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Ungulate damage and silviculture in the Cansiglio Forest (Veneto Prealps, NE Italy)

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Abstract

The Cansiglio Forest, situated in the Veneto Prealps, is of particular naturalistic and landscape interest, going back to the times of the Most Serene Republic of Venice. Its long silvicultural tradition, which is now even more "near to nature", remains unaltered. Over the last century there has been a considerable increase in the number of ungulates. This is partly due to prohibition of hunting since the beginning of the 20th century throughout the territory. It has therefore become necessary to survey forest regeneration, to ascertain whether deer pressure hampers silvicultural goals and also to investigate which factors are most involved. A review of management plans over the last 30 years identified areas in which regeneration is present, where transects were subsequently sampled. Inside every transect, all saplings (over 50 cm) were measured for diameter and height and monitored for degree and type of damage (browsing, debarking, fraying). Using the CART statistical method, the following key factors were singled out: *species*, proving that fir is the most frequently selected sapling; *silvicultural system*, clarifying that the regeneration of uneven-aged stands is more subject to damage; *aspect*, locating more damage in the southern and eastern areas, probably because they are more often frequented by deer. High densities of deer endanger fir survival, reduce biodiversity, and affect forest economy, limiting silvicultural choices, so that culling ungulate populations seems to be necessary.

Key words: Browsing, CART, cervids, game, management.

Introduction

The Cansiglio Forest (CF), covering about 6000 hectares, is the only example of beech (*Fagus sylvatica* L.) high forest on the southern side of the Italian Alps. Its geomorphological characteristics greatly influence the distribution of vegetation, making the area of particular naturalistic and landscape interest. For this reason, some areas of the Cansiglio are among proposed sites for the European Network "Nature 2000" (Dir. EEC 92/43). Its long silvicultural tradition, which goes back to the times of the Most Serene Republic of Venice, and the excellent technological characteristics of the wood that is produced, have led to the registration of part of the CF since 1977 as no. 145 in the National Seed-Woods Book, in compliance with Dir. EEC 66/404 and 75/445.

There is at present a considerable increase in ungulate populations, as in many other forests in Italy and Europe (Ballon et al. 1991; Havet 1993; De Battisti & Masutti 1995; Meier et al. 2000). Silvicultural practices, which over the last few decades have been oriented towards "near to nature" management, are almost exclusively based on natural regeneration and, wherever appropriate, promote the transformation of even-aged stands into uneven-aged ones. This study aims at determining whether deer pressure interferes with silvicultural management, hampering this transformation process. A survey of damaged saplings was conducted, in order to identify which key factors are best correlated.

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Study area

The CF is situated in the prealpine mountain zone of the Veneto Region (46° 06′ 50″ N, 12° 40′ 81″ E) at altitudes between 900 m and 1694 m (Mt. Croseraz). Mean precipitation is 1872 mm/year (weather station: Pian Cansiglio, 1029 m a.s.l., see Figure 1 for details). This high value is due to the fact that Cansiglio is surrounded by mountains and that the influence of the sea is still appreciable. Karst phenomena give the Cansiglio a typical bowl shape, with sinkholes and swallow holes. This morphology causes inversion on valley slopes, with differences in average temperatures of 2–3 °C with respect to other prealpine areas at the same altitudes. Minimum values during severe winters may reach –35 °C in the deeper valleys (e.g., year 2000).

The ground is snow-covered from the end of November until mid-March. Average annual snowfall is about 60–150 cm, although the snow layer has been lower than these mean values over the last ten years.

The year-round presence of fog is another characteristic phenomenon of the area, especially in the lowlands during the colder hours of the day, caused by the condensation of cold air masses which linger in closed valleys.

History and management

The first historical record of the CF appears in a document dated 923 AD by Berengario I, King of Italy: the CF was handed over as a feud to Aimone, the Bishop Prince of Belluno.

During the expansion of the Most Serene Republic of Venice in the Belluno area, the CF was included in the Republic territory with a decree dated 21/11/1528

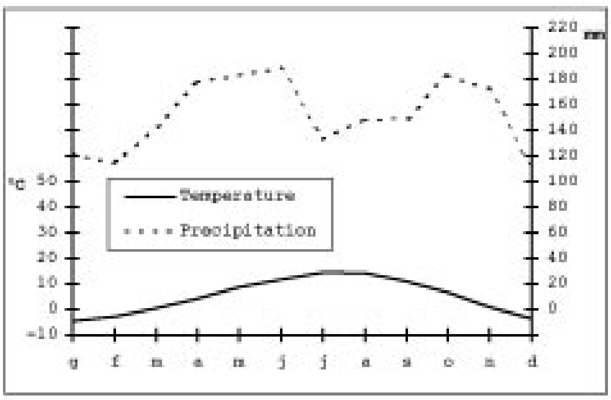


Figure 1. Rain and temperature chart (Bagnouls & Gaussen diagram) of Pian Cansiglio (precipitation 1965–1980, temperature 1961–1990).

by the Council of Ten, and its management was turned over to the Venice *Arsenale* (shipyards). The CF had indeed considerable strategic value as a source of beech wood for crafting oars for war and cargo ships.

The first boundary, called "*Prima general conterminazione*", dated 1550 by Antonio Canal, measured the forest area at about 12,000 ha. Some restrictions on grazing inside the CF were imposed during the following years, because of severe damage inflicted on beech regeneration. In 1576, the CF contained 1,900 head of cattle and 11,000 sheep; the imposed limit stated that no more than 500 head of cattle could graze in the forest (Di Bérenger 1859–1863).

Since 1866, the CF has belonged to the Italian State: the surface area covers 4,800 ha of high forest, 600 ha of meadows and pastures, and 50 ha of unproductive terrain.

Since 1930, the CF has been managed according to plans oriented towards preservation and increment of growing stocks. Beech-dominated forests have a total growing stock of about 1,660,000 m^3 (287 m^3/ha) and a mean annual increase of 4.46 m^3/ha. Nowadays, the CF is divided into 47 compartments and 192 sub-compartments, each characterised by homogeneous structure and composition and by the same silvicultural system. There are also extensive areas of fields and pastures, lying in the centre of the two main valleys.

Forest types and silvicultural systems

Most of the CF falls under the phytoclimatic zone of *Fagetum – sensu* Mayr-Pavari (Pavari 1916). Only small portions of it belong to the *Picetum* zone. The dominant element of the landscape is beech forest. The peculiar morphology and thermal inversion are also reflected in vegetational distribution, so that macrothermic species can be found in the high forest belt and microthermic ones in the bottom of the basin. The *Picetum* area here has a lower altitude than that of *Fagetum*.

The following forest types have been identified, *sensu* Del Favero & Lasen (1993) (Figure 2).

• Esalpic Typical Mountain Beechwood (ETMB): this is characterised by the almost complete absence of shrubs. The richness of the understorey greatly varies with crown coverage. The most important species of the floristic composition are: *Cardamine trifolia* L., *Stellaria nemorum* L., *Galium odoratum* (L.) Scop., *Luzula nivea* (L.) Lam. et DC., *Cardamine enneaphyllos* (L.) Crantz, *Dryopteris filix-mas* (L.) Schott, *Athyrium filix-foemina* (L.) Roth, *Gymnocarpium dryopteris* (L.) Newman, *Adoxa moschatellina* L., *Mycelis muralis* (L.) Dumort., *Ranunculus lanuginosus* L., *Senecio fuchsii* Gmelin, *Prenanthes purpurea* L., *Festuca altissima* All., *Milium effusum* L., and some others. These high forests (38%), located in the southern part of Cansiglio, are treated by the shelterwood system, usually carried out over large areas.

• Highmountain Beechwood: this forest type is greatly influenced by prolonged snowfalls. The floristic composition is characterised by *Rhododendron hirsutum* L., *R. ferrugineum* L., *Vaccinium myrtillus* L., *Cystopteris fragilis* (L.) Bernh., *Saxifraga rotundifolia* L., *Adenostyles alliariae* (Gouan) Kerner, *Luzula sylvatica* (Hudson) Gaudin, *Homogyne alpina* (L.) Cass. and *Polystichum lonchitis* (L.) Roth. Their extension is quite limited (it can be found, e.g., in the Millifret Reserve). Here, beech grows in severe climatic conditions and in locations difficult to reach, so that these stands have little economic interest and are rarely felled.

• Mesoesalpic Mountain Firwood (MMF): this forest type grows in areas characterised by greater atmospheric humidity (northern part). Fir and beech mixture changes are on spatial and temporal scales, depending on the development stage of the forest. In these stands, the two species tend to alternate in the overstorey. Spruce often grows as well and, in some areas, especially near planted sprucewood, it even becomes predominant – Mesoesalpic Mountain Firwood, subtype with spruce (MMFs). Shrubs are present, with some species of *Lonicera* genus, *Rubus idaeus* L. and even *Sorbus aucuparia* L. These high forests (43%) are usually treated by selection cuttings and regeneration is promoted in small areas.

• Mesoesalpic Mountain Pure Firwood: this forest type occupies some well-defined areas inside the CF. It is rich in shrubs, but ferns and mosses also grow. The most characteristic species are: *Circaea alpina* L., *Actaea spicata* L., *Polygonatum verticillatum* (L.) All., *Chrysosplenium alternifolium* L. and *Impatiens noli-tangere* L. Many fir trees, which here reach excellent diameters, are subject to damage by *Armillaria ostoyae* (Romag.) Herink, and thereafter to snowfalls and windfalls. Where gaps form, however, fir regeneration is absent.

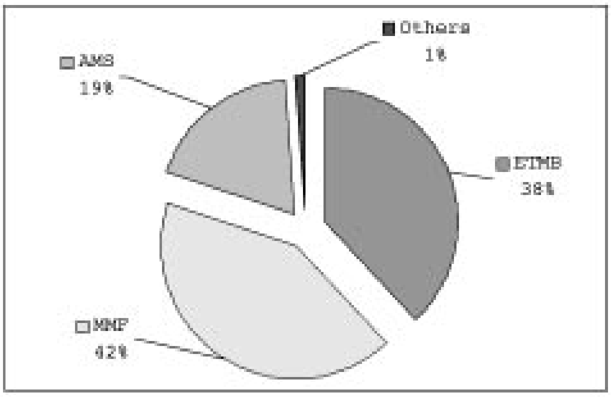


Figure 2. Main forest type percentages in Cansiglio Forest, *sensu* Del Favero & Lasen (1993): Mesoesalpic Mountain Firwood (MMF); Artificial Mountain Sprucewood (AMS); Esalpic Typical Mountain Beechwood (ETMB).

• Artificial Mountain Sprucewood: this is characterised by remarkable density, which sometimes causes a complete lack of the understorey. In areas where the stand is less well stocked, shrubs of *Lonicera* genus and, mostly, *Rubus idaeus* are abundant, so as to hamper the natural regeneration process. Here, spruce trees, because of little thinning in the younger stages, have low mechanical stability. Besides *Armillaria* infections, in the 1980s, clearcuts were carried out in some stands, heavily damaged first by *Cephalcia arvensis* (*Hymenoptera*, *Pamphiliideae*) and then by Coleoptera *Scolytidae* (Battisti et al. 1994).

Ungulate populations

The fauna of the Veneto Prealps has long suffered from the negative influence of colonisation and exploitation of the mountainous terrain, which climaxed around the end of the 19th century. During the course of the 20th century, large native predators – like wolf (*Canis lupus* L.), bear (*Ursus arctos* L.) and lynx (*Lynx lynx* (L.)) – and large herbivores – like red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* (L.)) – vanished from the Veneto mountains.

Italian law forbids game hunting within the State Domain. This protection has allowed species like roe deer to thrive inside the CF, although at low-density population levels.

Around the second half of the 1950s, roe deer populations began to grow, and since the 1970s red deer has reappeared in the area – probably due to colonisers from northern regions like Austria. There is also a small population of fallow deer (*Cervus dama* (L.)) (50–60 head), its growth being constantly monitored since fallow deer is not native to this area (De Battisti & Masutti 1995).

Red deer populations have been growing constantly even outside the CF boundaries, and hunting has also increased (Figure 3). The CF has long been a refuge for cervids. As a matter of fact, a rutting area has existed in the CF since 1975, the only one of its kind, and has been monitored annually since 1996.

A series of drive censuses, conducted over a homogeneous sample area, allowed measurement of roe deer mean density at about 9–10 head over 100 ha (Figure 4). Red deer population density has also been monitored with the aid of halogen spotlights: the value for the CF and surrounding area is 2.5–3 head over 100 ha (Figure 5). The population seems unbalanced in spite of its growth: eco-demographic surveys mea-

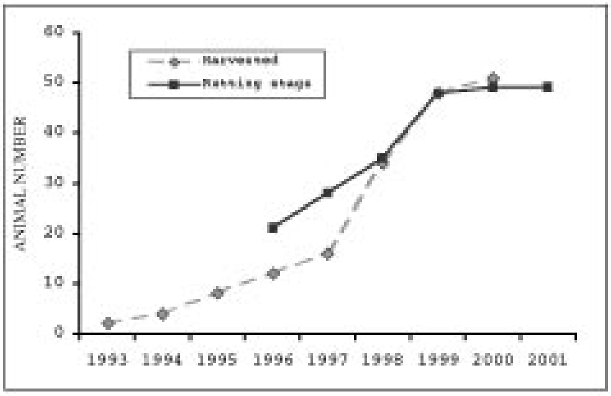


Figure 3. Since 1975, a red deer rutting area has existed in the Cansiglio Forest and since 1996 the number of rutting stags (full line) has been constantly monitored (Vazzola, unpubl. data). Red deer effective numbers increase outside the Cansiglio Forest, where hunting is not forbidden: culled animals (males and females) also increase (dashed line) (from technical reports of Game & Fishing Service of Belluno Province).

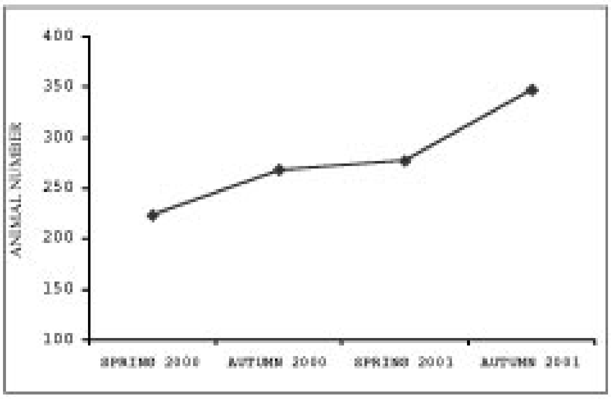


Figure 5. During spring and autumn, years 2000 and 2001, a series of halogen spotlight surveys was carried out every two weeks in Cansiglio. Thanks to the good road network and extensive fields and pastures, a census of red, roe and fallow deer could be carried out. Again, the diagram shows the positive trend of ungulate effective numbers.

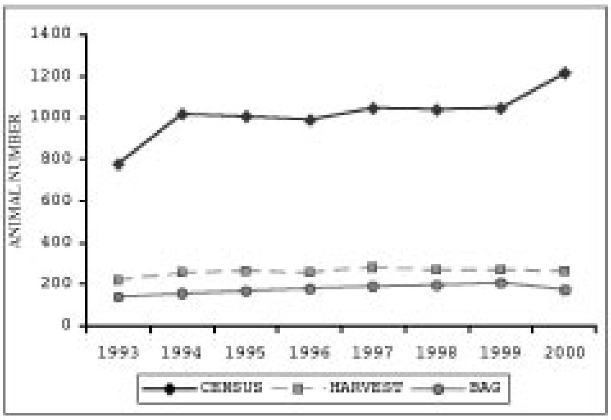


Figure 4. Roe deer management (census, harvesting, bag data) shows low population increases in areas surrounding Cansiglio Forest (from technical reports of Game & Fishing Service of Belluno Province).

sured a male/female ratio of 1/2. Moreover, analysing data from harvesting plans, adult males seem to be subject to poaching, since they are very rarely found in game-bags (Vazzola unpubl. data, Game & Fishing Service of Belluno Province).

It is indeed well known that, in difficult climatic conditions (conspicuous and permanent snowfalls), red deer tend to shift towards sunny slopes outside the CF. This behaviour is triggered not only by thermal needs, but also by food needs, which can easily be satisfied in areas with thermophilous trees and shrubs typical of lower altitude bands – hop hornbeam (*Ostrya carpinifolia* Scop.), hazel (*Corylus avellana* L.), oak (*Quercus pubescens* Willd.), flowering ash (*Fraxinus ornus* L.), briers, etc. These are the areas where numerous adult males may be hunted illegally.

Methods

Deer damage surveys were programmed in order to concentrate them in areas where regeneration is expected and only where it is required by silvicultural practices. To identify *a priori* these areas, the field phase was preceded by research in forest exploitation, by means of management plan data covering the last 30 years. Screening followed various criteria, one for even-aged and another for uneven-aged stands. For even-aged compartments, 30% standing crop felling during the considered timeframe was deemed to set the sufficient and necessary conditions to trigger natural regeneration. For uneven-aged compartments, fellings of any entity were considered.

In the year 2000, 18 transects were sampled (10 m wide, variable length) inside the stands where regeneration was expected (about 60% of compartments). The first point of every transect was randomly established, and the main axis kept the slope direction. Within sampled areas, all saplings higher than 50 cm (unprotected by snow mantle during winter) and with diameters smaller than 12 cm b.d.h. (at 130 cm) were recorded. Damaged saplings were classified according to type of damage (browsing, debarking, fraying).

To classify **browsing damage**, a qualitative ordinal scale was created, making a distinction between conifers and broad-leaved trees.

Broad-leaved

1. Slight damage (one or only a few parts of the tree are browsed)
2. Repeated damage (tree browsed several times, with close knots)
3. Severe damage (tree browsed repeatedly over the years, “bonsai” tree)

Conifers

1. Only lateral shoots are damaged
2. Vegetative apex is damaged
3. Apex and upper buds are damaged

Debarking damage: the maximum width (on the horizontal axis) of the debarked surface was measured. This value, related to the circumference in the middle of the damage, gives the debarking ratio (correlated with reduction of phloematic conduction).

Fraying damage: only occasional occurrences were recorded.

In order to single out the key factors which have the most influence on forest damage, the CART statistical method was used. This particular method analyses a phenomenon and hierarchically orders the variables, depending on their influence. Moreover, unlike traditional methods, it can use simultaneously both qualitative and quantitative variables. Results are shown as a tree, formed of binary nodes and son groups, creating several pathways. Along these pathways, according to the series of nodes, the independent or “predictor” variables are identified hierarchically: first nodes have a lower prediction error value and represent key decisional factors.

These “predictor” variables were used in CART analysis: on the sapling, species and size (height and diameter); on the site, elevation and aspect; on the stand, growing stock and forest type.

At the end of each pathway of the CART tree, as output data, the number of explained cases is reported, i.e. browsed, debarked and frayed saplings, and healthy ones (dependent variables).

Results

About 5000 saplings were recorded inside sampled areas. Beech is the most numerous species (83.1%), followed by spruce and fir (Figure 6). The large number of beech saplings is due to the silviculture system used. Application of the shelterwood system over extensive areas of beechwood yields abundant and contemporary seedlings. Accessory species such as sycamore maple (*Acer pseudoplatanus* L.), European ash (*Fraxinus excelsior* L.) and willows (*Salix sp. pl.*) are scarce or absent altogether. These species were eliminated by man, who favoured species of greater economic interest.

The absolute number of damaged tree is relatively similar for all three species studied (Figure 7) but, given the small number of conifers, the percentage of damaged trees with respect to healthy ones is high. In particular, the number of undamaged firs is very low.

Browsing is the most frequent damage for beech (Figure 8). However, it does not have much impact, since regeneration is quite high. Spruce is browsed more than beech, but far less than fir, which is heavily browsed, and only less than 7% of trees are completely healthy. In conclusion, all three species seem to be palatable to ungulates, but fir is by far the most frequently selected species. As regards debarking, fir is still the most heavily damaged species, whereas this type of damage is almost entirely absent in beech and spruce saplings. Lastly, fraying mainly affects spruce and fir saplings, but in low percentages.

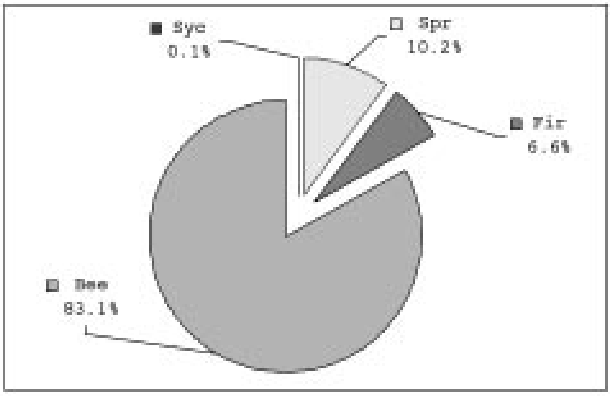
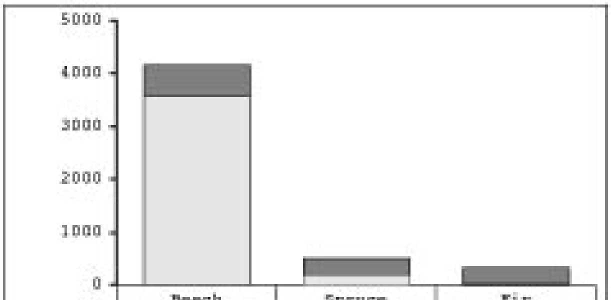


Figure 6. Species percentages in surveyed sample (about 5000 saplings): most representative species are beech (bee), spruce (spr) and fir; few sycamore (syc), and no other species.



	Beech	Spruce	Fir
Damaged	556	315	316
Healthy	3600	195	13

Figure 7. Number of healthy and damaged saplings. Ratios are very different for the three species.

The distribution of sapling diameter size classes shows efficient regeneration processes for beech, while spruce is deficient in smaller diameters Figure 9). The situation of fir is still worse, since individual trees with diameters smaller than 2 cm are missing. For this species, only trees taller than 2 m are found, i.e., taller than deer feeding limits. Probably, the trees that are today over this height threshold were able to grow tall in the past, before the ungulate population became so high. Presently, fir seedlings are unable to reach sufficient heights to avoid being browsed, because once the trees have grown over the protection of the snow cover, they are inevitably browsed during winter. The more mature trees do not have side-branches up to 2 m from the ground; this also makes debarking easier by deer.

The CART results, with a root node error of 0.43, show a relative prediction error with 10 split of 0.39 (Figure 10). Therefore, the absolute error of prediction is 17%. Some variables do not appear (e.g., site elevation), because they do not have a sufficient degree of significance. "Predictor" variables explaining the phenomenon seem to be: species and height of saplings, growing stock and forest type, and aspect. Each node is divided into two branches, according to a numerical value or a qualitative variable: 11 pathways are identified, indicated by letters from A to K.

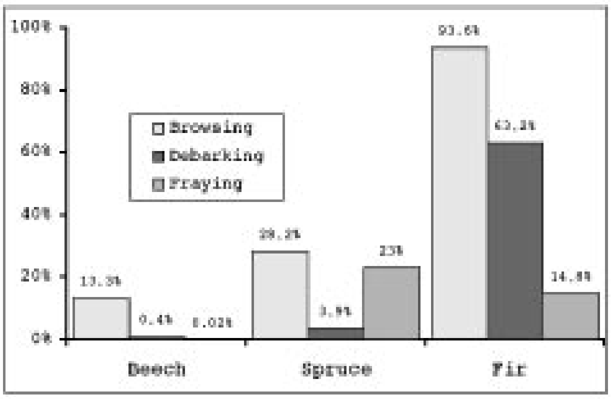


Figure 8. Percentages of browsed, debarked and frayed saplings, calculated on total sampled trees.

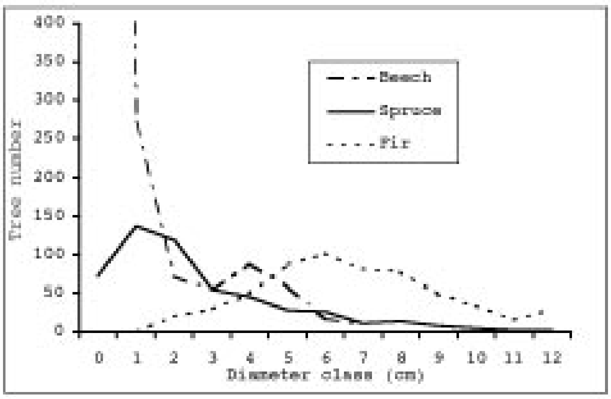


Figure 9. Diameter class distribution of monitored saplings. Spruce and fir regeneration distributions show very few smaller diameters.

Analysing the CART tree shows that the first node immediately separates, on the left, fir from the other two species, confirming that this tree species is severely damaged wherever it is found (pathway A).

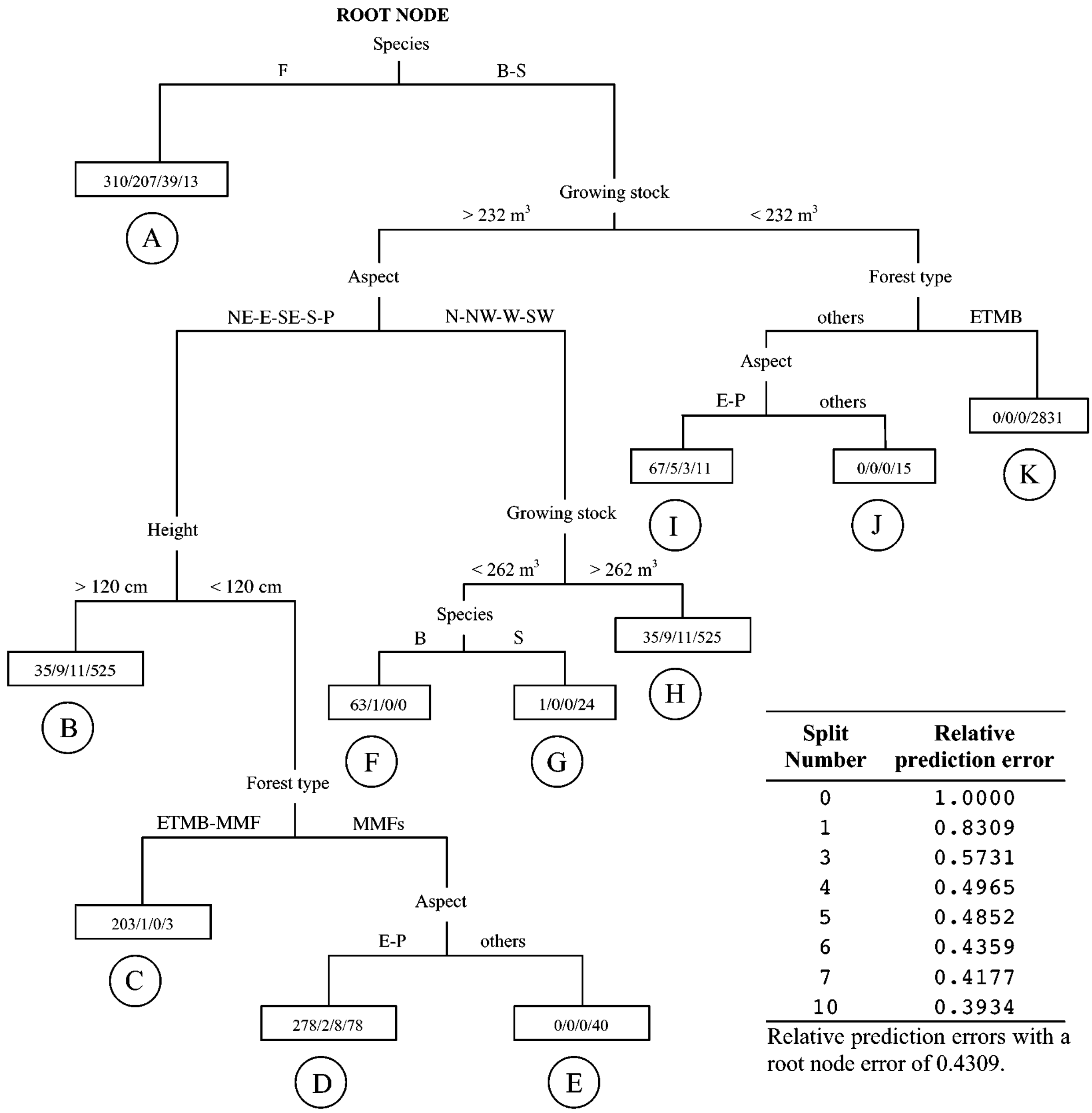
As for regeneration of the other two species (right-hand side), growing stock appears at the second node, separating low-density woods (less than 232 m^3/ha) from high-density ones (more than 232 m^3/ha). It should be recalled that these growing stocks always refer to mature stands, because only in these areas does regeneration occur and replace the crop for the future.

Pathway K shows that beech saplings suffer no damage in the forest type Esalpic Typical Mountain Beechwood (ETMB), where they are abundant. Some damage, found in pathway I, appears only in the plains or in easterly exposed areas.

In compartments with volumes greater than baseline values of 232 m^3/ha, aspect becomes a significant variable. Pathways F, G and H refer to northerly and westerly exposed areas. Here sapling damage is generally slighter (except for pathway F, where regeneration is scarce in any case). Probably, in winter, animals avoid these sites, since temperatures are lower.

In other aspects (mostly southern and eastern) or in the plains, the height of beech or spruce saplings becomes determinant, according to type of damage. Fraying and debarking are primarily seen on individual trees taller than 120 cm (pathway B). For lower trees (pathway on the right side), browsing damage is more evident, mostly concentrated in Beechwoods (ETMB) and Firwoods (MMF) (pathway C), as in Firwoods with spruce (MMFs), if exposed to the east or found in the plains (pathway D).

The particular vulnerability of easterly or plain areas is shown, as noted above, even in the case of low growing stocks (pathway I), and is mainly attributable to the high density of deer in most of the sampled areas, fitting these requirements. The frequent visits of deer to these areas, ascertained by observation, are not necessarily explainable only on the basis of site factors, i.e., auto-ecological characteristics of the species, but various elements, including ethological factors, are probably responsible. It should be noted that one wide, flat area, where much severe damage was found, is particularly close to meadows and quiet locations, because it has been turned into a reserve and is therefore less subject to anthropogenic disturbance.



Split Number	Relative prediction error
0	1.0000
1	0.8309
3	0.5731
4	0.4965
5	0.4852
6	0.4359
7	0.4177
10	0.3934

Relative prediction errors with a root node error of 0.4309.

Forest type	ETMB: esalpic typical mountain beechwood MMF: mesoesalpic mountain firwood MMFs: mesoesalpic mountain firwood, sub-type with spruce.
Aspect	9 classes, 8 for cardinal points (N, S, NW, etc.) e one for plain (P)
Species	B: beech S: spruce F: fir

Figure 10. Classification and regression tree yielded by CART analysis. "Predictor" variables are hierarchically ordered through nodes. Qualitative or quantitative values of variables split nodes into two branches. CART tree is composed of 11 pathways (from A to K); the end of each pathway shows number of saplings damaged by browsing, debarking, and fraying; the number of healthy trees is also indicated (de-

Discussion

There are two main causes for high deer densities in the CF: (1) extensive meadows surrounded by forest, which make it particularly attractive for ungulates (Thomas et al. 1979; Clark & Gilbert 1982; Bobek et al. 1993; Reimoser & Gossow 1996; Sheehy & Vavra 1996; Cook et al. 1998; Flueck 2000); (2) the prohibition of hunting throughout the CF, which has turned it into a place of refuge (Reimoser 1998; Burcham et al. 1999).

While in summer pasture areas are able to satisfy the feeding needs of these populations, in winter the abundant and persistent snow cover limits food supply, thus causing severe impact by deer on the forest vegetation in this season.

CART analysis revealed that forest damage depends on three key factors:

1. Species: fir is the most frequently selected and heavily damaged species, wherever it grows, as verified by many authors (Mattedi 1986; Adamic 1990; König & Baumann 1990; Motta 1993; Koubek & Homolka 1995; Ammer 1996; Reimoser 1998; Homolka & Matous 1999; Meier et al. 2000). Spruce and beech saplings are more or less damaged by ungulates, according to other factors.

2. Growing stock: this variable is correlated with both silvicultural system and forest type. Compartments with low growing stocks are mainly even-aged Esalpic Typical Mountain Beechwood (ETMB), where the shelterwood system promotes extensive regeneration areas. Here, on one hand ungulate damage is quite absent, both due to the great number of saplings and the lesser attractiveness of these stands. On the other hand, the compartments with higher growing stocks, represented by uneven-aged Mesoesalpic Mountain Firwood (MMF), where selection cutting is adopted, have a different structure, more highly detailed in layers and with more ecotones. Therefore these stands are more frequently visited by deer; regeneration is severely limited and where found is sporadic and not uniformly distributed.

3. Aspect: sapling damage is less severe in northerly areas, where the snow mantle persists for a long time, and in westerly areas, where the sun is absent in early morning. Ungulates are probably discouraged from frequenting these sites.

The aim of extending "near to nature" habitats in the CF, like uneven-aged stands, does not seem feasible with these high densities of ungulates. This observation contrasts with indications in the literature, according to which "near to nature" forest stands, treated with cutting over small surfaces, is less susceptible to damage (Gill 1992; Ballon & Guibert 1993; Bobek et al. 1993; Motta 1993; Reimoser & Gossow 1996; Reimoser et al. 1999; Mysterud & Østbye 1999;Völk 1999). In the Cansiglio firwoods, natural conditions are sufficiently satisfied from the stand structure point of view, but the same is not true of tree species mixture. Accessory species, which could constitute an alternative food supply for ungulates, are missing. Their presence should be encouraged, not only because a larger number of these species may reduce the risk of damage, but also because it is a fundamental requirement for biodiversity. Moreover, from the biodiversity point of view, the lack of fir saplings is a cause for concern, because this species may disappear in the CF in the future.

Deer populations exceed the "silvicultural carrying capacity" (*sensu* "cultural carrying capacity", Hansen et al. 1997), because forest damage not only affects wood economy, but also limits silvicultural choices and, in particular, endangers fir survival, therefore changing the species mixture (Frelich & Lorimer 1985; Staines 1991; Hope et al. 1996). It seems justified to promote reduction of deer density in Cansiglio (Staines 1991; Bobek et al. 1993; Rutberg 1997; Reimoser 1998; Flueck 2000). Moreover, if natural ecosystems are a model for forest management, the same should apply to game management. It should be remembered that deer population densities are quite low in virgin forests. In fact, if the food chain is still complete and efficient, the role of large predators is determinant (Flueck 2000).

The importance of forest and game management coordination emerges from this, through reciprocal integration and continuous exchange of information and priorities, in order to allow sustainable management of the forest as a single system. The goal of sustainable management of ecosystems is, as in the case of the Cansiglio, of fundamental importance, bearing in mind all aspects (naturalistic, historical, socio-economical, cultural) which contribute to the particular value of this territory.

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