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# ALTERNATIVE SILVICULTURAL OPTIONS FOR CHESTNUT COPPICE STANDS: EVALUATION OF SUSTAINABILITY BY SILVICULTURAL AND ECOLOGICAL INDICATORS

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## Abstract

In Italy, chestnut coppice is one of the most important forest types, due both to its extensive coverage and the high average productivity of stands. Socio-economic changes occurring in the last decades led, on one hand, to the abandonment of a considerable part of the coppice area and, on the other, to the increase in demand for high quality wood of various types. On this basis, the traditional management of chestnut coppices was reconsidered and new management systems, based on the adoption of long rotation periods, were proposed. This paper analyses two silvicultural models for chestnut coppices based on 30 and 50 year rotation periods and early, frequent, low-heavy thinnings as well as the consequences of their application at the bio-ecological level, by means of changes induced on stand structure and functionality.

Key words: chestnut coppice, forest management, thinnings, productivity, sustainability, sustainable management, Italy

# *ALTERNATIVNE GOJITVENE MOŽNOSTI V KOSTANJEVIH PANJEVCIH: OCENA TRAJNOSTI Z GOJITVENIMI IN EKOLOŠKIMI INDIKATORJI*

## *Izvleček*

*Upoštevaje razširjenost in visoko povprečno produktivnost sestojev so kostanjevi panjevci med najpomembnejšimi tipi gozda v Italiji. Socio-ekonomske spremembe zadnjih desetletij imajo za posledico opuščanje gospodarjenja v precejšnjem delu panjevcev ob hkratnem povečanju povpraševanja po različnih vrstah visoko kakovostnega lesa. Zavoljo teh sprememb je bil predlagan nov sistem gospodarjenja s kostanjevimi panjevci, ki temelji na dolgih časih obhodnje. V članku sta analizirana dva gojitvena modela za panjevce kostanja, ki temeljita na 30- in 50-letni obhodnji ter na zgodnjih, pogostih in zmernih redčenjih. Obravnavane so posledice uporabe teh gojitvenih modelov na bioekološki ravni, upoštevaje spremembe strukture in funkcionalnosti sestojev.*

*Ključne besede: kostanjev panjevec, gospodarjenje z gozdom, redčenje, produktivnost, trajnost, trajnostno gospodarjenje, Italija*

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**VSEBINA**

# 1 INTRODUCTION
UVOD

In the last decades, environmental, socio-economic and political reasons have led to a renewed interest in the forestry of the chestnut tree. The species is able to give diverse, high quality and ecologically compatible wood assortments such as sawed logs, differently sized poles and bioengineering materials. No wood products (fruits, tannin, honey) or other functions (landscape, habitat, tourism, fire prevention, hydro-geological regulation, soil protection) represent important additional elements. In the meantime, a sound management of chestnut forests can contribute to re-launching the economies in rural mountain and hilly areas (BOURGEOIS 1992, EVERAD / CHRISTIE 1995).

The exploitation of chestnut coppice and the elaboration of management models, as well as alternatives to short rotation periods, have been analysed to exploit the economic potential of the species and at the same time to guarantee stand functionality and stability. These themes have been investigated by the Istituto Sperimentale per la Selvicoltura (ISS) since the end of the 70's (AMORINI / GAMBI 1977, AMORINI / BRUSCHINI / MANETTI 1996, AMORINI / MANETTI 1997). The traditional system often coincided with short rotation coppicing for the production of poles. Some exceptions set in the past (PATRONE 1936) are not suitable in the present context, mainly due to the small quantity of the yield removed during the thinning practices. In this context, management models based on the extension of the rotation and the application of relatively frequent, low and moderate-heavy thinnings can be a good option for increasing wood quality, in keeping with the demands of the ownership and both the needs of a sustainable development and tourist - environmental values (AMORINI / BRUSCHINI / MANETTI 1997, CUTINI / FABBIO 1997).

The concept of sustainability is a controversial issue even in its definition (LUST / NACHTERGALE 2000). The term is so imprecise and ambiguous that, depending on various interests, scales and political intentions, it can have different meanings and focuses (OESTEN 1995, DI CASTRI 2000). Its application to forestry was fashionable even if putting this concept into practice is difficult. Therefore, sustainability in silviculture is often linked to an alternative way of managing forest stands in which the economic aspect is considered a real benefit when all the functions attributed to the

balanced and functional dominant storey. An important requisite for their applicability is represented by a good to excellent fertility, since the high degree of cultivation suggests managing only when it is possible to maximise the capacities of the species.

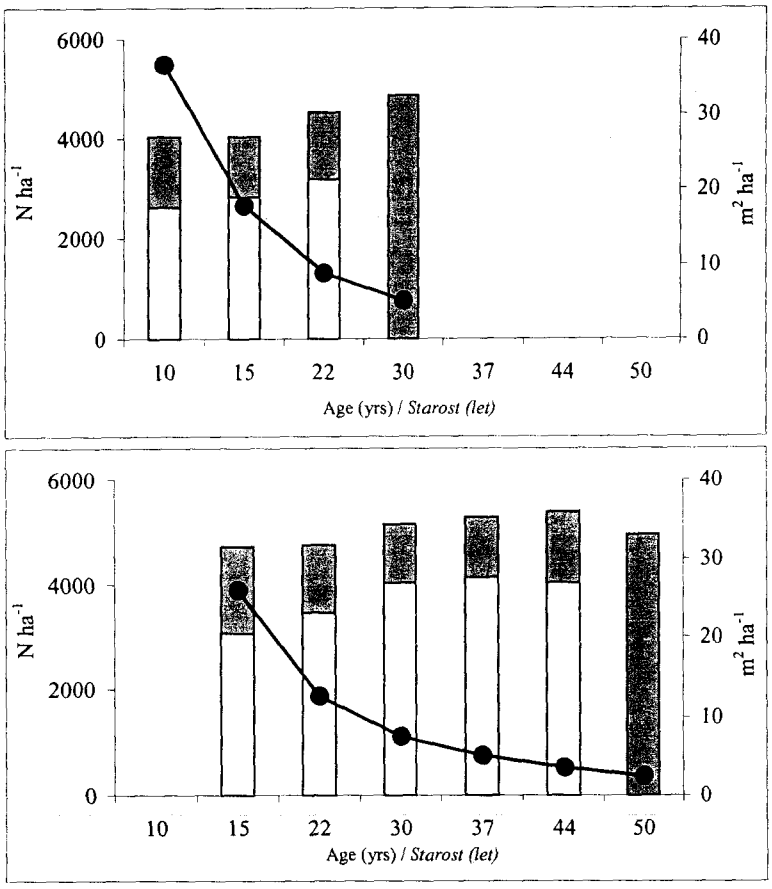


Figure 1: Medium (top) and Long (bottom) Rotation Models for Chestnut Coppices. Variation of number of shoots (-•-) and basal area (black bar - basal area before thinning; white bar - basal area after thinning) as a function of age and silvicultural treatment.

*Slika 1: Modela s srednje-dolgo (zgoraj) in dolgo (spodaj) obhodnjo za kostanjeve panjevce; prikazane so spremembe števila poganjkov (-•-) in temeljnice (črni stolpci - temeljnica pred rečenjem; beli stolpci - temeljnica po redčenju) v odvisnosti od starosti ter gojitvenih ukrepov*

## 2.2 SILVICULTURAL AND ECOLOGICAL INDICATORS
GOJITVENI IN EKOLOŠKI INDIKATORJI

The sustainability of the models was evaluated by means of qualitative and quantitative silvicultural and ecological indicators. More precisely, the impact of thinnings was appraised on stand productivity, growth increment, social reorganisation, and characteristics of the canopy cover of differently old coppices (AMORINI / BRUSCHINI / MANETTI 2000, CUTINI 2000).

The dendrometrical variables considered as quantitative indicators were: number of shoots (N), basal area (BA), basal area current increment (BAI) and mortality rate (M). These represent the most important and easily measured variables able to characterise tree density and productivity of a forest, as well as being able to evaluate stand dynamics as a function of natural evolution or silvicultural treatment. Among the qualitative indicators, the social structure analysis – the role of the dominant component (D) particularly - was chosen as a parameter able to assess both the stand complexity and the social rearrangement as a function of time and thinning practices. Ecological indicators such as transmittance ($\tau$, radiation measured below the canopy as a percentage of total incoming radiation above the canopy) and leaf area index (LAI), allowed evaluation of the stand functionality and stability, and verification of the response to heavy and frequent thinnings in terms of canopy cover restoration.

## 2.3 THE STUDY AREA
OBMOČJE RAZISKAVE

The experimental sites are located on Monte Amiata (Central Italy – latitude 42° 53' N; longitude 11° 40' W), a forest district characterised by a wide area of chestnut stands (3.500 hectares), a significant part under public ownership (20 %), a dynamic, innovative and diversified management, and the presence of specialised and qualified manpower.

Two coppice stands were considered: a young coppice (YC) and an older coppice (AC) 11 and 34 years old, respectively, at the beginning of the study (1993). The stands are on good sites, located at 850 m a.s.l., with south-south-western exposure, a 6-8° slope and

on rich soils from the volcanic substratum. The climate is mountainous-Mediterranean (annual rainfall = 1.547 mm; annual average temperature = 10°C) with a dry summer and rainfall concentrated in autumn and winter. Both the experimental areas matched the principal requisite of high fertility and productivity.

In both cases, two experimental plots were defined, one of control and one in which the thinning was applied according to the proposed models. Thinnings were carried out at 11 and 17 years in the young coppice and at 15 and 35 years in the older coppice.

The stands were characterised before thinning (1993 at 11 yrs YC; 1994 at 35 yrs AC) by means of permanent plots in which the dendrometrical (number of living and dead stools and shoots, dbh, height) and ecological (transmittance, LAI) variables were measured.

Indirect estimates of LAI were collected with the LAI 2000 Plant Canopy Analyzer (PCA, Li-Cor, Lincoln, NE, USA). The instrument is used to assess both temporal and spatial variations and to compare different stands (CUTINI / MATTEUCCI / SCARASCIA-MUGNOZZA 1998). The PCA measures light captured by a fish-eye lens. Light measurements are made using five concentric light-detecting silicon rings, sampling five concentric sky sectors (with a central zenith angle of, respectively, 7°, 23°, 38°, 53°, 68°). LAI is estimated by an inversion model comparing the transmittances, calculated simultaneously for each sky sector, measured above and below the canopy. In all the plots, a measurement cycle consisted of a reference measurement and nine below-canopy readings. The reference measurements were collected in large clearings or open areas near the experimental plots at the beginning of each cycle. The below-canopy measurements were carried out in each plot along permanent transects. All measurements were taken under conditions of totally diffuse light, with the sun at or below the horizon to avoid confusing brightly sunlit leaves for gaps. Furthermore, in order to avoid rapid and transient changes in sky conditions between reference and below-canopy readings, cloudless or uniformly overcast days were chosen. For each stand, 3-5 cycles of measurement were performed under full closed canopies. PCA LAI estimates were derived by the C2000 LI-COR software built into the instrument; the software was also used to post-process the data in order to make corrections and further evaluation.

Light measurements in the photosynthetically active radiation (PAR) waveband (0.4-0.7 μm) were taken by a Sunfleck Ceptometer SF 80 (Decagon Devices Inc., Pullman, WA, USA), a linear quantum sensor (CUTINI 2001). In each experimental plot, nine light measurements were collected at fixed points, on sunny days near noon, local solar time. At each sampling point, four instantaneous measurements were taken holding the ceptometer horizontally and pointing toward the four cardinal directions. At the beginning and at the end of each measurement cycle, a reference measurement was collected in a large clearing nearby. For each measurement cycle and plot, the below canopy measurements were related to the reference values to calculate transmittance. Mean stand transmittance measured at each survey and in each plot was considered for statistical analysis.

Stand structure was evaluated by permanent transects defining spatial distribution of each shoot, individual social rank (four classes: dominant, codominant, subdominant, dominated), crown area (by four radii according cardinal directions), and crown length. Surveys were also repeated after thinning and - in order to evaluate the effects of silvicultural treatment - on January 2000 for YC and on January 1998 for AC.

# 3 RESULTS
REZULTATI

## 3.1 QUANTITATIVE INDICATORS
KOLIČINSKI INDIKATORJI

In the young coppice (Figure 2), the control plot recorded a high mortality (M = 29%) and a good rhythm of growth (BAI = 2,18 $m^2$ $ha^{-1}$ $y^{-1}$) during the observation period (11-17 years). In thinned stand, the silvicultural practice markedly reduced mortality rate (M = 1,8%) and conversely, it slightly increased basal area current increment (BAI = 2,33 $m^2$ $ha^{-1}$ $y^{-1}$). Thinning eliminated 58% of the shoots and reduced 1/3 of the total basal area, decreasing the competition within and among stools and concentrating the growth on a few shoots. It is noteworthy that six years after the thinning, the basal area completely recovered. The second thinning was then carried out in winter of 1999-2000 according to

the criteria from the medium rotation model. The number of shoots and basal area were reduced by 47% and 30% respectively.

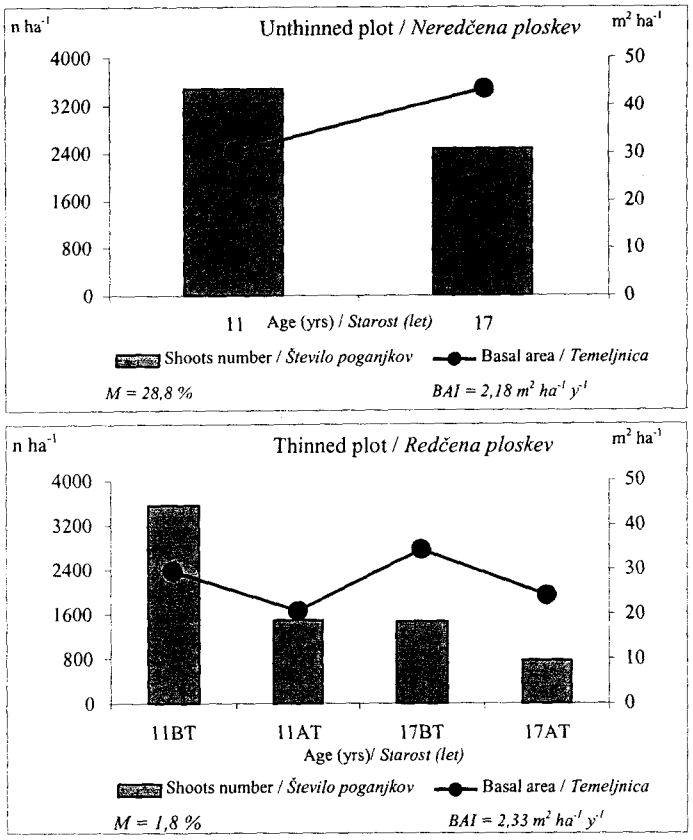


Figure 2: Young coppice - Number of shoots and basal area per hectare in the two inventories, both in unthinned and in thinned plots before (BT) and after (AT) thinning. Basal area increment (BAI) and mortality rate (M) are also reported.

*Slika 2: Mladi panjevci – število poganjkov in temeljnica na hektar na dveh ploskvah (neredčeni ter redčeni) pred (BT) in po redčenju (AT); prikazana sta tudi temeljnični prirastek (BAI) in odstotek smrtnosti (M)*

The same dynamics can be observed in the older coppice (Figure 3), but with slower rhythms. The effects of the treatment on stand productivity are underlined by the values of basal area current increment recorded in the control and thinned plots (0,7 vs. 1,1 m²

$ha^{-1}$ $y^{-1}$). Despite the short period between the two inventories (3 years), the thinned stand showed good reaction to the heavy thinning (46% of the shoots and 34% of the basal area removed). Thinning improved the performance both at stand and at single tree level.

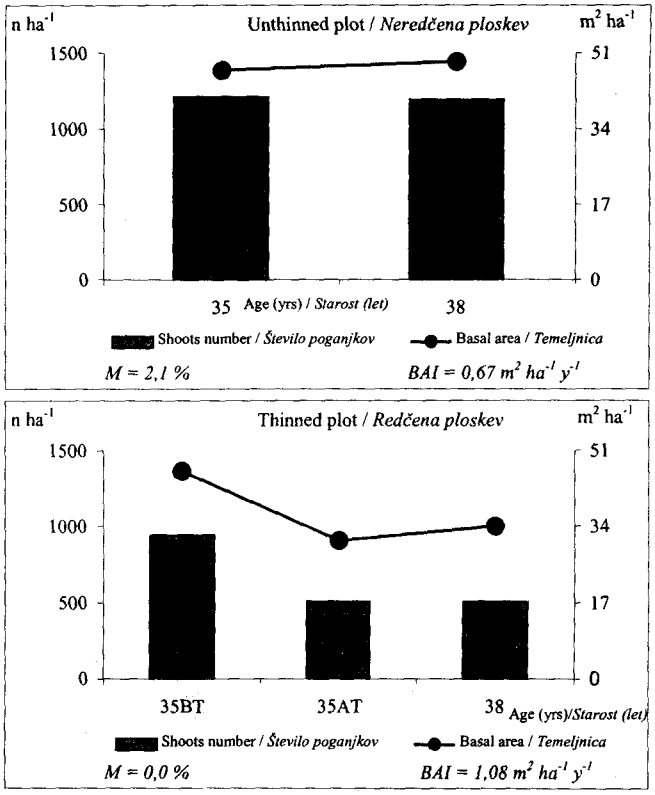


Figure 3: Older coppice - Number of shoots and basal area per hectare in the two inventories, both in unthinned and in thinned plots before (BT) and after (AT) thinning. Basal area increment (BAI) and mortality rate (M) are also reported.

*Slika 3: Starejši panjevci – število poganjkov in temeljnica na hektar na dveh ploskvah (neredčeni in redčeni) pred (BT) in po redčenju (AT); prikazana sta tudi temeljnični prirastek (BAI) in odstotek smrtnosti (M)*

## 3.2 QUALITATIVE INDICATORS
KVALITATIVNI INDIKATORJI

The importance of the dominant storey was evaluated in young and older coppices both in thinned and unthinned plots (Figure 4). In the unthinned young coppice, the increase of the dominant social class in time (from 34 to 48% of the basal area) was due to the high mortality rate in the dominated storey. Conversely, thinning almost entirely eliminated the dominated and sub-dominated shoots (99 and 80% respectively), reduced the co-dominant class (34%) and, with selective criteria, the dominant one (13%). This explains the apparent increase of dominant class immediately after the thinning. The rapid social rearrangement, due to the fast growth and the characteristics of light-demanding species, allowed the re-equilibrium between the two treatments (unthinned and thinned). Six years after thinning, the dominant shoots maintain the same consistency (from 47 to 45%), while the co-dominant class decreases from 47 to 27%.

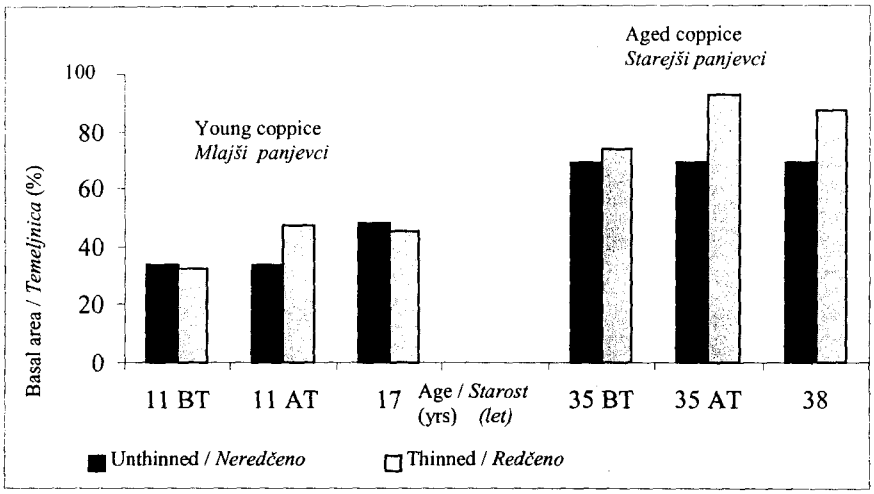


Figure 4: Percentage of basal area of the dominant storey in young and older coppice as a function of age and silvicultural treatment (BT before thinning, AT after thinning).

*Slika 4: Odstotni delež vladajočega sloja v temeljnici sestoja v mlajših in starejših panjevcih v odvisnosti od starosti ter negovalnih ukrepov (BT pred redčenjem, AT po redčenju)*

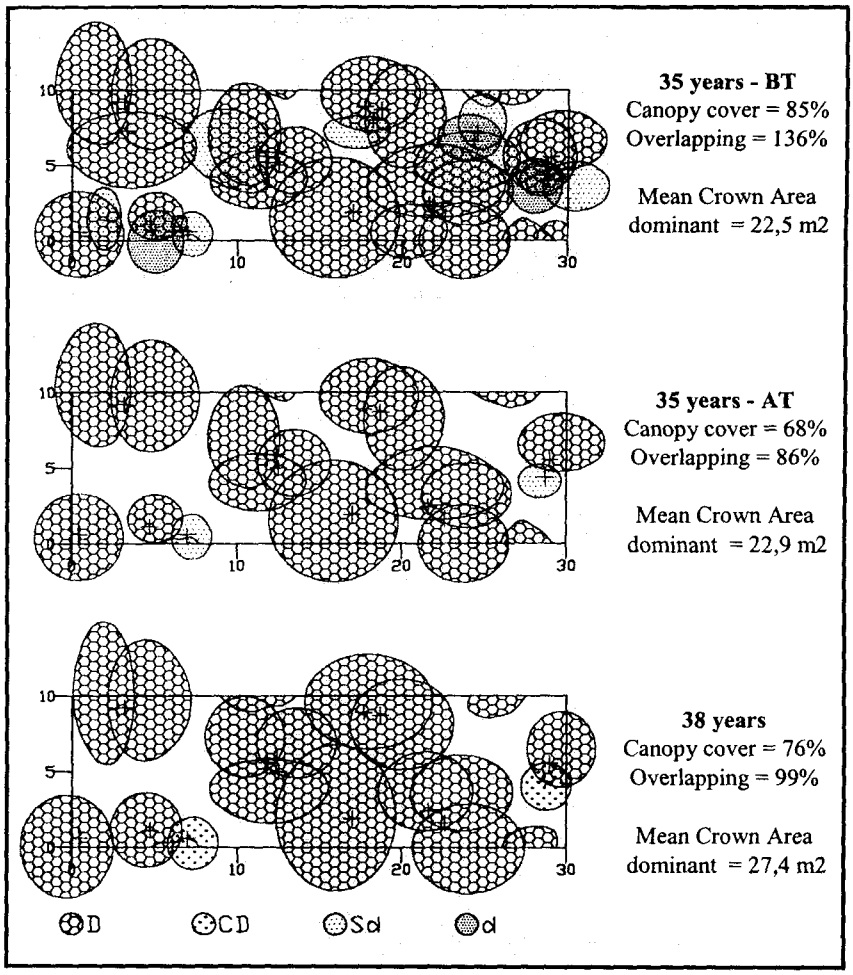


Figure 5: Stand structure dynamics of an older coppice as a function of age, silvicultural treatment (BT before thinning, AT after thinning) and social rank (D=dominant, CD=codominant, Sd=subdominant, d=dominated).

*Slika 5: Dinamika spreminjanja strukture sestoja v starejšem panjevcu v odvisnosti od starosti, gojitvenih ukrepov (BT: pred redčenjem; AT: po redčenju) in socialnega položaja (D: vladajoč; CD: sovladajoč; Sd: podvladajoč; d: obvladan)*

In the aged stands, the importance of the dominant storey is greater (more than 70% in basal area), but the slower dynamics did not allow substantial changes in the control

stand during the observation period. The low-thinning totally eliminated the dominated shoots (100%), reduced the sub-dominant (88%) and codominant (68%) ones and almost entirely released the dominant storey (18% removed). The fast social reorganisation determined the reduction of dominant social class (from 93 to 87% of the basal area) just three years after thinning.

Stand structure analysis of the thinned older coppice (Figure 5) highlighted a simplified organisation as shown by canopy cover and crown overlapping recorded at 35 years (before thinning). The difference between the two indexes characterises the complexity degree of a stand; in this case, the difference is not so evident as shown in other stands and species (GUIDI / MANETTI 1997). This is a consequence of the bio-ecological characteristics (fast growth, light demand, rapid social reorganisation). Therefore, the simplifying action of thinning is sustainable for the natural tendency of the species to establish monoplane structures. Thinning notably reduced canopy cover. Regardless, the stand was able to partially recover in only three vegetation seasons. The positive and dynamic evolution of the stand was also shown by the increase of the medium crown area.

### 3.3 ECOLOGICAL INDICATORS
EKOLOŠKI INDIKATORJI

The ability to restore forest canopy cover after frequent and heavy thinnings was analysed by means of transmittance ($\tau$) and Leaf Area Index (LAI) measurements. In the young coppices (Figure 6), the effect of thinning is evident in the first years where values are significantly different. Differences tend to nullify themselves in a short time. Transmittance in the older coppices was higher than in young stands, due to the lower complexity of the vertical structure. Thinning notably increased transmittance (from 4,4 to 21,9%) but the ability to recover was less evident than in young coppices as shown by other silvicultural indicators.

The opportunity of frequent thinnings is underlined by the rapid recovery of canopy characteristics in both stands: after thinning LAI values were 4,2 (young coppice) and 2,3 (older coppice) $m^2\ m^{-2}$; four vegetative seasons later, the young coppice was 5,4 and the

older coppice was 6,0 $m^2$ $m^{-2}$. Such values were similar to those recorded in the control plots (4,8 in the young coppice and 5,7 $m^2$ $m^{-2}$ in the older coppice).

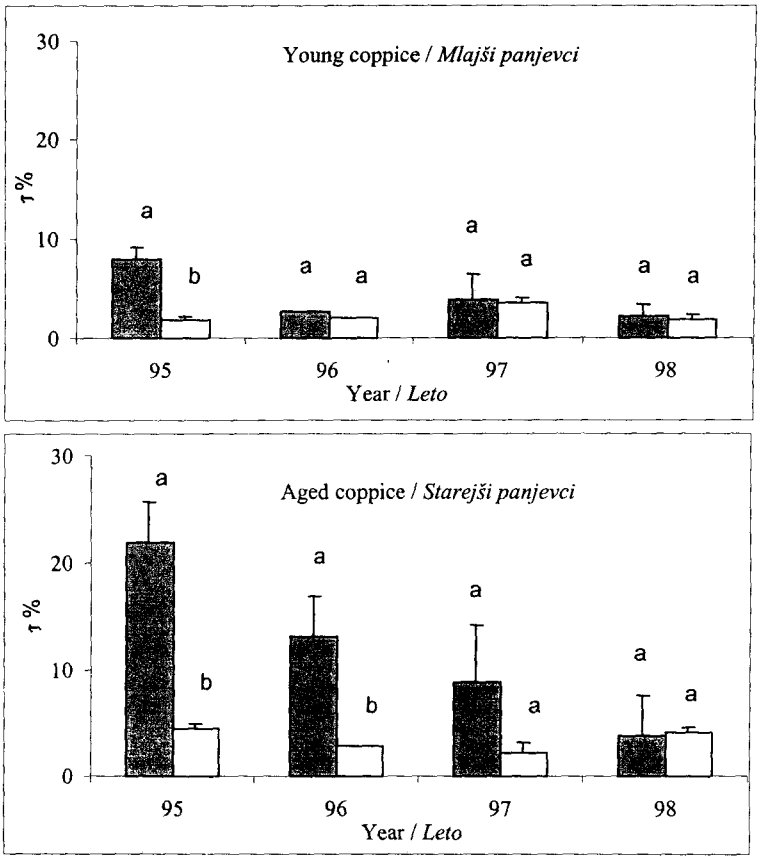


Figure 6: Mean values of transmittance (τ) of unthinned (white bars) and thinned (dark bars) plots established in young and aged chestnut coppices. Bars indicate + 1 s.e. of the mean. Means with different letters differ significantly at $p < 0,05$.

*Slika 6: Srednja vrednost presevnosti svetlobe (τ) neredčenih (beli stolpci) in redčenih (temni stolpci) ploskev v mlajših in starejših panjevcih kostanja (črte označujejo +1 s.e.; srednje vrednosti, ki se značilno razlikujejo (p<0,05), so označene z različnimi črkami)*

# 4 DISCUSSION AND CONCLUSIONS
# RAZPRAVA IN ZAKLJUČKI

The analysis of the selected indicators allowed evaluation of the suitability and the sustainability of the models based on the extension of rotation period and frequent heavy thinnings. In particular, the quantitative parameters analysis seems to be compatible with the adoption of heavy thinning, which - if carried out under conditions of good or excellent productivity - enhances the re-establishment of the removed yield.

The fast recovery of canopy cover and the loss of dominance supports frequent thinnings, which allow maintenance of a dominant storey, characterised by selected shoots with good morphological characteristics and a regular continued growth. This last feature is also one of the characteristics necessary to minimise the risk of ring shake, a defect often present in chestnut wood (AMORINI *et al.* 2001).

From a bio-ecological and functional point of view, the impact of the proposed silvicultural treatment (heavy and frequent thinnings) on canopy cover characteristics is consistent with the maintaining of a high stand efficiency level (CUTINI 2001). The relationship between LAI and growth efficiency (increase of above ground biomass per LAI unit), in fact, indicated a functionality loss for LAI above 5,0-5,5 $m^2 m^{-2}$ (CUTINI / FABBIO 1997). In addition, the increase of rotation period positively influences the bio-geochemical cycle because the nutrient incorporation rate decreases progressively up to 15-20 years; over this age, the balance between annually absorbed and released nutrients, due to litter, has positive results (RANGER *et al.* 1990, RANGER / NYS 1996).

Finally, the proposed silvicultural treatment allows associating good quality timber and the diversification of assortments during the whole productive cycle (CARBONE / RIBAUDO 1995). In relation to the Kyoto protocol, it assumes importance both for carbon storage capacity and for carbon immobilisation in wood assortments with a longer life cycle and less energetic input. A representative example is given by the employment of a chestnut pole in comparison to cement or impregnated coniferous poles.

The two models are sustainable both from the ecological and silvicultural points of view due to the positive response to thinnings, the biomass recovery in a very short time, the

rapid social reorganisation and the fast restoration of canopy cover. The extension of the rotation period and the thinning regime positively influence the morphological characteristics of stems, the quality of timber, the range of assortments, the resistance to disease and the cycle of nutrients.

## 5 POVZETEK

*Upoštevaje razširjenost in visoko povprečno produktivnost sestojev so kostanjevi panjevci med najpomembnejšimi tipi gozda v Italiji. V teh sestojih lahko pridobivamo različne lesne sortimente (npr. hlode za žago, drogove različnih dimenzij in gradbeni les) ter nelesne proizvode (sadeže, tanin, med). Poleg tega lahko ti sestoji opravljajo tudi druge funkcije (estetsko, turistično, varovanje pred požari, hidrološko, varovanje tal). Tradicionalni gojitveni sistemi, ki so bili večinoma prilagojeni proizvodnji drogov, so temeljili predvsem na kratkih obhodnjah. Modeli gospodarjenja, ki temeljijo na podaljšanih obhodnjah in relativno pogostih ter srednje močnih redčenjih, nudijo dobro možnost za zagotavljanje proizvodnje lesa; tako omogočajo zadovoljevanje potreb lastnika ob hkratnem zagotavljanju trajnostenga razvoja in turistično-okoljskih vrednot.*

*Namen raziskave je predstaviti značilnosti dveh gojitvenih modelov, predlaganih kot alternativa tradicionalnemu sistemu gospodarjenja s kostanjevimi panjevci, in s pomočjo analize strukture, stabilnosti ter funkcionalnosti sestoja potrditi njuno trajnostno naravnanost.*

*Predlagana gojitvena modela (slika 1 in preglednica 2) se razlikujeta predvsem glede intenzivnosti gospodarjenja oziroma glede količine in kakovosti lesnih sortimentov ob koncu obhodenj ter med celotnim proizvodnim obdobjem. Osnovne značilnosti, po katerih se razlikujeta, so: dolžina obhodnje (30 oziroma 50 let), starost sestoja ob prvem redčenju (10 oziroma 15 let), pogostost (5 oziroma 7 let) in intenzivnost posegov. Trajnost modelov smo ocenili s pomočjo količinskih (število, temeljnica, temeljnični prirastek, stopnja smrtnosti) in kvalitativnih gojitvenih (pomembnost vladajočega sloja) ter ekoloških (indeks listne površine, presevnost svetlobe) indikatorjev. Natančneje smo vpliv redčenj ocenili s produktivnostjo sestojev, prirastkom, spremembami v socialni strukturi sestojev in značilnostmi zastrtosti v različno starih panjevcih.*

*Poskusne ploskve se nahajajo na Monte Amiati (osrednja Italija); za območje so značilne velike površine sestojev kostanja (3500 ha); primeren delež javnih gozdov (20 %); dinamično, inovativno in raznoliko gospodarjenje; prisotnost specializirane in kvalificirane delovne sile. Študijo smo izvedli v dveh sestojih – mlad panjevec (YC) in starejši panjevec (AC); ob začetku študije (leta 1993) sta bila stara 11 oziroma 34 let. V obeh sestojih smo postavili po dve poskusni ploskvi – kontrolno in ploskev, na kateri smo izvajali redčenja glede na predlagana modela. Pred in po redčenjih smo na ploskvah izmerili dendrometrične in ekološke parametre.*

*Na osnovi analize izbranih indikatorjev smo ocenili primernost in trajnost modelov, ki temeljita na podaljšanih obhodnjah in močnejših, pogostejših redčenjih. Analiza količinskih parametrov (sliki 2 in 3) je pokazala, da so močnejša redčenja primerna, če se izvajajo v sestojih z dobro ali odlično produktivnostjo. Hitra regeneracija sklepa krošenj in izguba dominance (sliki 4 in 5) sta v prid pogostim redčenjem, ki omogočajo vzdrževanje vladajočega sloja, sestavljenega iz izbranih dreves z dobrimi morfološkimi značilnostmi in kontinuirano, enakomerno rastjo. Z bioekološkega in funkcionalnega stališča je vpliv predlaganih gojitvenih modelov na značilnosti sklepa krošenj (slika 6) v skladu z zagotavljanjem visoke ravni učinkovitosti sestoja.*

*Iz ekološkega in gojitvenega vidika (pozitiven odziv sestojev na redčenja, hitra obnova biomase, hitra socialna reorganizacija in hitra obnova sklepa krošenj) sta se modela izkazala kot trajnostno usmerjena. Podaljšanje obhodnje in spremenjen sistem redčenj vplivata pozitivno na morfološke značilnosti debel, kakovost lesa, strukturo sortimentov, odpornost na bolezni in na kroženje hranil v sestoju.*

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