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A CROSS-TIME ANALYSIS OF FOREST WORKING PLANS AS DETERMINANTS OF STAND STRUCTURE AND DIVERSITY IN SILVER FIR WOODLANDS

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ABSTRACT

Silviculture in the eastern Italian Alps has a long tradition based on the 'Cadorino' selection cutting system that has maintained fairly natural mixed uneven-aged conifer forests in the montane altitudinal belt. Nowadays, silvicultural treatments are very adapted to the wide range of forest typologies and its different structural types. The main goals of forest management in Veneto region are to respond to the silvicultural needs of the forest, to ensure the long term stability of the forest, and the provision of direct products and indirect services.

The convenience of using forest working plans was studied by comparing silver fir stands under management planning with abandoned and managed without planning, and analysing the evolution of the last four revisions of the working plans focusing on forest structure and cutting plans. Ten compartments with productive function from five forest working plans managed by Veneto region were selected looking for silver fir single-later mature woodlands in carbonate soils. One sample unit composed by a circular plot of 12.5 meters and two transects was performed in every compartment in order to obtain the dendrological composition, the understory species composition and the deadwood at structural type level. Four quality indicators of management plans were performed in order to study its evolution through the abundance of broadleaved species, the floristic surveys, the silvicultural treatment description and the performance of the yield.

The diametric distribution per species at structural type level represents an irregular bi-layer structure composed by a dominating layer of silver fir and Norway spruce and a dominated layer mainly formed by beech, very similar to abandoned silver fir woodlands. The intermediate values of volume of snags and stumps in planned forests between abandoned and not planned, suggest a greater influence of natural mortality and lower intensity of cuttings. At compartment level, the increase of lower and bigger trees observed in the evolution of the diametric distributions shows a more diversified structure due to the maintenance of uneven-aged structure through selection cuttings and the retention of big dimension trees. It was also observed the homogenization of the structure typical due to delayed or moderate cuttings in good site conditions. The improvement of the quality of the floristic surveys served for the application of the forest typologies classification system used in Veneto Region. Beech is the single broadleaved species present in the diameter surveys, although sycamore, rowan and ash are potential canopy tree species. The quality of the silvicultural treatment description increased along the revisions of the management plans, although it was not possible to relate it statistically with the better performance of the yield observed in the reduction of the deviation rate, most probably because of the lack of utilization registers per compartment.

To conclude, the combination of the silvicultural criteria and the silvicultural method of yield calculation has driven these silver fir woodlands to a higher mixture of canopy tree species and a higher structural diversity with a significant influence of natural processes. For a better control of other factors affecting the performance of the yield such as accidental events and timber market, it is suggested to introduce more elements of close-to-nature forestry regarding the forest stability and the economic efficiency per unit area. Lastly, forest management plans are considered a suitable framework for the monitoring of biodiversity and structural indicators at stand level.

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I) INTRODUCTION

I.1) Current silvicultural approaches

The increasingly awareness of environmental and social issues regarding the management and conservation of forest ecosystems induced the development of silviculture with ecological bases (Bagnaresi *et al.*, 2002; Schütz, 1999; Ciancio & Nocentini, 1997). The search for low environmental impact forest cultivation brought back the guideline of natural and virgin forest which functioning and structures are aimed to be imitated (Ciancio & Nocentini, 1997).

Nevertheless, the traditional forest management goals of maximising timber production through constant and annual yield are still determinants (Ciancio & Nocentini, 1997). Typically, this silvicultural approach is named synonymously close-to-nature forestry or naturalistic silviculture (Dunker *et al.*, 2012; Pommerening & Murphy, 2004).

The most characteristics measures for a sustainable production of timber in ecological bases proposed by ProSilva Europe (2012) are:

- Continous forest cover to protect soil productivity
- Full use of natural dynamic forest processes
- Adding value by selection felling and tending at all stages of development
- Maintaining growing stock at an optimal level
- Increase forest stability reducing production risks

Uneven-aged structures are considered one of the best options combining environmental and productive aspects (Susmel, 1980; Bagnaresi *et al.*, 2002). However, the perfect balanced uneven-aged structure is rather a theoretical concept than a real forest structural type to be pursued (Ciancio & Nocentini, 1997). Actually, maintaing this kind of structures requires delicate and frequent interventions which might contradict its natural character, pointing out the need to considered also the hemeroby (degree of human impact) of the silvicultural systems to be used (Çolak *et al.*, 2003; Schutz, 1999).

However, structural heterogeneity is expected in natural montane mixed forests due to the varied duration of growth cycle of the species involved (Schutz, 2002).

This thesis was conducted in irregular mixed silver fir (*Abies alba* Mill., 1768) woodlands managed with production function by Veneto region located in the highland of Asiago (Province of Vicenza), Cadore and Comelico (Province of Belluno) (Figure 1).

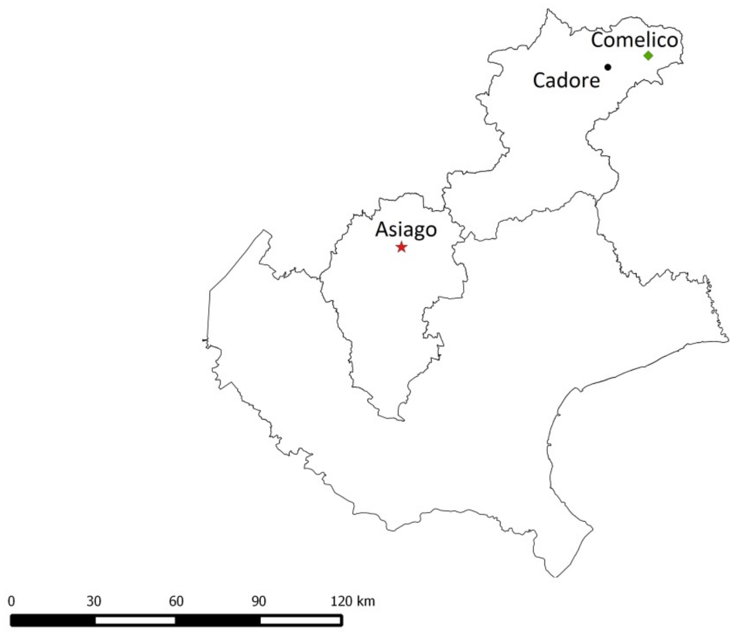


Figure 1: Geographical location of the three study areas

I.1.2) Silviculture in eastern Italian Alps

The mountain mixed conifer forests of eastern Italian Alps have been utilized since the XVI-XVII centuries with a particular silvicultural treatment, the so called 'Cadorino' selection cutting system. This kind of treatment was strongly influenced by commercial interests based on a target diameter of 43.5 cm. Silvicultural operations consisted both on the removal of valuable mature trees and thinning of younger even-aged stands (Susmel, 1980; Grassi *et al.*, 2003).

In the 1960s, the traditional selection cutting system was improved into more ecological bases developing cultural models for mixed silver fir and pure Norway spruce woodlands as a reference for cultivated forests. Since then, the cultural models are widely use in the conifer forests of Veneto, based on the dominant height as a response of site fertility (Susmel, 1980). Nowadays, the recognition of the high variability of mountain forests has driven forest management to adapt the traditional silvicultural systems to a wide range of forest typologies and structural types (Del Favero, 2000).

Typically, the target forest structure type for montane mixed silver fir woodlands is the uneven-aged structure in its different varieties (by single tree or in small groups), as it is found in many studies on virgin and abandoned forests (Susmel, 1980; Motta & Garbarino, 2003; Motta *et al.*, 2008; Motta & Edouard, 2005; Firm *et al.*, 2009). The shade tolerance in juvenile stages that allows to postpone the cuts of the canopy, and the tendency of silver fir to regenerate progressively in scattered small patches encourage to keep this structural type through single-tree and group selection cuttings (Bernetti, 1995).

The spatial arrangement and abundance of natural regeneration is one of the most important determinants, configuring the type and intensity of the silvicultural treatment. The main silvicultural treatments used in mixed mature silver fir structural types are:

- Mono-layer adult-mature: irregular and group shelterwood cuttings reducing density according to the presence or not of natural regeneration.
- Bi-layer: regeneration fellings considering the retention of big dimension trees.
- Multi-layer: group and single tree selection cuttings including harvest of mature trees and tending of intermediate size classes.

The general objectives of the silvicultural treatment are to respond to the silvicultural needs of the forest stands, ensure the long term stability of the forest and maximise the biological efficiency of the forest ecosystems through the provision of direct products and indirect services.

I.1.3) Yield calculation method

One of the best yield calculation methods that better adopt the silvicultural treatment and forest management plan objectives is the silvicultural method of yield regulation. The need to adapt forest management to the variability and irregularity of forest and structural types requires the use of a flexible yield calculation method subordinated to the forest cultural needs, rather than to rigid schematic norms mostly based on economic interests (Andrich, 2011; Novello & Dallasega, 2000a).

The silvicultural method of yield regulation is based on the *Dauerwald* theory of the permanent forest and the method of control (Ciancio & Nocentini, 1997). It mainly consists on the analytical determination of a volumetric yield attending to the silvicultural needs of each compartment in terms of composition, density, height and regeneration (Hellrigl, 1986b).

The methodology of this yield calculation method includes three different procedures depending on the use of cultural models, the attention given to the working group unit and the use of other yield calculation methods:

- Unconditioned selvicultural procedure: no prescribed 'normal' model; volumetric yield formulated case by case seeking to improve the individual functionality of the stand.
- Oriented silvicultural procedure: indicative use of cultural models as reference for volumetric yield formulation attending to the cultural needs of the single compartment.
- Integrated silvicultural procedure: prescribed use of cultural models formulating the volumetric yield by compartment taking also into account calculated yields at working group level.

The application of the silvicultural method of yield regulation should bear in mind that it is not able to ensure a constant yield by itself (Ciancio & Nocentini, 1997).

I.2) Forest diversity indicators at stand level

The need to preserve biodiversity in forest ecosystems has called the attention of different environmental policy and academic entities, developing indicators to assess sustainable forest management (Marchetti, 2004; Barbati *et al.*, 1999; Pro Silva Europe, 2012).

A biodiversity assessment was performed in north-eastern Italy in order to identify biodiversity indicators at landscape and stand-level for forest management practices (Barbati *et al.*, 1999). At stand level, the main approach was to link the forest typology classification (Del Favero, 2000) with forest structure and ground layer vegetation indicators.

I.2.1) Structural diversity

The indicator proposed for uneven-aged stands consists on a standard percent distribution of the number of trees among four broad diameter classes (small, medium, big and very big), defined by relaxing the algorithms proposed by Susmel (1980) and adapting them to each forest type. This guideline allows assessing the structure dynamics of the stand avoiding the application of rigid and numeric models such as the 'normal' distribution (Barbati *et al.*, 1999), which indeed are usually applied at working group or section level (Andrich, 2011).

Traditionally, forest management harvests trees at diameter always lower than the maximum biological diameter (Marage & Lemperiere, 2005; Grassi *et al.*, 2003). Therefore, excluding large trees (diameter>65 cm) from the cut and leaving them for natural evolution is considered a good measure to support ecological diversity (Humphrey *et al.*, 2004). Around 10 large stems per hectare is agreed to be a good indicator (Humphrey *et al.*, 2004; Marage & Lemperiere, 2005).

I.2.2) Ground layer vegetation

Several biodiversity indicators can be used from the ground layer species composition. The sensitiveness of some species or taxonomic groups to different environmental conditions, such as altitude or light and water availability, is widely used as an ecological indicator (Lindenmayer *et al.*, 2006). For instance, abandoned forests are more prone to host shade tolerant species, whereas light demanding species are more present in managed forest, given the differences in canopy cover (Sitzia *et al.*, 2012). However, the use of indicators species entails some difficulties due to the lack of documentation regarding the environmental conditions they are supposed to indicate or the variations of the response (Lindenmayer *et al.*, 2006).

Among the ground layer vegetation indicators proposed in the biodiversity assessment it will only be considered the mean number of herbaceous and woody species, that is, the species richness as indicator of forest naturalness. Nevertheless, it should be taken into account that vascular species richness may increase or decrease with increasing naturalness depending on specific conditions (Mayer *et al.*, 2004), and also according to the seasons of the year.

I.2.3) Deadwood

The quantity and quality of deadwood is also considered a key indicator of forest biodiversity and naturalness for forest management practices (Schuck *et al.*, 2004). The ecological importance of deadwood lies in its contribution to forest functioning and productivity, and the provision of habitat to a wide range of species from small vertebrate, cavity-nesting birds, lichens, saproxylix fungi and invertebrates (Humphrey *et al.,* 2004).

The natural disturbance regime, including natural thinning, is considered one of the main determinants for the accumulation of deadwood (Castagneri *et al.*, 2010; Hahn & Christensen, 2004; Humphrey *et al.*, 2004). Besides, the study of Coarse Woody Debris (CWD) in different decay stages can help to interpret the recent distrubances history and the present forest dynamics (Motta *et al.*, 2006). Commonly, the volume of snags represents the natural mortality and the amount of stumps is considered an indicator of human impact, while the significance of the volume of logs is more ambigous (Motta *et al.*, 2006; Castagneri *et al.*, 2010).

Deadwood studies from a wide range of European forest reserves and forest types (Hahn & Christensen, 2004; Humphrey *et al.*, 2004) suggest the use of intervals for application in forest management guidelines: CWD (m^3/ha) = (69-568).

I.3) Forest and Management Planning in Veneto Region

I.3.1) Forest surface and silver-fir woodlands

The forest in Veneto region counts with a high variety of forest types, up to 90 different sub-types (Del Favero, 2000). In total, the forested surface rises up to 414,894 ha (Regional Forest Map, 2005), which increased a 6.6% since 1980 (Unità di Progetto Foreste e parchi, 2012). Regarding the type of property, most of the forest surface is in private hands (60%), followed by municipalities (27.9%) and private collectively (6.3%) (Unità di Progetto Foreste e parchi, 2012). From data of 2001, the forested surface under a forest management planning tool represented the 49% of a total of 330,720 ha in that year (Carraro *et al.*, 2001).

Silver fir is prevalent in six different forest typologies according to different soil types (either acid or basic soils) and its species composition (Del Favero, 2000), typically mixed with Norway spruce (*Picea abies* (L.) H. Karst, 1881) and beech (*Fagus sylvatica* L., 1753) (Unità di Progetto Foreste e parchi, 2012). Silver-fir woodlands are mainly located in the montane altitudinal layer between 800 m and 1,400 m above sea level, in evolved and fertile soils with good water availability. In Veneto region they are principally spread in the Province of Belluno (16,560 ha) and in the Province of Vicenza (6,389 ha) (Unità di Progetto Foreste e parchi, 2012).

I.3.2) Multi-scale forest planning

Forest management policy in Veneto region derives from international, to community and national policies. The strategy programme for the forestry sector (PQSF in Italian) coordinates the international and European commitments at a national level, which general objective aims "*to encourage sustainable forest management*[1] *in order to protect land, mitigate climate change, enhance the production function of the forestry sector and ensure in the long-term, the multi-functionality and diversity of forest resources*" (Unità di Progetto Foreste e parchi, 2012). On the same general line, the Regional Forest Law (Regional law of 13 September 1978, n. 52) states among its main goals:

- Conservation of soil and natural environment
- Promotion of silvo-pastoral assets
- Production of timber
- Protection of the landscape.

At a regional level, the land planning policies regarding also forest management are developed through the Regional Territorial Plan of Coordination (PTRC in Italian) specifically for different landscape features, such as mountain forests, plain

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

woodlands, ecologic corridors and rural-urban areas (Unità di Progetto Foreste e parchi, 2012).

The multi-functionality of forest management in Veneto region is attributed to large landscape features such as mountain forests, in order to establish priorities to smaller landscape management units and to avoid conflicts of functions to forest properties. This is the scope of an intermediate management planning tool (PFIT in Italian) between regional strategy programmes and the traditional forest management planning, that it is still in experimental phase. By now it has been applied in two mountain areas of the region: highland of Asiago and Cadore-Longarone-Zoldo (Portoghesi *et al.*, 2013).

I.3.3) Forest management plans

Forest management planning in the mountain areas of Veneto is considered to be a tool to prevent the abandonment of silvo-pastoral activities, and thus its consequent loss of habitat and species biodiversity (Unità di Progetto Foreste e parchi, 2012). In fact, according to the regional law, all forests in the region must be managed and exploited following a management plan duly approved by the Regional Forest Administration.

The contents of forest management plan, also called forest working plans, is regulated by the Directive and Norm for forest planning (D.G.R. of 21 January 1997, n. 158), which introduced the use of forest typologies as an instrument of forest stand classification based on floristic, ecologic and silvicultural criteria becoming the basic silvicultural unit (Barbati *et al.*, 1999; Del Favero, 2000).

Lastly, according to the technical norm, the final goal of forest management planning is to regulate the forest ecosystem structure in such a way that ensures in time a forest stability compatibe with the provision of direct goods and indirect services (D.G.R. 21 January 1997, n. 158).

I.4) Background

This thesis is framed in a previous study by Sitzia *et al.* (2012) that compared dendrological composition and three groups of biodiversity variables (deadwood and vascular species richness and composition) within managed without planning and abandoned silver fir woodlands in Cajada and Tovanella in the area of Cadore (Province of Belluno).

The comparison of stand structure and diversity of managed forests with planning between managed forests without planning and abandoned forests, might serve to understand the convenience of forest planning to achieve the general forest management goals.

I.5) Objectives

The primary objectives of this thesis are:

- To compare the dendrological composition and diversity indicators of mature silver fir woodlands under management planning with abandoned and managed without planning stands.
- To analyse the evolution of five management plans in ten compartments with production function through the last four validation periods focusing on the forest structure and cutting plans.

II) MATERIALS AND METHODS

II.1) Study area

Among the compartments with productive function managed by the Forest and Parks Department (FPD) of Veneto Region, ten compartments in five different forest management plans were selected following the same criteria as the study of Sitzia *et al*. (2012), and adapted in terms of the description of compartments used in the management plans. The different characteristics of the stands were prioritized according to the following order:

1. Forest type: silver fir woodland in carbonate soil
2. Forest structure: single-layer canopy
3. Stand development stage: mature
4. Topography: slope lower than 20°
5. Type of survey: total calipering

It was also considered in the compartment description a high presence of silver fir, around 40% of the canopy composition. The structural type considered in the compartment descriptions were the irregular and even-aged forms. Stands older than 150 years-old and a growing stock around 300 m^3/ha (Susmel, 1980) were considered fully mature.

The following Table 1 shows the nomenclature and codes used by the forest and parks department for the selected management plans, and the forest parameters considered for the selection of two compartments in every management plan.

Table 1: Nomenclature and validation period of the selected management plans

Management Plan	Code	Validation period	Compartment
Auronzo di Cadore	012_1	1975 - 1984	044 105
	012_2	1986 - 1995	
	012_3	1996 - 2007	
	012_4*	2010 - 2019	
Campolongo	023_1	1976 - 1985	003/1 003/2 006/1 006/2
	023_2	1986 - 1995	
	023_3	1996 - 2005	
	023_4	2006 - 2015	
Roana	034_1	1977 - 1986	223 246
	034_2	1989 - 1998	
	034_3	2000 - 2009	
	034_4*	2011 – 2022	
Domegge di Cadore	040_1	1977 - 1986	025 029
	040_2	1987 - 1996	
	040_3	1998 - 2009	
	040_4	2011 - 2022	
Asiago	064_0†	1977 - 1986	106 113
	064_1	1985 - 1994	
	064_2	2000 - 2009	
	064_3*	2010 - 2022	

**: General part of the management plan not available (not yet approved by FPD)*

†: Compartment descriptions not available.

The first number of the code refers to the management plan, and the second number to the number of the revision, that is, 023_4 is the fourth revision of the management of Campolongo. The current complete management plan including the general description of Auronzo di Cadore, Roana and Asiago was not yet available by the administration, just the database (GPA) summarising the compartment descriptions.

At the second revision of Campolongo's management plan, the compartment 003 and 006 were divided in two sub-compartments respectively coded (/1 and /2).

Table 2: Forest parameters considered for the selection of the ten compartments.

Compartment	Forest type	Structure	% A. alba	Age	Structural type*	Slope (°)	Volume (m^3/ha)	Type survey†
044	ASC	Irregular	43	160	m2	10 - 20	378.5	rr
105	ASC	Irregular	47	145	m2	10 - 20	372.4	rr
003/1	ASM (2)	Irregular	53	155	-	20 - 30	488.8	rr
003/2	ASC (2)	Irregular	59	170	-	10 - 20	321.2	rr
006/1	ASC (2)	Even-aged	45	155	Bi-layer	0 - 10	329.8	ct
006/2	ASC	Irregular	45	180	-	20 - 30	307.5	ct
223	ASC	Irregular	47	160	m2	10 - 20	335.4	ct
246	ASC	Irregular	60	140	m2	10-20	315.7	ct
025	ASC	Irregular	26	182	m3	10-20	269.6	rr
029	ASC	Irregular	37	164	m4	20-30	335.0	ct
106	ASC	Irregular	53	179	m3	10-20	471.7	rr
113	ASC	Irregular	53	180	m3	10-20	452.2	rr

†: rr=relascopic survey, ct=total calipering;
**:according to uneven-aged cultural model (Susmel, 1980)*

In some of the sub-compartments of Campolongo the studied forest type (ASC) is considered in second term (2). In all the rest, it was always considered in first term or the single forest type present in the compartment. The structural type corresponds to the most advanced described in the compartment description.

As an example, Figure 2 shows the location of the sample units in the two compartments selected in Auronzo di Cadore.

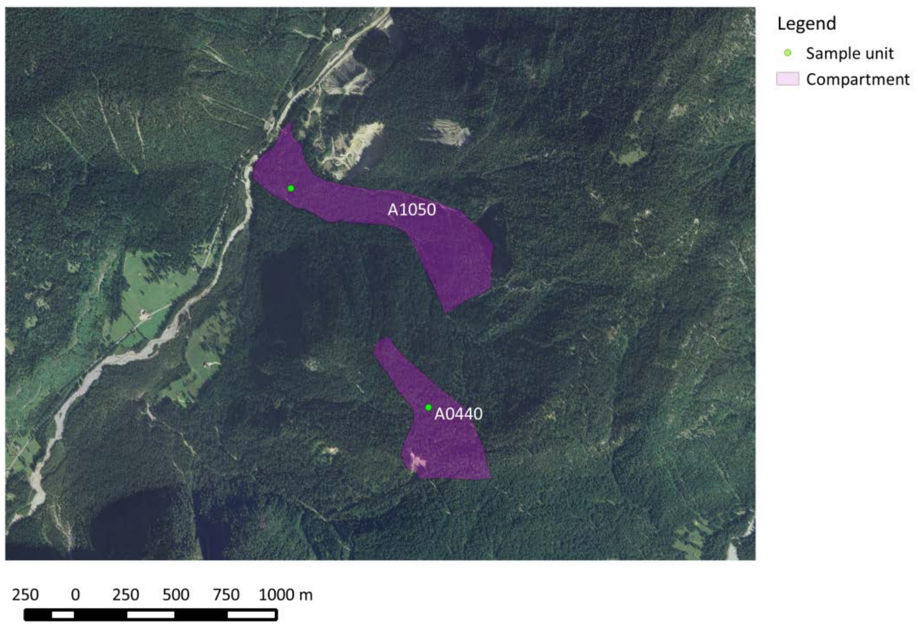


Figure 2: Location of sample units of compartments 044 and 105 in Auronzo di Cadore

II.2) Data collection

II.2.1) Forest structure and Coarse Woody Debris

In every compartment, one sample unit was located there were it was found a greater concentration of big dimension trees, that is, where it was more mature. Every sample unit consists on a 12.5 m radius plot with a 6 meters sub-plot and two transects.

The next thresholds were applied on the circular plot:

- Living tree with Diameter at Breast Height (DBH) over 7.5 cm
- Dead standing tree (snag) with diameter at 0.5 m of height over 10 cm.
- Stumps with superior diameter over 10 cm.
- Dead laying trees (logs) with bigger diameter over 10 cm.

The next features were sampled on the elements fulfilling these thresholds:

- Coordinates (azimuth and distance); for logs at both extremes
- Species
- DBH for standing living trees and snags; for stumps diameter at the base and the top; for logs diameter at both extremes.
- Height
- Height of first living branch
- Radius of crown projection at four sides (up-hill, down-hill, left and right)
- Vegetative conditions of living trees:
    1. Good vitality
    2. Slightly damaged or decayed, good vitality
    3. Damaged or decayed, reduced vitality
    4. Strongly decayed, few vitality
    5. Dead standing tree
- Decay class (Maser & Trappe, 1984) from 1 to 5 for logs and snags, and from 1 to 4 for stumps.

Decay class definitions are attached in Appendix A.

The concentric sub-plot of 6 m radius was used to sample the regeneration with the next thresholds:

- Height over 10 cm
- Diameter at 0.5 m of height below 4 cm

The next features were sample in the sub-plot.

- Species
- Diameter at 0.5 m height.
- Total height
- Height of the first branch (up-hill and down-hill)
- Radius of projection of the crown (up-hill, down-hill, left and right)
- Damage from browsing
- Type of damage:
    - simple browsing
    - repeated browsing
    - rubbing
    - debarking

Two transects were used to estimate the volume of deadwood per hectare in every sample unit. The volume of logs was surveyed following the Line Intersect Sampling (LIS) method (Van Wagner, 1982; Marshall *et al.*, 2000), while the snags and stumps were sampled in a rectangular transect along the linear transect.

The transects of 50 m length start from the central point of the circular plot, one towards the north and the other to the est. Along the transect, the following features were recorded:

- Coordinates respect to the linear transect
- Diameter (over 5 cm) at the intersecting with the line
- Decay class

Simultaneously, every stump and snag were recorded at a distance lower than 4 m on both sides of the liner transect. The next features for stumps and snags were sampled:

- Coordinates respect to the linear transect
- Superior and inferior diameter (over 5 cm) identifying the stump with the shape of a trunk cone.

- Height of the stump (higher than 1.3 m was considered a snag)
- Natural or artificial origin of the stump
- Decay class

For the snags the next features were sampled:

- Coordinates respect to the linear transect
- DBH
- Height of the snag
- Decay class

II.2.2) Vascular species composition

The floristic survey was conducted in every circular plot of 12.5 m radius. For every species identified it was estimated an index of cover following the Braun-Blanquet method (1932) based on the percentage of surface covered by every species.

Also, vascular species were recorded on every meter along the linear transects.

II.3) Data analysis

II.3.1) Dendrological composition and forest structure

Basic forest parameters were calculated up from the collected data by sample unit including tree species composition. Tree density, Basal Area (BA) and volume are referred to one hectare. This set of parameters is collectively named as dendrological composition (Hellrigl, 1986a). The next formulas were used for trees sampled in the circular plot:

$$BA(m^2/ha) = \frac{\pi}{4} \cdot \Sigma(n_i \cdot DBH_i) \cdot 10{,}000/S_p$$

where S_p is the surface of the circular plot.

The unitary volume of every tree was calculated with the double entrance table used in the Italian National Forest Inventory (Castellani *et al.*, 1984). The formulas for every tree species are attached in the Appendix B.

From the coordinates and crown features of every living tree (diameter, height, and crown parameters) it was possible to represent a three-dimensional realistic view of the circular plot with the software SVS 3.36 (Stand Visualization System). Through these representations SVS is also able to calculate the crown cover in percentage, by using a sub-plot of half of the size of the circular plot the estimation achieved is more robust (McGaughey, 2002).

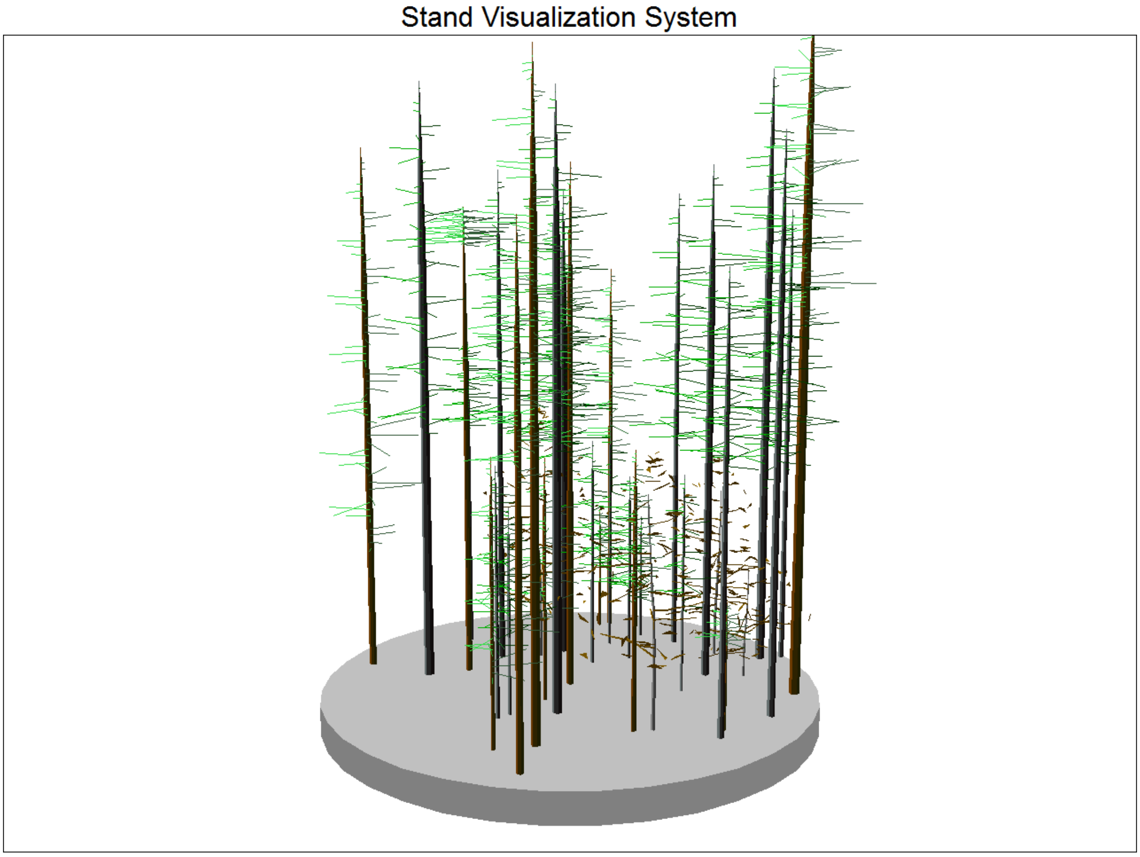


Figure 3: Perspective view of circular plot in compartment 012_115

To extend the analysis of the forest structure, two indicators of structural diversity were calculated: TDD (Tree Diameter Diversity) and THD (Tree Height Diversity) by using the formula of Shannon-Wiener. Previously, the height data is grouped in 5 m class and diameter data in 5 cm class.

$$T(D/H)D = H' = -\sum_{i=1}^{n} p_i \ln p_i$$

where p_i is the proportion of trees in the i-th diameter class or height class.

II.3.2) Coarse Woody Debris

Deadwood volume per hectare was calculated on every sample unit (circular plot and transects). The same formulas per species used for the living trees were used for the snags. All the stumps and the logs surveyed in the circular plot were estimated with the volume formula of Smalian:

$$v(m^3) = \frac{(S_1 + S_2)}{2} \cdot L$$

where $S_1$and S_2 are, in case of the stumps, the section area of the base and top, and for the logs the section area of both extremes; and L is the height of the stump, or the length of the log.

While the logs in the linear transects were estimated with the next formula:

$$v(m^3/ha) = \frac{\pi^2}{8 \cdot L} \cdot \Sigma d^2$$

where L is the length of the transect (50 m) and d is the diameter at the intersection of the log with the linear transect.

II.3.3) Vascular species composition

All the vascular species identified in the plots were divided in three groups: trees, woody and herbaceous species. The species richness was calculated as the mean number of total species per compartment.

II.3.4) Management plans

The structure and contents of the management plans is regulated since 1997 by the directive and norm of forest planning (D.G.R. 21 January 1997 n. 158). A management plan is commonly divided in three parts: environmental study and general features; management; and compartment description.

II.3.4.1) General part

From this part of the management plans it has been analysed the floristic surveys giving the next values according to the quality of the provided data for every revision:

0. Absent
1. List of species with no location
2. List of species with location
3. List of species with location and cover data

II.3.4.2) Compartment description

From all the information provided in the compartment description it has been summarised the evolution of the diametric distribution, the dendrological composition and the cutting plan.

Special attention is given to the evolution of the proportion of broadleaves in the canopy layer, as an indicator of the naturalness of the stand.

The utilization rate expressed in the cutting plans represents the portion of the growing stock that is proposed to be cut:

$$Utilization\, rate\ (\%) = \frac{Yield}{Volume} \cdot 100$$

The utilized volume for a cutting plan was included whenever it was available in the management plans. This data was used to calculate a deviation rate of the performed cut, either they were planned or caused by accidental events, generally windthrows. This rate is calculated in terms of growing stock at the year of the cut:

$$Deviation\, rate\ (\%) = \frac{Utilization - Yield}{Volume} \cdot 100$$

The quality of the treatment description was also evaluated according to the information given in the cutting plan. One of the next values was given to every treatment described along the revision available of the management plans:

0. Description of structural types. Type of cut.
1. Description and location of structural types. Type of cut
2. Description, location and surface of structural types. Type of cut specified by structural type or located in the compartment.
3. Description, location and surface of structural types. Type of cut specified by structural type or located in the compartment. Explanation of the harvesting method.

II.4) Statistical analysis

II.4.1) Stand structure and diversity

The main parameters regarding the stand structure, coarse woody debris and vascular species were analysed through an ANOVA test between three management regimes: abandoned, management without planning, and management with planning.

On the cases where the variances were proved not to be homogeneous through the Fligner-Killeen test, the percentage data was transformed to the arcsine of the square root, and absolute values were transformed to the log_{10}.

II.4.2) Evolution of management plans

Another ANOVA test was performed relating the evolution of the treatment description with the deviation rate, assuming that a precise description of the silvicultural treatment enables a correct execution of the planned cut, thus reduces the deviation rate.

The matter of the assumption is not the value of deviation rate, but the fact that a precise treatment description determines the accuracy of the cut. Therefore, deviation values within the range between -0.5 and +0.5 were considered as no deviated.

III) RESULTS

III.1) Structural type level

III.1.1) Dendrological composition and forest structure

The dendrological composition composed by the density, DBH, height, BA, volume and crown cover is shown in Table 3 per plot and in Table 4 per species.

The variability of the density between the ten plots, that ranges from 305.6 stems/ha to 713.0, determines also the results for BA and volume. The plot in compartment 012_105 is the lowest in terms of BA and volume (41.6 m^2/ha and 521.3 m^3/ha) whereas the highest results are found in the plot 012_044 (84.3 m^2/ha and 1337 m^3/ha) Mean values of BA (60.9 m^2/ha) and volume (871.7 m^3/ha) represents mature stands.

Values of DBH, height and crown cover presents less variability. Mean DBH ranges from 24.2 to 43 cm, and height from 18.3 to 27 m. Most of the values of crown cover are between 80% and 90%, except from the result the plot 040_028 which is considerably lower than the rest (48%). A mean crown cover of 80% can be considered as a fairly closed canopy.

Table 3: Forest structure parameters per plot

Plot	Density (N/ha)	DBH (cm)	H (m)	BA (m^2/ha)	Volume (m^3/ha)	Crown cover (%)
012_105	713.0	24.2	18.8	41.6	521.3	88
012_044	672.3	35.2	26.8	84.3	1337	82
023_003_2	570.4	24.6	18.3	42.8	608.3	84
023_006_2	468.6	34.5	23.2	59.6	882.3	73
034_223	611.2	31.8	20.1	65.4	854.4	88
034_246	611.2	37.1	26.5	73.0	1010.6	83
040_025	305.6	43.0	27.0	50.8	736.1	48
040_029	611.2	29.0	25.8	51.3	816.6	80
064_106	550.0	34.4	21.2	74.0	1004.9	84
064_113	488.9	37.3	25.2	66.3	945.5	90
Mean ± SD	560.2 ± 116.5	33.1 ± 5.9	23.3 ± 3.4	60.9 ± 14.2	871.7 ± 229.2	80.0 ± 12.2

Table 4: Dendrological composition per tree species

Density (N/ha)	Mean ± SD
Abies alba	309.7 ± 79.1
Fagus sylvatica	87.6 ± 91.6
Picea abies	163.0 ± 112
DBH (cm)	
Abies alba	38.2 ± 8.3
Fagus sylvatica	8.7 ± 6.3
Picea abies	33.6 ± 16.6
H (m)	
Abies alba	25.9 ± 3.2
Fagus sylvatica	8.0 ± 5.7
Picea abies	22.9 ± 10.2
BA (m^2/ha)	
Abies alba	40.8 ± 13.4
Fagus sylvatica	1.4 ± 2
Picea abies	18.7 ± 12
Volume (m^3/ha)	
Abies alba	595.1 ± 189.1
Fagus sylvatica	11.8 ± 18.5
Picea abies	264.8 ± 183.6
Crown cover (%)	
Abies alba	58.0 ± 17.7
Fagus sylvatica	19.7 ± 19.7
Picea abies	15.9 ± 15.9

Silver fir, Norway spruce and beech are the three tree species found in the canopy, although they were not always present in every plot (Figure 2). In the plots of compartments 012_044, 040_25 and 040_29 beech was not present in the canopy, and in the plot of compartment 064_106 Norway spruce was absent.

Silver fir is the main tree species found in the plots, except in the plot of compartment 012_044 where Norway spruce is more abundant, and in the plot of compartment 064_106 beech is slightly more frequent in terms of tree density (Figure 2).

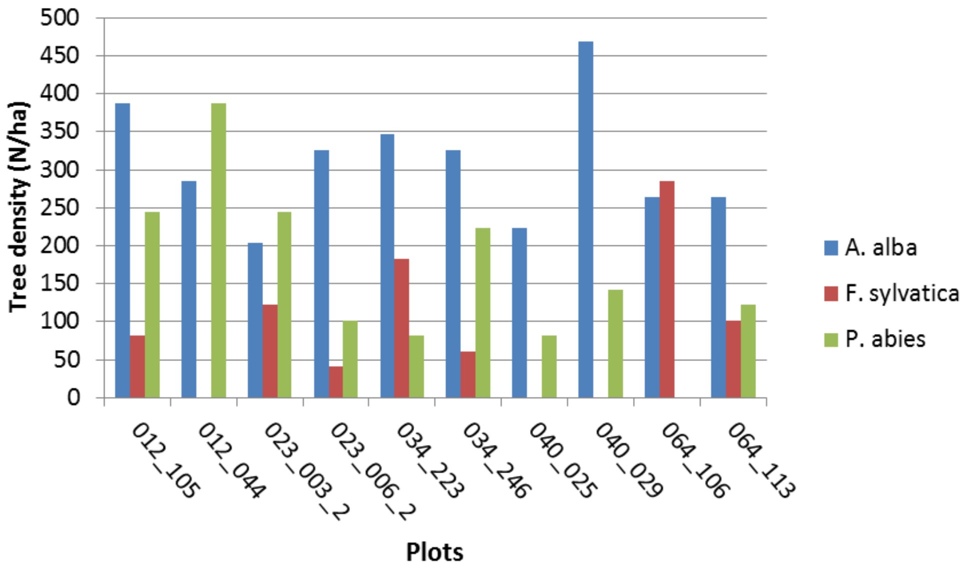


Figure 4: Tree species composition in tree density per plot

The distribution of the species composition is also represented in Figures 5 and 6 which shows respectively the contribution in percentage of the three tree species to tree density and BA. It is remarkable the low contribution of beech in terms of basal area.

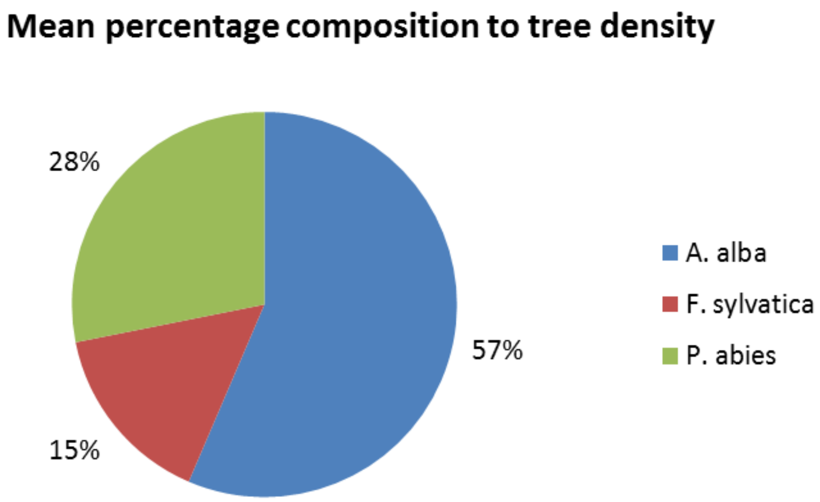


Figure 5: Mean percentage contribution of tree species to tree density

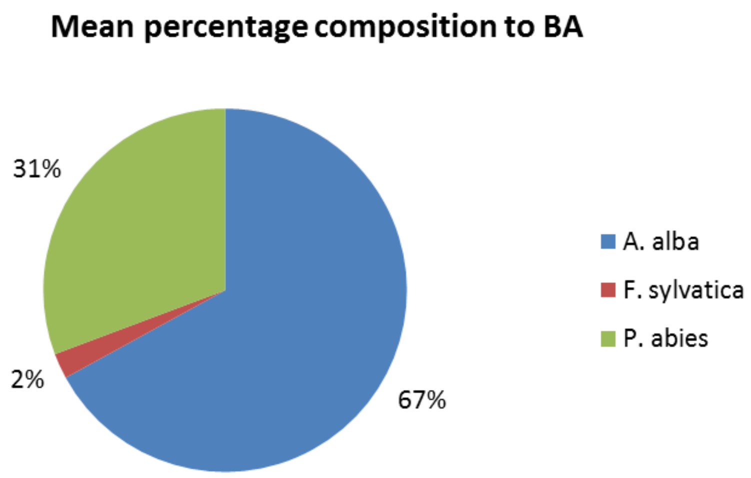


Figure 6: Mean percentage contribution of tree species to basal area

As an example, Figure 7 shows the overhead view of crown cover for the plot in compartment 064_113 performed with the software SVS 3.36.

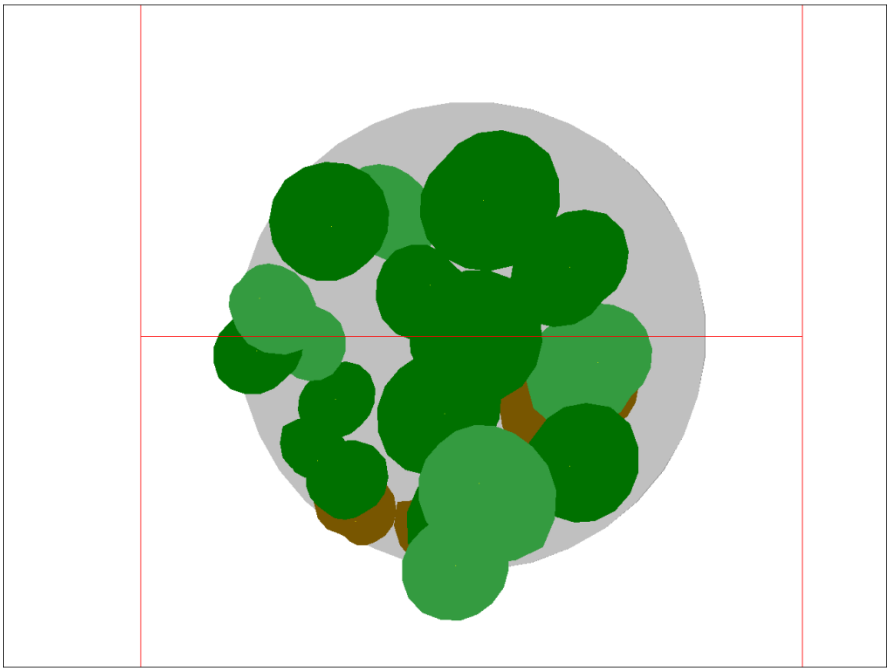


Figure 7: Overhead view of crown cover in plot 064_113

The proportion of mean crown cover per species (Figure 8) shows a very similar distribution as the proportion of tree density, being silver fir in first place over 50%, followed by Norway spruce in second place and beech in third place.

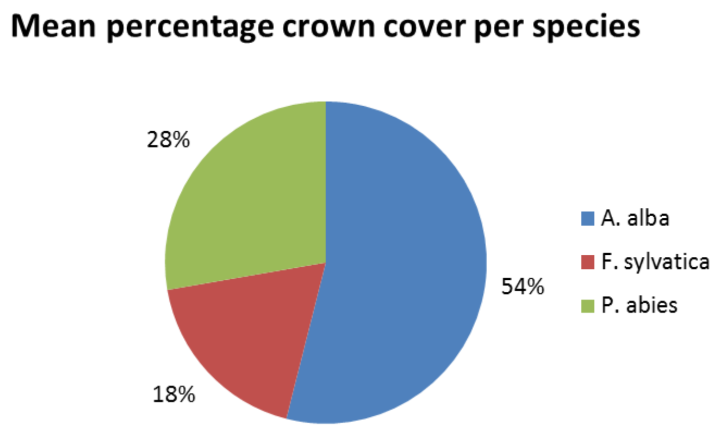


Figure 8: Mean percentage crown cover per species

In order to elaborate the diametric distribution (Figure 9), all the diameters surveyed were grouped in 5 cm classes, taking 7.5 cm as the lower threshold till 85 cm which is the maximum diameter surveyed. The diametric distribution for all the plots surveyed shows a classical inverted-J form of uneven-aged structures with a plateau within the medium diameter classes roughly from 30 to 55 cm. This distribution might serve to define the irregular structure, where it is not possible to identify at stand level whether it is even-aged or the uneven-aged, given the combined spatial distribution of both structures.

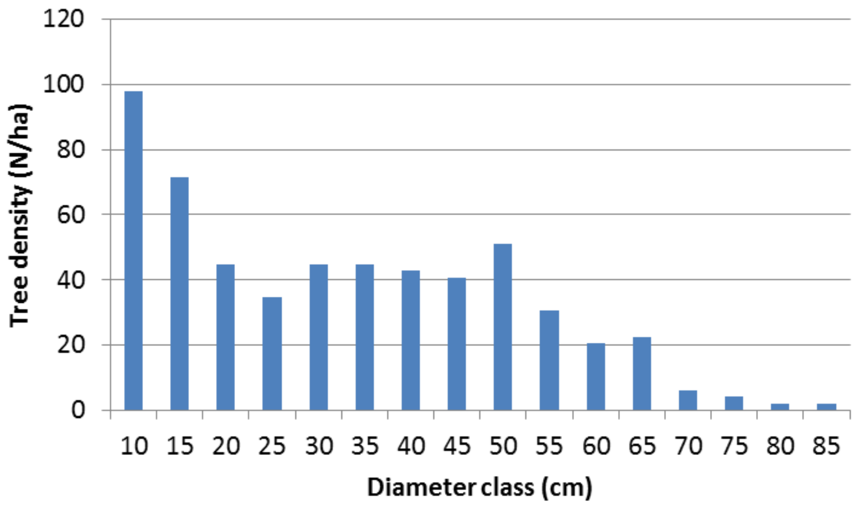


Figure 9: Mean total diametric distribution

As with the diameter, all the height values surveyed in the plot were grouped in 5 m height class, being 4 m the minimum and 40 m the maximum height surveyed. The height distribution shows two different peaks at 10 m and 30 m class (Figure 10), representing a bi-layer structure.

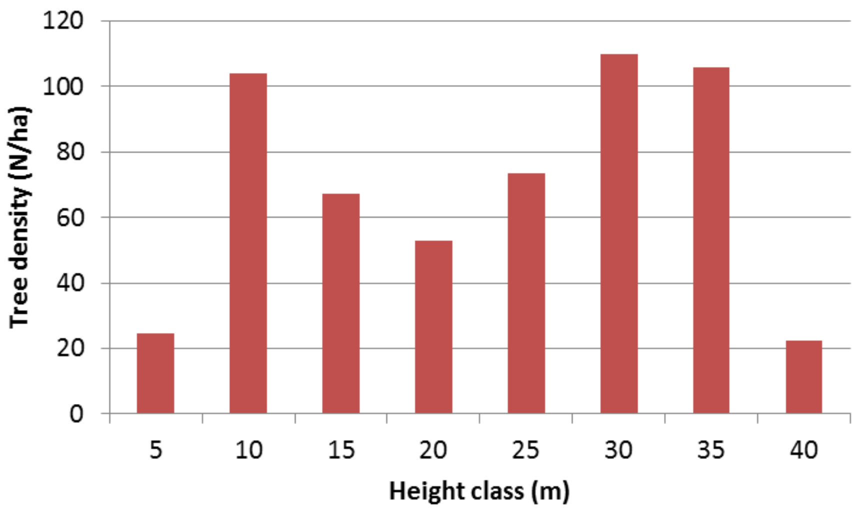


Figure 10: Mean total height distribution

The differentiation of tree species in the diameter distribution (Figure 11) and the height distribution (Figure 12) clarifies the different roles of the three tree species in the structure.

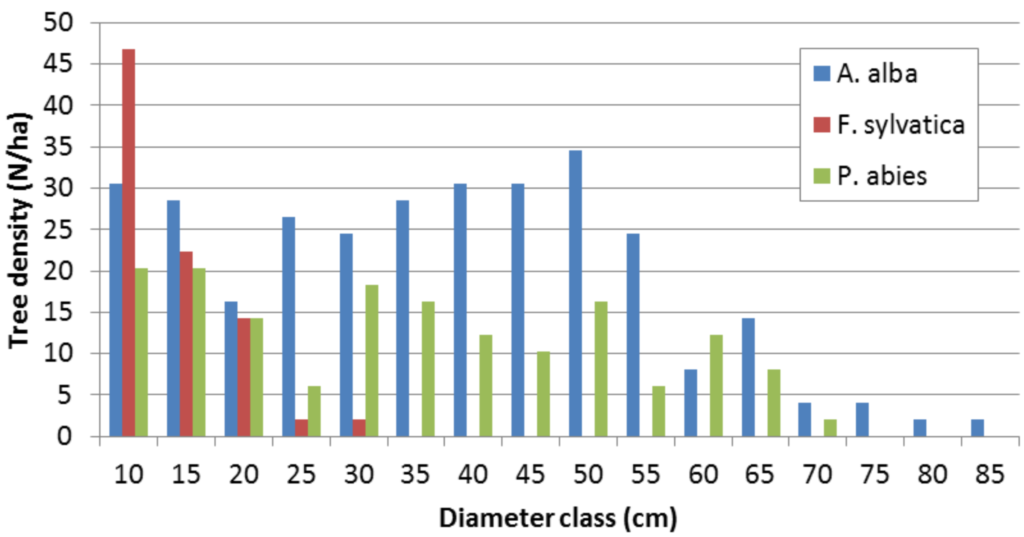


Figure 11: Mean total diametric distribution per tree species

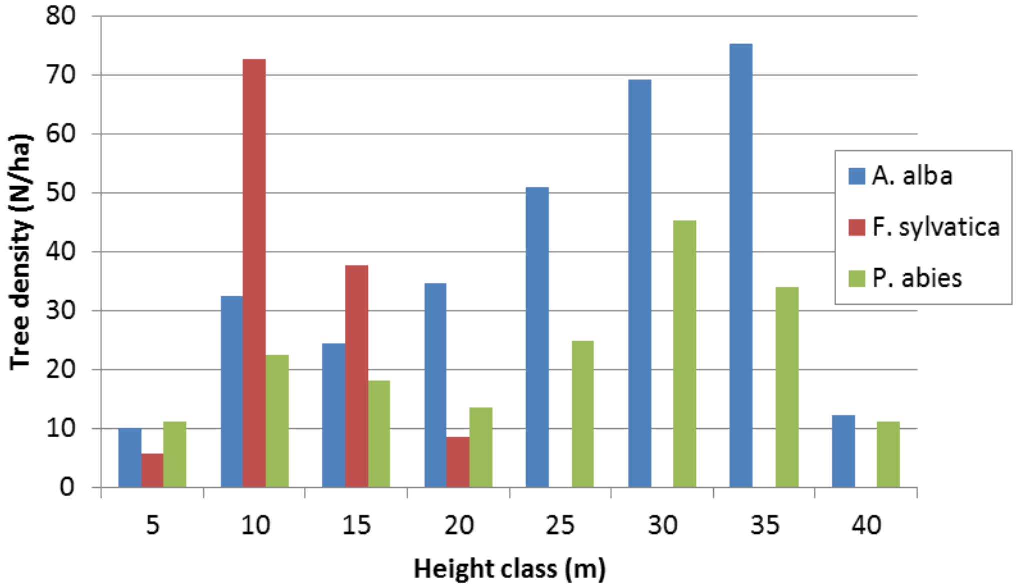


Figure 12: Mean total height distribution per tree species

From both distributions it can be stated that the conifer species are the single components of the main canopy layer. However, silver fir is more abundant than Norway spruce in the majority of diameter and height classes, in fact, being the single species present over 75 cm class. On the other hand, beech is the most abundant tree species in the lower diameter and height classes, for instance, being by far the main species at 10 cm diameter class and 10 m height, noting also the peaks of silver fir and Norway spruce in low diameter and height classes.

Overall, the species composition in diameter and height distributions reflect an irregular bi-layer structure with dominance of mature silver fir and Norway spruce trees over lower diameters class, presence of extra-mature trees, and abundance of beech in the dominated layer.

From all the trees surveyed, diameter values were divided in 16 classes and height values in 8 classes, giving a maximum TDD value of 2.8 and a THD of 2.1 according to the number of classes. The value of TDD ranges from 1.78 at plot 023_003_2 to 2.39 at 064_106, a THD ranges from 1.35 at 034_246 to 1.8 at 064_106 (Table 5).

Given the mean values of diameter (TDD=2.1) and height diversity (THD=1.68), it can be concluded its good variability mostly attributed to the abundance of beech in the dominated layer.

Table 5: Tree diameter and height diversity values per plot

Plot	TDD	THD
012_105	2.04	1.79
012_044	2.37	1.96
023_003_2	1.78	1.67
023_006_2	2.17	1.71
034_223	2.29	1.69
034_246	1.95	1.35
040_025	1.99	1.41
040_029	2.16	1.71
064_106	2.39	1.8
064_113	2.29	1.73
Mean ± SD	2.14 ± 0.2	1.68 ± 0.18

III.1.2) Coarse Woody Debris

The Coarse Woody Debris (CWD) is composed by the volume of deadwood coming from stumps, logs and snags (Table 6). The total volume of deadwood presents a high variability, almost equal to the mean. CWD ranges from 9 to 76.3 m^3/ha, with a mean of 22.7 m^3/ha, representing a deadwood ratio of 2.6% respect to the growing stock. This variability is due to the range of values of logs (0-59.9 m^3/ha) and snags (0-27 m^3/ha), with means of 9.8 and 5.5 m^3/ha respectively. It is remarkable the high volume of logs found in the plot of the compartment 040_025 with 59.9 m^3/ha, particularly due to the big dimension of three whole trees laying on the ground with superior diameter between 30 and 45 cm. Stump volume values presents less variability with a mean of 7.3 m^3/ha.

Table 6: Coarse woody debris volume per plot

Plot	Stumps (m^3/ha)	Logs (m^3/ha)	Snags (m^3/ha)	CWD (m^3/ha)
012_105	8.8	0.1	0.1	9
012_044	10.1	0.8	3.6	14.6
023_003_2	10.4	0	0	10.4
023_006_2	6.1	1.8	0.1	7.9
034_223	12.2	5.3	0.9	18.5
034_246	7.7	8.7	2	18.4
040_025	1.4	59.9	15	76.3
040_029	10.2	0.9	2.6	13.8
064_106	3.5	16.2	27.1	46.9
064_113	2.5	4.7	3.7	10.8
Mean ± SD	7.3 ± 3.8	9.8 ± 18.3	5.5 ± 8.8	22.7 ± 22.0

The distribution in terms of volume of three components of CWD is pretty proportionated with 32% of stumps, 44% of logs and 24% of snags (Figure 13)

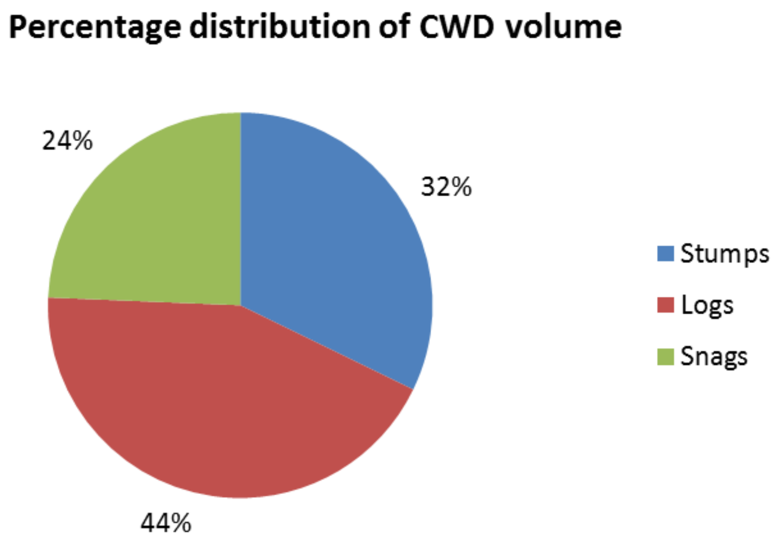


Figure 13: Percentage distribution of Coarse Woody Debris in volume

According to the decay classes, the majority of the stumps were found in advanced state of decomposition (58% at decay class 4), whereas logs and snags were more often found in earlier state of decomposition (65% of snags at decay class 1; 50% of logs at decay class 1 and 2) (Table 7).

Table 7: Decay class distribution (%) of Coarse Woody Debris

Decay class	Stumps (%)	Logs (%)	Snags (%)
1	8	19	65
2	10	31	10
3	24	20	16
4	58	27	10
5		3	0

III.1.3) Vascular species composition

The understory composition indicates the belonging of these silver fir woodlands to the *Adenostylo glabrae-Abietetum albae* vegetation of the regional phytosociological classification (Del Favero & Lasen, 1993), the same as the stands in Cajada and Val Tovanella from previous study of Sitzia *et al*. (2012) which are compared in the statistical analysis.

All the vascular species found in the survey are listed in the Appendix C. According to the three different groups of species, there were found a mean of 2.7 tree species, 7.2 woody species and 18.6 herbaceous species (Table 8).

Table 8: Species richness in number of species per plot at understory and tree layer

Species richness (nº of species)	Trees	Woody	Herbaceous
012_044	3	6	23
012_105	2	11	21
023_003_2	3	10	22
023_006_2	3	7	19
034_223	3	6	12
034_246	3	7	15
040_025	3	9	25
040_029	2	9	14
064_106	2	2	15
064_113	3	5	20
Mean ± SD	2.7 ± 0.5	7.2 ± 2.7	18.6±4.4

III.2) Statistical analysis: comparison of stand structure and diversity between three management regimes

From the results yielded in Cajada (managed forest without planning) and Val Tovanella (abandoned forest) (Sitzia, *et al.*, 2012), an ANOVA test was performed introducing the results on stand structure and diversity from silver fir woodlands managed with planning by the forest administration of Veneto region (Table 9).

Looking at the *p* level and the means, it is possible to identify differences with statistical significance ($p<0.05$) between the three groups.

First significant differences are found in the species composition of the canopy in terms of percentage of tree density, finding that in the abandoned forest silver fir is significantly lower and beech higher (Figure 14). The same differences are found in terms of BA (Figure 15).

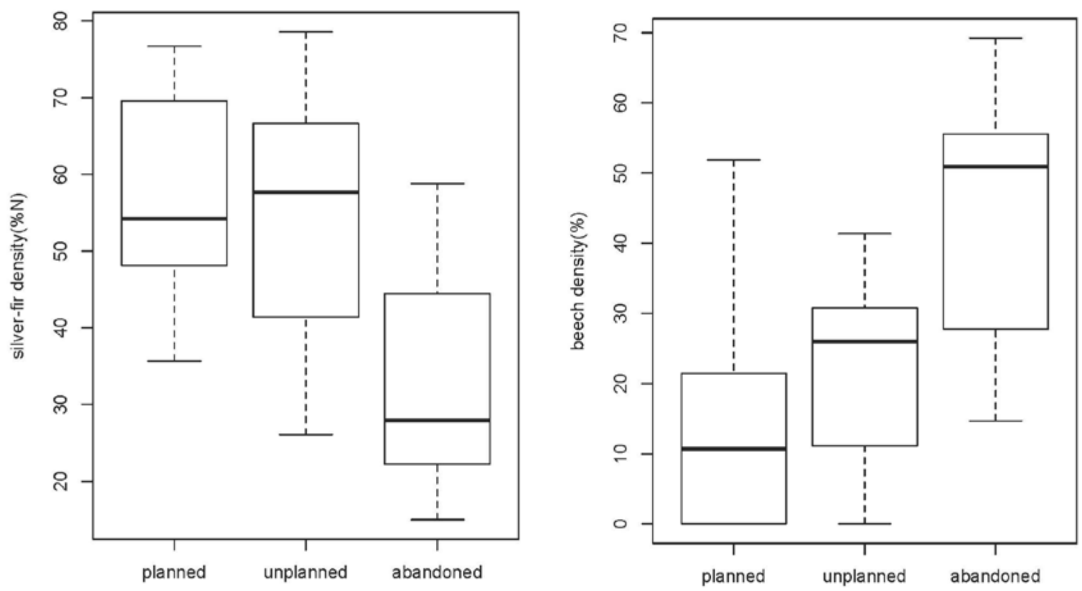


Figure 14: Box plots of silver fir and beech tree density (%)

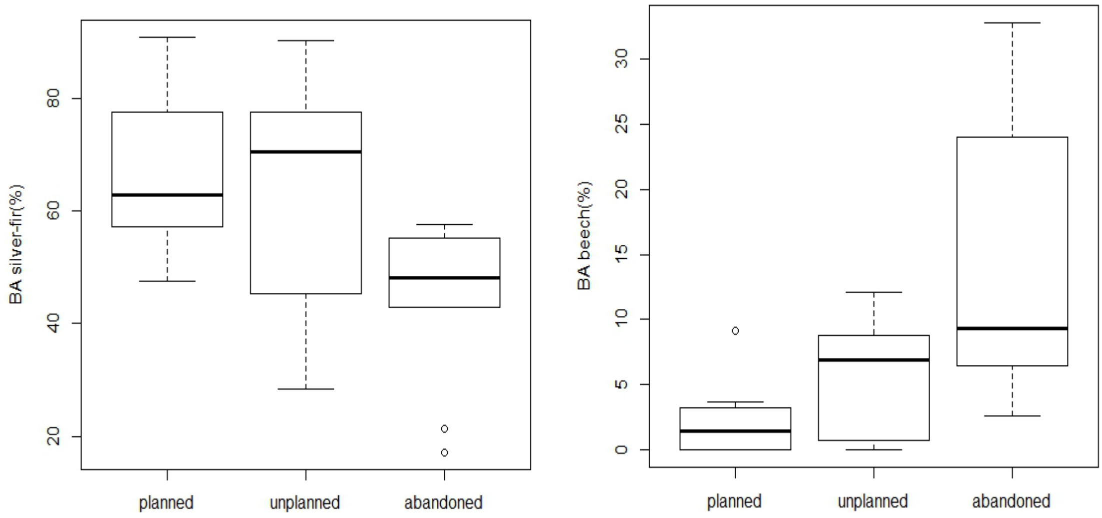
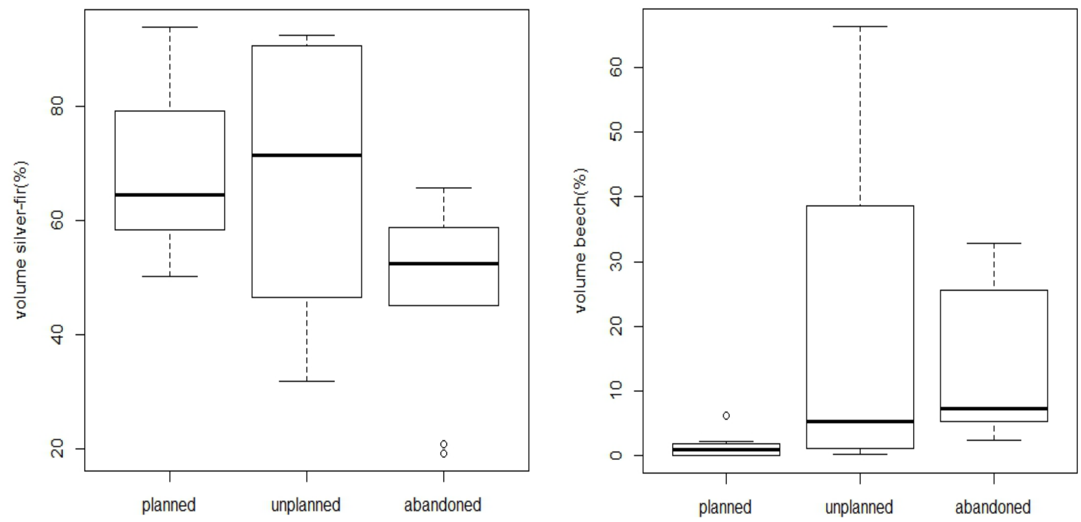


Figure 15: Box plots of silver fir and beech BA (%)

Instead, the proportion of species for relative values of volume shows a different arrangement: where the contribution of silver fir to the volume is fairly similar in both managed forests, and significantly lower in the abandoned forest, while for Norway spruce is significantly lower in the forest without management plan (Figure 16).



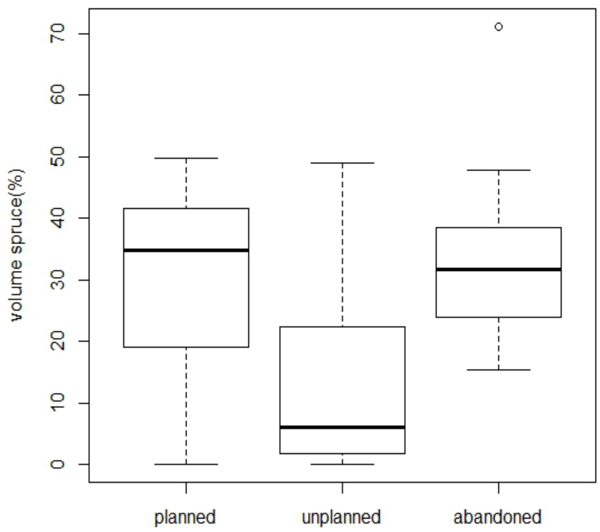


Figure 16: Box plots of silver-fir, beech and Norway spruce volume (%)

The greater abundance of beech in the abandoned forest is represented also in terms of crown cover being significantly higher than in both managed forests (Figure 16).

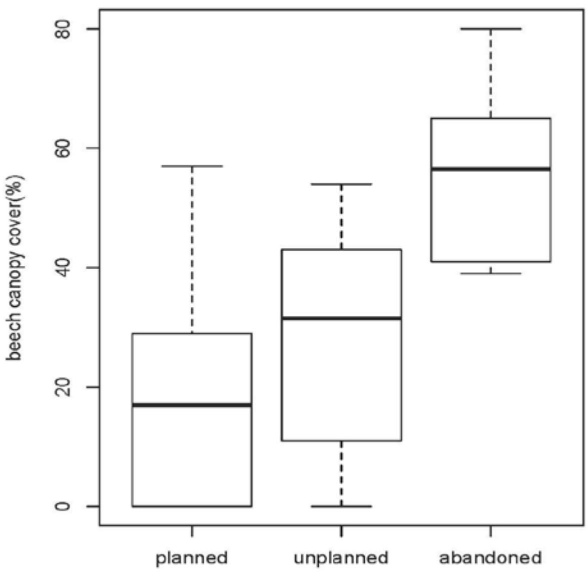


Figure 17: Crown cover (%) of beech

Absolute values of BA and volume are significantly different and increasing from abandoned, managed without planning to managed with planning, especially in terms of volume (Figure 18).

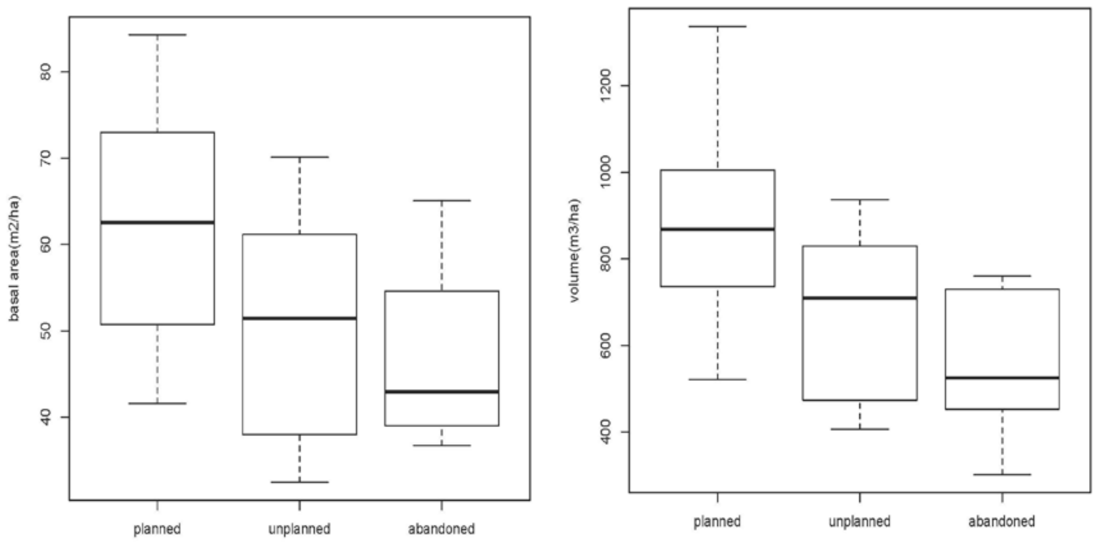


Figure 18: Box plot of total BA (m²/ha) and total volume (m³/ha)

Regarding the CWD, the volume of dead stumps is significantly higher by far in the managed forest without planning, being fairly similar in the abandoned and the managed forest with planning. On the other hand, the three means of volume of snags are clearly different, increasing from managed forest without planning, managed with planning to abandoned forest (Figure 19).

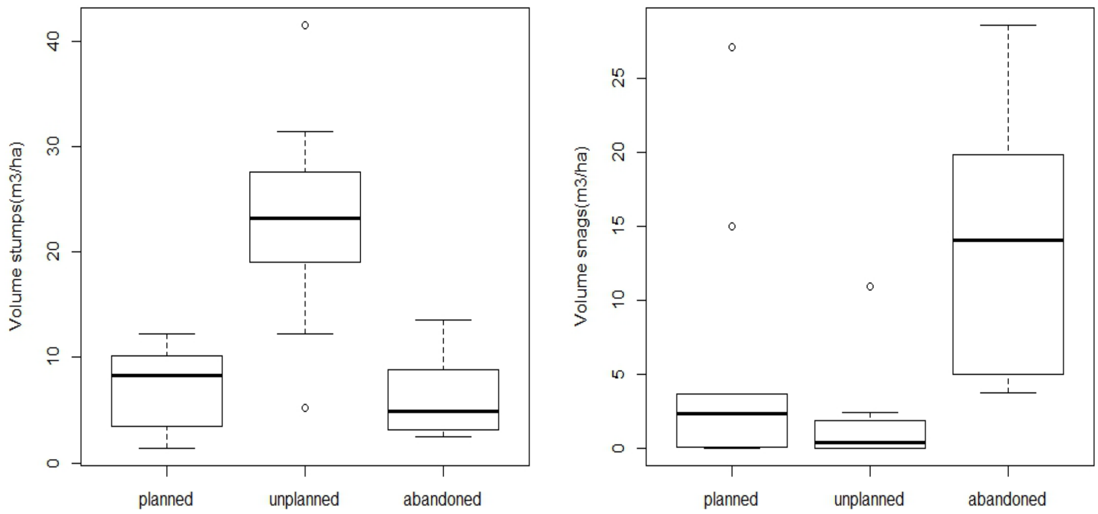


Figure 19: Box plots of volume (m³/ha) of stumps and snags

In terms of species richness, the number of tree species in the canopy is significantly higher in the abandoned forest; while the herbaceous species found in the planned forest is significantly lower than the rest (Figure 20), although these results should be interpreted cautiously given the time limitation of the performed floristic surveys.

No further significant differences are found between the three groups for the woody understory species.

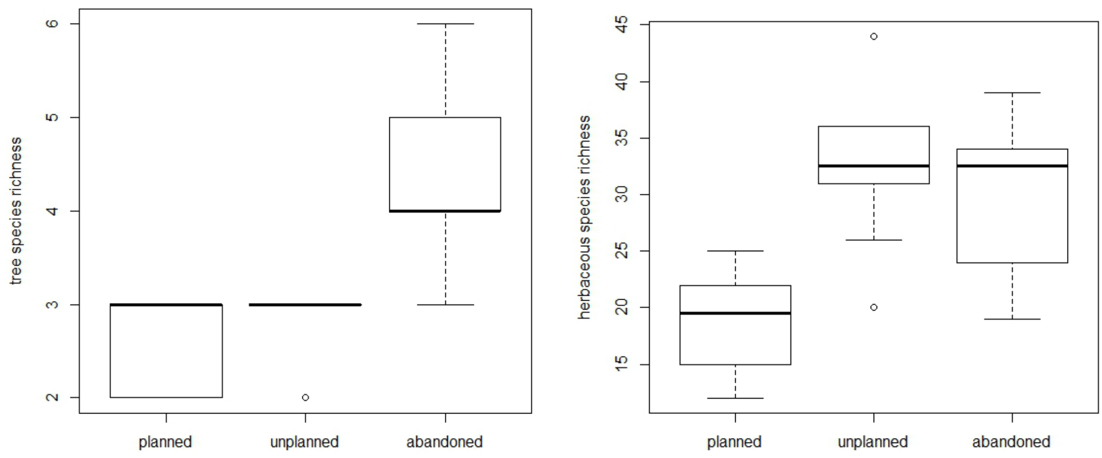


Figure 20: Box plot of tree and herbaceous species richness

Lastly, no further significant differences were found in TDD or THD between the three groups.

Table 9: Mean ± SD of stand structure and diversity parameters of the three management regimes

	With MP	Without MP	Abandoned	*F* value	*P* level
Altitude (m)	1191±166.4	1228.5±43.5	1221±102.8	0.294	0.748
Slope (°)	14.5±3.7	16.1±5.4	14.8±8	0.201	0.819
Density (N/ha)	560.2±116.5	491±196.7	641.7±202	1.836	0.179
Abies alba (%)	56.4±13.3	53.9±17.5	31.6±13.8	8.336	**0.002**
Fagus sylvatica (%)	15.4±16.4	23.5±12.6	44.8±18.5	9.01	**0.001**
Picea abies (%)	28.1±15.9	22.6±20.1	16.7±6	1.428	0.257
BA (m^2/ha)	60.9±14.2	50.5±13.2	46.8±9.9	3.404	**0.048**
Abies alba (%)	66.8±13.8	63.1±22.1	44.7±14.2	4.791	**0.017**
Fagus sylvatica (%)*	2.2±2.8	5.5±4.2	14.2±11	9.644	**<0.001**
Picea abies (%)	31±15.8	29±13.4	35.4±16.4	0.303	0.741
Volume (m^3/ha)	871.7±229.2	662.9±183	556.4±154.4	7.025	**0.003**
Abies alba (%)	68.5±14.4	67.1±22.4	48.1±16.1	4.014	**0.03**
Fagus sylvatica (%)*	1.4±1.9	19.3±25.8	13.5±11.7	3.102	**0.01**
Picea abies (%)	30.2±15.8	13.6±15.5	34.6±15.9	4.92	**0.015**
Crown cover (%)					
Abies alba	58±17.7	57.8±13.3	52.3±17.8	0.389	0.682
Fagus sylvatica	19.7±19.7	28.6±19.7	55.6±13.8	10.861	**<0.001**
Picea abies	29.8±15.9	20.3±13.8	34±14	2.302	0.119
Coarse Woody Debris (m^3/ha)					
Stumps	7.3±3.8	23±9.9	6±3.5	21.511	**<0.001**
Snags†	5.5±8.8	1.7±3.4	14.1±8.5	8.019	**0.002**
Species richness (nº of species)					
Tree	2.7±0.5	2.9±0.3	4.2±0.9	16.896	**<0.001**
Woody	7.2±2.7	6.5±2.5	5.7±2.4	0.883	0.425
Herbaceous	18.6±4.4	32.3±6.3	30.1±6.5	15.966	**<0.001**
TDD	2.1±0.2	2±0.2	1.9±0.2	2.766	0.081
THD	1.7±0.2	1.6±0.3	1.7±0.3	0.633	0.539

**: arcsin square root transformation; †: log_{10} transformation*

III.3) Compartment level

III.3.1) Description of the evolution of compartments

Bellow, the diametric distribution, the dendrological composition and the cutting plans of the ten selected compartments along the revisions of the five management plans are explained. Further graphs illustrating the evolution of the main forest parameters and cutting plan variables are attached in Appendix D.

III.3.1.1) Auronzo di Cadore

Compartment 012_044

The evolution of the diametric distribution in the compartment 044 of the management plan in Auronzo de Cadore (Figure 21) shows a transition towards a more uneven-aged structure at the level of compartment. The survey made in 1962 shows a lack of individuals less than 30 cm, an abundance of medium diameter classes from 35 to 45 cm and the absence of trees over 70 cm. Several alterations were followed along the surveys made in 1974, 1985 and 1998, especially in the medium diameter classes, till 2008 which diameter distribution shows a fairly clear inverted-J form typical of uneven-aged structures. Lower diameter classes became much more abundant since 1985, as well as big dimensions trees over 70 cm of diameter concretely since 1974.

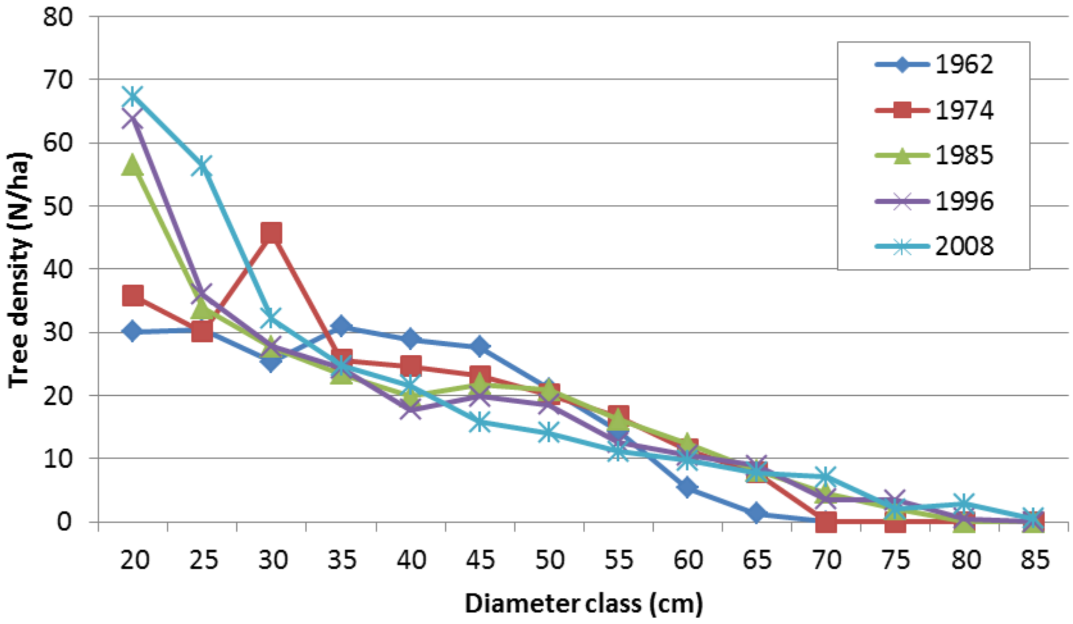


Figure 21: Evolution of diametric distribution from 1962 to 2008 in compartment 012_044

In the compartment description of the first management plan revision it is included some data from the previous survey made in 1962, coded as 012_0.

The dendrological composition of compartment 012_044 along the revisions shows a general increase of the main forest parameters such as density, BA and volume (Table 10). However, the Current Annual Increment (CAI) decreased from 8.4 m^3/ha·year at the first revision to 6.5 m^3/ha·year in the following one, although it has recovered since then till the last revision up to 7.2 m^3/ha·year. TDD seems to be stable around 2.2 since the small increase occurred from 1962 to 1974.

Regarding the species composition, the increase of broadleaves in percentage of tree density (from 0 to 9%) occurred together with the decrease of silver fir (from 53 to 43%), while Norway spruce stayed steady between 42 and 49.

Table 10: Evolution of dendrological composition in compartment 012_044

Management Plan		012_0	012_1	012_2	012_3	012_4
Year of survey		1962	1974	1985	1996	2008
Forested surface (ha)		17	17	17	17	17
Species composition (N %)	*Abies alba*	53	58	46	45	43
	Picea abies	47	42	49	49	47
	Broadleaves	0	0	5	6	9
Density (N/ha)		215.3	241.1	247.1	247.6	273.1
BA (m^2/ha)		24.7	28.8	30.4	29.2	30.6
Volume (m^3/ha)		321.9	367.7	358.5	357.9	378.5
CAI (m^3/ha·year)		-	8.4	6.5	6.8	7.2
TDD		2.15	2.2	2.26	2.23	2.2

As the general part of the 4th revision of the management plan was not available, it was not possible to include the registers of utilized volume of the previous validation period. The planned cut proposed in the first two revisions was correctly executed with deviations of 0 and -0.4% respectively (Table 11). On the last two revisions the proposed yield decreased roughly half of the volume.

Table 11: Evolution of cutting plan in compartment 012_044

Management Plan	012_1	012_2	012_3	012_4
Year of cut	1976	1988	1999	2016
Volume† (m^3/ha)	368	378	381	436
Yield (m^3/ha)	59	58.8	23.5	29.4
Utilization rate (%)	15.9	15.6	6.5	6.7
Utilization (m^3/ha)	58.8	57.2	-	-
Deviation (%)	0	-0.4	-	-

†: Volume at the year of cut.

Compartment 012_105

The diametric distribution in compartment 105 (Figure 22) did not experience drastic changes especially at the medium diameter classes between 30 and 40 cm. However, the density of young trees increased considerably from 80 stems/ha in 1974 to 140 stems/ha in 1985, decreasing later till 100 stems/ha in 2008. On the other hand, trees over 65 cm started to be registered since 1974 arriving to a maximum of 75 cm in 2008.

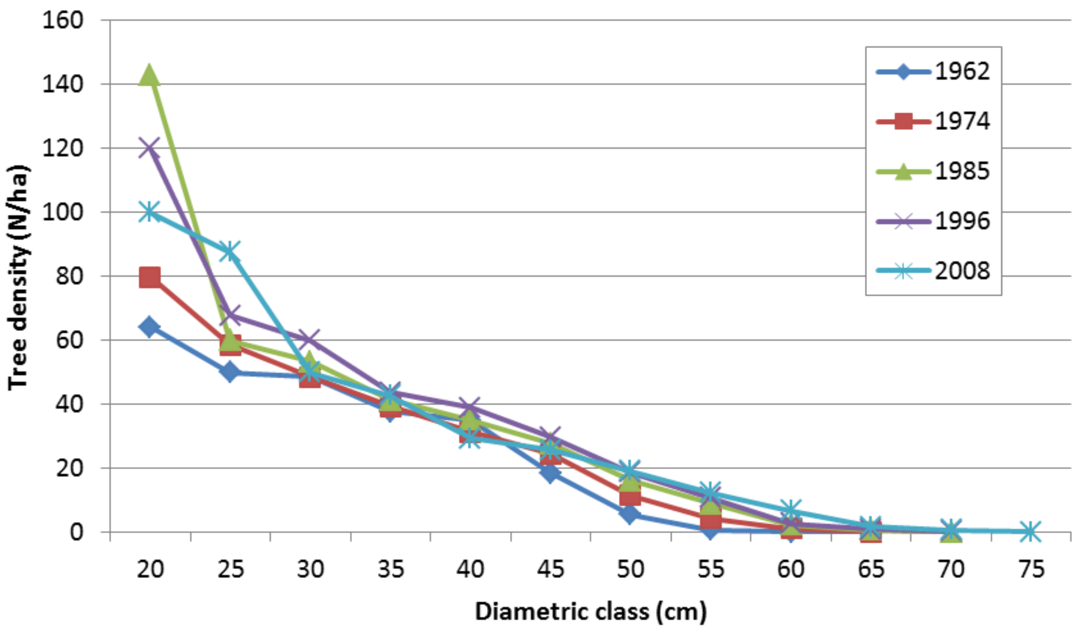


Figure 22: Evolution of diametric distribution from 1962 to 1008 in compartment 012_105

The forested surface in compartment 105 increased just 1 ha in the last 5 validation periods (Table 12). All forest parameters increased in every revision from 1962 to 2008 in terms of density, BA, volume and TDD. Just the CAI stayed equal to 7.1 m^3/ha·year in the last two revision periods. Norway spruce keept being the dominant species in the canopy even though it decreased along the revisions as the presence of silver fir and broadleaves increased.

Table 12: Evolution of dendrological composition in compartment 012_105

Management Plan		012_0	012_1	012_2	012_3	012_4
Year of survey		1962	1974	1985	1996	2008
Forested surface (ha)		32	32	31.5	31.5	33
Species	*Abies alba*	44	46	46	46	47
composition	*Picea abies*	55	54	52	52	50
(N %)	Broadleaves	0	0	1	1	2
Density (N/ha)		261.0	299.6	389.2	394.1	376.5
BA (m^2/ha)		20.2	24.1	30.3	32.7	32.5
Volume (m^3/ha)		252.7	302.2	342.9	372.9	372.4
CAI (m^3/ha·year)		-	6.8	5.8	7.1	7.1
TDD		1.82	1.89	1.84	1.92	1.97

The yield proposed in compartment 105 decreased along the revisions from 28 to 16.6 m^3/ha (sum of the three cut proposed in 012_3) (Table 13). Just two registers of utilization were found for this compartment, both of them out of the “no deviation” range. The cut in 1979 was deviated -8.3% respect to the yield in terms of growing stock and the cut in 1989 by excess in 0.9%.

Table 13: Evolution of cutting plan in compartment 012_105

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Deviation (%)
012_1	1979	302	28	9.3	2.8	-8.3
012_2	1989	366	19	5.2	22.2	0.9
	Available	359	3.2	0.9	-	-
012_3	1996	372.9	0.2	0	-	-
	1997	379.9	0.5	0.1	-	-
	1999	393.7	15.9	4	-	-
012_4	-	372.4	0	0	-	-

†: Volume at the year of cut

III.3.1.2) Campolongo

As well as in Auronzo di Cadore, the data from the previous survey to the first revision is included in the compartment description and coded as 023_0.

Compartment 023_003

The diametric distribution of the compartment 003 (Figure 23) represents the irregularity of the structure where small and big dimension trees are present together with a rather abundant presence of medium dimension trees. This structure has been achieved by the increase of lower diameter classes from 1964 to 2006 reaching nearly 100 stems/ha, and with the increase of trees over 65 cm since 1985.

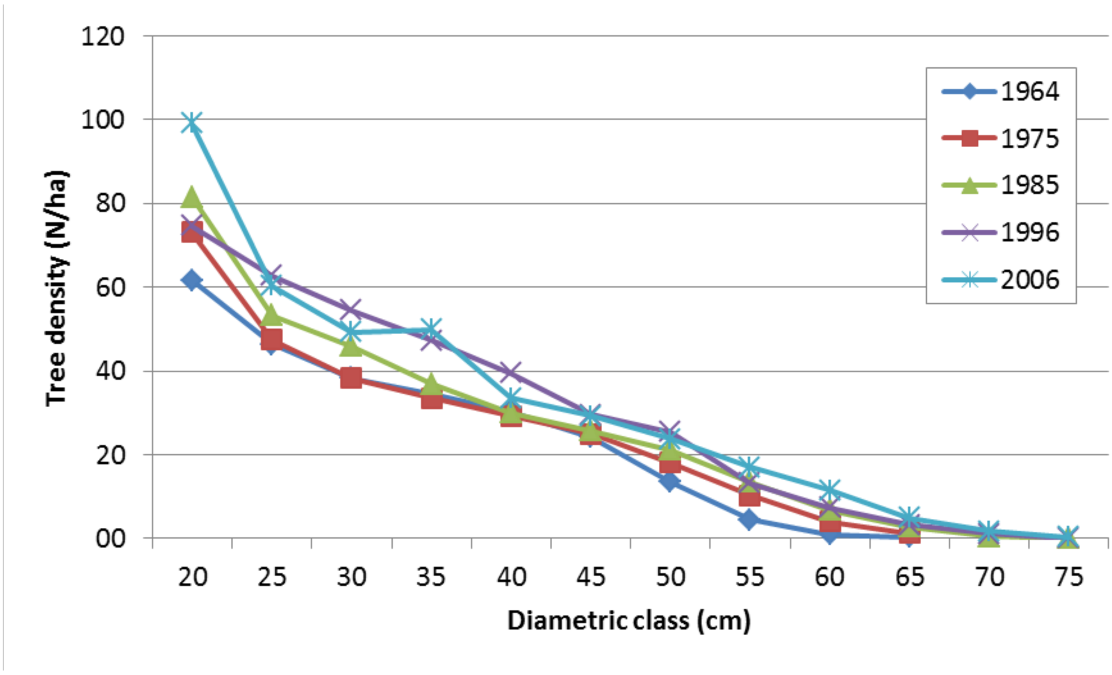


Figure 23: Evolution of diametric distribution from 1964 to 2006 in compartment 023_003

The forested surface in the compartment 003 decreased just in 0.4 ha from 1964 to 1006 (Table 14). All the rest of forest parameters increased on every validation period, reaching in the last survey 380.4 m^3/ha of tree density, 37.6 m^2/ha of BA, 410.9 m^3/ha of volume, 10.4 m^3/ha·year of CAI and, a TDD of 2.09. Regarding the species composition, silver fir is still the dominant species in the canopy although it has been reduced from 64 to 55% along the revisions and Norway spruce has increased from 36 to 45%. However, broadleaves has been always absent in this compartment.

Table 14: Evolution of dendrological composition in compartment 023_003

Management Plan		023_0	023_1	023_2	023_3	023_4
Year of survey		1964	1975	1985	1996	2006
Forested surface (ha)		37	37	37.3	36.6	36.6
Species composition (N %)	*Abies alba*	64	58	52	51	55
	Picea abies	36	41	47	49	45
	Broadleaves	0	0	0	0	0
Density (N/ha)		255.0	280.0	317.7	358.7	380.4
BA (m^2/ha)		22.4	25.7	30.2	35.3	37.6
Volume (m^3/ha)		251	298	328.3	384.1	410.9
CAI (m^3/ha·year)		-	5.2	7.2	7.4	10.4
TDD		1.95	2.01	2.05	2.09	2.09

The second revision brought the division of compartment 003 in two different sub-compartments. Both sub-compartments were joined to analyse the diametric distribution and the forest parameters. However, in the cutting plan the distinction of sub-compartments is kept given that the cuts are analysed independently.

It can be noted the general increase in the yield from 37.9 to 54.5 m^3/ha, with a peak in the second revision when the yield was concentrated in the sub-compartment 3/1 up to 51.1 m^3/ha. Just one of the ordinary cuts in sub-compartment 3/2 in 2001 surpassed the planned yield by a 6.4%, all the rest were executed correctly according to the planned yield. The other deviations were caused by accidental events.

Table 15: Evolution of cutting plan in compartment 023_003

Management Plan / Sub-compartment		Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
023_1	3	1983	298	37.9	12.7	37.9	-	0
023_2	3/1	1987	368.0	51.1	13.9	46.5	4.6	0
	3/2	-	293.1	0	0	0	5.4	1.8
023_3	3/1	2001	406.3	48.5	11.9	0	2.1	-11.4
	3/2	2001	334.9	44.1	13.2	65.5	-	6.4
023_4	3/1	2008	526.9	53.9	10.2	53.9	-	0
	3/2	2008	336.6	54.5	16.2	54.5	-	0

†: Volume at the year of cut

Compartment 023_006

The evolution of the diametric distribution in compartment 006 shows specially alterations of the density of low diameter classes (Figure 24). For instance, the density of 20 cm diameter class dropped from about 80 stems/ha in 1964 to lower than 50 stems/ha in 1995, altough it has recovered up to nearly 65 stems/ha in the last validation period.

The presence of trees over 65 cm has increased considerable in the last validation periods arriving to a maximum diameter class of 85 cm. The diametric distribution from the last survey shows a fine inverted-J shape, perhaps with a density of low diameter classes a bit low.

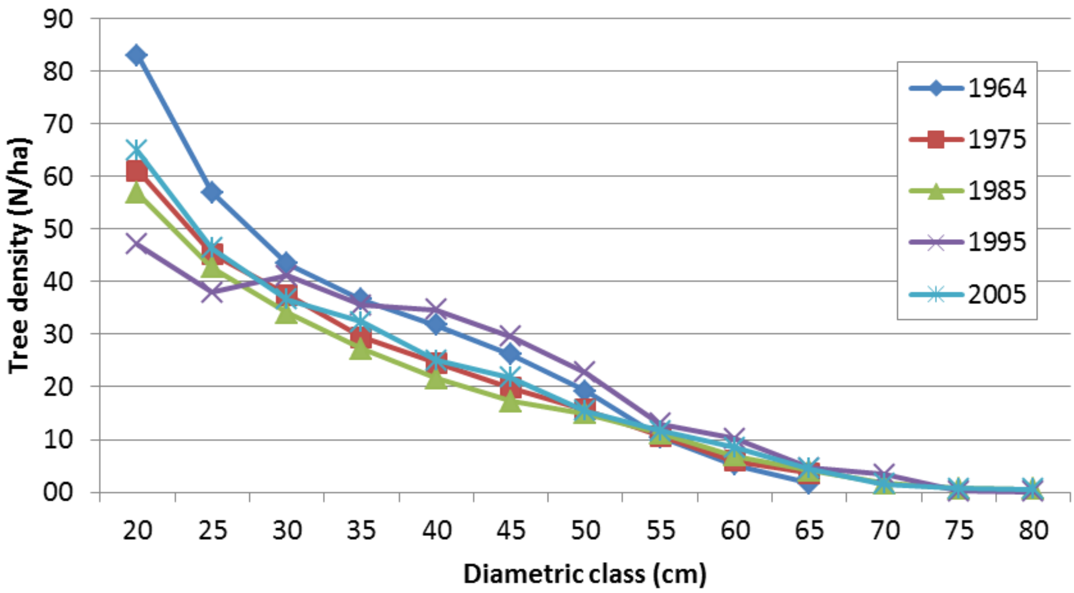


Figure 24: Evolution of diametric distribution from 1964 to 2005 in compartment 023_006

The forested surface of compartment 006 increased in the second revision and stayed equal to 42.1 ha since then (Table 16). The dominant species in terms of density has shifted in every management period from Norway spruce to silver fir, with maximum difference of 15% in 1995. As in the previous compartment, broadleaf species were never present in the canopy according to the diametric distribution. As it can be observed in Table 16, the values of the main forest parameters had a peak in 1995, followed by small decrease in 2005 but still higher than the previous revision to peak in 1985, except from the TDD that went back to 2.13.

Table 16: Evolution of dendrological composition in compartment 023_006

Management Plan		023_0	023_1	023_2	023_3	023_4
Year of survey		1964	1975	1985	1995	2005
Forested surface (ha)		37.7	37.7	42.1	42.1	42.1
Species composition (N %)	*Abies alba*	48	51	45	57	45
	Picea abies	52	49	54	42	54
	Broadleaves	0	0	0	0	0
Density (N/ha)		268	260	242.6	283.4	269.9
BA (m^2/ha)		24.1	24.9	24.8	32.6	27.5
Volume (m^3/ha)		279	291.0	283.6	370.4	311.9
CAI (m^3/ha·year)		-	5.6	4.3	5.9	4.9
TDD		2.00	2.06	2.13	2.21	2.13

The two ordinary cuts planned in the first two revisions were executed correctly resulting in very low deviation rates (Table 17). For the second revision, the cut was concentrated in the sub-compartment 003/1, while in the sub-compartment 003/2 it was removed 3.3 m^3/ha of timber coming from an accidental event. In the third revision, both ordinary cuts surpassed the proposed yield, adding 9.8 m^3/ha of accidental utilization to the cut in the first sub-compartment. The proposed yield also had a peak in the third revision, and was reduced for the current validation period.

Table 17: Evolution of cutting plan in compartment 023_006

Management Plan / Sub-compartment		Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
023_1	6	1978	242	29.2	12.1	28.7	-	-0.2
023_2	6/1	1989	411	81.9	19.9	81.9	-	0.0
	6/2	-	272.2	0	0	0	3.3	1.2
023_3	6/1	2003	366.1	48.2	13.2	58	9.8	2.7
	6/2	1999	399.5	38.5	9.6	52.1	-	3.4
023_4	6/1	2016	384.2	30.1	7.8	-	-	-
	6/2	2015	356.7	17.8	5	-	-	-

†: Volume at the year of cut

III.3.1.3) Roana

Compartment 034_223

It can be noted from the evolution of the diametric distribution in compartment 223 (Figure 25) that the abundance of lower diameter classes stayed rather high along the revisions. However, the situation from the first survey made in 1977 where the abundance of medium diameter classes (from 30 to 45 cm) and the low presence of trees over 55 cm was balanced lowering the density of medium diameter class and increasing the amount of big dimension trees, arriving to a maximum diameter class of 85 cm since 1999. In any case, the diametric distribution of the last survey shows still a certain abundance of medium diameter classes (from 35 to 50 cm).

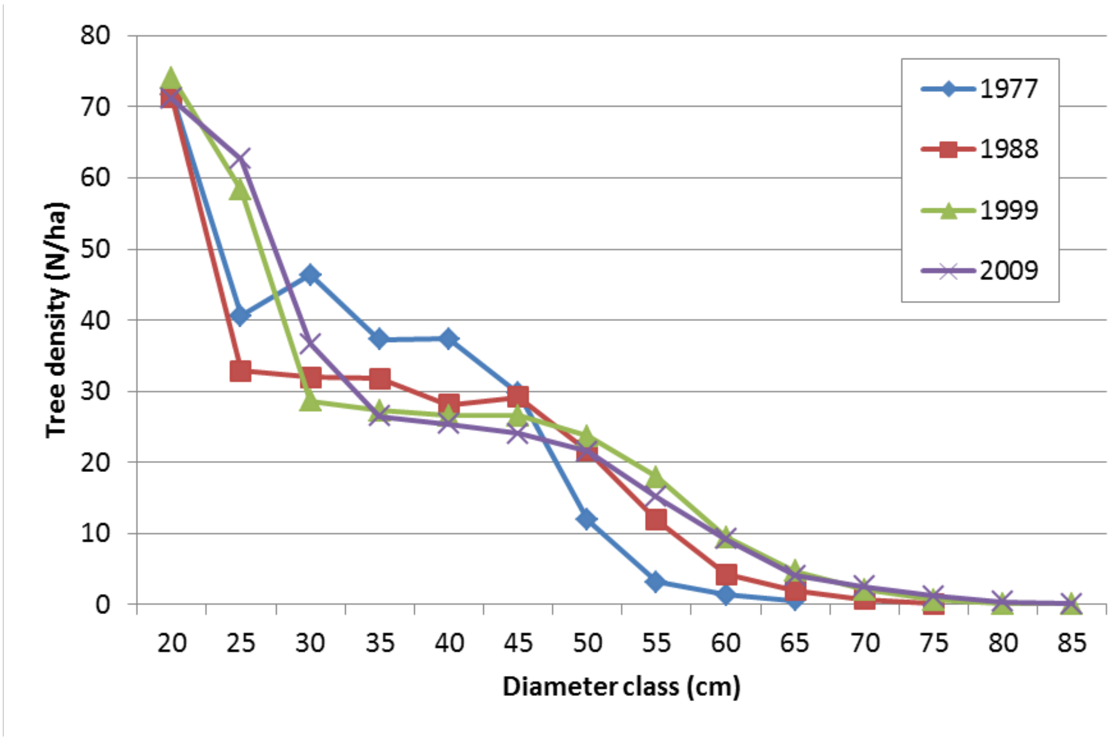


Figure 25: Evolution of diametric distribution from 1977 to 2009 in compartment 034_223

Compartment 223 was formed in the third revisions from the joint of three compartments (44, 45 and 46) of the previous management division. The forested surface increased just in 0.7 ha along the four validation periods (Table 18). In the first revision, Norway spruce was the dominant species present in the canopy. With the appearance of broadleaves in the diametric survey, this dominance changed favouring the silver fir since the second revision. The main forest parameters increased till the third revision, followed by a small decrease in the next period.

Table 18: Evolution of dendrological composition in compartment 034_223

Management Plan		034_1	034_2	034_3	034_4
Year of survey		1977	1988	1999	2009
Forested surface (ha)		17.1	17.6	17.6	17.8
Species composition (N %)	*Abies alba*	42	53	47	43
	Picea abies	58	32	37	34
	Broadleaves	0	12	16	23
Density (N/ha)		279.8	265.8	300.1	300.3
BA (m^2/ha)		24.2	26.6	31.7	30.9
Volume (m^3/ha)		246	290.4	335.4	326.1
CAI (m^3/ha·year)		6	6.6	5.7	5.5
TDD		1.92	2.06	2.13	2.13

Utilization registers of this compartment were available just for the second revision (Table 19), where the ordinary cuts in 1993 and 1996 resulted to be deviated in -2.5% and 0.8 respectively, and the other two in 1990 and 2000 were performed correctly with no deviation (-0.2% and -0.4%). Summing the yields within every validation period, it can state the increase of the yield along the first three revisions: 21.3, 35.5 and 35.9 m^3/ha respectively. For the last management plan no cuts were programmed.

Table 19: Evolution of cutting plan in compartment 034_223

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Deviation (%)
034_1	1978	252	5.9	2.3	-	-
	1979	258.1	4.1	1.6	-	-
	1979	258.1	4.7	1.8	-	-
	1982	271.9	7.6	2.8	-	-
034_2	1990	303.5	8	2.6	7.4	-0.2
	1993	315.2	5.7	1.8	8.1	-2.5
	1996	329.3	13.1	4	11.6	0.8
	2000	342.4	8.5	2.5	0	-0.4
034_3	2002	352.5	34.2	9.7	-	-
	2003	323.7	1.7	0.5	-	-
034_4	2018	375.6	0	0	-	-

†: Volume at the year of cut

Compartment 246 was formed in the third revision from the joint of compartment 60 and 61 of the previous revisions. Unfortunately, the survey in 1988 on compartment 61 was made through estimation of certain parameters, and so, the diametric distribution, and density and BA values are missing (Table 20).

Compartment 034_246

The diametric distribution in compartment 246 shows the trend towards the irregularity of the structure (Figure 26). It is remarkable the abundance of medium diameter classes (from 35 to 50 cm) together with high density of young trees and big dimension trees reaching the maximum diameter class of 85 cm.

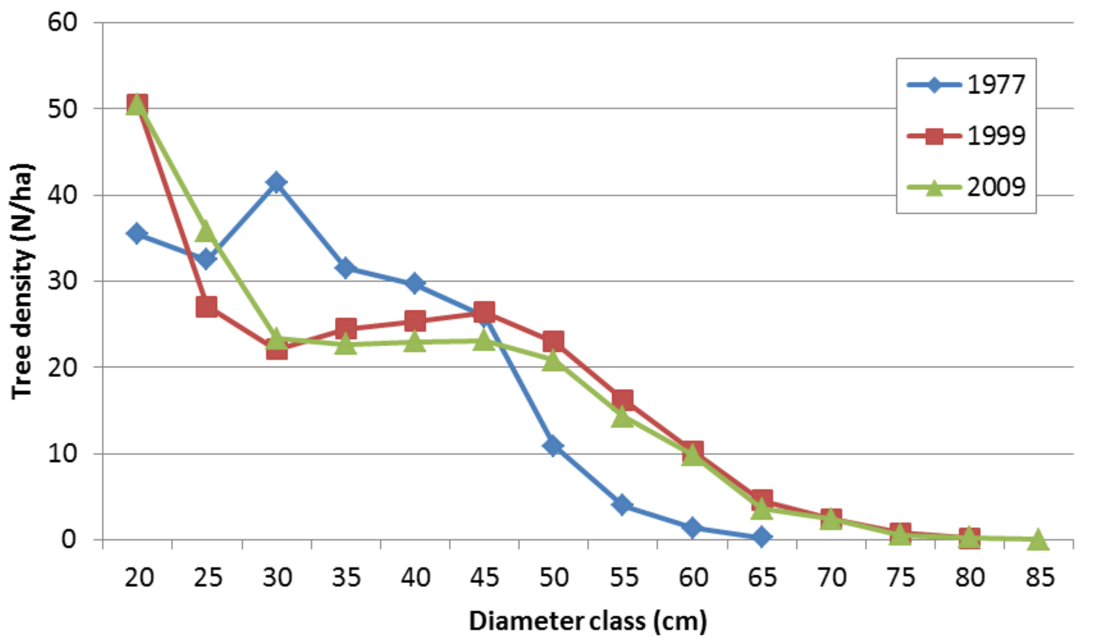


Figure 26: Evolution of diametric distribution from 1977 to 2009 in compartment 034_246

The rearrangement of the compartment mentioned above, resulted in a diminution of the surface from 11.6 to 10 ha (Table 20). Silver fir has been the dominant species in the canopy along the revisions although it decreased from 76 to 55%, at the same time that broadleaves increased its presence up till 19%; Norway spruce stayed always lower than 30%. From the first till the third revision, all the main forest parameters increased, after which they slightly diminished.

Table 20: Evolution of dendrological composition in compartment 034_246

Management Plan		034_1	034_2	034_3	034_4
Year of survey		1977	1988	1999	2009
Forested surface (ha)		11.6	12	10.3	10
Species composition (N %)	*Abies alba*	76	74	60	55
	Picea abies	24	25	27	26
	Broadleaves	0	1	13	19
Density (N/ha)		213	-	233.4	230.6
BA (m^2/ha)		20.1	-	28.4	26.6
Volume (m^3/ha)		206.8	226.9	315.7	295.1
CAI (m^3/ha·year)		3.8	4.5	5.1	4.7
TDD		1.98	-	2.23	2.21

Unfortunately, registers of utilization were missing for this compartment. Anyhow, yield values were still present, and for every revision it was proposed to be cut around 50 m^3/ha, except for the second revision with a total value of 35.2 m^3/ha of which 7.1 m^3/ha are available according to the decision of the forester.

Table 21: Evolution of cutting plan in compartment 034_246

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Deviation (%)
034_1	1986	234.2	35.4	7.4	-	-
	1984	233.5	13.6	3	-	-
034_2	1996	262.9	28.1	5.7	-	-
	available	-	7.1	-	-	-
034_3	2001	325.8	48.5	14.9	-	-
	2002	281.7	1	0.3	-	-
034_4	2014	318.7	50.2	15.7	-	-

†: Volume at the year of cut

III.3.1.4) Domegge di Cadore

Compartment 040_025

The diametric distribution in compartment 025 (Figure 27) shows a considerable increase of the lowest diameter classes, namely from 30 stems/ha in 1976 to nearly 60 stems/ha in 1987 and 1997, as well as the higher participation of big dimension trees during the last three validation periods. However, the medium diameter classes rearranged differently with different peaks, but certainly abundant along the revisions.

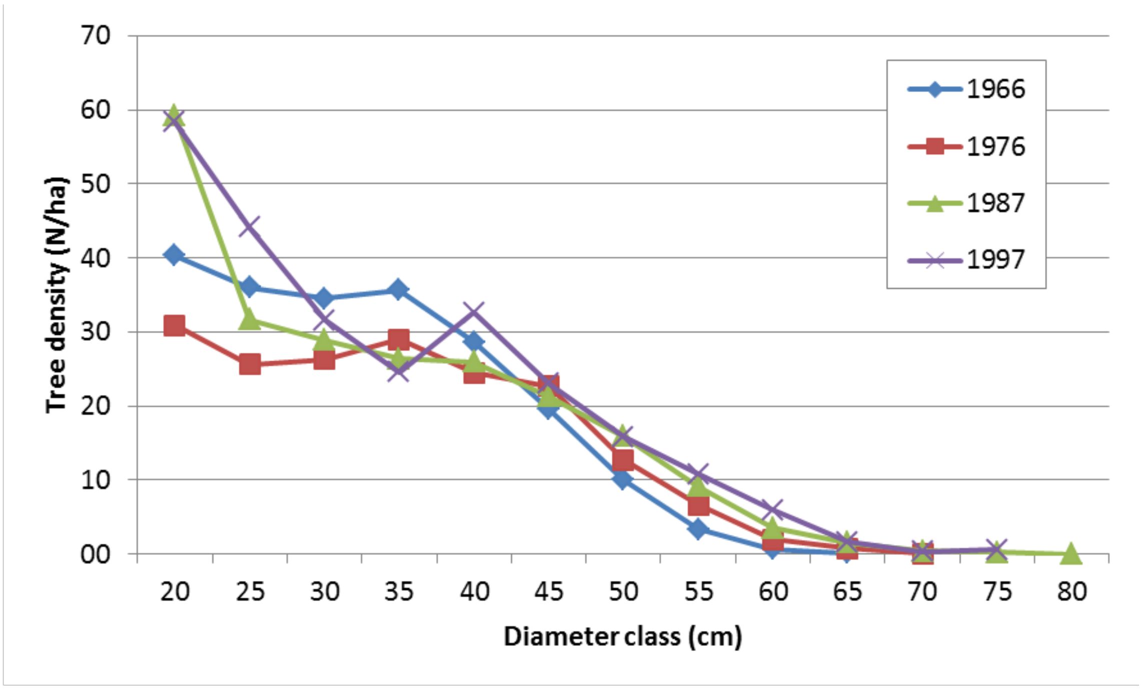


Figure 27: Evolution of diametric distribution from 1966 to 1997 in compartment 040_025

It is remarkable the reduction in surface registered in the third revision from 42 to 34 ha, although in the last survey made in 2007 it recovered 2.3 ha (Table 22). Norway spruce is the main species in the canopy over 60% along all the surveys made. The inclusion of broadleaves in the canopy occurred as the silver fir diminished from 31 to 26% in terms of density. The type of survey made in 2007 did not include the elaboration of a diametric distribution, just the estimation of the species composition, volume and CAI. Anyway, the increasing trend of the main forest parameters is still evident.

Table 22: Evolution of dendrological composition in compartment 040_25

Management Plan		040_0	040_1	040_2	040_3	040_4
Year of survey		1966	1976	1987	1997	2007
Forested surface (ha)		42	42	42	34	35.3
Species composition (N %)	*Abies alba*	31	29	23	24	26
	Picea abies	69	69	69	64	61
	Broadleaves	0	0	2	5	7
Density (N/ha)		209	181.2	224.3	249.5	-
BA (m^2/ha)		18.6	18.5	21.8	24.7	-
Volume (m^3/ha)		198.5	205.2	237	269.6	303
CAI (m^3/ha·year)		-	2.7	3.6	4	4.8
TDD		1.95	2.07	2.06	2.08	-

From the registers of utilized volume available, just one ordinary cut in 2001 was performed with a low deviation rate (0.2%), which was the highest yield proposed for this compartment (Table 23). The rest of cuts were considered accidental as they were executed in years not previously planned.

Table 23: Evolution of cutting plan in compartment 040_025

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
040_1	1980	216.4	5.9	2.7	-	-	-
	1987	237	-	-	-	2.5	1.1
040_2	1994	261.9	0	0	-	0.7	0.3
040_3	2001	285.8	23.5	8.2	24.1	-	0.2
	2008	290.5	-	-	-	0.3	0.1
040_4	2018	341.8	14.2	4.1	-	-	-

†: Volume at the year of cut

Compartment 040_029

The diametric distributions of compartment 29 (Figure 28) show a pretty fine inverted-J shape typical of uneven-aged forests. Besides, the increase of density along the revisions has been fairly even in every diameter class, with the exception of the diameter class 20 cm that decreased from 80 stems/ha in 1987 to around 65 stems/ha in 1997. Just in the last survey they were found trees over 75 cm until 85 cm.

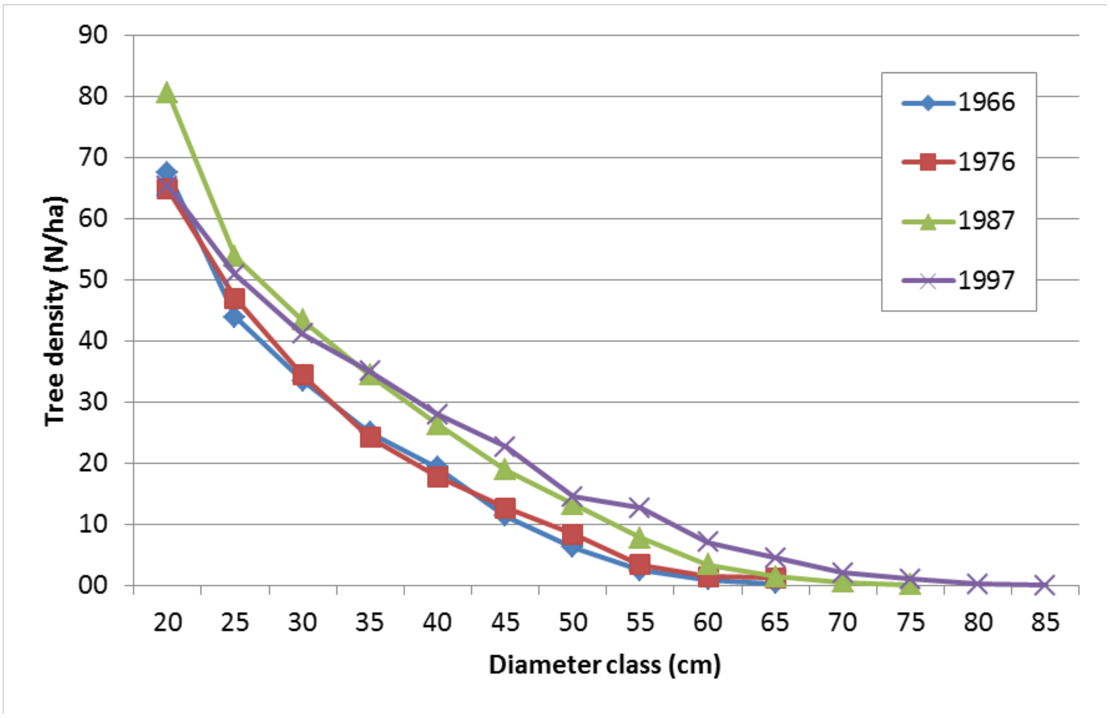


Figure 28: Evolution of diametric distribution from 1966 to 1997 in compartment 040_029

As happened with the previous compartment, the survey in 2010 was done by estimation, so certain parameters derived from the diametric survey such as density and BA are missing (Table 24). Nevertheless, the trend in all forest parameters is to increase. Regarding the species composition, although the percentage in density of Norway spruce has been decreasing along the revisions, it is still the main species in the canopy in around 50%; silver fir stayed steady with values between 36 and 39%, and broadleaves started to appear since the second revision up till 10% in the last survey.

Table 24: Evolution of dendrological composition in compartment 040_029

Management Plan		040_0	040_1	040_2	040_3	040_4
Year of survey		1966	1976	1987	1997	2010
Forested surface (ha)		23.0	23.0	23.0	22.7	20.7
Species composition (N %)	*Abies alba*	38	39	36	37	37
	Picea abies	59	59	56	52	49
	Broadleaves	0	0	5	8	10
Density (N/ha)		210.8	215.6	284.7	285.7	-
BA (m^2/ha)		15.5	16.7	24.2	28.8	-
Volume (m^3/ha)		156.7	172	276.2	335	392
CAI (m^3/ha·year)		-	4.2	5.8	6	7.1
TDD		1.80	1.86	1.96	2.12	-

Just one register of ordinary cut was found in 2006, surpassed with respect to the yield in terms of the growing stock by 1.4% (Table 25). The other register corresponds to an accidental utilization of 0.2 m^3/ha performed in 1991.

Table 25: Evolution of cutting plan in compartment 040_029

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
040_1	1977	172	0	0	-	-	-
040_2	1987	276.2	0	0	-	-	-
	1991	299.4	-	-	-	0.2	0.1
040_3	2006	389.3	35.2	9.1	40.8	-	1.4
040_4	2022	476.6	29	6.1	-	-	-

†: Volume at the year of cut

III.3.1.5) Asiago

Compartment 064_106

The diametric distribution from the three surveys made in compartment 106 (Figure 29) shows a decreasing trend along the diameter classes. The abundance of lower and higher diameter classes has increased with respect to first distribution, but especially the range between 30 and 40 cm.

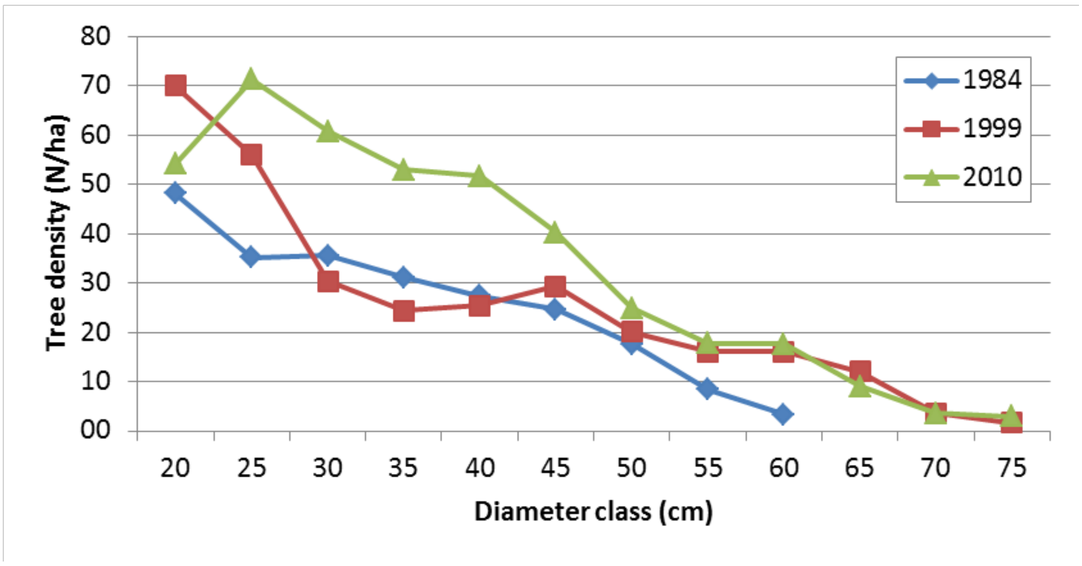


Figure 29: Evolution of diametric distribution from 1984 to 2010 in compartment 064_106

In order to respect the code given to the recent revisions, the first revision was coded as 064_0.

The forested surface of compartment 106 reduced from 13.1 ha in 1984 to 12.8 ha in 2010 (Table 26). Silver fir is by far the dominant species in the canopy, although it reduced its abundance from 69% to 53%, giving space to broadleaves species that reach nearly 20% of the tree density; Norway spruce instead stayed close to 30%. All forest parameters increased sharply reaching in the last survey values over 400 stems/ha of density, 40 m^2/ha of BA, and 400 m^3/ha. CAI and TDD values reached also fairly high values, respectively 9 m^3/ha·year and 2.22.

Table 26: Evolution of dendrological composition in compartment 064_106

Management Plan		064_1	064_2	064_3
Year of survey		1984	1999	2010
Forested surface (ha)		13.1	13.2	12.8
Species composition (N %)	*Abies alba*	69	53	53
	Picea abies	31	29	28
	Broadleaves	0	18	19
Density (N/ha)		231.5	305	407.2
BA (m^2/ha)		22.5	35.7	47.3
Volume (m^3/ha)		219.8	355.9	471.5
CAI (m^3/ha·year)		3.1	6.8	9
TDD		2.04	2.21	2.22

Two ordinary cuts in 1986 and 1993 were not performed resulting in high deviation rates (-17.2% and -7.8% respectively) (Table 27). On the other hand, two cuts in 1987 and 1990 were performed due to accidental events. Regarding the yield values, the first two proposed cuts were pretty different, 45 m^3/ha for the first revision and 19.1 m^3/ha for the following one. Instead, the last two yields stayed around a value of 30 m^3/ha.

Table 27: Evolution of cutting plan in compartment 064_106

Management Plan	Year of cut	Volume† (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
064_0	1986	262	45	17.2	0	-	-17.2
064_1	1987	229	-	-	-	11.8	5.1
	1990	226.5	-	-	-	2.6	1.1
	1993	244.4	19.1	7.8	0	-	-7.8
064_2	2008	416.7	30.4	7.3	-	-	-
064_3	2022	579.1	31.2	5.4	-	-	-

†: Volume at the year of cut

Compartment 064_113

The diametric distributions from the last three surveys made in compartment 113 (Figure 30) show a clear decreasing trend along all the diameter class, which abundance has increased on every validation period. It is remarkable the increase of the lowest diameter class (20 cm) from around 60 stems/ha in 1984 to 120 stems/ha in 2010. Despite the general increase of density in all the diameter classes, the medium ones between 35 and 50 cm are still rather low, below 40 stems/ha.

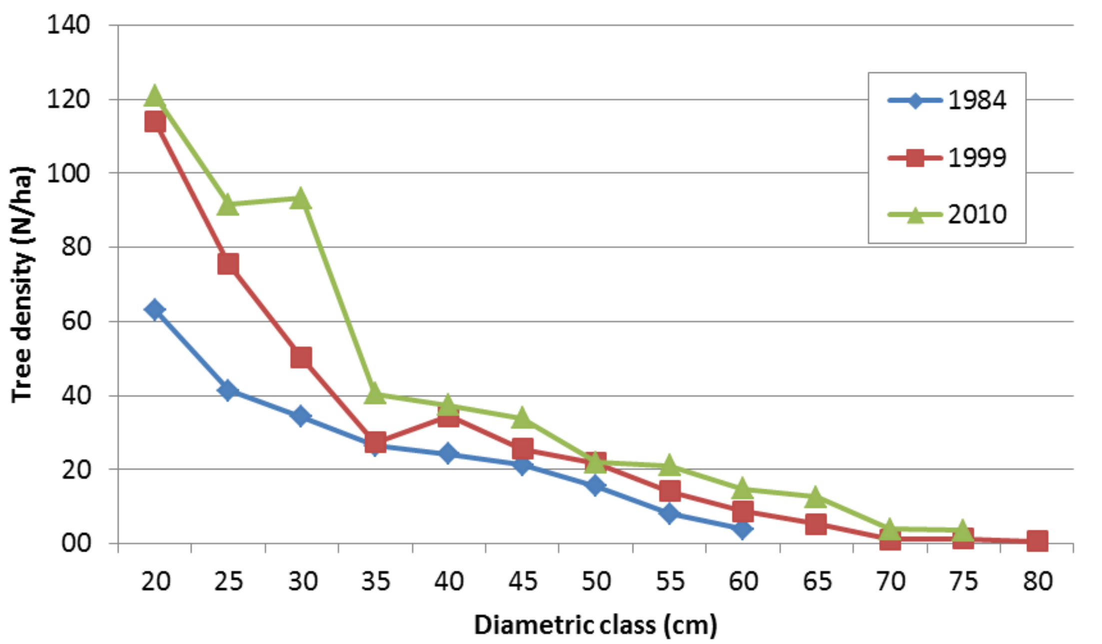


Figure 30: Evolution of diametric distribution from 1984 to 2010 in compartment 064_113

Silver fir is still the dominant species in the canopy, although it decreased in the last three revisions from 64% to 52% in terms of tree density (Table 28). At the same time, Norway spruce stayed between 32% and 39% as maximum, and broadleaves reached a maximum value of 17% in the last survey made in 2010. The increase of the main forest parameters along the three revisions reached values even higher than in the previous compartment, almost arriving to 500 stems/ha of density, nearly 50 m^2/ha of BA, and around 450 m^3/ha.

Table 28: Evolution of dendrological composition in compartment 064_113

Management Plan		064_1	064_2	064_3
Year of survey		1984	1999	2010
Forested surface (ha)		20.5	20.5	20.6
Species composition (N %)	*Abies alba*	64	53	52
	Picea abies	36	39	32
	Broadleaves	0	8	17
Density (N/ha)		238.7	380.7	495.7
BA (m^2/ha)		21.5	35.2	49.7
Volume (m^3/ha)		323.6	368.6	452.2
CAI (m^3/ha·year)		3.8	7.7	9
TDD		1.99	2.02	2.08

As happened in the previous compartment, two ordinary cuts in 1985 and 1993 were not performed resulting in rather high deviation rates: -9.6% and -5.3% respectively (Table 29). Just one accidental utilization of 8.1 m^3/ha was registered in 1987. The highest yield was proposed in the first revision with 9.6 m^3/ha, followed by 5.3 m^3/ha, 7.1 m^3/ha and lastly for 2015 just 1 m^3/ha.

Table 29: Evolution of cutting plan in compartment 064_113

Management Plan	Year of cut	Volume (m^3/ha)	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Accidental utilization (m^3/ha)	Deviation (%)
064_0	1985	251	24	9.6	0	0	-9.6
064_1	1987	216.8	10.7	4.9		8.1	-1.2
	1993	228.3	12.2	5.3	0	-	-5.3
064_2	2005	415.1	29.3	7.1	-	-	-
064_3	2015	497.5	4.9	1	-	-	-

†: Volume at the year of cut

III.3.2) Summary of the evolution in the compartments

III.3.2.1) Evolution of diametric distributions

For a better understanding of the general evolution in each compartment, it has been summarized the main trends in forest structure, species composition, dendrological composition and cutting plans (Table 33).

Two basic shapes are found in the diametric distribution of the compartments, the typical inverted-J representing uneven-aged structures, and an irregular where it is noticeable the dominance of certain diameter classes, usually medium ones (Table 33). Generally, the forest structure in each compartment has tended to diversify due to the increasing abundance of low and high diameter classes.

III.3.2.2) Forest structure indicators

Following the structural indicators, the percent diametric distribution in each compartment (Table 30) varies differently according to the standard proposed for silver-fir woodlands in carbonate soils (ASC) (Del Favero, 2000). Looking at the mean values, it can be observed a deficit of small trees and certain excess of medium and big tress. However, in relative and absolute values, the amount of big trees seems to be satisfactory.

Table 30: Percent diametric distribution per compartment and standard distribution for silver-fir forest type in carbonate soils

Compartment (last revision)	Small (20-30 cm)		Medium (35-45 cm)		Big (50-60 cm)		Very big (>65 cm)		Very big (stems/ha)
012_044	57	-6	23	-1	13	4	7	3	20.2
012_105	63	0	26	2	10	1	1	-3	2.7
023_003	55	-8	30	6	14	5	2	-2	7.1
023_006	55	-8	29	5	13	4	3	-1	7.4
034_223	57	-6	25	1	15	6	3	-1	8.1
034_246	48	-15	30	6	20	11	3	-1	7
040_025	54	-9	32	8	13	4	1	-3	2.6
040_029	55	-8	30	6	12	3	3	-1	8.1
064_106	46	-17	36	12	15	6	4	0	15.6
064_113	62	-1	23	-1	12	3	4	0	20.1
Mean	55	-8	28	4	14	5	3	-1	9.9
ASC	**63**		**24**		**9**		**4**		**10**

Regarding the dominant species, it can be observed that silver fir and spruce can be equally dominant in different stands. It is worth noting the shift observed in compartment 012_044, where silver fir was substituted as dominant species by spruce along the last five validation periods.

III.3.2.3) Evolution of dendrological composition

The main forest parameters analysed in the compartment descriptions (density, BA, volume, CAI and TDD) increased on every validation period, except in compartments 023_003, 034_223 and 034_246 where in the last period they slightly decreased or settled.

Mean values for each revision of management plan show the same general increasing trend (Table 31), reaching in the current validation period a mean density of 341.7 stems/ha, a mean BA of 35.3 m^2/ha, a mean volume of 371.4 m^3/ha, a mean CAI of 7 m^3/ha·year, and a mean TDD of 2.13.

Table 31: Mean±SE of forest parameters for each revision of management plan

Revision of management plan	Density (N/ha)	BA (m^2/ha)	V (m^3/ha)	CAI (m^3/ha·year)	TDD
0	236.5±11.3	20.9±1.4	243.3±23.9	-	1.94±0.05
1	246.3±14.4	22.9±1.4	261.1±23	5.3±0.6	2±0.04
2	271.3±17.7	25.8±1.2	288.7±15.6	5.1±0.5	2.04±0.04
3	303.8±17.9	31.4±1.1	346.5±10.8	6.3±0.4	2.12±0.03
4	341.7±31.2	35.3±3.1	371.4±19.6	7±0.6	2.13±0.03

III.3.2.4) Evolution of cutting plans

Although the parameters considered in the cutting plans might vary along the validation periods, it has been attempted to generalize an evolution for each compartment (Table 33). Thus, it is appreciable a general decrease on the planned yield, and consequently on the utilization rate, on the majority of the compartments concurring in most cases with those compartment where the main forest parameters have always increased. Instead, in the compartments where the yield has tended to increase or vary, coincide with those that experienced a slight drop in the forest parameters in the last validation period.

Despite the difficulty to describe a general trend on the utilization due to the lack of registers per compartment, it has been pointed in every compartment whether the yield has been correctly or not performed, and the abundance of utilization coming from accidental events (Table 33).

The mean rotation period of the silvicultural interventions along the revisions of the management plans ranged from 10 to 12 years. Mean values of the cutting plan variables show that the trend of the yield and utilization rate were not even, but utilization and deviation rate clearly tended to decrease along the validation periods (Table 32). Again, it should be bear in mind that the lack of utilization registers makes these results not robust enough.

Table 32: Mean±SE of cutting plan variables for each revision of management plan

Revision of management plan	Rotation period	Yield (m^3/ha)	Utilization rate (%)	Utilization (m^3/ha)	Deviation rate (%)
1	-	30±5.8	9.6±1.7	21.4±10	-5.9±2.9
2	11	26.3±7.8	7.7±2	28.1±10	-1.3±1.1
3	10	35.3±3.2	9.6±0.9	40.4±9.7	0.4±2.5
4	12	26.3±5.7	6.5±1.6	54.2±0.3	0±0

Table 33: Summary of the evolution of diametric distribution, dendrological composition and cutting plan per compartment

	Diametric distribution		Dominant tree species		Dendrological composition		Cutting plan				
	Inverted-J	Irregular	*Abies alba*	*Picea abies*	General increase	Drop after increase	Yield	Utilization rate	Yield not/bad performed	Yield well performed	Abundant accidental events
012_044	X		1^{st}	2^{nd}	X		↘	↘		X	
012_105	X			X	X		↘	↘	X	X	
023_003		X	X		X		↗	↔		X	
023_006	X			X		X	↘	↘		X	
034_223		X	X			X	↗	↗↘		X	
034_246		X	X			X	↗	↗	-	-	-
040_025	X			X	X		↘	↘↗		X	
040_029		X		X	X		↘	↘	X		X
064_106	X		X		X		↘	↘	X		X
064_113	X		X		X		↘	↘	X		X

III.4) Analysis of quality indicators of management plans

III.4.1) Floristic survey

From the values given to the floristic survey included in the general part of the management plans, it was possible to see the evolution of the quality of the information surveyed along the revisions. The floristic surveys found in the current validation periods were dismissed since just two general parts were available.

It is evident the improvement along the revisions of the information provided in the floristic surveys, as shown in Figure 31.

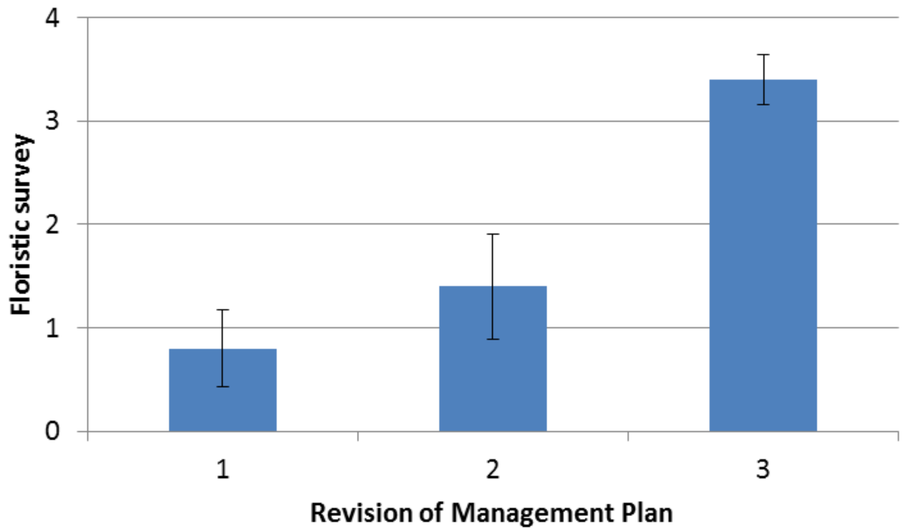


Figure 31: Mean ± SE of qualitative values of floristic surveys along the revisions of management plan

III.4.2) Abundance of broadleaves species

From the data gathered in the compartment description the abundance of broadleaves species registered in the diametric surveys has been increasing along the revisions of the management plans, arriving to a mean around 10% in terms of tree density (Figure 32). It should be noted that in all the cases beech is the single broadleaf species appearing in the diametric surveys.

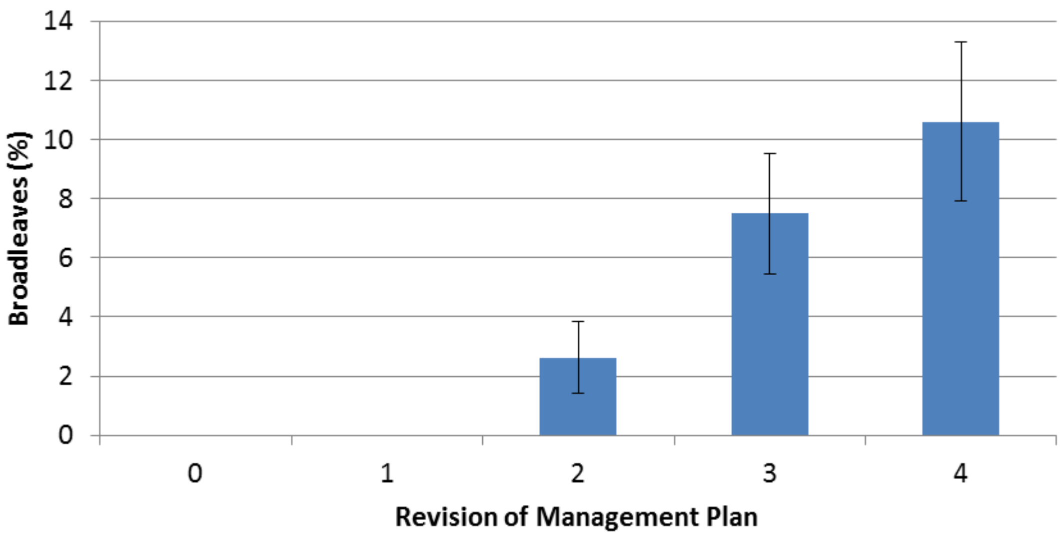


Figure 32: Evolution of the presence of broadleaves (%) in the canopy along the revision

III.4.3) Treatment description

According to the values given to the treatment description in every compartment, it can be stated that the quality and accuracy of the provided information has been improving along the revisions of the management plans (Figure 33).

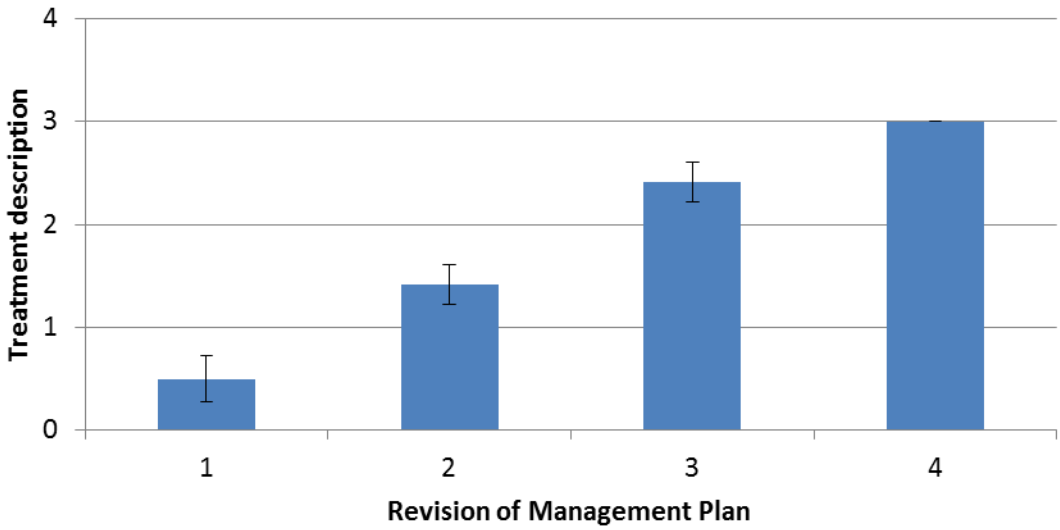


Figure 33: Evolution of the quality of the treatment description along the revisions

III.4.4) Relation between treatment description and deviation of utilization

Twenty three ordinary cuts were grouped in two according to the registers of utilization (no deviation and deviation) and assigned the value given to its corresponding treatment description. Thereby, it is calculated a mean treatment description value for both groups and compared through an ANOVA test.

Table 34: Mean ± SD of treatment description values for deviated and not deviated ordinary cuts

	No deviation	Deviation	*F* value	*P* level
Treatment description	1.6±1	1.4±0.9	0.299	0.59

Even though the mean of the treatment description value of not deviated ordinary cuts is higher than the deviated group, the difference is not statistically significant (*P*=0.6) (Table 34). These results are also illustrated in Figure 34.

Figure 34: Relation between the quality of the treatment description and the deviation of utilization

IV) DISCUSSION

IV.1) Tree and understory species composition

The results regarding the evolution of the species composition by compartment show very different arrangements between each other. In general lines, silver fir tends to be steady, although it can cyclically be shifted by Norway spruce as dominant species (Unità di Progetto Foreste e parchi, 2012). In fact, the alternation of regeneration between silver-fir and spruce is a primary characteristic of this kind of conifer mixed forest (Bernetti, 1995; Hofmeister *et al.*, 2008). For instance, in compartment 012_044 the dominant species shifted from silver fir to Norway spruce during the last five validation periods; whereas in compartments 012_105, 023_003, 040_25 and 040_29 Norway spruce has always been dominant.

Looking at the values of species composition from all the compartments along the revisions, Norway spruce has tended to decrease and beech has remarkably increased, which might be due to the response to the attenuation of the cuts (Bernetti, 1995), and the cessation of coppicing (Sitzia *et al.*, 2012; Motta & Garbarino, 2003). Actually, looking individually to the compartments, the yield tends to increase just in three of them (023_003, 023_006 and 034_246), and generally the utilization rate decreased along the last four validation periods.

Besides, the species richness of the tree layer appeared to be much lower than in abandoned forest, where broadleaf species such as *Acer platanoides*, *Sorbus aucuparia* and *Salix caprea* are present (Sitzia *et al.*, 2012). Nevertheless, some of the ecologically potential and accesory species of silver-fir forest types (Del Favero, 2000; Motta & Garbarino, 2003) were found in the floristic surveys performed in the compartments, like *Sorbus aria*, *Acer pseudoplatanus* and *Fraxinus excelsior*. However, a high diversity of tree species is not expected in compartments with production function, since the domination of few competitive species tends to create naturally relative unmixed forests (Schütz, 1999).

The significant lower herbaceous species richness found in the production compartments compared with the unplanned and abandoned stands, might be due to the fact that the floristic surveys did not cover the whole vegetative season, since they were made in late summer (August 2013). For this reason, further analyses on herbacaeous species composition were dismissed.

IV.2) Forest structure and dendrological composition

The diameter and height distribution per species at structural type level represent an irregular bi-layer structure, with dominant layer composed by silver fir and Norway spruce and a dominated layer mainly composed by beech, similarly to the abandoned stands studied by Sitzia *et al.* (2012). However, the different arrangements of the diametric distributions at compartment level suggest two different situations.

The inverted-J diametric distribution found in half of the compartmet might represent the fine-grained shifting mosaics generated by moderate and frequent interventions, as found in other mixed uneven-aged conifer forests of the region managed with the same kind of silvicultural treatment (Bagnaresi *et al.*, 2002; Grassi *et al.*, 2003).

On the other hand, the diametric distributions with abundance of intermediate and big trees found in the other half of the comparments, might represent the effect of delayed interventions that tends to the homogenization of the structure favoured by good site conditions (Bernetti, 1995; Schütz, 1999; Bagnaresi *et al.*, 2002; Grassi *et al.*, 2003).

Overall, the forest structure of the compartments along the last validiton periods has evoluted towards a more diversified structure, observed by the tenous increase of TDD. Concretely, the general increase of lower diameter classes might indicate the favourable effect of irregular distribution of crowns to understory vegetation provided by better light availability, as well as a reduction of inter and intra-specific competition caused by the silvicultural interventions (Bagnaresi *et al.*, 2002; Grassi *et al.*, 2003). However, according to the standard percent diametric distribution for silver fir woodlands in carbonate soils (Del Favero, 2000), the proportion of small trees is still insufficient in mean terms.

On the other hand, the general increase of very big trees in the diametric distribution along the revision of the management plan, might respond to the awareness of the silvicultural treatments to exclude from the cuts some big dimension trees in good vitality that might contribute to a better dissemination of the ground layer (Casanova

Borca, 2006; Novello & Dallasega, 2000a; Novello & Dallasega, 2000b). According to the standards, the mean amount of big trees in relative and absolute terms is rather satisfactory.

As expected, the dendrological composition at structural type level in the managed with planning stands clearly assimilates to adult-mature structural type of the even-aged model (Susmel, 1980) (Appendix E). Despite the homogenization of the forest structure is regarded in the silvicultural treatments as an issue to be avoided (Bernetti, 1995; Balzan & Bino, 1999; Novello & Dallasega, 2000b; Andrich, 2011), the significantly higher BA and volume in managed with planning stands, might indicate that the intensity of the silvicultural interventions has not been sufficient. The decrease of the yield observed in some of the compartments and the bad performance of the utilization, sometimes not even executed, might have contributed to this fact.

On the other hand, the dendrological composition at compartment level seems to have surpassed the 'normal' values, at least for the cultural model used (H=30 m) for the selection of the productive compartments (Susmel, 1980) (Appendix E). In fact, the cultural model of reference used in the last validation periods at comparment level ranges from 28 m to 35 m, as a proof of the adaptability of the silvicultural method of yield regulation to the situation of each compartment (Hellrigl, 1986b).

However, when the 'normal' state seems to be reached, the method includes the possibility to assign more rigidly cultural models at forest working group level (Hellrigl, 1986b). For instance, in the current forest management plan of Domegge di Cadore Andrich (2012) applied the cultural model for 32 m for entire working group, generally used in other areas of Cadore and Province of Belluno.

IV.3) Deadwood

The most relevant differences regarding CWD between managed and abandoned forests were already found by Sitzia *et al*. (2012). As deadwood is often considered to be unequally distributed in the landscape, even in the same structural type (Motta et al., 2006), the high variability of CWD values in managed mature stands with planning can be assumed also at compartment level.

However, it is meaningful to point out that volume values of stumps, logs and snags in managed stands with planning are intermediate to managed stands without planning and abandoned forests. These results might indicate that natural mortality in planned stands represented by logs and snags (Motta et al., 2006) is less intense than in abandoned forests, but higher than in managed stands without planning.

Logs at early decay stages can indicate recent silvicultural interventions, while the ones in more advance stage of decomposition might come from a previous fallen snag (Sitzia *et al.*, 2012; Motta et al., 2006), given that most of the snags were concentrated in the first two decay classes.

On the other hand, the intermediate volume value of stumps might indicate a decrease of the intentisy of cutting (Castagneri *et al.*, 2010) compared with managed stands without planning. This is consistent with the abundace of stumps found in higher decay classes, and with the reduction of yield values observed in most of the compartments.

It would be expected a moderate increase of deadwood in managed stands with planning given the high values of tree density and BA which are positive correlated with the quantity of CWD (Castagneri *et al.*, 2010), and the general negative trend of utilization rate in the compartments. However, the inclusion of phytosanitary cuts in the silvicultrual treatment guidelines of the management plans (Andrich, 2011; Casanova Borca, 2006; Novello & Dallasega, 2000), with the consequent removal of decayed, suppressed or dead trees, might also explain the low volume of total CWD found in managed stands with planning.

In fact, this kind of treatment contributes to the stability and good vegetative condition of the forest which is one the common principles of the management plan and silvicultal treatment objectives (D.G.R. 21 January, 1997; Andrich, 2011; Casanova Borca, 2006; Balzan & Bino, 1999).

IV.4) Forest management plan indicators analysis

The quality of the information provided by the floristic surveys of the management plans clearly improved along the revisions. More detailed information on the location where the surveys were performed and cover data per species were the main additions. These improvements were required in order to apply correctly the classification of the forested surface into the forest typologies (Del Favero, 2000).

As discussed in the evolution of the species composition, the increase of beech along the revisions of the management plan observed in the diametric surveys points out the tendency towards a higher mixture of tree species, although it is still limited to the dominated layer. This is consistent with the exclusion of beech from the cuts regarded in the silvicultural treatment of the management plans (Andrich, 2011; Casanova Borca, 2006; Novello & Dallasega, 2000a; Novello & Dallasega, 2000b).

The treatment description has been remarkably improved thanks to a better definition of the silvicultural intervention, specifying either the location of the cutting area in the compartment, or the structural type where it should be performed. Also, indications of the type of harvesting method might contribute to a better performance of the silvicultural interventions. In addition, generally in the last revision of management plans a map or sketch of the different structural types, as well as an estimation of its surface were included in the compartment descriptions.

Unfortunately, the lack of registers of forest utilization did not allow proving yet the influence of the treatment description in the accuracy of the utilization. However, the directive and norm of forest planning (D.G.R. 21 January 1997 n.158) states the requirement to register correctly any kind of utilization performed in the frame of a management plan, with indication of the species, number of logs and diameter class.

In any case, as reported in some of the management plans (Andrich, 2011; Balzan & Bino, 1999), timber market and accidental events are main drivers that still can determine the execution of the cuts. Within the utilization registers, a mean volume of 4.3 m^3/ha was removed caused by accidental events during the first three revisions.

If the economic issue is regarded to be a further constraint, an emphasis on the production of high quality timber in order to increase the economic efficiency per unit area could be considered (Pro Silva Europe, 2012). As the use of natural regeneration is fairly generalized, the evaluation of individuals' potential growth (Bagnaresi *et al.*, 2002) and the use of natural stem number reduction (bio-rationalisation) (Pro Silva

Europe, 2012; Schütz, 1999) might be interesting aspects to be included in future silvicultural treatments.

V) CONCLUSIONS

The frequent and moderate cuttings observed in the evolution of the cutting plans, usually through irregular shelterwood system and single tree or group selection system; combined with the flexibility and adaptability of the silvicultural method of yield regulation to the silvicultural needs of different forest and structural types, has allowed natural processes and disturbances to influence the stand structure and diversity together with human interventions (Schütz, 2002) based on the next observations:

- Increase of the abundance of beech observed in the diametric surveys, although it is still limited to the dominant layer. Potential of other broadleaf species to participate in the canopy.
- Increase of lowest diameter classes thanks to the maintenance of high structural variability through moderate and frequent silvicultural interventions.
- Increase of highest dimeter classes contributing to the structural heterogenity and ecological diversity associated with big dimension trees.
- Homogenization of the structure in certain patches observed by the abundance of medium and big trees in the percent diametric distribution of some compartments, indicating good site conditions and low intentsity of the cuttings observed also in the amount of stumps.
- Higher volume of logs and snags indicating natural mortality compared with other managed stands. Potential to increase the CWD volume depending on the intensity and the target of future silvicultural interventions.

Despite the lack of utilization registers at compartment level, other factors such as timber market and accidental events might be influencing the correct performance of the prescribed yields. It is suggested to incorporate more elements based on close-to-nature forestry in the silvicultural treatments, in order to improve the economic efficiency per unit area and the stability of the forests.

The improvement of the quality of the forest management plans along the frequent revisions seems to be a potential framework to incorporate the monitoring of biodiversity and structural indicators especially at stand level.

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APPENDIX A

Decay class definitions

Stumps

Characteristics of stumps	Decay class			
	1	**2**	**3**	**4**
Bark	Intact	Intact or partially trace	Trace	Absent
Texture	Intact	Beginning of decay, presence of internal	Intact in blocks, initial detachment	Absent, advanced decomposition state

Snags

Characteristics of snags	Decay class				
	1	**2**	**3**	**4**	**5**
Bark	Intact	Partly present	Absent	Absent	Absent
Secondary branches	Present	Absent	Absent	Absent	Absent
Principal branches	Present	Present	Present just the base	Present just the base	Absent
Texture	Compact	Compact	Compact	Soft	Soft, more than 70% of sapwood
Colour of the wood	Original colour	Original colour	Orignal colour to light brown	Light brown to reddish brown	Light brown to red brown

Logs

Characteristics of logs	Decay class				
	1	**2**	**3**	**4**	**5**
Bark	Intact	Intact	Trace	Absent	Absent
Branches (<3 cm)	Present	Absent	Absent	Absent	Absent
Texture	Intact	Intact to partly soft	Hard, large pieces	Small, soft blocky pieces	Soft and powdery
Shape	Round	Round	Round	Round to oval	Oval
Colour of wood	Original colour	Original colour	Original colour to faded	Light brown to reddish brown	Red brown to dark brown
Portion of tree on ground	Tree elevated on support points	Tree elevated on support points but sagging slightly	Tree is sagging near ground	All of tree on ground	All of tree on ground

APPENDIX B

Volume formulas

Abies alba

$$v = a + b_1 d^2 h + b_2 d + b_3 dh + b_4 d^2 + b_5 dh^2 + b_6 d^2 h^2 + b_7 h^2 + b_8 d^3 + b_9 d^3 h + b_{10} d^3 h^2$$

[v (m^3); h (m); d (cm)]

$a = -0.656435 \cdot 10^{-2}$	$b_1 = 0.400928 \cdot 10^{-4}$	$b_2 = -0.169942 \cdot 10^{-3}$	$b_3 = 0.162460 \cdot 10^{-3}$
$b_4 = -0.219327 \cdot 10^{-4}$	$b_5 = -0.407627 \cdot 10^{-6}$	$b_6 = -0.248575 \cdot 10^{-7}$	$b_7 = 0.317508 \cdot 10^{-4}$
$b_8 = -0.140341 \cdot 10^{-6}$	$b_9 = -0.983342 \cdot 10^{-7}$	$b_{10} = -0.531640 \cdot 10^{-10}$	

Picea abies

$$v = a + b_1 d^2 h + b_2 d + b_3 d^3 + b_4 h^2 + b_5 dh^2 + b_6 d^2 h^2 + b_7 d^3 h$$

[v (m^3); h (m); d (cm)]

$a = 0.956615 \cdot 10^{-3}$	$b_1 = 0.351034 \cdot 10^{-4}$	$b_2 = 0.182680 \cdot 10^{-3}$	$b_3 = -0.109054 \cdot 10^{-5}$
$b_4 = -0.848230 \cdot 10^{-4}$	$b_5 = 0.137602 \cdot 10^{-4}$	$b_6 = -0.135874 \cdot 10^{-6}$	$b_7 = -0.456717 \cdot 10^{-7}$

Fagus sylvatica

$$v = a + b_1 d^2 h + b_2 d + b_3 h + b_4 dh + b_5 d^2 + b_6 h^2 + b_7 dh^2 + b_8 d^2 h^2 + b_9 d^3 + b_{10} d^3 h + b_{11} d^3 h^2 + b_{12}/h$$

[v (m^3); h (m); d (cm)]

$a = 0.140099 \cdot 10^{-3}$	$b_1 = 0.381535 \cdot 10^{-4}$	$b_2 = 0.370368 \cdot 10^{-3}$	$b_3 = 0.151173 \cdot 10^{-3}$
$b_4 = -0.821778 \cdot 10^{-4}$	$b_5 = 0.124442 \cdot 10^{-3}$	$b_6 = 0.378640 \cdot 10^{-6}$	$b_7 = 0.690078 \cdot 10^{-6}$
$b_8 = 0.131890 \cdot 10^{-7}$	$b_9 = -0.277001 \cdot 10^{-6}$	$b_{10} = 0.959694 \cdot 10^{-8}$	$b_{11} = 0.103466 \cdot 10^{-8}$
$b_{12} = 0.489632 \cdot 10^{-1}$			

APPENDIX C

Understory species list

Frequency, minimum, mode and maximum cover data per species found in the floristic survey performed in the compartments.

Species	Frequency	Min.	Mode	Max.
Abies alba	0.8	+	{+}	+
Acer pseudoplatanus	0.3	+	{+}	+
Aconitum lycoctonum	0.5	+	{+}	+
Actaea spicata	0.4	+	{+}	+
Adenostyles glabra	0.8	+	{+}	1
Anemone nemorosa	0.3	+	{+}	+
Anemone trifolia	0.5	+	{+}	1
Aposeris foetida	0.4	+	{+}	+
Aremonia agrimoides	0.4	+	{+}	+
Asplenium trichomanes	0.4	+	{+}	+
Athyrium filix-femina	0.5	+	{+}	+
Calamintha grandiflora	0.2	1	{ }	2
Calamagrostis villosa	0.4	+	{+}	1
Cardaminer trifolia	0.4	+	{1}	1
Carex sp.	0.1	1	{ }	1
Chaerophyllum hirsutum	0.2	+	{+}	+
Corylus avellanae	0.4	+	{+}	+
Crepis pyrenaica	0.1	+	{ }	+
Cyclamen purpurascens	0.1	+	{ }	+
Daphne mezereum	0.5	+	{+}	+
Dryopteris filix-mas	0.4	+	{+}	+
Euphorbia dulcis	0.2	+	{+}	+
Fagus sylvatica	0.5	+	{+}	+
Fragaria vesca	0.6	+	{+}	+
Fraxinus excelsior	0.1	+	{ }	+
Galium odoratum	0.3	+	{+}	+
Gentiana asclepiadea	0.1	+	{ }	+
Geranium robertianum	0.1	+	{ }	+
Gymnocarpium dryopteris	0.3	+	{+}	+
Hepatica nobilis	0.5	+	{+}	+
Hieracium bifidum	0.6	+	{+}	+
Homogyne alpina	0.2	+	{+}	+
Lamium flavidum	0.7	+	{+}	1
Lilium martagon	0.1	+	{ }	+
Lonicera nigra	1	+	{+}	1
Luzula nivea	0.8	+	{+}	2
Lycopodium annotinum	0.2	+	{+}	+
Maianthemum bifolium	0.6	+	{+}	+

Melampyrum sylvaticum	0.4	+	{+}	+
Melica nutans	0.1	+	{ }	+
Mercurialis perennis	0.4	+	{+}	+
Mycelis muralis	0.2	+	{+}	+
Oxalis acetosella	1	+	{+}	1
Paris quadrifolia	0.3	+	{+}	+
Petasites albus	0.1	+	{ }	+
Phegopteris connectilis	0.2	+	{+}	+
Picea abies	0.3	+	{+}	+
Polygonatum verticillatum	1	+	{+}	+
Polypodium vulgare	0.1	+	{ }	+
Prenanthes purpurea	1	+	{+}	+
Pulmonaria officinalis	0.1	+	{ }	+
Ranunculus lanuginosus	0.1	+	{ }	+
Rosa sp.	0.2	+	{+}	+
Rubus sp.	0.7	+	{+}	+
Salvia glutinosa	0.2	+	{ }	1
Sanicula europaea	0.2	+	{ }	1
Saxifraga rotundifolia	0.1	+	{ }	+
Solidago virgaurea	0.3	+	{+}	+
Sorbus aria	0.3	+	{+}	+
Sorbus aucuparia	0.9	+	{+}	+
Stachis sylvatica	0.3	+	{+}	+
Thalictrum aquilegifolium	0.3	+	{+}	+
Vaccinium myrtillus	0.8	+	{+}	+
Vaccinium vitis-idaea	0.2	+	{+}	+
Valeriana tripteris	0.2	+	{+}	+
Veronica urticifolia	0.3	+	{+}	+
Viola sp.	0.5	+	{+}	+

APPENDIX D

Evolution of dendrological composition and cutting plan

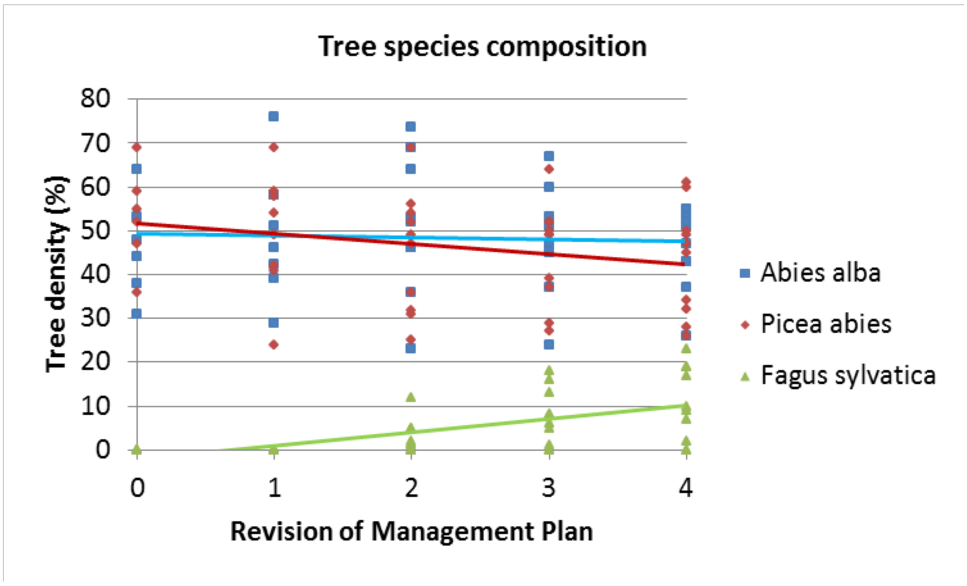

Figure 35: Evolution of tree species composition along revisions in all compartments

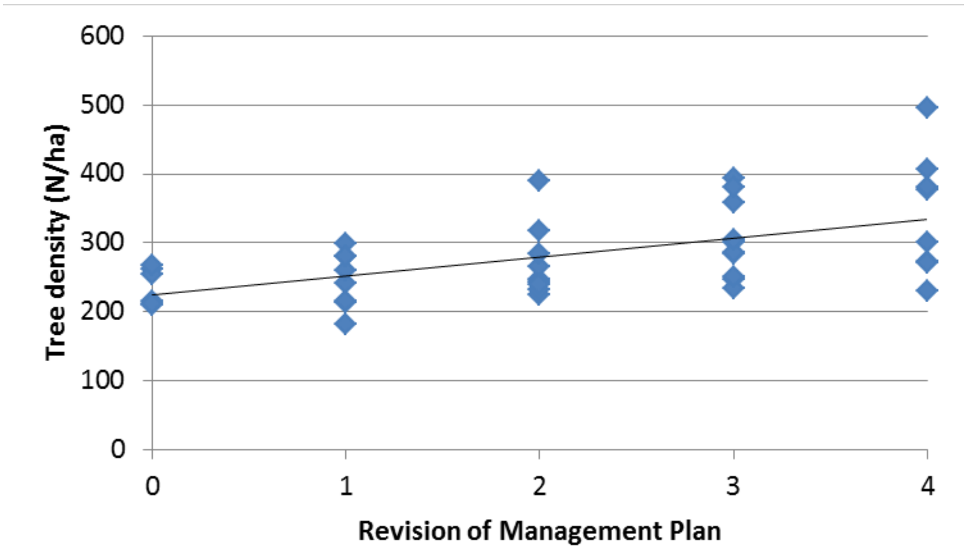

Figure 36: Evolution of tree density along revisions in all compartments

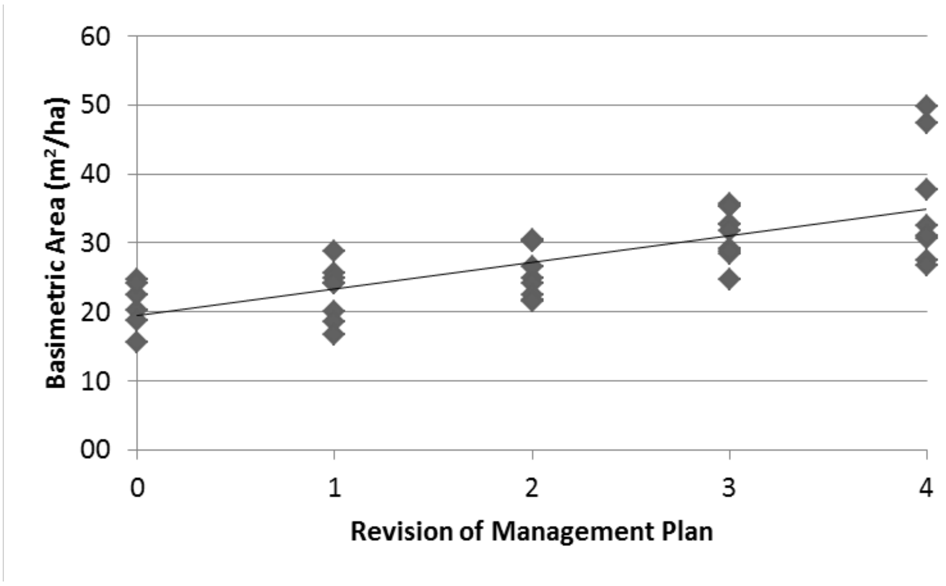

Figure 37: Evolution of BA along revisions in all compartments

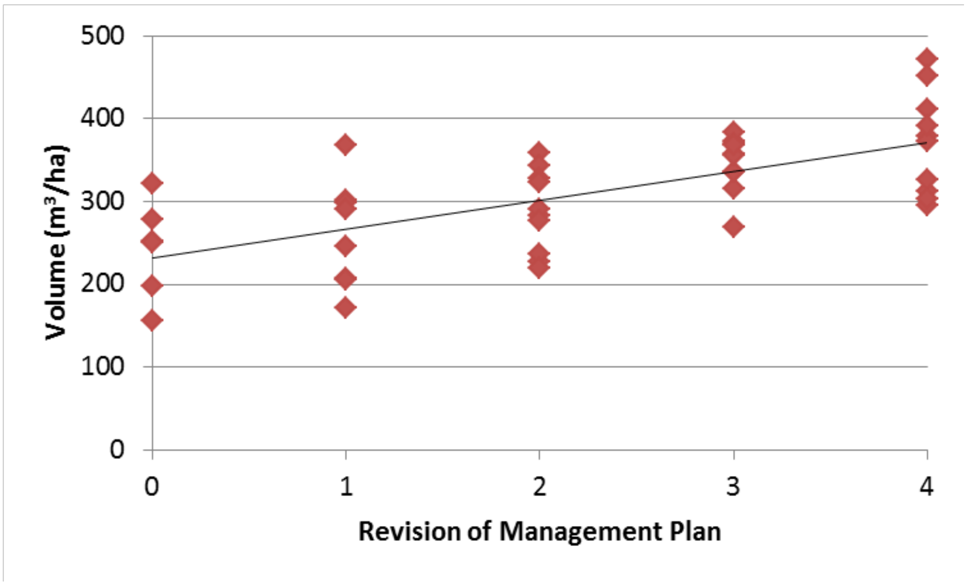

Figure 38: Evolution of volume along revisions in all compartments

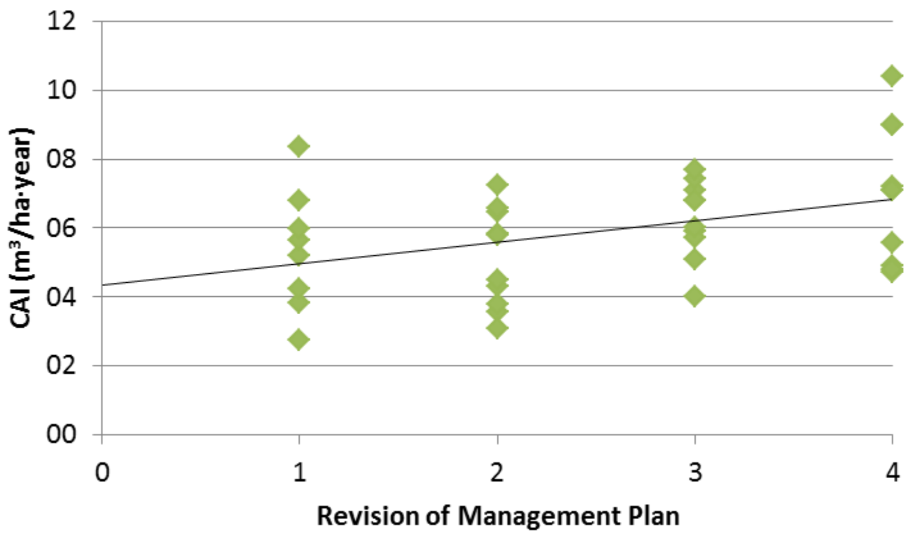

Figure 39: Evolution of CAI along revisions in all compartments

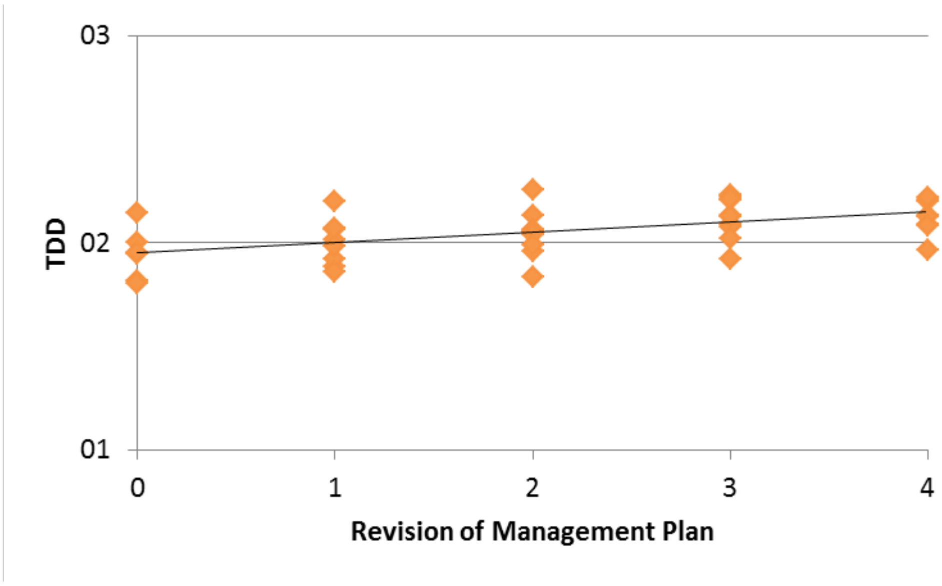

Figure 40: Evolution of TDD along revisions in all compartments

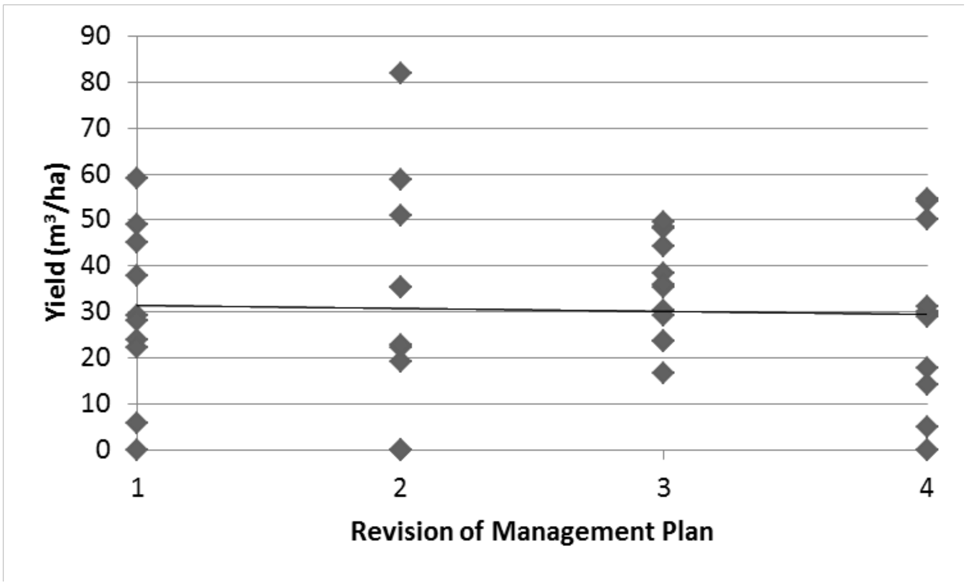

Figure 41: Evolution of yield along revisions in all compartments

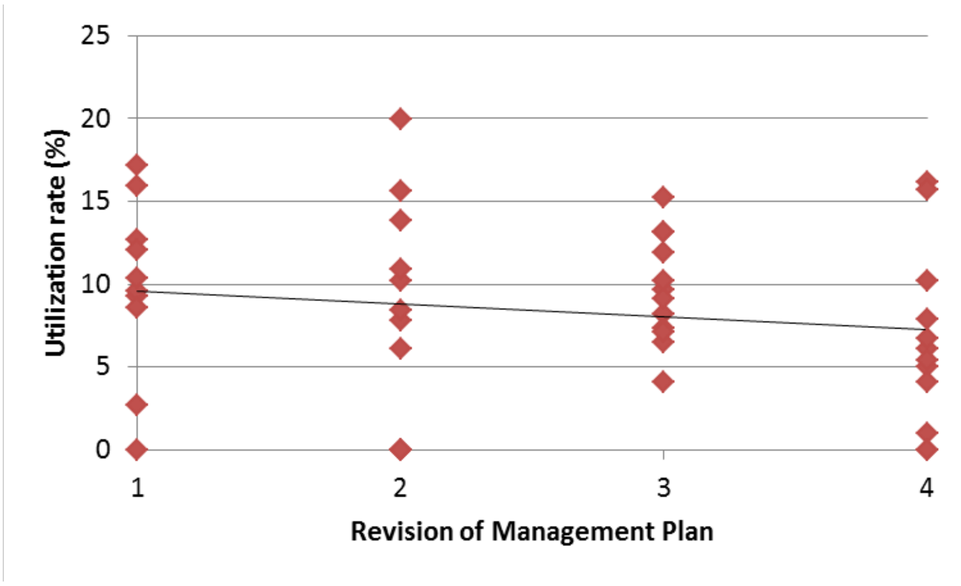

Figure 42: Evolution of utilization rate along revisions in all compartments

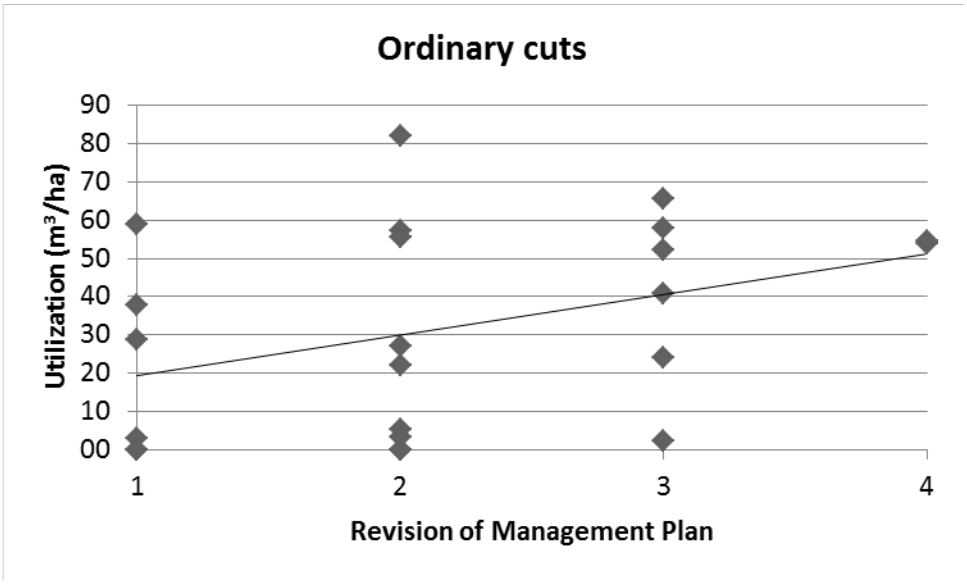

Figure 43: Evolution of ordinary cuts utilization along the revisions in all compartments

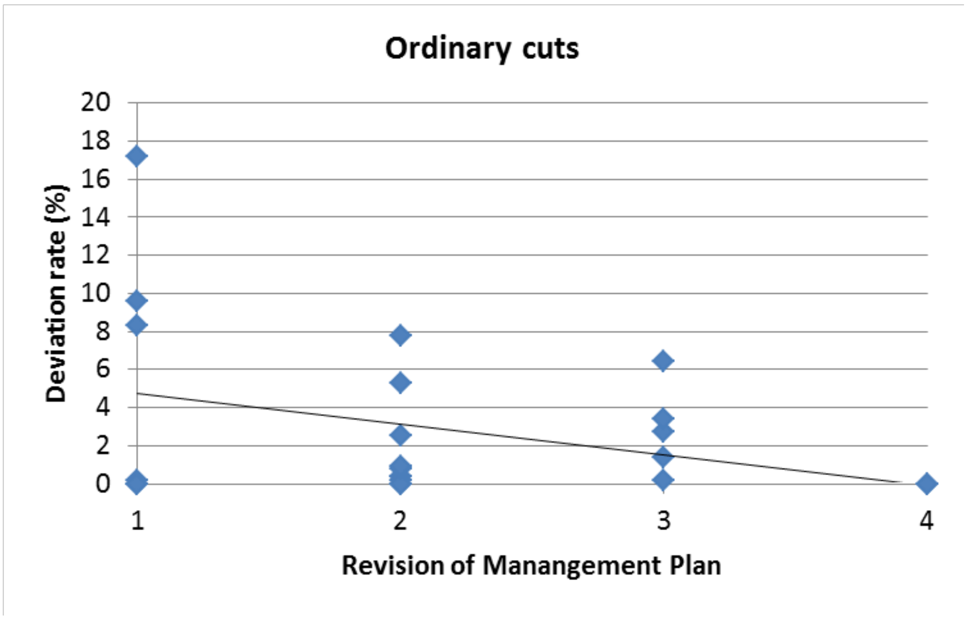

Figure 44: Evolution of ordinary cuts deviation rate along revisions in all compartments

APPENDIX E

Cultural models of silver-fir mixed woodlands

Uneven-aged (H=30m, Inc=2.38%)

Diameter class (cm)	Density (N/ha)	BA (m^2/ha)	Volume (m^3/ha)	CAI (m^3/ha·year)
20	87	2.73	25.57	0.71
25	63	3.09	30.86	0.78
30	45	3.18	30.86	0.74
35	33	3.17	32.33	0.75
40	24	3.02	32.92	0.76
45	17	2.7	29.98	0.7
50	12	2.36	25.87	0.61
55	9	2.14	23.81	0.57
60	6	1.7	19.4	0.46
65	5	1.66	19.11	0.45
70	3	1.15	13.23	0.3
75	2	0.88	10.19	0.21
80	1	0.5	5.88	0.11
Total	**307**	**28.29**	**300**	**7.15**
Dendrological composition at compartment level	341.7	35.3	371.4	7

Even-aged

Structural type	Density (N/ha)	DBH (cm)	Height (m)	BA (m^2/ha)	Volume (m^3/ha)
Novelleto	9712	-	-	-	-
Spessina	3718	8.4	10	21	108
Perticaia	2029	18	21	52	486
Adult	**625**	**35.3**	**33**	**61**	**809**
Mature	**426**	**45.7**	**40**	**70**	**1029**
Multi-layer	503	27.8	22	31	257
Dendrological composition at structural type level	560	33.1	23.3	60.9	871.7