Competition and dynamics in abandoned chestnut orchards in southern Switzerland

Compétition et dynamique dans les châtaigneraies abandonnées de Suisse méridionale

Marco CONEDERA¹, Pietro STANGA¹, Christian LISCHER² & Veronika STÖCKLI³

¹ Swiss Federal Institute of Forest, Snow and Landscape Research, corresponding author: WSL Sottostazione Sud delle Alpi, casella postale 57, CH- 6504 Bellinzona, phone: 0041 91 821 52 31, fax: 0041 91 821 52 31, mail marco.conedera@wsl.ch

² Botanisches Institut der Universität Basel, Schönbeinstrasse 6, CH- 4056 Basel

³ Swiss Federal Institute for Snow and Avalanche Research, CH-7260 Davos-Dorf

ABSTRACT

After the second World War, socio-economic developments and the spread of the chestnut blight meant that many of the heavily used chestnut orchards in southern Switzerland were left without any management. In the absence of cultural inputs, the anthropogenic origin of the stands became less apparent and their structures tended to disintegrate. A hierarchical approach was used to study the changes in stand characteristics over time. The species composition, structure and percent cover of the stands were studied at medium level using aerial photographs, with particular regard to medium term (35 years) changes. On a smaller scale, dendroecological methods were used to investigate the timing and ecology of the regeneration and growth of both invading and orchard trees. The results show clearly that the chestnut orchards were invaded by a large variety of species, which varied according to site conditions. These powerful natural dynamics are due to both the open structure of the chestnut orchards and the lack of resilience shown by the orchard-trees when suddenly submitted to natural competition. The main factors influencing the evolution of these stands are presented and discussed. A better understanding of these kinds of evolutionary processes is a prerequisite if future forest and landscape management is to be sustainable.

Key-words: *Castanea sativa*, chestnut stand, abandonment, natural evolution, landscape management, Switzerland

RESUME

L'évolution socio-économique qui a suivi la seconde guerre mondiale et la propagation du chancre de l'écorce du châtaignier ont entraîné, en Suisse méridionale, l'abandon de nombre de châtaigneraies pourtant intensément utilisées jusque-là. En l'absence de soins culturaux, l'origine anthropogène de ces peuplements s'est estompée et leurs structures se sont désagrégées. Les changements qui se sont produits à la longue au niveau des caractéristiques des peuplements ont été analysés au moyen d'une approche hiérarchique. La composition en espèces des peuplements, leur structure ainsi que leur taux de recouvrement ont été étudiés à moyenne échelle à l'aide de photographies aériennes prenant spécialement en compte les changements à moyen terme (35 ans). A une échelle plus précise, des méthodes dendro-écologiques ont été employées pour examiner la durée et l'écologie de la régénération et de la croissance des châtaigniers ainsi que des essences apparaissant spontanément. Les résultats montrent clairement que les châtaigneraies ont été envahies par un grand nombre d'espèces variant suivant les conditions stationnelles. Cette dynamique naturelle puissante peut se développer grâce à la structure ouverte des châtaigneraies et à la faible plasticité des châtaigniers face à la soudaine concurrence naturelle. Les principaux éléments qui influencent l'évolution de ces vergers sont présentés et traités. Une meilleure compréhension de ces processus évolutifs est indispensable pour une gestion durable des forêts et des paysages du futur.

Mots-clés : *Castanea sativa*, peuplements de châtaigniers, abandon, évolution naturelle, gestion du paysage, Suisse

INTRODUCTION

Chestnut cultivation has a long tradition in many areas of Europe. The success of the introduction and the growth of this species derives from its suitability as a wood and crop producer and its ecological relevance. Humans have long known how to manage the chestnut in extremely profitable and diversified ways (e.g. in coppices or orchards) to produce fruit, timber and other goods. The chestnut became a basic source of food for the local population, especially in mountainous regions (Pitte, 1986). Socio-economic developments during the nineteenth century and the related abandonment of the rural areas led to a decrease in the importance of the chestnut and to a progressive decline in its cultivation (Arnaud *et al.*, 1997).

When cultivated, both the main types of chestnut stands (orchard and coppice) are artificially kept as monocultures. In the absence of cultural inputs chestnut stands tend to be invaded by other tree species, giving way to mixed forests (Eccher & Piccini, 1985; Mondino 1991; Stanga, 1997; Maltoni *et al.*, 1997). Among chestnut stands, open-structured orchards show an extreme susceptibility to invasion by various tree species (Stanga, 1997; Maltoni *et al.*, 1997). Chestnut orchards, therefore, represent useful objects of study for the understanding of secondary succession in formerly cultivated stands.

The ability to predict the development of abandoned chestnut orchards should be very important for future decision-making policy concerning the management and protection of forests and the environment. Chestnut stands contain, in fact, more historical, cultural and ecological elements than most other forest stands, so that the development of new concepts for their sustainable management is particularly worthwhile (Conedera *et al.*, 1997).

In this study different aspects of the natural development of abandoned chestnut orchards were analysed in order to :

- (i) quantify the regression of the chestnut stands over the medium term (35 years),
- (ii) detect the driving forces of the evolutionary process,
- (iii) interpret the observed dynamics ecologically.

MATERIAL AND METHODS

Study area

The climate in the hilly regions of Southern Switzerland is warm-temperate and rainy, with a mean annual precipitation of 1600-1700 mm and a mean annual temperature of about 12 °C. Summer rain (about 800 mm in the period June-September) is much more intensive than in Mediterranean areas. The chestnut (*Castanea sativa* Mill.) was introduced into the area by the Romans nearly 2000 years ago (Zoller, 1961). Due to human activity, chestnut stands became the dominant forests on acid soils. The so-called chestnut belt stretches over more than 20,000 ha up to 700-1000 m a.s.l., depending on aspect (see Figure 1). In previous centuries the chestnut played an essential role as a staple food for the population. Since the introduction of alternative crops (mostly potatoes and maize) at the beginning of the 19th century and with progressive improvements in transportation, the nutritional importance of the chestnut has decreased. At the same time, the management of the chestnut stands has been reduced. Many stands were cut down at the beginning of this century to produce wood for tannin extraction, and most of the remaining orchards were abandoned completely after the appearance in 1948 of chestnut blight (*Cryphonectria parasitica* (Murr.) Barr.). As a result, the area of southern Switzerland covered by chestnut orchards decreased from an estimated 9 000 ha at the beginning of the century (Merz, 1919) to 3 000 ha at the end, as recorded in the second Swiss national forest inventory (Stierlin & Ulmer, 1999).

Diachronic analysis of aerial photographs

The historical development of the chestnut stands was assessed on a meso-scale by comparing aerial photographs from two different periods (1959/60 and 1995). The photographic material collected in 1959/60 while producing the Chestnut Distribution Map of southern Switzerland (IFRF, 1959) was used as a reference for the diachronic analysis. In these photographs it is possible to distinguish chestnut trees from other tree species (the photos were taken during the chestnut flowering period) and to identify the

Figure 1: Locations of the study sites in southern Switzerland

structure of the stands even though a wide range of scales was used (varying from 1:15 000 to 1:20 000), and despite all the photos being black and white. In 1995, colour aerial photos on the scale of 1:10 000 were taken for comparative analysis in 10 sample areas covering in total a surface of about 600 ha (Figure 1).

The sample areas were selected so as (i) to include as many different types of chestnut stands, in particular chestnut orchards, as possible according to the following criteria : geographical distribution in southern Switzerland, elevation, aspect, site conditions, and stage of abandonment, and (ii) to include extended chestnut stands with homogeneous characteristics (the minimum stand size considered in the aerial photographs was 0.2 ha).

A detailed interpretation was not possible since the 1959/60 photos were not of good quality. The following main characteristics were analysed :

- chestnut stand type (orchard, coppice, high forest) ;

- degree of mixture (contribution of chestnut to crown cover vs. other species contributions grouped in 20% contribution classes). Stands in which the crown projections of chestnuts in 1960 represented less than 20% of the total cover were not considered. Stands in 1995 that contained less than 20% chestnuts were classified as « other species »;

- cover (cover percentage of the crowns of all tree species in the stand, in 20%-classes).

In addition, for each stand other descriptive features were recorded :

- site conditions (poor, medium, good). The site conditions were determined on the basis of the maps derived from the aerial photographs. For each stand the site conditions class was defined according to the aspect (north-facing, south-facing), relief (knoll, hillside, depression) and elevation according to the simplified key proposed for the sites on crystalline rocks by Keller (1979) ;

- fire events between 1959/60 and 1995 (0, 1-2, more than 2). classified according to Conedera *et al.* (1993) ;
 - the presence of other species in the stand was determined from the aerial photographs and, if necessary, verified in the field. The following classes were considered according to the dissemination strategy of the species : no other species, pioneer species (birch) and other widely disseminating species (ash, lime, etc.), or climax species with heavy seeds (beech, oaks) ;
 - the dominant species in neighbouring stands in 1959/60 were also determined on the basis of the aerial photographs. Only two classes were considered: chestnut stands or other species (degree of mixture of chestnut <20%).

This expanded set of explanatory variables was used to investigate which factor or which combination of factors had a statistically significant influence on the dynamics of the abandoned chestnut stands. The evolution of the degree of mixture ($Y = 1$ when the proportion of chestnut had decreased, $Y = 2$ when the proportion of chestnut had remained unchanged or increased) was defined as a binary response variable. In order to reduce the degrees of freedom of the model, the classes of some explanatory variables were regrouped in 2 : this is the case for the degree of mixture («pure» if > 80% ; «mixed» if between 20-80%) and cover («close» if > 0.8 ; «open» if between 0.2-0.8). For the statistical analysis, a model describing the probability that the response variable assumes the value 1 (decrease in proportion of chestnut) was applied (where $P(Y_i=1)$ is a function of the explanatory variables $x_{i1}, x_{i2}, x_{i3}, \dots, x_{im}$). The probability was logarithmically transformed to avoid values exceeding 1, so that the following logistic regression model was obtained (Cox, 1980) :

$$\text{Log} \left(\frac{P(Y_i=1)}{1 - P(Y_i=1)} \right) = h(x_i(1), \dots, x_i(m)) = \alpha + \beta_1 x_i(1) + \beta_2 x_i(2) + \dots + \beta_m x_i(m)$$

The analysis was performed using the CATMOD (CATegorical data MODeling) of the SAS statistical package.

Dendroecological analysis

Five test plots of 20m x 20m were selected in abandoned chestnut orchards representing different site conditions (Figure 1). In each test plot, a

phytosociological *relevé* (10m x 10m) was carried out according to Braun-Blanquet (1964). Based on these data, the index of nutrient content according to Landolt (1977) was implemented. In order to compare the results with those of other authors (Maltoni *et al.*, 1997), species diversity was calculated using the Shannon-Weaver and the Evenness index (Southwood, 1978; Magurran, 1991):

Shannon: $H_s = - \sum p_i \ln p_i$, where : p_i = relative abundance of the i -th species,

Evenness: $E_s = H_s / \ln S$, where : S = Number of species.

All the trees standing in each test plot which had already reached 2 m in height were cored at 0.3 m above ground (if higher than 8 m) or cut and a disc retained at 10 cm above ground. For each tree the following data were recorded : species, social position, position in the plot, birth date and radial growth.

RESULTS

Evolution of the chestnut orchards on the meso-scale

Of the 606.3 ha covered by the 1125 forest stands belonging to the 10 sample areas of the aerial photographs analysis, 122.1 ha (277 stands) were classified as chestnut orchards on the basis of the 1959/60 aerial photographs. Of these, only 88.8 ha (72.7%) were classified as chestnut orchards in 1995: 9.8 ha (8.0 %) had been transformed by human activity into coppice stands or open areas, while the remaining 23.5 ha (19.2%) had evolved naturally below the threshold of 20% of chestnut cover and were registered as «other species» (Table 1). Tables 2 and 3 show the detailed evolution in terms of the degree of mixture, and the cover of the 112.3 ha of orchards unaffected by human activities during the study period. The percentage of chestnuts in the mixture tended, in most cases, to decrease naturally. Very few stands showed an increase in the proportion of chestnuts. In general, the percentage of the area where the degree of mixture decreased was lower in pure stands (degree of mixture > 80% in 1960) than in mixed stands (see Table 2). In addition, the cover in the abandoned chestnut orchards increased. In 1995, 60.3 ha (53.7%) were reclassified as belonging to a class with a higher cover than in 1960, while only 5 ha (4.5%) showed a decrease in

cover. In 1995, 93.2 ha (82.2%) of the studied orchards were attributed to the highest class of cover. Membership of this class increased 228% (from 40.7 to 93.2 ha, see Table 3). Table 4 shows the explanatory variables that form the best model, based on the probability that the degree of mixture of chestnuts in a given orchard stand has diminished since 1960. The model fits since the goodness-of-fit test for the likelihood-ratio is not significant ($p^{\text{obs}} = 0.1164$). Only the explanatory variables: «degree of mixture» (MX), «presence of other species in the stand» (OS) and «cover as a function of the presence of other species in the stand» (CO(OS)) proved to be significant according to the model. The maximum likelihood estimates of the model sources are reported in Table 5. The positive coefficient for the parameter estimates indicate that the corresponding level of the explanatory variable is associated with a greater probability that the response variable will assume the value 1 (which means decreasing chestnut presence). In the case of MX = 1 (pure chestnut

stands), the positive coefficient of the parameter estimate (1.0577) means therefore that pure chestnut stands are associated with a greater probability of a decrease in chestnut presence than is the case with MX = 2 (mixed chestnut stands). It is worth noting that the parameter estimate for the case where MX = 2 is not reported, being constrained to be -1.0577 since the parameter estimates for a given effect must sum to zero. Table 5 shows how the model can be interpreted ecologically and sylviculturally. In summary: there is a higher chance that the proportion of chestnuts in pure orchards (where the percentage of chestnuts > 80%) will have decreased by 1995, i.e. that there will be a change towards mixed orchards, than that the proportion in already mixed ones will have decreased (parameter estimate for MX = 1 is 1.0577). With respect to the speed of invasion by other species, pure chestnut orchards take longer than mixed ones to be colonised by other species (parameter estimate for OS = 1 is -1.8033). In addition, pure orchards are more rapidly

1960			1995									
			Chestnut forests						Other species		Open areas	
Chestnut forest	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Orchards	122.1	100.0	88.8	72.7	8.0	6.6	0.0	0.0	23.5	19.2	1.8	1.5

Table 1. General evolution of the chestnut orchards between 1960 and 1995

1960			1995									
			>80%		60-80%		40-60%		20-40%		<20%	
Degree of mixture	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
>80%	59.8	100.0	19.2	32.1	18.5	30.9	8.7	14.5	6.3	10.5	7.1	11.9
60 - 80%	32.1	100.0	0.7	2.2	7.4	23.1	8.3	25.9	6.8	21.2	8.9	27.7
40 - 60%	14.8	100.0	0.6	4.1	0.1	0.7	2.5	16.9	7	47.3	4.6	31.1
20 - 40%	5.6	100.0	0.0	0.0	0.0	0.0	0.1	1.8	2.6	46.4	2.9	51.8
total	112.3	100.0	20.5	18.3	26.0	23.2	19.6	17.5	22.7	20.2	23.5	20.9

Degree of mixture increased

Degree of mixture diminished

Table 2. Evolution of the degree of mixture in the undisturbed orchard stands between 1960 and 1995

1960			1995							
			>0.8		0.6-0.8		0.4-0.6		0.2-0.4	
Cover	ha	%	ha	%	ha	%	ha	%	ha	%
>0.8	40.7	100.0	37.6	92.4	3.1	7.6	0.0	0.0	0.0	0.0
0.6 – 0.8	44.4	100.0	35.1	79.1	8.5	19.1	0.5	1.1	0.3	0.7
0.4 – 0.6	19.7	100.0	14.4	73.1	3.9	19.8	0.3	1.5	1.1	5.6
0.2 – 0.4	7.5	100.0	6.1	81.3	0.1	1.3	0.7	9.3	0.6	8.0
<0.2	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-
total	112.3	100.0	93.2	83.0	15.6	13.9	1.5	1.3	2.0	1.8

Cover increased

Cover decreased

Table 3. Evolution of the cover of all tree species in the undisturbed orchard stands between 1960 and 1995

Explanatory variables	Classes	DF	Chi-square	P ^{obs}
Intercept		1	39.91	<0.0001
Initial mixture MX	1=pure (>80%) 2=mixed (20-80%)	1	19.25	<0.0001
Presence of other species OS	1=none 2=pioneer and other species 3=climax species	2	34.15	<0.0001
Cover as function of presence of other species CO(OS)	1=close (>0.8) 2=open(0.2-0.8)	3	17.32	0.006
Likelihood ratio		5	8.82	0.1164

Table 4. Maximum likelihood analysis of variance

Effect	Parameter	Estimate	Standard error	Chi-square	P ^{obs}
Intercept		0.9072	0.1436	39.91	<0.0001
MX	1	1.0577	0.2411	19.25	<0.0001
OS	1	-1.8033	0.3309	29.70	<0.0001
	2	1.0868	0.2242	23.50	<0.0001
CO(OS)	1 when OS=1	-0.5245	0.1384	14.37	0.0002
	1 when OS=2	0.0628	0.1531	0.17	0.6817
	1 when OS=3	0.5726	0.3435	2.78	0.0955

Table 5. Analysis of maximum likelihood estimates (MX = degree of mixture, OS = other species)

colonised by other species if they are widely spaced (parameter estimate for CO=2 and OS=1 is 0.5245). On the other hand, closed stands are more sensitive to the evolution toward mixed stands if they are initially mixed (parameter estimates for CO=1 and OS=2 or 3 are both positive). Where other species were initially present, the evolution toward mixed stands is slower if the species present have climax character (in our case *Fagus sylvatica* L., *Quercus petraea* (Mattuschka)

Liebl., *Q. robur* L. and in certain cases *Q. pubescens* Willd.; the parameter estimate for OS=3 is 0.7135 and is therefore lower than the parameter estimate for OS=2, which is 1.0868).

Detailed ecological analysis

The timing of the colonisation by other species shows a surprisingly homogeneous pattern among the

sites. As shown in Figure 2, most individuals higher than 2 m high in 1997 germinated between 1955 and 1987. The number of tree species tended to increase in abandoned chestnut orchards as a function of the nutrient content index of the site (Table 6). The Shannon and the Evenness index show the highest value on sites with medium nutrient-content conditions. Poor sites (Arosio I and II) were characterised by very low Shannon and Evenness indices. Chestnut orchard-trees showed a progressive and continuous decrease in radial growth after confronting the competitive pressure of invading

species in the early 60's (Figure 3a). The only site where chestnuts did not show a decreasing trend is Arosio. In the test plot there, the invading species is the light-demanding and less competitive birch (*Betula pendula* Roth), which is not able to compete at the crown level. This invading species has shown a decrease in growth rate since, at the latest, the late 80's (Figure 3b). Only the shade-tolerant beech (*Fagus sylvatica* L.), which started earlier, managed, in the test plot at Miglieglia, to increase its growth rate constantly.

	plots	Monte Ceneri	Aranno	Miglieglia	Arosio I	Arosio II
Site conditions	Elevation (m a.s.l.)	570	700	780	895	900
	Aspect (g)	0	375	125	180	180
	Slope (%)	26	20	40	53	53
	Nutrient content* / **	3.12	3.00	2.50	2.38	2.36
Diversity indexes**	cover	95	100	95	100	80
	Total species richness	25	23	18	13	14
	Shannon index (Hs)	1.93	2.31	2.08	1.27	1.51
	Hs variance	0.0010	0.0004	0.0014	0.0006	0.0004
	Hs evenness	0.59	0.77	0.71	0.49	0.56
Invading tree species***	<i>Acer pseudoplatanus</i>	□ ● ○	□ ● ○	□ ○	□ ○	
	<i>Alnus glutinosa</i>	□ ● ○				
	<i>Betula pendula</i>	□ ○	□ ○	□ ○	□ ●	□ ●
	<i>Castanea sativa</i>	□ ● ○	□ ● ○	□ ● ○	□ ● ○	□ ● ○
	<i>Fagus sylvatica</i>		□ ● ○	□ ● ○		
	<i>Frangula alnus</i>		□ ○		□ ○	
	<i>Fraxinus excelsior</i>	□ ● ○	□ ○	□ ○		
	<i>Pirus malus</i>	□ ○				
	<i>Prunus avium</i>	□ ●	□ ○		□ ○	
	<i>Quercus petraea</i>			□ ● ○		□ ○
	<i>Robinia pseudoacacia</i>			□ ○		
	<i>Sorbus aria</i>	□ ●	□ ○	□ ○	□ ○	
	<i>Sorbus aucuparia</i>		□ ● ○	□ ●	□ ●	
	<i>Tilia cordata</i>	□ ○	□ ● ○	□ ○		□ ●

*Average nutrient value according to Landolt (1977): 1 = very poor soil; 2 = poor soil; 3 = medium poor to medium rich soil; 4 = rich soil; 5 = over rich soil.

** Referred to the 10x10 m phytosociological relevé.

*** ● species present at the tree stadium; ○ □ species present in the regeneration (< 2 m).

Table 6. Site conditions, diversity indexes and presence of arboreal species in the five 20m x 20m dendroecological plots

Figure 2. Colonisation year of the invading tree species which reached a height of at least 2 m in 1995

Figure 3. Moving average on 9 years of the radial growth rate of the chestnut-trees (a) and of some invading species (b).

sp = social position (1 = dominant; 2 = codominant, 3 = dominated); n = number of considered trees

In general, chestnuts revealed a greater reduction in growth than the invading species. Between 1968

and 1972 the chestnut orchard-trees showed a mean annual ring growth rate of 2.08 mm per year (excluding

the site at Arosio), and the invading species one of 2.78 mm per year. The mean growth rate of the chestnut-trees dropped to 1.06 mm per year (50.1% of that in 1970) during the period 1990-1994, whereas the invading species showed a growth rate of 1.64 mm per year during the same period (excluding the very high performance beech in Miglieglia, see Figure 3b), which is a reduction of only 59.0% of that in 1970.

DISCUSSION

In our study we have been able to confirm the observations of previous authors that chestnut orchards tend to disperse in the absence of cultural inputs (Magini & Piussi, 1966; Mondino, 1991; Bernetti, 1995; Angelini, 1995; Maltoni *et al.*, 1997; Arnaud *et al.*, 1997). What is surprising is the breadth of the phenomenon and the rapidity of the processes. According to Münch (1995), 30-40 years is quite a short period in terms of the evolution of forest ecosystems. The fact that cultivated orchards are artificially kept at a very low stage in terms of biomass means that these ecosystems are in a disequilibrium that makes them particularly sensitive to invasion (Gouyon, 1990). After abandonment, orchards are rapidly colonised by invading species, making the effects of this dynamic observable at the crown level within a few decades. The synchronism of the start of the colonisation process strengthens the hypothesis that, in southern Switzerland, there is a direct relationship between the invasion of the chestnut belt by other species and the general abandonment of landscape management. Assuming that the main period of abandonment of chestnut orchards was in the late 40's (in southern Switzerland chestnut blight was found for the first time in 1948), colonisation of the stands by invading species started with a time lag of 5-10 years. This follows the pattern Angelini (1995) found in Valtellina (Italy).

The invading tree species initially exploit the gaps in the orchard structure and take advantage of the late foliation of the chestnut trees. This is the case especially for pioneer, light-demanding species (e.g., *Betula pendula*) that show aggregated spatial regeneration patterns (Maltoni *et al.*, 1997). Our results confirm the scanty competition potential of the chestnut at the regeneration stage. Bacilieri *et al.*

(1993) suggest that the susceptibility of the seedlings to water stress, their unfavourable shoot / root ratio, and the staggered and longer period of germination of chestnuts are possible reasons for the chestnut's poor competitiveness.

The statistical analysis of the evolution on the meso-scale showed that the degree of mixture, the cover and the presence and the type (pioneer or climax) of the invading species were the major factors influencing the ongoing processes. The introduction of the explanatory variable "dominant species in neighbouring stands" did not improve the model. This could be a consequence of the stronger effect of the species already present in the stands at the time of the reference photographs (1959/60). The role played by the vicinity of mother trees with respect to the composition of invading species was emphasised by Guidi *et al.* (1994), but it was not possible to analyse this in our study with the data available.

As a rule, species richness and composition depend strongly on the nutritional conditions of the site, as already discussed by other authors (Mondino, 1991; Guidi *et al.*, 1994; Arnaud *et al.*, 1997). In terms of diversity indices, however, medium sites show high values and a more balanced species distribution (Evenness index), as already found by Stanga (1997) in coppice stands. In fact, extremely good or extremely poor sites tend to be dominated by site-adapted species. The Shannon indices obtained in our study are in good agreement with the values reported in Maltoni *et al.* (1997) for similar conditions in northern Italy. On poor sites the dominant invading species is mainly birch (*Betula pendula*). Due to its extreme sensitivity to shade, the birch does not seem to compete with the chestnut at the crown level. In nutrient-rich sites, the invading deciduous trees show very strong competition fitness and tend to over-grow the old chestnut orchard-trees. The results of the radial growth analysis suggest a rapid shift toward a phase of intense competition for limited resources, in which the shade-tolerant species (beech and lime) are favoured. Chestnut orchard-trees seem to be very poor competitors when under such pressure. This is probably due to the advanced age of the trees and to their having been selected as grafted trees for crop production, with the emphasis on producing flower buds in the crown.

While in the U.S.A. the pandemic character of the chestnut blight was so strong as to be easily

recognisable in the evolution of the species composition and in the growth rates of the trees (Ruffner & Abrams, 1998), in southern Switzerland it does not appear to have had any conclusive and measurable influence on the evolution of abandoned chestnut orchards. We assume, however, that the repeated attacks of chestnut blight must have been an additional stress on the chestnuts in competing for available space at the crown level.

In general, an increase in stand darkness (increase in the cover) and a decrease in open areas were observed in the chestnut belt. Thus, the processes which develop after the abandonment of the chestnut stands lead to a homogenisation of the forest structures with a complete loss of open stands, even when the processes involved are completely natural and even when they correlate with an increase in the number of tree species. In the short term this causes negative effects on such forest functions as landscape architecture and ecological value (Ewald 1978, Peterken & Jones, 1989; Schiess & Schiess-Bühler 1997). In addition, the accumulation of biomass in abandoned chestnut stands increases the risk of forest fires, as postulated by Arnaud *et al.* (1997) and Maltoni *et al.* (1997) and as already demonstrated for southern Switzerland by Conedera & Tinner (2000).

In conclusion, our results confirm that, without any anthropogenic management, chestnut orchards will be lost. The size and rapidity of the described transformations give political weight to the problem. This is all the more so as the current evolution of the abandoned chestnut stands can be considered as just one of the typical consequences of a gradual reduction in landscape management. Others include the spread of the forest area, the homogenisation of landscape patterns, and an increased risk of natural hazards. Several silvicultural options are conceivable. The orchards could be recovered as multifunctional forest stands (multifunctional with respect to landscape, ecology, tourism, nut production, pasture and other agricultural products, fire breaks, *etc.*), they could be treated silviculturally so as to develop as mixed stands for timber production, or they could be left to evolve naturally without direct intervention by humans. Which option to put into practice where is one of the main questions that will have to be answered very soon to

ensure a sustainable approach to landscape management in southern Switzerland.

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