves the use of pitfall traps (pitfall-traps) (Greenslade 1964, Adis 1979, Van Den Berghe 1992) for the capture of Coleoptera Carabidae. They are constituted by plastic glasses (height 12 cms and diameter to the mouth 8,5 cms) buried up to the edge and containers a saturated solution of chloride of sodium in vinegar of wine and little alcohol to 95% for the maintenance of the champions.
In order to protect the traps on rainfall, from the foliage and the disturbance of animals, each beaker was covered with stones. The collection of material falling into the traps was carried out at intervals of 10-15 days during the season of activity of Coleoptera Carabidae. The material falling into the trap is collected in the field and separated from the liquid (rainwater and vinegar solution) through a fine mesh strainer (about 0.75 mm), and introduced into suitable plastic containers. The containers, numbered on the basis of the plot (1 to 9), are equipped with double closing cap. In containers it was added pure alcohol at 95% to conserve the collected material until the time of the analisys.
Through this analysis we perceive changes in the degree of soil biodiversity mesofauna because Carabidae beetles are predators and therefore important representatives of this component.

Bibliography

Adis J., 1979 - **Problems of interpreting arthropod sampling with pitfall traps.** Zool. Anz. 202: 177-184.

Brandmayr P., 1980 - **Entomocenosi come indicatori delle modificazioni antropiche del paesaggio e pianificazioni del territorio: esempi basati sullo studio di popolamenti a Coleotteri Carabidi.** Atti del XII Congr.Naz.Ital.Entomol. Roma : 263-283.

Brandmayr P., Zetto T., Colombetta G., Mazzei A., Scalercio S., Pizzolotto R., 2002 - **I Coleotteri Carabidi come indicatori predittivi dei cambiamenti dell’ambiente: clima e disturbo antropico.** Atti XIX Congresso nazionale italiano di Entomologia Catania 10-15 giugno 2002: 283-295

Gobbi M., Rossaro B., Vater A., De Bernardi F., Pelfini M., Brandmayr P., 2007 - **Environmental features influencing Carabid beetle (Coleoptera) assemblages along a recently deglaciated area in the Alpine region.** Ecol. Entom., 32: 282-289.

Greenslade P.J.M., 1964 - **Pitfall trapping as a method for studying populations of Carabidae (*Coleoptera*).** J. unim. Ecol. 33: 301-310.

Van den Berghe E., 1992 - **On pitfall trapping invertebrates.** Entomol. News. 103, 149-156.

4.4 EFFECT OF THINNING ON THE SOIL MESOFAUNA

Silvia Landi, Giuseppe Mazza, Giada d'Errico, Giulia Torrini, Pio Federico Roversi

The litter and forest soil are important for several processes of recycling of materials and nutrients and they are the major animal biodiversity reservoirs, in particular for Arthropoda and Nematoda. The soil arthropods significantly contribute to the destruction of the organic matter, feeding on plant tissues and/or dead animals. Furthermore, they contribute to the formation of humic substances and aggregate complexes of organic matter with mineral elements of the soil. Nematodes are the most numerous multicellular animals on the earth and their communities in the soil play key roles in the regulation of microbial and arthropods populations. Thus, micro-arthropods and nematodes provide complex and synergistic interactions with various trophic levels, participating to the delicate system for the maintenance of homeostatic capacity and for the productive capacity of forest ecosystems (Roversi and Nannelli 2012).

For these reasons, it is pivotal the role played by the soil mesofauna to evaluate the impact of the different forestal practices. In the past, soil mesofauna was not considered in depth because of the lack of standardized methods of sampling and taxonomic/identification problems. Nowadays, thanks to the consciousness of the importance of these two phyla, their abundance in the soil, their capacity to reply quickly time to several disturbance factors, nematodes and microarthropods are used as valid tools to determine the impact of several human activities on the soil ecosystem.

Soil quality is, for example, estimated using the QBS-ar index (Parisi *et al*. 2005). The QBS-ar index is based on the following concept: the higher the soil quality, the higher will be the number of micro-arthropod groups which are well adapted to soil habitats. QBS-ar is applied to soil micro-arthropods, separated according to the biological form approach with the aim of (1) evaluating the microarthropods' level of adaptation to life in the soil environ-

Soil nematode sampling by corer and nematode extraction by modified Baermann method.

Microarthropods extraction by modified Berlese-Tullgren funnels.

ment and (2) overcoming the well-known difficulties of taxonomic analysis to species level for soil mesofauna. Edaphic micro-arthropods show morphological characteristics that give evidence of adaptation to soil environments, such as reduction or loss of flying, jumping or running adaptations, thinner cuticle for reduced water-retention capacity.

Since the soil nematode assemblages are abundant, diverse and contribute to soil nutrient turnover, they have been increasingly used as indicators of soil condition, in particular valid tools are: Maturity Index (MI), an ecological measure of environmental disturbance based on nematode species composition (Bongers 1989) and Ferris indices based on trophic levels and food web system (Ferris *et al*. 2001). MI is calculated as the sum of the weighted relative abundance of families classified in the *cp* scale for free-living and plant parasitic nematodes (*c*, colonizer nematodes *r* strategy; *p*, persister nematodes *k* strategy), while Ferris indicators add information on functional guilds to develop food web.

The thinning of forest stands is largely used for keeping optimal lighting conditions and to ensure the roots room enough for the needs of water and nutrients. While the effects of these practices have been widely investigated with reference to the productivity, few studies are available in terms of their impact on soil animal biodiversity. Huhta *et al*. (1967) carried out a study in pinewood stand in Finland. They supposed that the effects were basically the same of those resulting from clear-cutting, but much milder. A remarkable decrease of the densities of Nematoda, Collembola and Coleoptera was found. The causes can be mainly three: felling residues, climatic conditions and vegetation changing. The felling residues are rather small in amount and it is probable that changes in both litter layer and in the soil structure as a whole were not very marked. On the contrary, a greater effect is produced by the changes in the microclimatic conditions. As a result of thinning the soil remains exposed to the changes in light, moisture and temperature. The shelter and food afforded by the litter soon disappeared and the climatic extreme is more accentuated by lack of the closed canopy. Moreover, the development of the herb and grass vegetation progresses and the roots begin to fill the uppermost layer of the soil.

Soil microarthropods.

About forty years ago, along the Apennine ridge, a reforestation with black pines was made to provide a first coverage with pioneer species in degraded areas with an extremely risk of erosion. The selective cutting, performed in the spring 2015, amended the rate of light and the temperature at ground level. In the following three years, the monitoring of both sites will be performed in order to investigate the changes in the composition of micro-arthropods and nematodes.



Soil nematodes.

Bibliography

Bongers T., 1990 - **The maturity index - an ecological measure of environmental disturbance based on nematode species composition.** Oecologia 83: 14-19.

Ferris H., Bongers T., de Goede R.G.M., 2001 - **A framework for soil food web diagnostics: extension of the nematode faunal analysis concept.** Appl. Soil Ecol., 18: 13-29.

Huhta V., Karpinen E., Nurminen M., Valpas A., 1967 - **Effect of silvicultural practices upon arthropod, annelid and nematode populations in coniferous forest soil.** Annales Zoologici Fennici, 4: 89-145.

Parisi V., Menta C., Gardi C., Jacomini C., Mozzanica E., 2005 - **Microarthropod communities as a tool to assess soil quality and biodiversity: a new approach in Italy.** Agr Ecosys. Environ., 105: 323-333.

Roversi P.F., Nannelli R., 2012 - **Arthropods and nematodes: functional biodiversity in forest ecosystems.** In: Forest Ecosystems more than just trees, Edited by Juan A. Blanco and Yueh-Hsin Lo, INTECH, pp. 29-52.

METHOD

MICRO-ARTHROPODS

- Collection of soil sample (10 cm cube) by means of a special corer devoted to the mesofauna sampling.
- Micro-arthropods extraction from the soil samples using modified Berlese-Tullgren funnels following the Standard methodology (Parisi *et al.*, 2005).
- Micro-arthropods observation at the stereomicroscope and classification at level order.
- Edaphic micro-arthropods community characterization using: individual abundance/m2; richness determined by counting the number of taxa; Acarina and Collembola ratio (A/C); QBS-ar index according to Parisi *et al.* (2005). This index is based on the life-form approach and its values are the summa of EMI (Eco- Morphological Index) scores, ranging between 1 and 20 for each organism depending on the adaptation to the edaphic habitat.

NEMATODES

- Collection of soil samples (0-15 cm depth) by means of a special corer devoted to the nematofauna sampling.
- Samples homogenization.
- Nematodes extraction from 100 ml of soil with a Baermann Funnel for 48 hours.
- Nematodes observation at microscope and classified at family level.
- nematofauna characterization using: individual abundance / 100 ml of soil; taxa richness;
- qualitative indices such as Maturity Index (MI), Plant Parasitic Index (PPI), Basal Index (BI), Enrichment Index (EI), Structure Index (SI), Channel Index (CI).

4.5 THE EFFECTS OF SELECTIVE THINNING ON SOIL MICROBIAL DIVERSITY

Stefano Mocali, Arturo Fabiani, Carolina Chiellini, Fabrizio Butti

Ecological theories in biological diversity study (biodiversity) have been developed mainly for the ecosystems present on the soil surface, overlooking for a long time all those life forms that are present inside it, in particular microorganisms, and which represents a huge amount of "invisible life" essential for all life on earth (Wardle e Giller 1996). In fact, soil microbial community represents the most relevant part of soil biomass, and it is the component that most affects soil biological properties by driving all biochemical processes that determine the soil nutritional properties fundamental for plants (Nannipieri *et al.* 2003). Microorganisms, in fact, play a relevant role in the organic matter mineralization, nitrogen synthesis, humus formation and contribute to the mobilization of mineral elements and the maintenance of soil fertility. Moreover, it must be underlined the relationships that microorganisms establish with plants at rhizospheric, phyllospheric and spermospheric level and also in the mycorrhizal symbiosis. Therefore microorganisms represent a principal component of soil fertility and play a irreplaceable role, failing which the soil would simply represent an inert mechanical support. Microbial diversity is then a key element for the maintenance of an healthy status for soil and ecosystem (Borneman 1996). Furthermore, many microbial communities can maintain the same composition but modifying some metabolic processes with consequences at both functional and ecological level. Thus, the concept of "functional diversity" of soil microorganisms should be introduced.

Since the number of microorganisms present within soil and the relative abundance of each microbial group greatly differs either between different soils or in relation to environmental conditions in general, they can be used as excellent "bioindicators" for soil quality (Bloem *et al.* 2006). They, in fact, carry out some key functions in degradation and turnover of organic matter and nutrients, responding promptly to changes in the soil environment. One of the main soil components that affects the growth of microorganisms and, consequently of soil fertility, is organic matter which is the source of essential energy for microbial community development. Organic matter is then a very important parameter for soil biological fertility because it contributes not only to humus formation but also to the formation of specific microbial substances and to their metabolism. Biological fertility with chemical and physical fertility constitutes the agronomic fertility that determines the productivity. However, fertility is not synonymous of productivity because the first one depends from soil while the second one both from soil and plant. Soil productivity is strictly related, in fact, to the concept of "quality": "The capacity of soil to interact with ecosystem to maintain the biological productivity, the environmental quality and to promotes the animal and plant health".

What kind of effects can have temperature and soil moisture?

It is well known that pedoclimatic conditions significantly influence genetic biodiversity but - especially - functional biodiversity of soil. It has been observed how microbial activity decreases either with the temperature or with water deficiency (Papatheodorou et al. 2004). Therefore, after the silvicultural treatment, the reduced canopy of the pine forest leads to an increase of light (and then temperature) and water at soil level. Consequently, microbial biodiversity should take a general benefit, increasing both in absolute terms and in metabolic activity. To avoid the seasonal effects due to very low temperature (winter) and very hot (summer), the soil sampling is realized in spring.

Soil sampling from the top layer (0-20cm).

Bibliography

ALEF K., NANNIPIERI P., 1995 - (eds) **Methods in Applied Soil Microbiology and Biochemistry.** Academic Press, London.

BLOEM J., BENEDETTI A., HOPKINS D.W., 2006 - **(eds) Microbiological Methods for Assessing Soil Quality.** CABI, Wallingford, UK, pp. 23-49.

BORNEMAN J., SKROCH P.W., O'SULLIVAN K.M., PALUS J.A., RUMJANEK N.G., JANSEN J.L., NIENHUIS J., TRIPLETT E.W., 1996 - **Molecular microbial diversity of an agricultural soil in Wisconsin.** Appl. Environ. Microbiol. 62: 1935-1943

DORAN J.W., PARKIN T.B., 1994 - **Defining and assessing soil quality.** In: J.W. DORAN, D.C. COLEMAN, D.F. BEZDICEK, B.A. STEWART (Eds.), Defining Soil Quality for a Sustainable Environment, Soil Sci. Soc. Am., Spec. Pub. No. 35 (1994) Madison, WI

NANNIPIERI P., ASCHER J., CECCHERINI M.T., LANDI L., PIETRAMELLARA G., RENELLA G., 2003 - **Microbial diversity and soil functions. Europ.** Journal of Soil Science, 54, Iss. 4: 655-670.

PAPATHEODOROU E.M., ARGYROPOULOU M.D., STAMOU G.P., 2004 - **The effects of large- and small-scale differences in soil temperature and moisture on bacterial functional diversity and the community of bacterivorous nematodes.** Appl. Soil Ecol., 25, Issue 1: 37-49.

VANCE E.D., BROOKES P.C., JENKINSON D.S., 1987 - **An extraction method for measuring soil microbial biomass C.** Soil Biol. Biochem. 19, N.6: 703-707.

WARDLE D.A., GILLER K.E., 1996 - **The quest for a contemporary ecological dimension to soil biology.** Soil Biol. Biochem., 28, No. 12: 1549-1554.

Morphological analysis of the bacterial colonies isolated from soil.

METHOD

The study of microorganisms require different instruments and methods compared to those used for the study of higher organisms. In fact, it is relatively easy to count and classify plants and animals on the basis of parameters easily identified without the requirement of instruments. On the other hand, it becomes more difficult to observe and catalog thousands of organisms that, despite their high number, are not visible to the naked eye (the average size of bacteria are in fact about one millionth of a meter) and required the use of sophisticated instruments and technology.

DNA massive sequencing (Next Generation Sequencing - NGS)

The starting point of molecular analysis is the direct extraction of DNA from soil, performed for all samples using the commercial kit "FastDNA™ SPIN Kit for Soil" (MP Biomedicals) which provides for the extraction of the DNA from 0,5 g of 2 mm sieved soil. The DNA obtained from the extraction was then quantified and sent to a specialized company to perform the massive sequencing (NGS). From the data obtained with this kind of analysis it is possible to characterize the composition of microbial community (bacterial and fungal) of analyzed soils and, comparing data from different plots, to evaluate the effects of different treatments.

Biochemical analysis

To obtain quantitative and qualitative data of the entire microbial community, the following biochemical analysis were performed: determination of microbial respiration (ALEF 1995 method) and microbial biomass (VANCE *et al.* 1987 method). From the data obtained with this kind of analysis it is possible to evaluate the physiological status and the relative abundance of soil microbial community in relation to the quality of organic matter present in soil.

4.6 EFFECTS OF THINNINGS ON DEADWOOD COMPONENT

Isabella De Meo, Anna Graziani

What is the deadwood component? According to the definition of the Global Forest Resources Assessment 2005, deadwood is the all non living woody biomass both standing or lying on the soil and included in it, but not classified as litter. In this defined group we include whole dead trees, woody debris lying on the ground, dead roots and stumps, over a minimum size threshold (FAO 2004).

The presence of deadwood in forest has had different roles during time, due to the evolution of the forest management concept. In particular, until few decades ago, the presence of deadwood in forests was considered a trouble and was seen as a sign of negligent silvicultural management. The presence of deadwood in forest, in fact, could favour pathogenic attacks and heighten fire risk as well as could have a negative aesthetical appeal (Camia *et al.* 2001, Morelli *et al.* 2007). Then, trough the development of Sustainable Forest Management (SFM) model, the deadwood performance in many positive forest ecosystem effects has been acknowledged. Some of them can be: conservation of biodiversity (deadwood provides microhabitats that are very important for saproxylic organisms, which, by themselves, represent about 30 % of forests biodiversity (Vallauri *et al*. 2005)), carbon storage (Laiho and Prescott 1999), keeping of soil fertility for natural forest rinnovation, soil protection and defense from hydrogeological risk (Hagan and Grove 1999). At present the quantity of deadwood is a SFM indicator ratified by European Interministerial Conference and its survey is included in national forest inventories (Pignatti *et al*. 2009).

In SelPiBioLife project, we study soil and vegetation biodiversity in *P.nigra* plantations in order to compare the effects of two silvicultural treatments (from-below thinning and selective thinning) among themselves and also with the absence of any treatment. Accordingly to this aim deadwood, which performs an important role in biodiversity safeguard, has been evalutated both in quantitative (mass volume, number of fragments and diametric class distribution) and qualitative term (species, when possible, and decay class). Then, together with other project partners, also fungal and microbial communities referred to the deadwood decay classes have been analyzed.

Deadwood highly decomposed.

Deadwood volume estimation using the LIS methodology.

METHOD

Deadwood survey has been realized in the two study areas of the SelPiBioLife Project, in 27 sample plots in each area, divided among tree different treatment hypotesis. The deadwood survey has been carried out before the thinning and, after it, repeated every year of the Project.
The used methodology is the Line Intersect Sampling (LIS) (Warren and Olsen 1964).
In each sample plot, have been set up two transects of 26 m, the first in direction North-South (N-S) passing through the center of the sample plot, and the second one in direction East-West (E-W), perpendicular to the first transect. For each deadwood piece intercepted by the two transects the following information have been be recorded:

- Two perpendicular diameters measured in the intersection point of the transect (cm);
- Species or, if not recognizable, the botanical category distinguishing between: “conifer” and “broadleaf”;
- Decay class considering five decay classes: recently dead, weakly decayed, medium decayed, very decayed and almost decomposed. The visual assessment of rates of decay has been executed by forest experts considering some key variables/visible characteristics: (1) structure of bark, (2) presence of small branches (diameter < 3 cm), (3) softness of wood; (4) other visible characteristics (rot extension and development of fungus mycelium);

The collected data in the field have been be used to calculate the lying deadwood volume (*V*) using the following algorithm by Van Wagner (1968):

$$V = (\pi^2/8 * L) * \Sigma d_i^2$$

Where:
V = volume (m^3/ha);
L = length of the two transect in meter;
d_i = diameter (mean of the two diameters) of the i intersection point (cm).

Advantages:

- the survey can be carried out with easiness and rapidity.

Disavantages:

- there may be the risk of underestimating or overestimating real deadwood volume

Bibliography

Camia A., Corona P., Marchetti M., 2001 - **Mappatura delle componenti ambientali predisponenti il rischio di incendi boschivi in Italia.** L’Italia Forestale e Montana 6: 455-476.

FAO, 2004 - **Global Forest Resources Assessment Update 2005: Terms and Definitions.** Working Papers 83/E, Forest Resources Assessment Programme, Rome.

Hagan J.M., Grove S.L., 1999 - **Coarse woody debris.** Journal of Forestry 1: 6-11.

Laiho R., Prescott C.E., 1999 - **The contribution of corse woody debris to carbon, nitrogen, and phosphorus cycles in three Rocky Mountain coniferous forests.** Canadian Journal of Forest Research 29: 1592-1603.

Morelli S., Paletto A., Tosi V., 2007 - **Il legno morto dei boschi: indagine sulla densità basale del legno di alcune specie del Trentino.** Forest@ 4: 395-406.

Paletto A., De Meo I., Cantiani P., Ferretti F., 2014 - **Effects of forest management on the amount of deadwood in Mediterranean oak ecosystems.** Annals of Forest Science,71(7), 791-800.

Pignatti G., De Natale F., Gasparini P., Paletto A., 2009 - I**l legno morto nei boschi italiani secondo l’Inventario Forestale Nazionale.** Forest@ 6: 365-375.

Vallauri D., André J., Dodelin B., Eynard-Machet R., Rambaud D., 2005 - **Bois mort et à cavités. Un clé pour des forêts vivantes.** Editions Tec & Doc, Paris, pp. 405.

Van Wagner C.E., 1968 - **The line intersect method in forest fuel sampling.** Forest science, 14(1), 20-26.

Warren W.G., Olsen P.F., 1964 - **A line intersect technique for assessing logging waste.** Forest Science, 10(3), 267-276.

THE PILOT AREAS OF THE PROJECT

5

THE "PRATOMAGNO" PILOT AREA

Paolo Cantiani, Maurizio Marchi, Manuela Plutino, Lorenzo Gardin, Stefano Samaden

5.1 GEOGRAPHICAL, GEOLOGICAL, lithological and climatic overview

The Pratomagno pilot area is located in the municipality Loro Ciuffenna (AR) municipality, in the "Massiccio del Pratomagno" (Figure 5.1). From a geological point of view the present formation, called Arenarie del Monte Falterona, emerges throughout the area and constitutes basic structure of "Massiccio del Pratomagno". Lithologically it is characterized by quartz-feldspar sandstones alternated by siltstones and argillites. The argillites and siltstones provide a very thin layer whose thickness ranges from a few up to 15 centimetres, while thickness of the sandstone layers is more considerable, exceeding half metre; this implies the emersion of large banks of thick sandstone whose heads are well visible. They are responsible for frequent rock cliff and bumpy morphology, mostly consisting of medium long slopes with small subparallel valleys, often with very large erosion channels, from very slanting to very steep (slope from 40 to 100%). This area is vulnerable to strong, mainly channelled, hydro-erosion.

The area is situated on a slope with small "v" valleys exposed to south- west, whose slope varies from strong at the top to extreme at the bottom. There are rocky outcroppings in moderate quantity and stoniness of small, medium and large dimensions is always frequent in number, abundant locally. Erosion is apparent near the incisions and where the topsoil cover is not continuous. The soils in the sampling area, type O -A-Bw-R profile, are from shallow to moderately deep, with high content of organic matter in the A horizon, from gravelly coarse to strongly coarse gravelly, pebbles and stony soils throughout the profile, predominantly loamy- sand and loamy soil, non-calcareous, from extremely to moderately acidic soil, with saturation in moderately low bases, sometimes over drained.

As for depth available to the tree's roots, the soils we have investigated are generally moderately deep, though shallow soils are locally deeper, due to strong erosion; for both soils the obstacle to radical deepening is the presence of coherent rock; the significant amount of rock fragments, the gravel size, pebbles and stones, constitutes a major limitation.

The Pratomagno landscape was subjected to drastic changes following the work of reforestation (begun in mid 900). Today it is dominated by coniferous forests (especially black pine and silver fir).

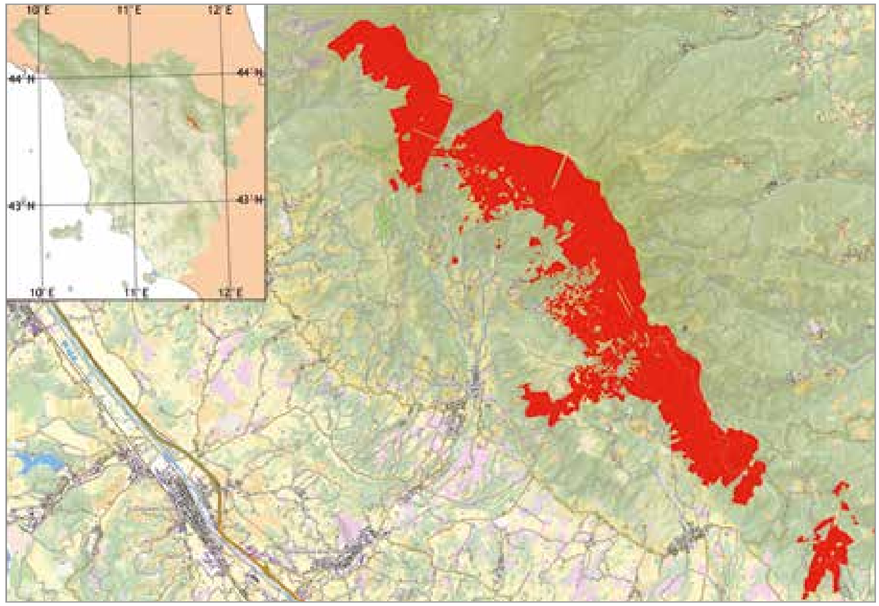


Figure 5.1 - Pratomagno pilot area.

Rainfall follows the Apennines sub-mountain regime (997 mm average rainfall), with a maximum peak in autumn and a second in spring, absolute minimum precipitation occurs in July. The average annual temperature is 10.5°C (maximum 19°C in July and minimum of 1.5°C in January) (data from thermo-pluviometric station of Villa Cognola, 663 m above sea level).

5.2 LAND USE CHANGE IN PRATOMAGNO pilot area

5.2.1 Materials and methods

The test area was initially analyzed through the 1936 Italian Kingdom Forestry map (Figure 5.2). Later diachronic analyses were carried out in pairs of land use change by aerial photogrammetry of 1954, 1978 and 2015. The interpretation was limited to only these types of land use due to the poor photo magnification and the inability to get the "ground truth" for materials dated 1954.

The forest area in 1936 appears very fragmented, interrupted by wide no-forest areas described by archive material as mostly pastures and, locally, arable land (Figure 5.3). The ridge zone was grazed. Below there was a zone of beech coppice selection system. Some plots had been reforested with silver fir while oak-dominated coppice forests (especially Turkey oak) were very limited.

The forest situation in 1954 is of particular interest, as it reveals the land use immediately before the reforestation. The aerial image shows that the area was almost entirely terraced, in some cases for agriculture purpose, mostly for reforestation site preparation.

The decrease of forest cover during the war was remarkable: from a coverage of approximately 76% of the 1936 to 20% 10 years after the end of the war. As for the 1954-1978 period of time, analysis demonstrates the reforestation impact on district land use (Figure 5.4). Forest coverage after reforestation changes from 20% to 72%. It's interesting to note that, even fragmentation of land use patches is affected by a sharp decrease. The ratio area/perimeter of land use patches express that rank (Table 5.1). The decrease of this index is an evidence of a more "monotonous" lands use : there is an increase of single patch surfaces while their number is decreasing (expressed as the sum of the patches perimeters).

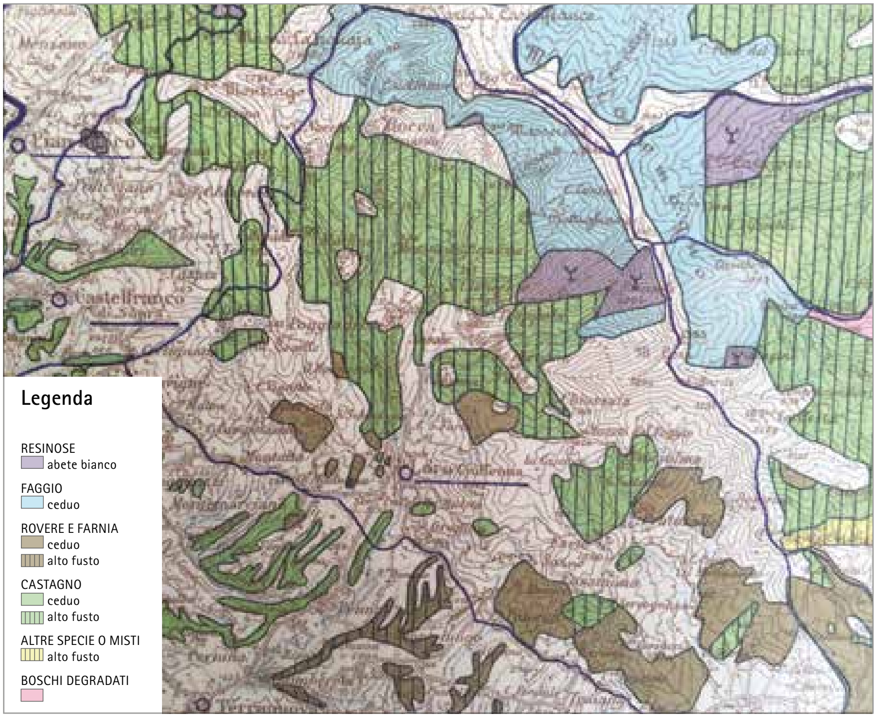


Figure 5.2 - Italian Kingdom Forestry map 1936. Sheet 114 (Arezzo). Scale 1:100.000 (detail from original).

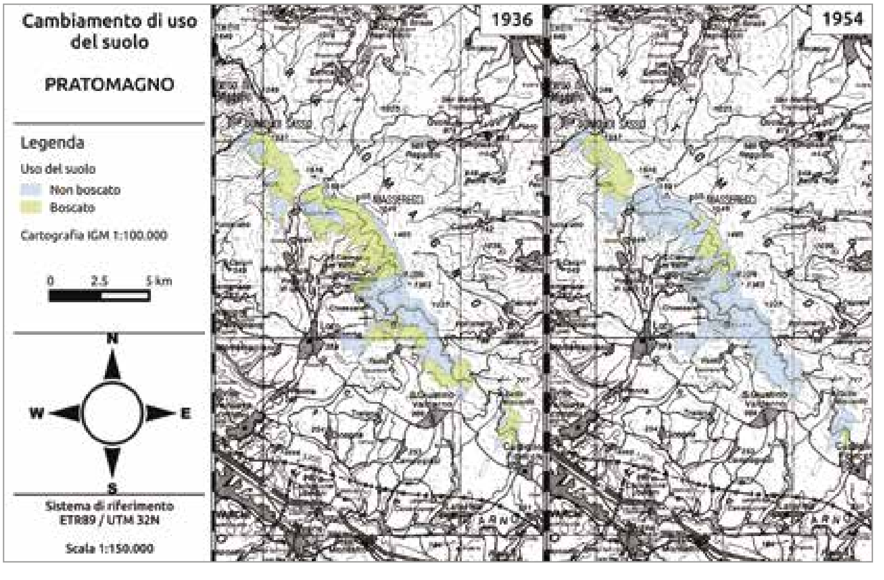


Figure 5.3 - Land use changes during the period 1936 - 1954.

“No forest” area	1936	1954	1978	2015
Total Area (ha)	1882.3	2631.2	917.8	158.9
Total Perimeter (m)	186426	192309	150603	31196
Area/Perimeter (m)	101.0	136.8	60.9	50.9
“Forest” area				
Total Area (ha)	1429.3	679.3	2396.0	3151.7
Total Perimeter (m)	149303	41959	212059	181601
Area/Perimeter (m)	95.7	161.9	113.0	173.5

Table 5.1 - Analysis of land use change between 1936 and the 2015.

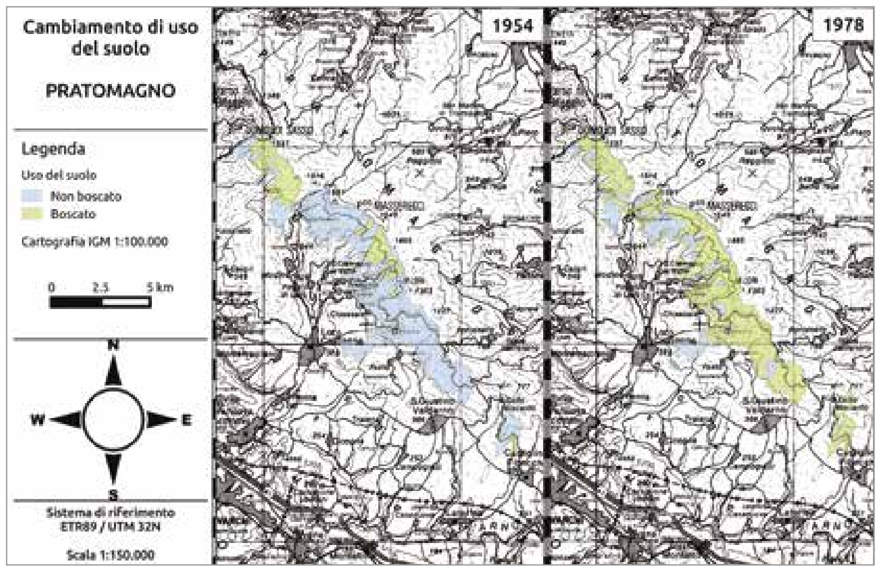


Figure 5.4 - Land use changes during the period 1954 - 1978.

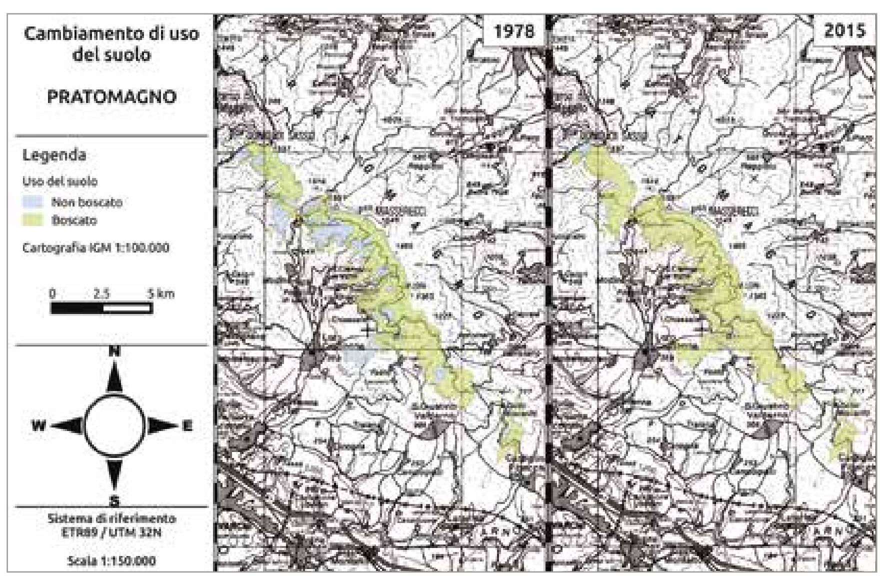


Figure 5.5 - Land use changes during the period 1978 - 2015.

From 1978 to present the work of reforestation in the area has been completed. At the same time, especially at lower altitudes, we notice a natural reforestation mainly by a coppiced oak - chestnut mix. In 2015 the percentage of forested areas is equal to 95%. (Figure 5.5).

Land use referred to the specific plot areas of the Project shows that in 1954, about 2 years after beginning reforestation, most monitoring plots were not wooded. Reforestation was carried out on covered ground by degraded beech coppice only in the upper plots of monitoring area (Figure 5.6). Today the entire area appear covered by forest (Figure 5.7).

5.2.2 The reforestation work in Pratomagno

In Pratomagno district, reforestation work began in 1954 and ended in the 1980's. The investment was remarkable not only in the ecological and hydro-geological terms but also in monetary value. The soil was worked in holes, which are about 2 m deep and 40x40x50 cm in size, and with steps, one for every 3 rows, 80 cm width and 50 cm deep, where the slope was an obstacle. Not all the forest area was affected by reforestation. The degraded but persistent forest areas, where possible, were improved: Turkey oak coppices, chestnut and beech forests, etc..

The species used in the early years of reforestation was the *laricio* pine (80%). The *Pinus austriaca* was privileged in areas with low fertility (especially pasture ridge). For Pratomagno monitoring plot areas was possible consult the register of reforestation works:

Angerilli A., 1970- Loro Ciuffenna municipality. Reforestations performed in A.S.F.D areas by Ispettorato Ripartimentale delle Foreste di Arezzo. Document cadastral-based.

The document shows that, in the area in question, the reforestation was made in two year 1955-1957. The whole area it was submitted, before planting, to soil management in hole and steps (clearly visible from aerial image of 1954). The main species in all plots of reforestation was the *laricio* pine. The most adopted associate species was the silver fir (mostly in small groups of a few hundred square metres in areas most suitable orographically) and, in areas closer to the ridge also beech. In a few cases, sycamore maple was also planted.

Black pine forest, if not subject to regular thinning, shows a very poor undergrowth.

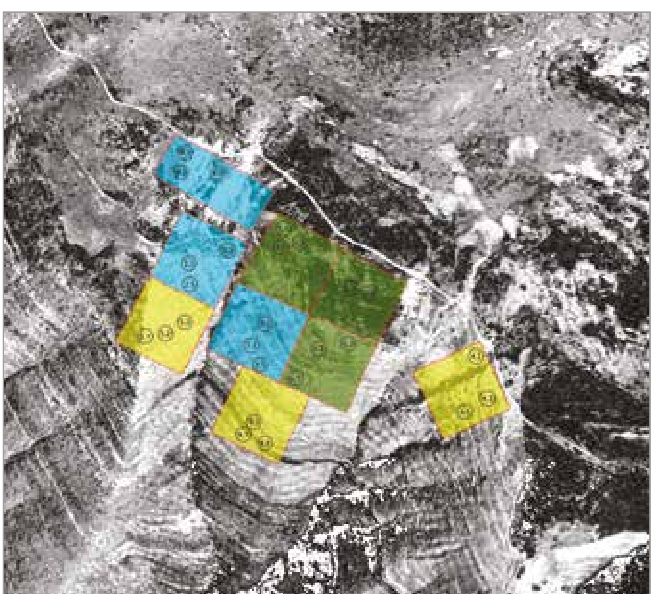


Figure 5.6 - Aerial photograph 1954.

Figure 5.7 - Aerial photograph 2015.

One year after planting a reinforcement planting was made, mostly of *larico* pine. Only in a few cases it was necessary a second reinforcement planting 8 years from the planting for which was adopted black pine and hornbeam.

About a decade after planting all reforested areas were cleaned up.

5.3 THE CHARACTERISTICS OF STANDS AND thinnings in SelPiBioLife

The test area of Pratomagno is placed at an average elevation of 1150 metres a.s.l., at a prevailing south-west exposition and average slope of 40%.

The pine forest in 2015 had an average age of 59 years.

Growth parameters are briefly described in Table 5.2.

This is an even-aged and single-storied pine forest with the absolute predominance of *laricio* pine, associated locally with silver fir groups (especially at higher altitudes of the area) and a marginal contribution of sporadic broadleaved species. All the other species account for 13.8% of the basal area on total (Figure 5.8).

The density of the pine forest is too high for the stand age with respect to the yield model, which predict about 800 plants per hectare. The *laricio* pine forests of average characteristics have a slenderness ratio of 65, as evidence of a good degree of average stability of stand.

Thinning carried out according to the treatment provided for two theses (thinning from below and selective thinning) are synthesized according to the main growth parameters related to *laricio* pine in Table 5.3. Before the treatment the stands did not show significant differences in growth parameters between the plots with two different thinning types.

The two treatment types substantially change the silvicultural structure of pine forest. In particular selective thinning, while removing fewer trees than thinning from below, also

Species	Trees n ha^{-1}	Quadratic mean diameter cm	Mean height m	Basal area m^2 ha^{-1}	Volume m^3 ha^{-1}	Slenderness ratio HD
Black pine	889	29.5	19.2	59.1	538.4	65.0
Other	188	20.5	15.5	9.5	-	-
TOTAL	1077	28.7	18.8	68.6	632.6	68.0

Table 5.2 - Main growth parameters of pilot stand (average values for all plots).

High forest of black pine in good condition of fertility. Thinning is required to regulate the high density.

acts on large trees. The purpose of the treatment, in fact, is to get rid candidate trees from their competitor, therefore dominant and co-dominant trees were cut (see Paragraph 3.4).

The percentage of trees felled in terms of basal area and volume between the two thinning theses have strong differences (statistically significant) in favour of selective thinning. In particular, the larger trees felling with selective thinning ensures a greater differentiation of the potentially obtainable wood assortments. As for the impact on canopy, the customary thinning has reduced the coverage of 7% in average while selective thinning of 18%.

The two thinning theses affect the crown coverage in very different ways. Figures 5.9 and 5.10 are examples of horizontal structure effects post-treatment, for the two thinning theses applied.

Table 5.4 shows the morphometric characteristics of candidate trees, with selective thinning.

Candidate trees are at a regular distance of about 10 meters. All these trees show a particular vigour and stability. Average diameter and tree height are parameters higher than the average stand value. The slenderness ratio is significantly lower than the average stand value and well below the limit for the mechanical stability of the black pine (see Paragraph 3.3).

With selective thinning, competitors of the candidate trees were cut. This creates greater irregularities of the horizontal structure and the openings of gaps that contribute to increasing biodiversity at ground level.

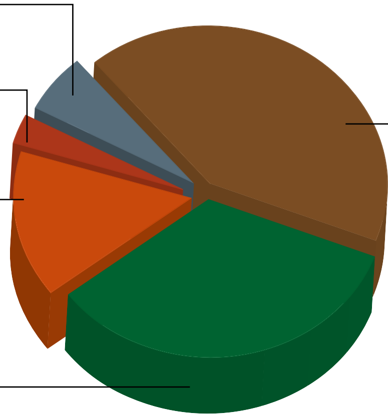


Figura 5.8 - Percentage contribution, in basal area, of species different from pine and silver fir.

	before thinning					after thinning					harvest percentage		
	N ha⁻¹	**G ha⁻¹**	**V ha⁻¹**	**dgm**	**Hm**	**N ha⁻¹**	**G ha⁻¹**	**V ha⁻¹**	**dgm**	**Hm**	**N ha⁻¹**	**G Ha⁻¹**	**V ha⁻¹**
		m²	**m³**	**cm**	**m**		**m²**	**m³**	**cm**	**m**			
Customary	1085	72.6	722.3	29.3	19.1	695	56.1	582.9	32.1	19.9	35.9	22.6	19.3
Selective	1056	66.6	586.6	28.6	18.9	731	47.0	412.6	28.6	19.0	30.8	29.4	29.7

Table 5.3 - Growth characteristics of thinnings.

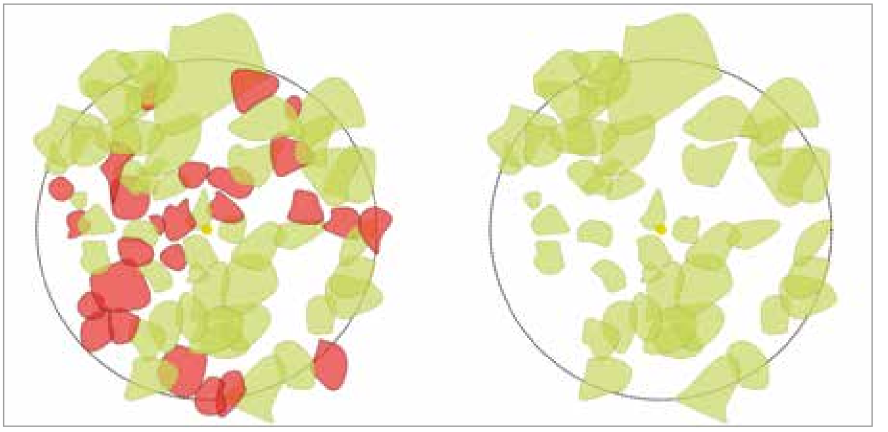


Figure 5.9 - Horizontal structure of the pine forest, before and after thinning from below.

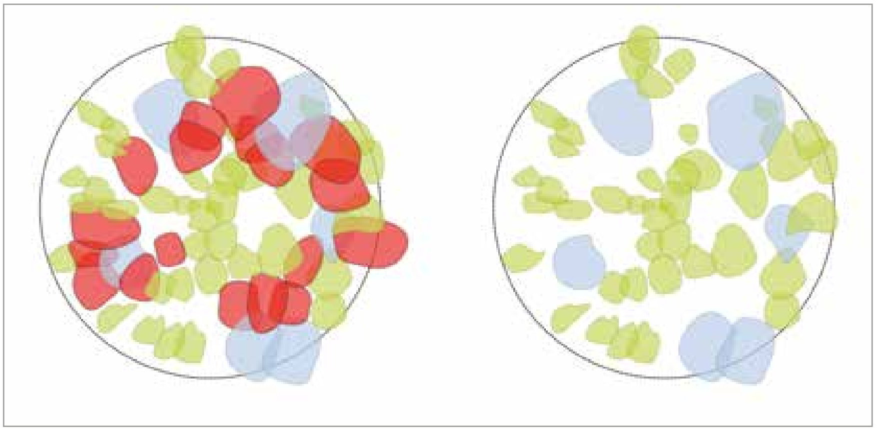


Figure 5.10 - Horizontal structure of the pine forest, before and after selective thinning.

Monitoring area	DBH 1.30m	H total	H Dominant	Crown radius	Distance	N. competitor trees	
1	39.3	21.7	55	2.89	8.33	4	MEDIA
	±5.2	±1.79	±6	±0.5	±4.09	±2	DEV.ST.
2	37.4	20.5	55	3.00	12.38	3	MEDIA
	±3.3	±1.14	±4	±0.48	±3.24	±1	DEV.ST.
6	38.9	20.5	53	2.89	10.44	3	MEDIA
	±3	±0.93	±2	±0.48	±2.76	±1	DEV.ST.

Table 5.4 - Selective thinning. Candidate trees characteristics.

Canopy structure after moderate-intensity thinning from below. The coverage doesn't shows sensible changes after treatment.

Canopy structure after selective thinning. Gap around candidate trees is evident.

6

THE "AMIATA" PILOT AREA

Paolo Cantiani, Maurizio Marchi, Manuela Plutino, Lorenzo Gardin, Piergiuseppe Montini

6.1 GEOGRAPHICAL, GEOLOGICAL, lithological and climatic overview

The Amiata pilot area is located in Castiglione d'Orcia (SI) municipality, thereabouts of Laghi place near Vivo d'Orcia (Figure 6.1).

A large part of the Castiglione d'Orcia territory shows various geological formations of clay, including Unità delle Argille a Palombini, calcareous and marly lithofacies, lithological formation by fissile clays, silty clays, marly clays with sporadic inclusions of limestone, basic limestone. Sometimes such inclusions get closer each other and then calcareous-marly elements become darker and thicker layers.

This lithotypes form morphologies consisting of long, wavy sides with slope mainly moderate to strong, subject to erosion by channelled water and mass movement. Indeed, instability phenomena, landslides and mudflows are frequent.

The sample area is situated on a long and wavy side, exposed to North-East, having a slope ranging from weak to strong. There are no rock outcrops very occasionally, while the small surface stoniness is common, scarce or absent the stoniness of medium and large size. There aren't apparent erosion of significant importance.

The soils in the sampling area are deep, with O-A-Bw-(Bg)-C profile, with high content in organic matter at the surface A horizon, from poorly gravelly to gravelly in deep, predominantly loamy silty clay and clay, from weakly to moderately calcareous, slightly alkaline, with high-level of bases saturation, from well drained rather poorly drained.

Regarding the useful depth for the growth of root system, the soils we detected are generally deep (> 100 cm) and secondary moderately deep (between 50 and 100 cm); very localized and occasional there are impediments to the deepening roots due to the presence of coherent rock (limestones) in profile; there are soils with quantities of skeleton of gravel and pebbles size that constitute a moderate limitation of deepening roots.

As for the climate, referring to the thermo-pluviometric station of Castiglione d'Orcia (516 m a.s.l.), it is warm and temperate. Winter is much more rainy than summer. According

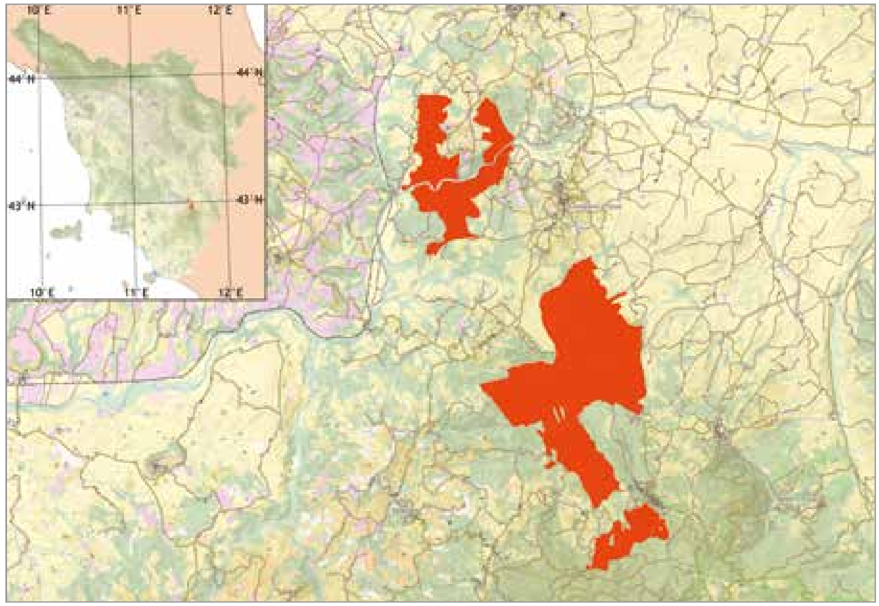


Figure 6.1 - Amiata pilot area.

to the Köppen and Geiger climate classification its rank is Csb. Castiglione d'Orcia average temperature is 12,5 °C and an average rainfall is 687 mm.

July is the driest month with 28 mm while January gets the max rain- snow-fall (average of 88 mm). July is the hottest month with an average temperature of 21.7°C, while January has an average temperature of 4.5°C, the lowest in the year.

6.2 LAND USE CHANGE IN THE AMIATA pilot area

6.2.1 Materials and methods

The project area was initially analyzed by Italian Kingdom Forestry map of 1936 (Figure 6.2). Later diachronic analyses were carried out in pairs of land use change by aerial photogrammetry of 1954, 1978 and 2015 and it was analysed the patches of forest land use and no forested surface. The interpretation limit that led to the distinction only of these types of land use depends on the yields scale and the inability to operate the "ground truth" for the material of 1954.

From a perspective of spatial tissue mutation analysis of forest - no forested surface components, the mutation of the mosaic landscape during this period differs much less sensitive to what is found in the Pratomagno (Table 6.1). The real difference is in replacing almost complete of forest type, both in terms of specific point of view (from broadleaved forests to coniferous forests) both in terms of management system (from coppice to high forest).

The forestry map of the 1936 show the area covered by no forested areas (mostly pastures interspersed with arable areas) and areas occupied by mixed coppice oak-dominated (Turkey oak and pubescent oak).

In the period 1936-1954 there was an increase in woodland, (from 77 to 94 of the total area) very likely due to abandonment of farming activities (Figure 6.3). The forests (espe-

Thinning is not intended to promote the regeneration. However the greatest light opening on the ground determines ecological conditions that promote the seedlings emergence. The analysis of "pre- regeneration " in pine forest can provide useful information about future natural dynamics cially oak coppices) show an incomplete coverage, basically coppices with a double aptitude: wood production and pasture.

From 1954 to 1978 instead, a decrease in woodland was observed (from 94% to 89% of the total district area) (Figure 6.4).

From 1978 to 2015 the forested area increases back again, mainly because of the work of reforestation both of degraded coppice and bare soil (former grazing and arable land) (Figure 6.5). Reforestation has the landscape effect of decreasing the patches fragmentation (at woodland level significantly increases the Area/Perimeter index) (Table 6.1).

Considering the area examined within the project, the trend of land use change is com-

Figure 6.2 - Italian Kingdom Forestry map 1936. Sheet 129 Santa Fiora. Scale 1:100.000.

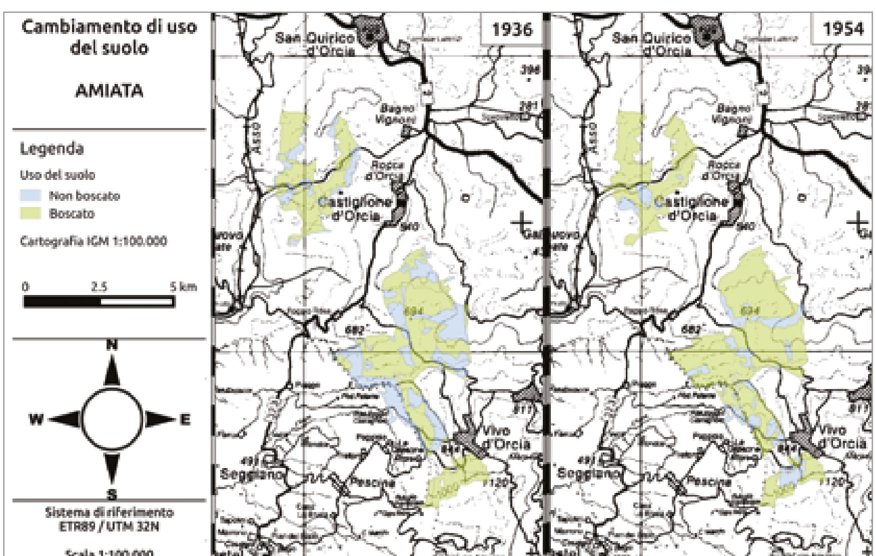


Figure 6.3 - Land use changes during the period 1936 - 1954.

"No forest" area	1936	1954	1978	2015
Total Area (ha)	710.4	366.9	459.9	276.4
Total Perimeter (m)	84861	51253	89297	38733
Area/Perimeter (m)	83.7	71.6	51.5	71.4
"Forest" area				
Total Area (ha)	1499.9	1839.5	1759.1	1930.1
Total Perimeter (m)	123898	94148	120727	85731
Area/Perimeter (m)	121.1	195.4	145.7	225.1

Table 6.1 - Analysis of land use change between 1936 and the 2015.

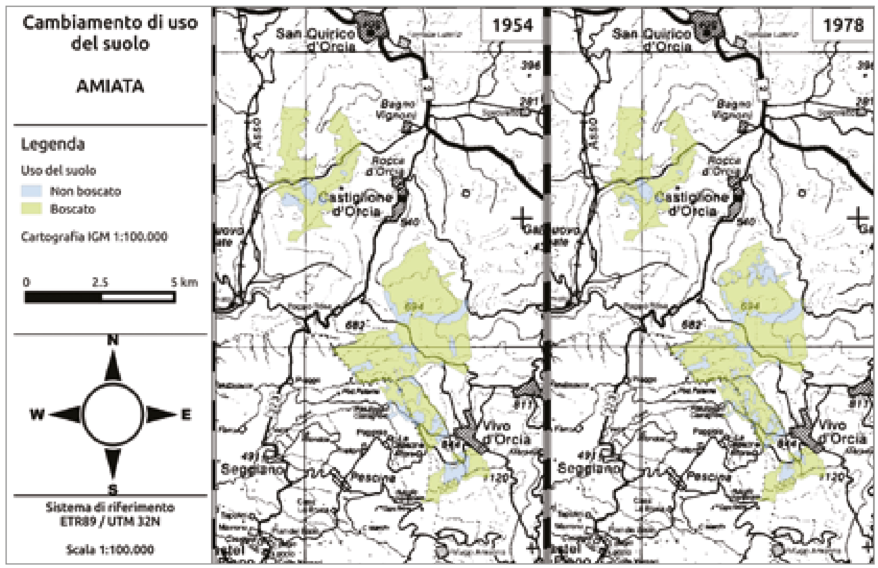


Figure 6.4 - Land use changes during the period 1954 - 1978.

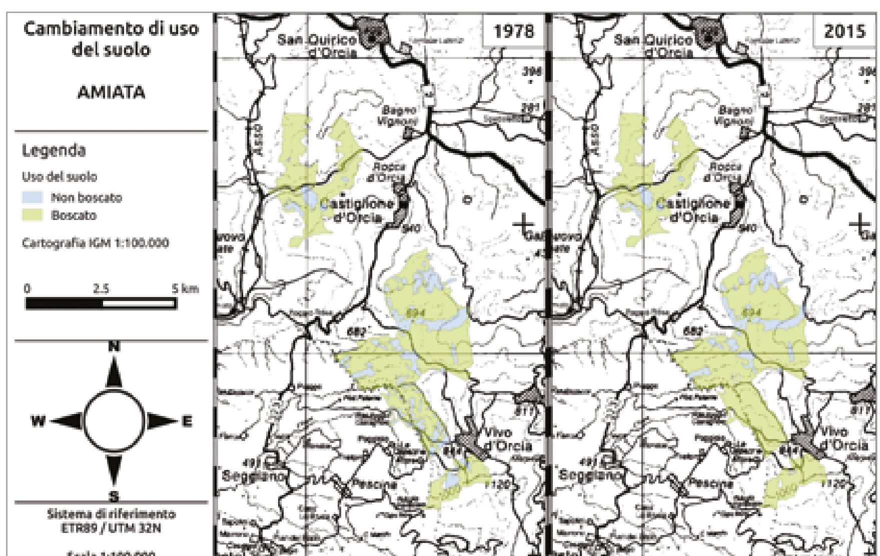


Figure 6.5 - Land use changes during the period 1978 - 2015.

parable with the one reported for the whole district. The decrease between forest and no forested areas is particularly evident in the pre-war period but presently the effect of reforestation results in an almost total coverage (Figures 6.6, 6.7, 6.8).

6.2.1 The reforestation work in Amiata

The history of reforestation in Amiata is closely linked to the decline of mining in the area. One of the most important reasons that determined the reforestation activities was the intent to find a solution to the unemployment, caused by the mining sector crisis, with “socially useful activities”(Gatteschi and Fedeli 1994). Since the beginning of the 1950s (establishment of the Inspectorate of Piancastagnaio, 1952) to the mid-90s areas surrounding Monte Amiata were reforested with about 3,700 ha of conifers. Prior to the Second World War (especially between 1922 to 1933) around 1.000 ha had been reforested mainly with black pine and silver fire. To this purpose funds were provided by public sources or mining companies.

In 1952 was established by the Ministry of Agriculture the Ispettorato Distrettuale autonomo of Piancastagnaio forests, that managed the funds for subsequent works of reforestation. Beside large area of reforestation there was also a flourishing of small reforestation works not always sensible and consistent.

Actually, the activity depended on the flow of ad hoc public funds. In some cases there were till 600 men at work on reforestation and hydraulic arrangements of the slopes.

The project area, namely “Madonna della Querce” in the 1960s becomes property of the Azienda di Stato for State-owned forests. The property was subsequently transferred to the Tuscany Region and further expanded to the current 2,177 ha.

Reforestation management passed successively to the “newly” constituted Comunità Montane, while the Inspectorate ceased in 1982. Since then the management was more focused to the maintenance of existing forests rather than to further reforestation.

6.3 THE CHARACTERISTICS OF STANDS AND thinnings in SelPiBioLIFE

The monitoring area of the Monte Amiata is placed at an average elevation of 780 metres a.s.l., prevailing south-west exposition and average slope of 15%.

The pine forest in 2015 had an average age of 44 years.

Breaking the monotony of black pine forests structure favours an accessory species layer for the future forest succession.

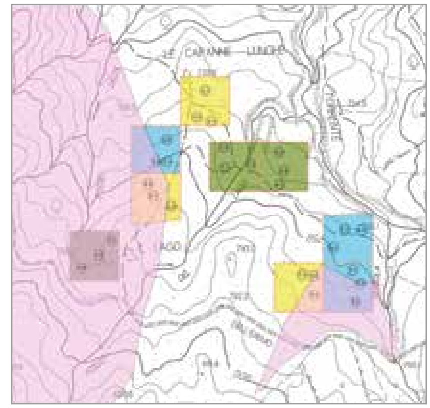


Figure 6.6 - 1936. Land use before reforestation.

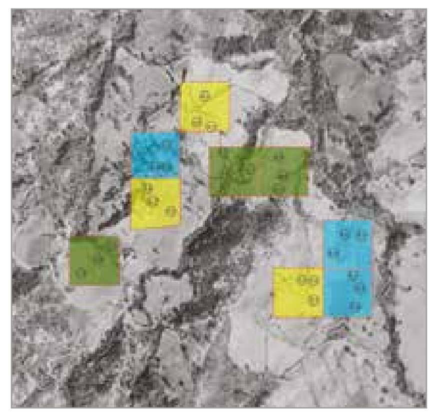


Figure 6.7 - 1954. Land use before reforestation.

Figure 6.8 - Aerial photograph 2015.

In Table 6.2 are shown the main average stand characteristics before cutting.

This pine forest is one-storied, second class of fertility respect to the black pine yield model in Tuscany. The specific composition is of laricio pine absolute predominance, associate locally with other species (especially Turkey oak) originate mainly from previous land use residue patches (degraded coppice and pasture with isolated oak trees). In terms of percentage of basal area other species contribute to specific composition for less than 3% of the total. The species diversity of sporadic tree species is much more mixed in terms of number of species compared to Pratomagno stand (Figure 6.9).

The average density of the pine forest is less than that of Pratomagno even if the pine forest is younger. Probably some pine forest sections, in the past, have been exposed to a light thinning from below. Laricio pine trees of average characteristics have a slenderness ratio of 75, value greater than that seen in the Pratomagno, although in the stability range for the species.

Thinnings carried out according to the two planned treatment theses (thinning from below and selective thinning) are synthesized, according to the main growth parameters of laricio pine, in Table 6.3.

Before the treatment the stands did not show significant differences in growth parameters between the plots with two different thinning theses.

In terms of basal area and removed volume, treatments closely followed what made in

Species	Trees n ha^{-1}	Quadratic mean diameter cm	Mean height m	Basal area $m^2\ ha^{-1}$	Volume $m^3\ ha^{-1}$	Slenderness ratio HD
Black pine	959	24.3	18.1	43.6	386.4	76.0
Other	91	16.7	12.8	1.2	-	-
TOTAL	1050	23.6	17.8	44.8	394.1	78.0

Table 6.2 - Main growth parameters of pilot stand (average values for all plots).

The years immediately following the thinning denote a drastic decrease in the undergrowth flora layer for the impact of cutting and extraction. The greater lighting on the ground determines, however in a few vegetative seasons a quick re-growth and flora increased.

the Pratomagno (see Chapter 5). Given the structural diversity between the two pilot area stands, also due to different ages and then different hierarchy, treatments were differentiated as for number of tree cuts: the number of competitor's cut for single candidate tree is greater in Amiata (Table 6.4) and in terms of numbers, in selective thinning thesis, the harvest exceeds that done in the thinning from below. After the treatment the stands structure between the two thinning theses is significantly different for all the growth parameters. 13% of crown coverage was removed with customary thinning, 20% with selective thinning.

In Figures 6.10 and 6.11 the variation of horizontal structure before and after thinning in two treatments sample plots is shown.

In Table 6.4 candidate trees parameters in selective thinning are synthesized. The average distance between trees is 10.1. The candidate trees have heights and diameters higher than average ones and low slenderness ratio (average 66.7) and regular-shaped crowns to ensure mechanical stability.

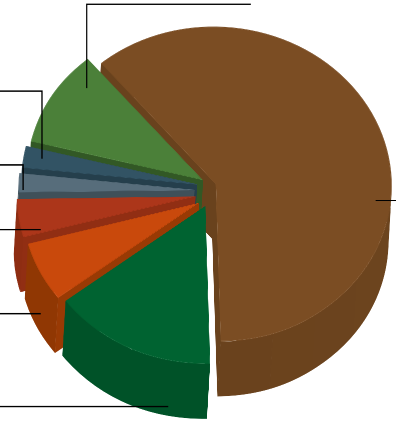


Figure 6.9 - Percentage contribution, in basal area, of species different from pine and silver fir. In "other" the species with total basal area below 0.1 m^2ha^{-1} (sweet cherry, wild pear, juniper, goat willow, wild service, Italian alder, black alder, sycamore maple, Douglas-fir, wild apple, manna ash, hop-hornbeam, broom, hawthorn and cornelian cherry.

	before thinning					after thinning					harvest percentage		
	N ha^{-1}	G ha^{-1}	V ha^{-1}	dgm	Hm	N ha^{-1}	G ha^{-1}	V ha^{-1}	dgm	Hm	N ha^{-1}	G ha^{-1}	V ha^{-1}
		m^2	m^3	cm	m		m^2	m^3	cm	m			
Classic	971	42.3	357.6	23.7	17.9	675.7	34.0	290.8	25.3	18.3	30.4	19.7	18.7
Selective	971	47.4	446.4	24.9	18.2	638.3	32.3	309.2	25.4	18.4	34.3	31.9	30.7
Customary	935	41.2	354.8	23.9	17.9	935.3	41.2	354.8	23.9	17.9			

Table 6.3 - Growth characteristics of thinnings.

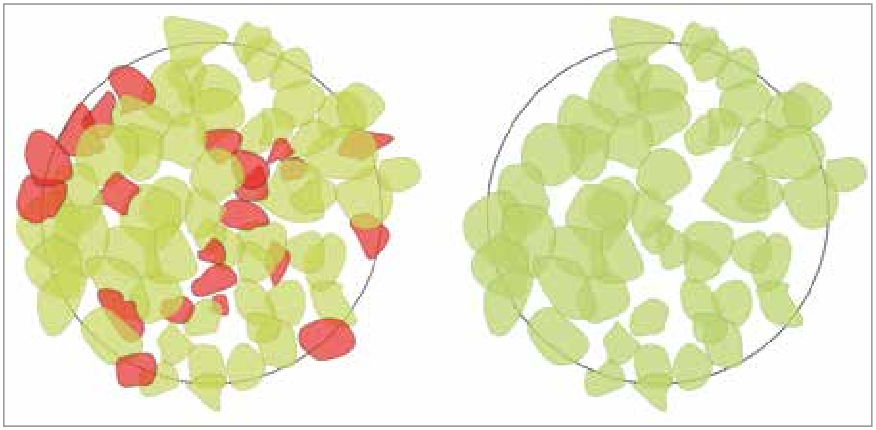


Figure 6.10 - Horizontal structure of the pine forest before and after thinning from below.

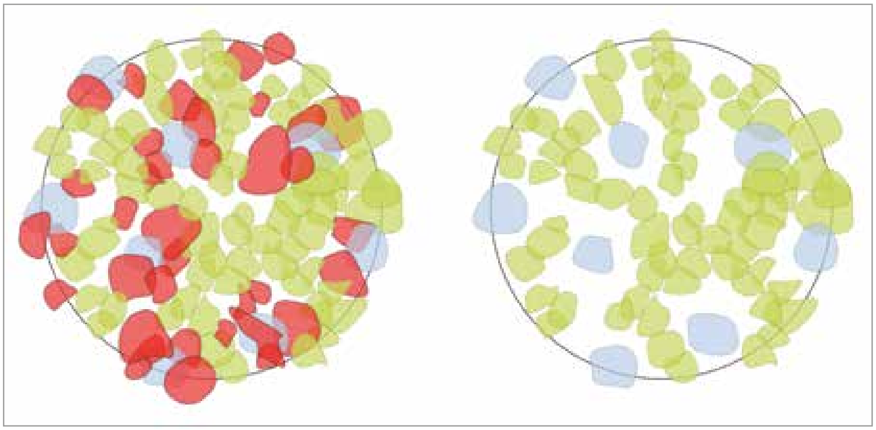


Figure 6.11 - Horizontal structure of the pine forest before and after selective thinning.

Monitoring area	DBH 1.30m	H total	H Dominant	Crown radius	Distance	N. competitor trees	
1	30.1	20.6	69	2.59	11.55	4	MEDIA
	±3.3	±1.61	±7	±0.36	±1.65	±1	DEV.ST.
5	30.9	20.8	68	2.44	9.90	4	MEDIA
	±3	±1.51	±8	±0.92	±2.88	±1	DEV.ST.
6	32.6	20.2	63	2.60	9.01	4	MEDIA
	±7.5	±2.97	±6	±0.63	±2.83	±1	DEV.ST.

Table 6.4 - Selective thinning. Candidate trees characteristics.

7

CONCLUSIONS

Thinning is essential in the silvicultural treatment of even-aged high forests.

Thinning is expected to improve the forest system with regard to its various functions:

- wood production, both in quantity and quality;
- hydrogeological protection: the lower trees density cause to a more harmonious growth of trees remaining, and then their improved phenotype with regard to mechanical characteristics useful for wind resistance and to other agents;
- improved usability of the forest for excursion and tourism: the increase of light on the ground determines greater visibility and makes the surrounding more pleasant and enjoyable;
- biodiversity: micro-climatic changes on the ground stimulate overall diversity by acting on all its components.

Any human intervention on the forests, beside the expected positive effects, also causes some drawback. The harvest of some trees of the stand may result in mechanical damage to trees still standing up; the customary activities of extraction, although made with lightweight forms of mechanization, have some impacts at ground level (localized soil incisions, compaction etc.).

The skidding of entire logs also can produce mechanical damage to trees left (bark-peeling, wounds, etc.). We have already discussed how the decrease in trees density, determined by thinning, involves a stand weakened from the point of view of mechanical stability, over a period of several years after the treatment (Chapter 3). The positive effects of the increased space between trees result in incremental stimulus to crown and stems growth within a few years (period depending on the species and the development stage when the thinning occur) increase the degree of mechanical stability of the stand.

In order that thinning is incisive for overall functional improvement of forest it must be really incisive. In other words it is necessary that the positive effects of the treatment outweigh the negative effects due to system disturbance. In other words, the silvicultural treatment must have effective influence on competition between trees (both at canopy and soil levels) by positively changing the microclimatic regime in the forest.

Forest management practice of the last decades, has been led by excessive prudence in the silvicultural treatment. This cause, in the specific case of thinning in high forests, to act almost exclusively in the dominate layer, according to the logic of “disturbing” as little as possible the dominant stand component. Thinning laws often establish a percentage limit of trees harvested, in number, and prescribe to act from below, that is generally on the dominate layer. The reasons for this behaviour lie mainly on easing the cut control aimed at respecting regulations and reducing visual impact after treatment. However, as seen in Chapter 2, in the case of light-demanding species (like pines) this does not result in any benefit on the phenomena of real competition between trees and climatic and physiological parameters. Often these treatments do not respond to the improvement of productive, protective, social and ecological functions but could also induce mere negative effects on the forest system.

Considering that often thinnings on low productive high forests such as those of black pine represent a cost for the manager, it is believed that interventions should be as effective as possible for the improvement of all forest functions, in the logic, therefore, to minimize the cost/benefit ratio. In this sense, beside the modality and intensity of the single treatment, the reasoning should be extended also to the thinning system within the entire life cycle of the stand. It might be appropriate, where allowed by the structural setting of the stand, to lengthen the time between thinning by carrying out single treatments more effectively; this would ensure a lower cost and a lower overall impact on the system (reduction in the number of treatments).

Selective thinning proposed by the SelPiBioLife Project is consistent with this strategy. The key points of the treatment modality are:

- the incisive treatment to produce effective growth increment and improvement of the candidate trees shape (productive and protective functions);
- the implementation of an optimal overall microclimatic environment for increasing flora and fauna biodiversity.

The method we propose implies that the stand analysis will be more accurate than with customary thinning from below. The choice of candidate trees and their competitors requires then a thoughtful consideration in the marking phase, as it is a sensible responsibility for the foresters.

We believe that the simple and reproducible rules for selective thinning described in this manual will support the action of forest technicians. The manual is also intended as a tool at a later stage, when the quality of the marking choices will be checked.

Published in October 2016

Coordinatore Progetto

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

Partner

Unione dei Comuni Amiata Val d'Orcia

Compagnia delle Foreste

Unione dei Comuni del PRATOMAGNO (Provincia di AREZZO)

www.selpibio.eu

ISBN 978-88-98850-26-6