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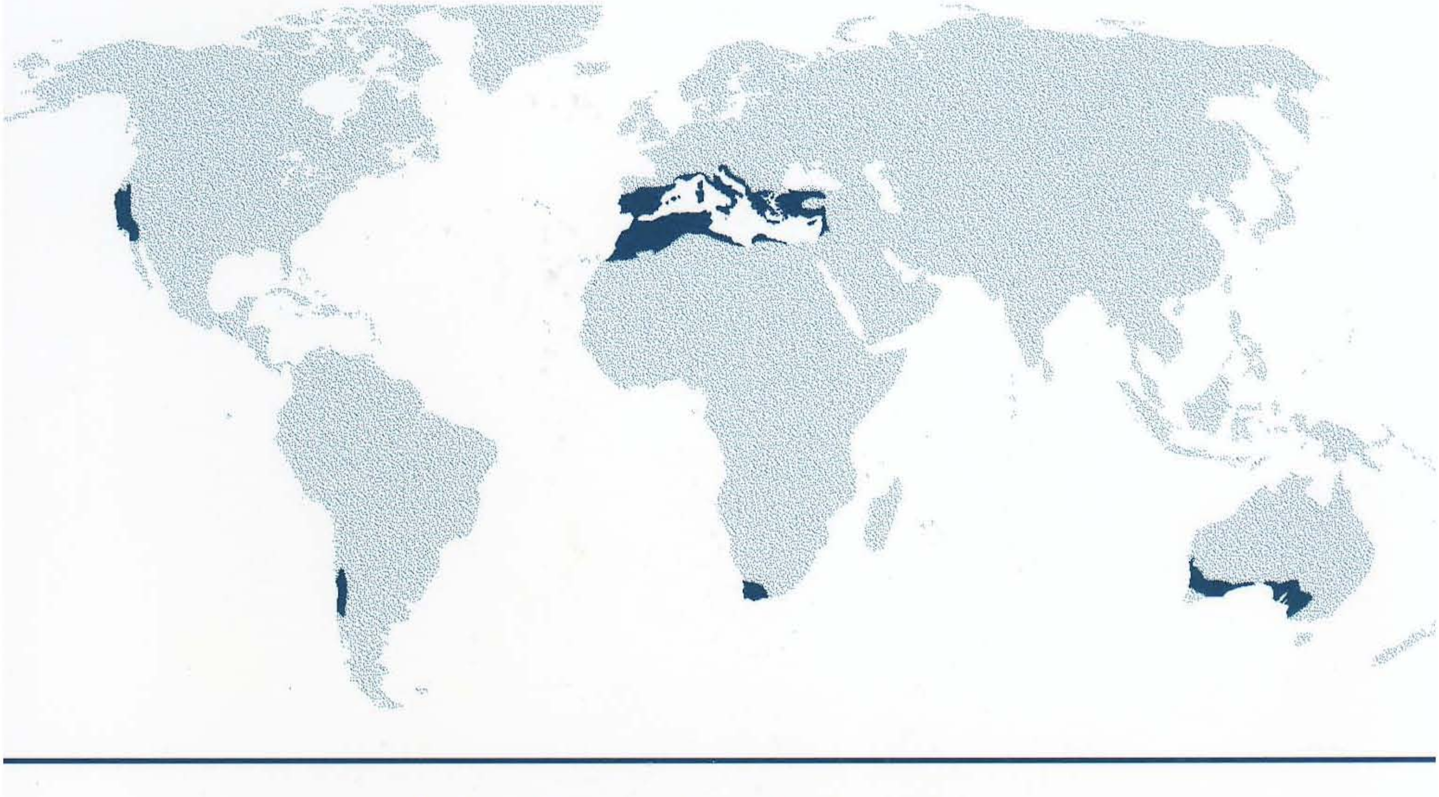

The sustainability of chestnut forest in the Mediterranean region

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ecologia mediterranea
Faculté des Sciences et Techniques de Saint Jérôme
Institut Méditerranéen d'Ecologie et de Paléoécologie, case 461
F - 13397 MARSEILLE Cedex 20 FRANCE

Tél. : + 33 4 91 28 85 35 - Fax : + 33 4 91 28 80 51
E-mail : ecologia.mediterranea@botmed.u-3mrs.fr
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THE SUSTAINABILITY OF CHESTNUT FOREST IN THE MEDITERRANEAN REGION

International Symposium organised by the Università degli Studi di Catania (Dipartimento Fisiche e Chimiche per l'Ingegneria)

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Edited by S. LEONARDI, M. RAPP & F. ROMANE

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AN INTRODUCTORY SUMMARY

Sustainability of chestnut forest ecosystems: Is it possible?

Emilio AMORINI[1], Gregor CHATZIPHILIPPIDIS[2], Orazio CIANCIO[3], Francesco DI CASTRI[4], Fulvio GIUDICI[5], Salavatore LEONARDI[6], Maria Chiara MANETTI[1], Suzanna NOCENTINI[3], Mario PIVIDORI[7], Maurice RAPP[4], François ROMANE[4*], Eric SEVRIN[8] & Andreas ZINGG[9]

[1]Istituto Sperimentale per la Selvicoltura, Viale S. Margherita 80, I-52100 Arezzo, Italy
[2]Forest Research Institute, GR-57006 Vassilika-Thessaloniki, Greece
[3]Istituto di Asssestamento e Tecnologia Forestale, Università di Firenze, Via San Bonaventura 13, I-50145 Firenze, Italy
[4]CNRS-CEFE (UPR 9056), 1919 route de Mende, F-34293 Montpellier Cedex 5, France (Phone: +33 4 67613277, romane@cefe.cnrs-mop.fr)
[5]DMFCI, Università di Catania, V.le Andrea Doria 6, I-95125 Catania, Italy
[6]Swiss Federal Research Institute WSL, Sottostazione Sud delle Alpi, Via Belsoggiorno 22, cp 57, CH-6504 Bellinzona, Switzerland
[7]Dip. Agronomia, Selvicoltura e Gestione del Territorio, Univ. Torino, Via Leonardo da Vinci 44, I-10095 Grugliasco - Torino, Italy
[8]Institut pour le Développement Forestier, 13 avenue des Droits de l'Homme, BP 9013, F-45921 Orléans, France
[9]Andreas Zingg, Swiss Federal Research Institute WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland
*Corresponding author

FOREWORD

(S. Leonardi, M. Rapp & F. Romane)

Few years ago when we planned to launch an international symposium in Catania (Sicily, Italy) during September 1998 about the *"Sustainability of chestnut forest ecosystems"* in co-operation with the Working group 4 ("silviculture" led by F. Giudici and F. Romane) of the COST Action G 4 (*"Multidisciplinary chestnut research"*; responsible for E. Wilhelm). We did not realised how the task was perilous. But we already were warned about the difficulty of this challenge through two contracts with the European Union including about 15 teams around the Mediterranean Basin dealing with this theme. Thus, the objective of this symposium was to "synthesise" our results from the "sustainability" point of view. This symposium clearly showed we did not reached our target, even each presentation and its discussion were interesting and fruitful by itself. To illustrate, that we only present shortly in this introduction-like part, the totally opposed opinions of the key-note speakers: (i) Ciancio & Nocentini discussed the concept of sustainable forest management but (ii) Conversely, and perhaps provocatively, di Castri "demonstrated" that the concept of sustainable management could not exist. We also added, to be more optimistic, (iii) some proposals and comments of a group of scientists and managers that try to introduce in concrete terms this concept in the chestnut ecosystems management (Giudici, Amorini, Manetti, Chatziphilippidis, Pividori, Sevrin & Zingg). These three parts, also give to us the opportunity, particularly in the third part, to propose some general information about the chestnut in Europe as well as some definitions. These remarks press us to adopt the point of view of Shearman (1990) which attempt "to show that is not sustainability that requires definition or clarification, but rather its implications for any given context which it is applied" (Romane & Houssard, 1995).

I. BIODIVERSITY AND SUSTAINABLE MANAGEMENT IN FOREST SYSTEMS

(O. Ciancio & S. Nocentini)

Sustainable management of natural resources is the challenge for the third millennium. It is no longer possible to ignore degradation caused by uncontrolled use that does not respect natural dynamics and equilibria. The forests are an indispensable asset for guaranteeing the continuation of life on our planet. Concern for the conservation of natural resources has become part of the international agenda. The Helsinki resolutions in 1993 on climatic changes, conservation of biodiversity, sustainable forest management and desertification comprise an ineluctable point of reference.

Some recent facts and events have brought what were long considered certainties into doubt. They concern not so much the possibility of the forest deterioration if they are not managed in a sustainable manner, as the acknowledgement that, as a result of technological developments and their growing impact on the environment, human actions are becoming increasingly powerful and destructive. This new awareness has led to the birth and growth of a common desire to pay more attention to forest management, that is the technical and economic management of the renewable forest resource.

Forest management has evolved through time, shifting from a mainly production-oriented concept that evaluated cultivation systems and techniques on the basis of wood production to the current concept where management is associated with the adjective "sustainable" that considers not only wood production but also ecological and social variables.

Systemic silviculture

Traditional forest management and silviculture consider the forest as a mere group of trees with economic significance. In reality, the forest is an autopoietic, complex adaptive and composite system that learns and evolves. It consists of adaptive agents that function like complex systems with each one adjusting to the behaviour of the others.

The concept of "system" is relatively recent in forestry. It is an innovative and revolutionary concept in some ways, and its consequences have not been entirely grasped and evaluated. Consideration of this concept has led to both theoretical and practical changes concerning the contents, goals and limits of silviculture (Ciancio, 1998).

Sustainable forest management must be based on systemic silviculture, that is “extensive silviculture” in harmony with nature. It is a silvilculture that is configurable with the actions of man in his role as an essential component of the forest system. Systemic, non-linear, extensive silviculture is based on the principle of autopoiesis. It works on behalf of the forest, that is, according to a cultivation algorithm with the aim of preserving, conserving, enhancing and promoting the system's biological complexity in a co-evolutionary continuum which *de facto* excludes the finalism typical of the linear processes that lead to the normalisation of the forest (Ciancio *et al.*, 1994a; 1994b).

Systemic silviculture favours and corroborates the system's functional efficiency. It is based on continuous, natural regeneration and low-environmental impact actions, that is, actions aimed at conserving and augmenting the system's biological diversity, promoting lack of homogeneity, and structural and composite diversification in order to increase the capacity for self-organisation and integration of all its biotic and abiotic structures. This action, furthermore, will help overcome the conflict between two extreme viewpoints: on the one hand are those who consider the forest an unavailable asset, on the other those who see the forest as a totally available asset to be exploited according to market laws.

The classic forestry system

The newly acquired knowledge in the fields of ecology, silviculture, forest management and forest economy now permit an objective comparison between the classic forestry system and what we, on other occasions, have defined as the autopoietic forestry system, that is, a system capable of self-organisation and of combining functional efficiency with a high level of biological diversity (Ciancio, 1988). The comparison reveals the salient aspects of the two systems which, for convenience, are identified as (SF_1) and (SF_2) in Table 1. These aspects concern structural features of the two systems and the repercussions in regard to management, ecological evaluation and the primary objective to pursue (Ciancio, 1998).

Classic Forestry System **(SF_1)**	**Autopoietic Forestry System** **(SF_2)**
Linear system, lacking in alternatives	Non-linear system, rich in alternatives
Uniformity and homogeneity Of the system	Lack of uniformity and homogeneity Of the system
Reduction of diversity and loss of genetic information	Diversity is a source of genetic information, it has culture and useful value
MANAGEMENT	
Cultivation uniformity demands centralised control in relation to profit and market	Cultivation diversity requires decentralised control and properly exploits "local knowledge"
Rigidly structured forest in age or diameter classes	Unstructured forest capable of "self- organisation"
Product uniformity: primarily wood (PR_1)	Diversified products: including wood (PR_2)
ECOLOGICAL EVALUATION	
Stable and sustainable system with input of energy, labour and capital. Productivity, yield and economic value are independent of the ecosystem	Stable, sustainable and autonomously renewable system. Productivity, yield and economic value are dependent on the ecosystem.
PRIMARY OBJECTIVE(S)	
To maximise profits through Commercial use of the forest	To increase complexity and conserve biodiversity

Table 1. Broad comparison of the Classic Forestry System (SF1) and the Autopoietic Forestry System (SF2). [(SF2) is preferable to (SF1) because the system is ecologically balanced and sustainable. PR1 is greater than PR2, but the scientific control rarely takes the entire range of inputs and outputs into consideration: it does not make a true ecological evaluation and therefore the comparison between PR2 and PR1 is distorted.]

The classic forestry system (SF_1) is a "linear system", that is a system based on the principle that the estimated results, in terms of wood production is linear. This means that, within certain limits, the yield increases proportionately to the energy used. Furthermore, it follows specific reference standards and for this reason, is lacking in alternatives.

A linear system involves a silvicultural orientation that tends towards an uniform and homogeneous forest, and hence to a reduction in biodiversity. A forest managed according to these criteria is almost monospecific or it consists of a main species and one, or at most two, secondary species. Its structure is rigidly even-aged or uneven-aged and it is arranged chronologically or according to diameter.

Forest planning is anchored to the theory of economic development which in turn is firmly based on exponential growth models. Management plans are evaluated on the basis of their ability to sustain a high rate of wood production. The rotations are relatively short with respect to the longevity of the species. This type of management presupposes centralised control and a generic crop uniformity.

Crop uniformity simplifies control, even if, for the obligated subjects it is more costly to abide by the reference standards. To realise this phenomenon, it is sufficient to review the management plans for beech forests for example. Wherever, and in whichever station they may be, shelterwood cutting is almost always the rule. Therefore, crop uniformity is matched by product uniformity (PR_1).

The predominant, if not exclusive interest in wood production has led to a unidimensional forestry paradigm that systematically tends to maximise soil rent. Over the short and medium term, the classic forestry system (SF_1) is a stable and sustainable system.

In the classic forestry system (SF_1) productivity, yield and economic value are independent of the ecosystem while sustainability is dependent upon the input of energy work and capital. This means that production is linked to a high level of external input. And this, since it markedly affects the ecosystem's equilibrium, leads to high vulnerability and ecological instability, significant erosion of biodiversity, lack of alternatives and few options.

The autopoietic forestry system

The autopoietic forestry system (SF_2) is a "non-linear system". It is rich in biodiversity and, since it does not follow reference standards, it varies within small spaces and adapts to different situations. A system of this type involves a silvicultural orientation that alms at conserving or increasing biodiversity and therefore less uniformity, less homogeneity, in other words, the structural complexity of the forest.

Biodiversity has cultural value and use value because it makes it possible to properly exploit "local knowledge", the property of communities that live with the forest, and to obtain products that differ from valley to valley. Wood is an important product, but it is not the sole aim of management. As Perry & Amaranthus (1997) affirm, "The protection of biodiversity is the best insurance foresters and society can buy to protect the long-term integrity of the world's forests."

Forest planning is anchored to systemic management. The silvicultural unit is the stand. Actions are based on the needs of the stand and are undertaken cautiously, continuously and in a capillary manner. Their objective is active participation in the ecosystem's evolutionary processes. Verification of feedback and reactions to the interventions is an essential aspect of management. During planning, operational decisions do not take common parameters such as rotation or diameter class into consideration. A systemic management means decentralised control and crop diversification.

Crop diversification renders control more complicated, and for this reason it is very decentralised. Foresters, however, have the non-negligible advantage of not having to abide by reference standards. The management plans follow highly flexible criteria. The study of the forest is an essential prerequisite for the selection and prescription of silvicultural interventions on a case by case basis. Therefore, crop diversification is matched by production diversification (PR_2).

The multiple, innate interests in the autopoietic forestry system (SF_2) have led to the development of a multidimensional paradigm. (SF_2) is a system capable of satisfying society's needs and properly exploiting the wealth of experience of the local communities. Management aims at pursuing the functional efficiency of the ecosystem and orienting "silvosystems" towards environmental equilibrium.

Systemic management is highly sustainable because it enhances the potential for distributing the forest's services and products. Productivity, yield and economic value are **dependent** on the ecosystem. Sustainability is **independent** of the input of energy, labour and capital. This means that production is tied to a low level of external input. And, as this does not significantly impact the ecosystem's equilibrium, it leads to high ecological stability, the ability to conserve or augment biodiversity, a wealth of alternatives and many options.

Conclusion

In conclusion, it seems evident that if we consider the entire range of inputs and outputs, the autopoietic forestry system (SF_2) is preferable to the classic forestry system (SF_2) because, in addition to being sustainable and independently renewable, it is ecologically and economically balanced.

A forestry system of this type has benefits that extend far beyond the economic level. It enriches the soil with waste products that feed a myriad of micro-organisms, it provides protection against the wind and rain attenuating erosion, it holds the soil with its roots on slopes reducing the amounts of silt in waterways and along the coasts. It configures itself as a reservoir where carbon is collected, helping to keep atmospheric carbon dioxide levels in balance and to combat the greenhouse effect. It hosts and nourishes animals. Since it is a renewable resource it gives rise to processes of utilisation and production.

In practice it is a type of management based, on the one hand on care of the forest according to the needs of all its components beyond any possible structural prefiguration, and on the other on crop recovery. In addition, this type of management exploits the forester's professional competence and skills to the utmost. Some could raise the objection that management based on systemic silviculture is not sustainable from the financial standpoint. This, in fact, is the argument most frequently heard against the method. At first glance it seems strong, but it is not and there are at least two reasons.

First of all: silviculture, in any case is an activity that involves high costs and low profits. Secondly: the forest is always subject to various types of restrictions. Therefore, we must remove the financial and social obstacles. It is not a matter of silviculture or forest management, but rather of forestry policy. As Hilborn *et al.* (1995) have stated, the future success of sustainable management does not depend so much on better science as it does on better institutional organisation that can control the users and create incentives for them to act in a wiser manner.

Some will ask whether it is possible to reconcile the constantly growing demand for wood with sustainable management and the conservation of biodiversity. This issue can be dealt with in several ways, for example, by reducing the consumption of wood and wood derivatives - which is sometimes so high that it is heedless waste - by recycling wood and paper, by increasing the efficiency and optimising processes in the woodworking and construction industries. And also perhaps mainly, by giving a strong impetus to tree cultivation, that is with the creation of "agrosystems" destined for the production of high quality or large quantities of wood. These "tree farms" attenuate the impact on the silvosystems.

This does not mean to say that the forest must be left to itself. On the contrary, the forest must be cultivated with discreet interventions and actions aimed at maintaining the system's equilibrium while producing wood and at the same time preventing the extinction, disappearance or temporary withdrawal of some plant and animal species which, along with the quality of the air, water and soil, are resources that are as important, if not more so than wood.

II. THE ECOSYSTEM IN A SCIENTIFIC, ECONOMIC AND SOCIAL CONTEXT. IS SUSTAINABILITY POSSIBLE?

(F. di Castri)

Hundred definitions of sustainable development have been proposed that have quite different connotations and the excessive use of this term induced a loose of its meaning. Nevertheless this concept more often evokes an alternative, ideological model of development that is opposite and inherently contradictory to present practices (di Castri, 1998).

Some remarks could help us to delimit these concepts of ecosystems and sustainable development:

1 – The ecosystem is defined by the whole of the populations and communities of plants, animals and microorganisms, and of their non-living environment, inhabiting a given space and at a given time, and interacting as a single functional unit for the exchanges of matter, energy and information. Emphasis on elementary ecosystem units has shifted over time from atoms and calories, to genes and bits. the ecosystem is not a kind of fixed supraorganism, but a level of integration whose limits vary in space and time.

2 – The present scientific context of the ecosystem is determined by conditions of openness, permeable and fluctuating boundaries, invasive species, non-linearity, non-equilibrium, chaotic behaviour, complexity caused by multiple interactions and interfaces, hierarchical interactions between different levels of integration from the gene to the ecosystem, nested structures, fuzzy behaviour, emergence of surprises and inherent unpredictability.

3 – The present economic context is the one of globalisation of exchanges, free market a blossoming international trade, including international tourism, and the magnified foreign private direct investment world-wide. The rules of the game of economic development are radically changed, from protectionism, public investment, standardisation, centralisation and concentration on a given space, to free exchange, private investment, diversification, decentralisation and diffusion over space of productive activities. The availability of natural renewable resources, as produced by the functioning of local ecosystems, is no more the main factor of economic development. This is rather driven by the skill of human resources, their capacity of multiplying resources and, above all, their ability to adapt timely to change. The economic importance of ecosystems shifts from the production of resources any goods to the delivery and the maintenance of ecological services.

4 – The present social context is determined by the global information society, with fragile frontiers, open to flows of information, capital, people and species, with dominance of services over agricultural and

industrial activities jobs. Connectivity among societal members is provided mainly by a cultural territory, where interactions, links and networks are maintained even at the distance by electronic means and devices, now available at low cost almost everywhere. Accessibility and use of information become the main societal factor. The scales of space and time of any given ecosystem are not fixed, but are defined by societal or research choices. Most ecosystems include therefore, and according to the choices made, a variable mosaic of heterogeneous situations.

5 – With the emergence of the globalisation of economy and of the information society, the disturbance regimes acting upon ecosystems and landscapes are strongly modified. The transboundary transfer in real time of capital information and decisions across the world, over ecological, bio-geographical, genetic, administrative and political frontiers, changes scales of space and time of the impact, and the adaptative response of species and ecosystems to new disturbance regimes. Ecosystems, landscapes, territories and human-use systems become open and often virtual. Their non-linear and non-equilibrium behaviour is accentuated; unpredictability is the inherent feature. Mobility in space and time becomes the main factor of disturbance and of successive regulation, as referred to species, ecosystem boundaries, resources, peoples, jobs, capital and knowledge.

6 – These new rules, as applied to economic development and ecosystem health, are at the origin of both bright emerging opportunities and gloomy emerging risks. The winner-loser syndrome is the peculiar feature as regards the reaction of ecosystems, species, economies, societies, and countries, depending on their adaptability to change. New approaches and tools for resources management are intended to maximise opportunities and minimising risks. The four pillars to seize and expand present opportunities are openness, diversification, innovation and partnership.

7 - Environmental risks may be aggravated because of widening gaps, uncontrolled mobility, diruption of scales of time and space no more compatible with the evolutionary and ecological pace, human had-off, failure of a precautionary approach and, above all, slow reactiveness and lack of societal and institutional adaptation to change, with special emphasis on university and research institutions.

According to these comments the concept of sustainable development is not and cannot be applied, because of intrinsic contradictions, and does not represent the right response to long-term trends and inherent predictability. Application is even more hazardous under present conditions of a global economy and of an open information society. This concept is rather opportunistically or ideologically taken over, because of completely different motivations, political leaders, environmentalists, businessmen and entrepreneurs. The main weakness and inconsistencies of sustainable development lie on the following six considerations: (i) there is no equilibrium between human populations, resources and environment. Both human populations and resources migrate. The concept of carrying capacity does not apply to present circumstances; (ii) Natural resources are not fixed nor predetermined. (iii) It is not possible to freeze species, ecosystems and resources, to be transmitted to future generations, at any given state of their evolution; (iiii) It is not possible to interpret needs, aspirations and value systems of future generations by simply projecting and extrapolating present trends; (v) Sustainable development is not measurable and is not accountable and (vi) The two terms, development and sustainable, are incompatible from a methodological viewpoint, when considering system dynamics, linearity, openness, stability and adaptation to change.

If we can not apply the concept of sustainable development, conversely we can use the sustainability but it is not supported by maintenance and preservation of present conditions in closed systems. It depends rather on continuous adaptation to change in open environments, through diversification and innovation.

III. SUSTAINABLE MANAGEMENT OF SWEET CHESTNUT (*CASTANEA SATIVA* MILL.) COPPICE FORESTS BY MEANS OF THE PRODUCTION OF QUALITY TIMBER

(F. Giudici, E. Amorini, M. C. Manetti, G. Chatziphilippidis, M. Pividori, E. Sevrin, A. Zingg)

Chestnut forests in Europe

Chestnut (*Castanea sativa* Mill.) is widely present in Mediterranean and central Europe. The present state of the resource is not well known. A distribution map of European chestnut with the relevant statistical information was produced in the fifties (Morandini, 1958, 1 unpuplished map) but it does not consider all European countries.

Nowadays the area of chestnut forests in Europe is estimated to be about 1 800 000 ha (Table 2). We also know that chestnut forests are spreading over the south-eastern part of the European continent (*e.g.*, in Slovakia, Slovenia, Hungary, Bulgaria, Former Yugoslavian Republic of Macedonia, Albania, Turkey). We therefore estimate the presence of sweet chestnut in about 15 countries and that the total area covered by chestnut amounts to approximately 2.0 million ha. In chestnut forests the private ownership is generally prevalent (70-80%) even if there is also important public forest ownership.

Significance of chestnut in the past

In Europe chestnut has been present for centuries (Pitte, 1986), especially in the hilly and mountainous areas. The ownership structures, the local socio-economic organisations and the need for autarkic and economic self-sufficient systems have considerably influenced the cultivation methods.

Up to the middle of the XXth century, the main cultivation method was the orchard for fruit production. In the context of a poor and marginal economy, chestnut fruit was the staple food and an important economic income for rural communities. The decline of the rural areas, the onset of diseases (especially the chestnut blight caused by *Cryphonectria parasitica* and the ink disease due to *Phytophthora* spp.) and the demand for timber for tannin production led to the abandonment and the conversion to the coppice management of many chestnut orchards. This practice created new and wide areas of coppice stands, especially in Italy and France. Today, chestnut fruit production is dramatically reduced and is rather oriented toward high quality products in limited areas.

Origin and importance of chestnut coppices

Coppices have been a well-known management system for centuries, the technique of cultivation ("*caeduo*" = coppicing) having been already described by Roman authors such as Plinius and Columella (Krebs, 1999). The easy application due to the high resprouting ability from stools, the lasting vitality of the root system and the high productivity (8-16 m^3 ha^{-1} $year^{-1}$ depending on site conditions) facilitated the implementation of coppice stands in many countries.

The traditional management system applied to chestnut coppices was based on short rotations (12-20 years) according to the required assortments. The main products from coppices were small and medium poles used in agriculture (fences, vineyard stakes), for transmission lines, in constructions, as fuel and for handicrafts. Very short rotations (2-6 years) were applied locally for special assortments (flower-pickets, baskets, trellis posts). This large variety of assortments preserved the coppice system economically active in large areas until the '50s - '60

During the '60s and '70s, the traditional products from chestnut coppices progressively lost their economic importance due to the labour-intensity of this kind of mass production and because of the competition from synthetic materials. Cement or impregnated wood products, considered innovative and more durable, replaced chestnut poles thus causing a production excess of these assortments and making the coppice system unsuitable to the new market demand of large sized stems. The rotation period was simply extended in order to get assortments of larger dimensions, but neither an active silviculture nor well-defined long or medium-term goals were foreseen. Moreover, the extension of the rotation was often caused by deferral or the discontinuation of treatments and was not a real silvicultural choice. The presence of many defects (ring shake) in the wood makes the use of timber for saw wood or furniture difficult. As a consequence, the local economic organisations in the rural areas were not motivated any longer to invest and to care for their chestnut forests. At present, in several European regions, many chestnut coppices are therefore aged, abandoned or improperly managed resulting in a heavy and progressive reduction of their ecological, environmental and economical value.

Moreover, in the recent past, the coppice management system was neglected because of its bad reputation: for the owners the coppice forest

Country	Coppice-timber	Orchard (fruit)	Total chestnut forests in ha	Source
France		133 759	996 834	FNI 1997
Italy	375 300	209 113	584 413	FNI 1993
Spain	92 538	40 119	132 656	FNI 1980
Portugal	6 000*	26 200*	32 100	FNI 1989
United Kingdom	19 091	9 871	28 962	FNI 1982
Switzerland	22 100	4 100	26 200	FNI 1985
Greece			17 000	Bourgeois 1992
Austria			5 000*	Regner (pers. com.)
Germany	2 000*	-	2 000	Bourgeois 1992
Netherlands	500*	-	500	Oosterbaan (pers. com.)

FNI = Forest National Inventory; *: estimation

Table 2. Chestnut forest in Europe (in ha)

symbolised the hard struggle for survival (chestnut as the "poor people's tree"), nowadays many specialists consider coppice as a brutal management system to abhor. This negative prejudice may be explained by the past overexploitation of widespread chestnut forests that were very often associated with extended and repeated clear cuts, that often provoked the exhaustion of forest soils.

Revival of chestnut coppices and chestnut timber?

Chestnut is however one of the most versatile woods of the European continent! It is highly appreciated for its technological efficiency and aesthetic qualities. The demand for sawn timber of high value assortments in sectors like joinery, furniture, flooring and internal cladding, carpentry, will also be important in the future. Moreover, for numerous outdoor facilities (*e.g.*, in the agricultural sector and in environmental engineering), chestnut timber has advantages due to its high natural durability and the decorative aspects, especially in comparison with impregnated timber or cement/iron products, the production of which provokes a more severe environmental impact.

New silvicultural methods, alternative to the traditional management and compatible with the principles of the sustainable development, could restore a relevant part of chestnut coppices for quality timber production. The improvement of the quality and especially the reduction of ring shake risk, are the decisive steps in order to encourage owners and authorities to invest in the chestnut coppices.

The ability of the stools to produce an abundance of shoots facilitates the regeneration of chestnut coppice. This important advantage, the vitality and the responsiveness of the selected trees in the thinned areas are decisive basic requisites to reintroduce the chestnut coppices compatible with the exigencies of the modern society.

Research activities in the last 20 years

The problem of putting a value to chestnut coppices was emphasised for the first time at the end of the seventies, due to the high presence of aged coppice stands (Gambi & Amorini, 1978; Cabannes & Rolland, 1982; Bacchetta, 1984). From a technical point of view, the first alternative silvicultural concepts were proposed at the end of the eighties (Bourgeois, 1987). Some years later such models were better characterised by the same author in her important synthesis publication "*Le châtaignier : un arbre, un bois*" (Bourgeois, 1992). In the following years, the basic principles (extension of rotations up to 30 or 50 years and application of early and frequent thinning operations of moderate-heavy intensity) have progressively been better defined (Amorini *et al.* 1997a).

In this context some national and European research projects were launched in order to analyse specific themes such as the evaluation of the technological characteristics of chestnut timber (project FOREST 1990) and the estimation of stand efficiency and functionality in relation to the silvicultural system (project CAST in 1994). The first results are promising and seem to prove the bio-ecological validity of such models, even if they are carried out in well defined and specific test conditions.

Real experimental applications or case studies were carried out in order to verify the applicability of these alternative management systems aimed to improve the quality of timber production, the stand stability and the environmental benefits (Aumasson & Guerrin, 1995; Cutini & Fabbio, 1997; Romane & Grossmann, 1997).

The state of the art

The main results of the recent research activities dedicated to improve the management and to boost the value of the products from chestnut coppices can be summarised as follows:

Silviculture

In absence of silvicultural management, a rapid and positive structural evolution takes place in aged coppices. It is possible to improve timber production by a silvicultural management which is able to increase the management choices and, at the same time, is capable of ensuring the functionality of the stands and their stability.

Some silvicultural models have already been defined and experimental trials have been established to study the effect of thinning on crown development and growth. A regular and sustained growth trend on released stems seems to be a promising silvicultural tool to decrease the risk of ring shake (Chanson *et al.* 1990; Amorini *et al.*, 1996b; Amorini *et al.*, 1997a; Amorini *et al.*, 1997b; Amorini *et al.* 1997c; Fonti *et al.*, 1997; Amorini *et al.* 1998a; Macchioni & Pividori, 1996).

Studies concerning methods to promote the natural regeneration of chestnut coppice forests were started recently. The seeding and the development in the first years is often successful but the competition of the stools still creates problems in maintaining the natural regeneration during the following years (Sevrin, 1994, Pelcé, 1994).

Technology

Chestnut timber can be processed with modern technological methods (cutting, gluing, drying) which offer possibilities for modern manufacturing or industrial products (thick sliced veneer, laminated veneer boards, glulam, solid wood panels, finger jointed timber, *etc.*) It is also suitable for valuable furniture, carpentry products (Everard & Christie, 1995; Macchioni, 1995; Negri & Uzielli, 1997).

One of the main problems is the risk of ring shake whose presence heavily devalues the timber. The risk increases with the higher age of the trees (Chanson, 1990): in determining the rotation time of chestnut coppices this important aspect must be considered. Preliminary studies with ultrasonic measurements showed new means of using an non damaging diagnostic method that could help analyse and classify the chestnut stems qualitatively (Giudici *et al.*, 1997).

Ecology

The effects of different thinning intensities on the above ground biomass and crown characteristics were tested on young and aged coppices on good sites. The first results show that in both situations the canopy cover is re-established a few years after the thinning (Gambi & Amorini, 1978; Cutini, 1997; Cutini & Fabbio, 1997). Moreover, in aged coppice stands, the extension of rotation time allowed the branch biomass to increase progressively, contributing to the improvement of soil fertility, which had been reduced in the past by short rotations (Ranger *et al.*, 1990; Ranger & Nys, 1996). Furthermore, studies carried out in Britain show that in managed chestnut coppices the opening of tree cover at regular intervals influences the species richness of ground vegetation positively (Ford & Newbould, 1977; Barkham, 1992) and breeding birds increased (Fuller & Moreton, 1987).

Landscape ecology

The dynamics of chestnut forests is very fast. In the absence of cultivation and especially in opened structures, chestnut forests tend to evolve naturally towards mixed stands due to the invasion of pre-existing broadleaved species (Mondino, 1991, Conedera *et al.*, 1998). This trend is typical in areas where chestnut was introduced outside of its ecological optimum, whilst in good site conditions, the natural evolution often caused an homogenisation of the stand structures, with negative effects on the environmental functions (landscape architecture and ecological value).

Genetics

The silvicultural system does not significantly influence the genetic constitution and diversity of the stands (Amorini *et al.*, 1998b). The observation of a "stool effect" in the ring shake incidence suggests that the genetics could represent one of the predisposing factors in explaining the presence of this timber defect (Macchioni & Pividori, 1996; Fonti *et al.*, 1997).

Pathology

The presence and impact of diseases are strictly related to the individual vigour. For the chestnut blight (*Cryphonectria parasitica)* it seems possible to reach an ecological equilibrium host-parasite by means of an active silviculture (Amorini *et al.*, 1998b). Besides, in order to improve the biological control of the cancer, it is important to leave some shoots with hypo-virulent infections in the clear-felled and thinned areas (Conedera, 1993).

Economy

There is a significant lack of studies concerning the entire timber chain, however some analyses seem to indicate that the extension of rotation times are more advantageous both to the owners and the forest enterprises (Carbone & Ribaudo, 1995).

A new management concept for multifunctional chestnut coppices

The chestnut stands in Mediterranean and sub-Mediterranean Europe, overexploited in the past, are at present not well managed if not abandoned. On the other hand, we strongly believe that the coppice system is one of the few systems able to satisfy the demand for good quality timber and at the same time also the needs for biological, economical, environmental and landscape benefits required by society.

From the social, cultural and economical points of view, the *Castanea sativa* tree is a strategic factor for the integrated development of rural and mountainous areas in Europe. In our vision the management of chestnut coppices could therefore be an exemplary model of integrated management of the living resources with multipurpose criteria (agroforestry, environment, culture, arts and crafts) of rural areas. For the interested regions this could imply a series of advantages:

- avoid the abandonment of marginal areas by maintaining economic opportunities (jobs in environmental engineering, handicraft, enterprises in the timber chain sector, cultural education, tourism);
- offer of complementary employment opportunities to farmers and family companies (favouring especially the young generation) to be integrated into the agro-touristic and cultural activities of their native region;
- guarantee a constant presence and control of the rural territory, important to safeguard the environment;
- integration of resource exploitation, combining forest production with agricultural activities (*e.g.*, complementary to the management of chestnut orchards).

All of these elements are substantially compatible and in line with the objectives of the new European Union policy (*i.e.*, Reg. 1257/99 from 17.5.1999 concerning the support of a multifunctional management of forests in order to improve the production and the development in rural areas). We believe that the application of our silvicultural concept of spatial and temporal differentiated treatment (or non treatment) of forest lots coupled with an increase of chestnut timber utilisation, represents a real implementation of the principles of the sustainable management of the forests!

A flexible transdisciplinary research approach

Our research activities aim to define, verify and implement alternative silvicultural concepts for the coppice forests. To avoid "one-way solutions" the new management systems should present alternative options to the following conventional means, the traditional coppicing, generally without thinning, and the simple abandonment of the coppice (giving up of any management). Our common research approach foresees the integration of silvicultural studies with ecological, technical, economic and socio-cultural elements. The most important product of silviculture is timber: hence it is very important to consider the demands/requirements and the experiences of the timber sector. In the ideal case the different actors should collaborate during the whole "chestnut forest-timber chain" to better distribute economic risks and benefits. Ideally the results reached in different countries under different environmental, social and economic conditions should be comparable and in principle be applicable under various conditions. Moreover they should be easily transformed into decisional tools of practical use to forest managers, private owners, technicians and artisans and provide a foundation for an objective discussion at scientific and technical levels.

In our opinion, it is very important to join the efforts and co-ordinate the different research activities carried out at national level. The COST Action G4 (Multidisciplinary research on chestnut) offers a good opportunity to exchange and discuss ideas, protocols, experiences and scientific information. In the "working group silviculture" we try to collect new and better data regarding diffusion area, types and distribution of chestnut forests in Europe and further afield. Furthermore, starting from dendro-auxometrical methods, we are trying to define common indicators and criteria showing the efficiency of silvicultural and management methods (Giudici *et al.*, 1999).

REFERENCES

Amorini E., Bruschini S., Fioravanti M., Macchioni N., Manetti M.C., Thibaut B. & Uzielli L., 1997c. *Studi sulle cause di insorgenza della cipollatura nel legno di castagno (*Castanea sativa *Mill.)*. Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 269-292.

Amorini E., Bruschini S., Manetti M.C., 1996b. I cedui di castagno del Monte Amiata: Parte II Analisi auxometrica ed osservazioni sulla cipollatura di alcuni popolamenti sottoposti a diverso trattamento selvicolturale. *Ann. Ac. It. Sci. For.*, XLV: 235-248.

Amorini E., Bruschini S. & Manetti M.C., 1997a. *La sostenibilità della produzione legnosa di qualità dal ceduo di castagno: modello di trattamento alternativo al ceduo a turno breve*. Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 217-231.

Amorini E., Bruschini S. & Manetti M.C., 1997b. *Conversion into high forest of chestnut coppices: hypothesis for an alternative and sustainable management*. Proceedings of XI World Forestry Congress, 13-22.10.1997, Antalya, Vol. 3.

Amorini E., Bruschini S. & Manetti M.C., 1998a. Alternative silvicultural systems in chestnut coppice: effects of silvicultural practices on stand structure and tree growth. *In*: Leonardi S. (ed.) *Sustainability of chestnut forest ecosystems*. Proceedings (abstracts) of an International Symposium, 18-23.9.1998, in the University of Catania,: 26. (also accepted by Ecologia Mediterranea, this volume).

Amorini E., Manetti M.C., Turchetti T., Sansotta A. & Villani F., 1998b. Impact of the silvicultural treatment on *Cryphonectria parasitica* incidence and genetic variability in a chestnut coppice in the central Italy. *In*: Leonardi S. (ed.) *Sustainability of chestnut forest ecosystems*. Proceedings (abstracts) of an International Symposium, 18-23.9.1998, in the University of Catania,: 27. (also accepted by Ecologia Mediterranea, this volume).

Aumasson P. & Guerrin J.L., 1995. Consequences of some chestnut silvicultural management practices in the Cevennes for sustainable development. *In*: Romane F. (ed.) *Sustainability of Mediterranean ecosystems. Case study of the chestnut forest*. Report EUR 15727 EN, European Commission, DG XII, Brussels, Ecosystems research report, 19: 165-169.

Bacchetta R., 1984. *Le châtaignier à bois et la mise en valeur des taillis de châtaignier. Ministère de l'agriculture, Paris, Bulletin CEMAGREF*, BI 322: 75-98.

Barkham J.P., 1992. The effects of coppicing and neglet on the performance of the perennial ground flora. *In:* Buckley G.P. (ed.). *Ecology and management of coppice woodlands*. Chapman & Hall, London, 325 pp.

Bourgois C., 1987. Améliorer les taillis de châtaignier. *Forêt-Entreprise*, 44: 8-15.

Bourgois C., 1992. *Le châtaignier. Un arbre, un bois*. Institut pour le Développement Forestier (IDF), Paris, 367 p.

Cabannes B. & Rolland M., 1982. *Enquête sur les possibilités d'amélioration des taillis de châtaignier en Languedoc-Roussillon*. Internal Report, Centre Régional de la Propriété Forestière du Languedoc-Roussillon, Montpellier, 20 p.

Carbone F. & Ribaudo F., 1995. Allungamento del turno dei cedui castanili. *Linea Ecologica*, 5: 47-52.

Chanson B., 1990. *Roulure ou roulures : les différents mécanismes conduisant au même défaut. Forêt-Entreprise*, 69, 5 pp.

Ciancio O., 1998. La gestione sostenibile dei boschi dell'Appennino. *In*: *Selvicoltura dell'Appennino centrale. In: Atti della giornata preparatoria al secondo congresso nazionale di selvicoltura per il miglioramento e la conservazione dei boschi italiani*. Edizioni Regione Toscana, Firenze : 59-84.

Ciancio O., Iovino F. & Nocentini S., 1994a. The theory of the normal forest. [*La teoria del bosco normale*]. *L'Italia Forestale e Montana*, 49(5): 446-462.

Ciancio O., Iovino F. & Nocentini S., 1994b. Still more on the theory of the normal forest: why we insist on saying no to it. [*Ancora sulla teoria del bosco normale: perché si insiste nel dire no*]. *L'Italia Forestale e Montana*, 50(2): 118-134.

Conedera M., 1993. *Cancro corticale del castagno: principali caratteristiche epidemiologiche e misure pratiche di controllo*. Ber. Eidgenöss. Forsch. Anst. Wald Schnee Landsch., Birmensdorf,. 335: 40 p.

Conedera M., Stanga P., Lischer C. & Stöckli V., 1998. Competition and dynamics in abandoned chestnut orchard in southern Switzerland. *In*: Leonardi S. (ed.)

Sustainability of chestnut forest ecosystems. Proceedings (abstracts) of an International Symposium, 18-23.9.1998, in the University of Catania: 30. (also accepted by Ecologia Mediterranea, this volume).

Cutini A., 1998. Biomass, litterfall and productivity in chestnut coppices of Monte Amiata (central Italy). *In*: Leonardi S. (ed.) *Sustainability of chestnut forest ecosystems*. Proceedings (abstracts) of an International Symposium, 18-23.9.1998, in the University of Catania: (also submitted to Forest Ecology and Management)

Cutini A. & Fabbio G., 1997. *Impatto della gestione selvicolturale sulla funzionalità dei cedui di castagno*. Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 245-257.

di Castri F., 1998. The ecosystem in a scientific economic and social context. Sustainability possible? *In*: Leonardi S. (ed.) *Sustainability of chestnut forest ecosystems*. Proceedings (abstracts) of an International Symposium, 18-23.9.1998, in the University of Catania: 22-24.

Everard J. & Christie J.M., 1995. Sweet chestnut: silviculture, timber quality and yield in the forest of Dean. *Forestry*, 68(2): 133-144.

Fonti P., Giudici F., Kucera L., Ott E. & Pohler E., 1997. *Studio sulla cipollatura in un ceduo castanile. Atti Convegno Nazionale sul castagno*, Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 293-302.

Ford E.D. & Newbould P.J., 1977: The biomass and production of ground vegetation and its relation to the tree cover through a deciduous woodland cycle. *J. Ecol.*,. 65: 201-212.

Fuller R.J. & Moreton B.D., 1987. Breeding bird populations of kentish sweet chestnut (*Castanea sativa*) coppice in relation to the age and structure of the coppice. *J. Appl. Ecol.*, 24: 13-27.

Gambi G.& Amorini E., 1978. *Il trattamento del castagno e la produzione di legname da lavoro dal ceduo*. Atti Incontro "Il Castagno nella regione padano-alpina: diffusione, trattamento, patologia", Milano: 19-25.

Giudici F., Fonti P., Pohler E. & Sandoz J.L., 1997. *Qualità del legname di castagno: diagnosi della cipollatura per mezzo di ultrasuoni*. Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 259-267.

Giudici F., Pividori M., Zingg A., Amorini E. & Manetti M.C., 1999: *Key about common words used in chestnut silviculture*. Working paper presented on the 3rd annual meeting COST G4 29.9-2.10.1999, Nitra.

Hilborn R., Walters C.J. & Ludwig D., 1995. Sustainable exploitation of renewable resources. *Annual Review of Ecology and Systematics*.

Krebs P., 1999. *Le radici del castagno nell'antichità e nel medioevo: ipotesi sull'avvento e l'evoluzione della castanicoltura al Sud delle Alpi. Studio bibliografico e di sintesi*. Documento interno dell'Istituto federale di ricerca per la foresta, la neve e il paesaggio (Sottostazione Sud delle Alpi), Bellinzona, 159 pp.

Macchioni N., 1995. Mechanical strength and ring shake in chestnut (*Castanea sativa* Mill.) wood. *For. Médit.*, 16 (1): 67-73.

Macchioni N. & Pividori M., 1996. Ring shake and structural characteristics of the chestnut (*Castanea sativa* Mill.) coppice stand in the northern Piedmont (north-west Italy). *Ann. Sci For.*, 53(1): 31-50.

Mondino P.G., 1991: *Caratteristiche dei boschi di sostituzione e loro tendenze evolutive*. Atti del simposio: I boschi italiani: valori naturalistici e problemi di gestione, 9.10.1989, Castiglione dei Pepoli (BO): 53-61.

Negri M. & Uzielli L., 1997. *Semilavorati di legno di castagno prodotti con moderne tecnologie industruali*. Atti Convegno Nazionale sul castagno, 23-25.10.1997, Cison di Valmarino (TV): 353-366.

Pelcé J., 1994. Régénération naturelle du châtaignier : cas particuliers rencontrés dans des opérations menées depuis 8 ans. *Forêt-Entreprise*, 99: 15-17

Perry D.A. & Amaranthus M.P., 1997. Disturbance, recovery and stability. *In*: Khom K.A. & Franklin J.F. (eds.) *Creating a forestry for the 21st century*. Island Press, Washington D.C.: 31-56.

Pitte J.R., 1986. *Terres de castanide : homme et paysages du châtaignier de l'antiquité à nos jours. Editions* Fayard, Paris, 471 p.

Ranger J., Felix C., Bouchon J., Nys C. & Ravart M., 1990. Dynamique d'incorporation du carbone et des éléments nutritifs dans un taillis simple de châtaignier (*Castanea sativa* Miller). *Ann. Sci. For.*, 47: 413-433.

Ranger J., & Nys C., 1996. Biomass and nutrient content of extensively and intensively managed coppice stands. *Forestry*, 69(2): 91-110.

Romane F. & Grossmann A. (eds.), 1997. *Dynamics and function of chestnut forest ecosystems in Mediterranean Europe. A biological approach for a sustainable development. CAST Final Report*; CNRS - CEFE, Montpellier and European Commission (DG XII), Brussels, 222 pp.

Romane F. & Houssard C., 1995. The sustainability of chestnut ecosystem. *In*: Romane F. (ed.) *Sustainability of Mediterranean ecosystems. Case study of the chestnut forest*. Report EUR 15727 EN, European Commission, DG XII, Brussels, Ecosystems research report, 19: 173-176.

Sevrin E., 1994. Améliorer les taillis de châtaignier. *Forêt-Entreprise*, 97: 13-17.

Shearman R., 1990. The meaning and ethics of sustainability. *Environment Management*: 14.

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The chestnut culture in Italy towards 2000

La culture du châtaignier en Italie 2000

Mario ADUA

ISTAT, Italy's National Statistical Institute,Via A. Ravà 150, 00142 Rome, Italy

ABSTRACT

Chestnut cultivation has been strongly connected with human history since the most ancient times. During the 19th century the chestnut was still important for the mountains population in Italy. In 1911, the largest harvest of chestnuts was made: 829 000 tons of fruits (ISTAT, Istituto Nazionale di Statistica), in 652 000 hectares (Ministry of Agriculture). Thereafter, the reduction of the surface areas for fruit-bearing chestnut trees and the following increase of chestnut forest continued until the 80s. Actually, according to ISTAT, the chestnut cultivation for fruits has become stable at 209 000 hectares of surface area producing about 70 000 tons of fruits; moreover, 67 000 hectares of high forests represent an important ecosystem. In the present paper, the market of chestnut products and data related to the chestnut tree, from the seedling nursery and wood production are discussed as well. The sustainable agriculture, the identification of the chestnut as quality biological product, the rural development and the recovery of the traditions represent the base of the revaluation and the best use of the chestnut tree surface area.

Key-words : chestnut orchards, production, castaneiculture, sustainable development

RESUME

La culture du châtaignier est liée à l'histoire de l'homme depuis des millénaires. Au XX ème siècle, en Italie, la castanéiculture a été de grande importance pour les populations des montagnes. Ultérieurement, la réduction des châtaigneraies fruitières et l'augmentation consécutive des bois de châtaigniers, ont eu lieu, jusque vers les années 1980. Actuellement, selon les résultats de l'ISTAT (Istituto Nazionale di Statistica), la culture de châtaigneraies fruitières est stable et occupe 209 000 hectares de surface, pour une production d'environ 70 000 tonnes des fruits. De plus, les 6 7000 hectares de bois de châtaigneraies représentent un important écosystème forestier. Le présent travail analyse l'évolution, en Italie, de la surface des châtaigneraies, la production de bois et le marché des produits issus de la castanéiculture. La mise en pratique d'une agriculture durable, l'identification de la châtaigne comme produit biologique de qualité, le développement rural et le maintien des usages, constituent la base pour une ré-évaluation de la châtaigne et d'une meilleure utilisation des châtaigneraies.

Mots-clés : chataigneraies, production, castanéiculture, agriculture durable

INTRODUCTION

The life of man, especially of people leaving in the Alps and the Apennines, has been closely tied to the presence of the chestnut tree in the forestry landscape. During the Middle Ages and in Modern Times, mountain people founded a new village where chestnut trees could grow and produce wood and fruit which were indispensable to their daily lives (nourishment, heating, construction, handicrafts, etc). For centuries, the chestnut tree, the real, true "tree of life", has thus supplied food to millions of people, particularly the poor and needy during the long mountain winters and recurrent famines. Its delicious fruit were also served at the banquets of kings and princes throughout Europe.

During the most golden periods of its history, the chestnut tree has developed into a true "chestnut civilization" (Bignami & Salsotto, 1983), rich in uses, customs, traditions, judiciary norms, communal statutes, agronomic techniques, forest and land control, processing of the products, handicrafts, etc. What is more, the chestnut tree has contributed to the survival of hundreds of thousands of farmers in the mountainous regions of the Iberian peninsula, France, Italy, Switzerland and the Balkans; this phenomenon is known as "International on poverty and the chestnut" (Le Roy Ladurie, 1984).

In the 50s, firstly World War II, then the economic reconstruction and evolution of the way of life and food consumption, a number of factors affected negatively chestnut-growing ("the autumn of the patriarch") till the beginning of the 80s. During the 80s and even more in recent years, the chestnut tree has shown signs of productive resumption and renewed cultural and alimentary interest ("the reawakening of the good giant") in Europe and especially in Italy. The reappraisal of history, anthropology, culture, tradition, gastronomy and uses of the chestnut tree, as well as its role in the conservation of the forestry landscape and the hydrologic and geological defence of the soil allow for a more peaceful look at the majestic "bread tree" which is preparing to enter the Third Millennium with refound agility and new vigour.

It is up to man to improve the living conditions of the chestnut tree and cultivate it carefully in order that this great tree might accompany our descendants and contribute to a general improvement in the quality of life and the environment for a long time to come.

History of the chesnut tree

In Italy and in Europe the chestnut tree is an autochthonal plant that preceded and then accompanied the history of man from prehistoric times, furnishing him with edible fruit and water-resistant wood for pile-dwellings and canoes (Fenaroli, 1945). The first races cultivated were developed in Asia Minor and were quickly disseminated throughout the Hellenic peninsula from which they reached Italy during the times of Magna Grecia (Piccioli, 1922).

The ancient Romans greatly appreciated chestnut trees and contributed decisively to the dissemination and cultivation of the species, not only in Italy but also throughout central and southern Europe. Chestnut trees for fruit and copses for posts were planted in Spain, Portugal, France, Switzerland, Germany, etc (Adua, 1996). During the first centuries of the Middle Ages, convents and monasteries were the principal preservers and propagators of the chestnut tree, considered "the fruit-bearing tree par excellence"; even King Longobard Rotari and Emperor Carlo Magno were interested in the chestnut tree (Montanari, 1993). Following recurrent demographic crises, famines and the choice of cereal, between the 9th and 15th centuries the acreage of chestnut trees was markedly developed in Piemonte, Liguria, Toscana, Campania and Calabria and also occupied a notable position in Lombardia, Veneto, Emilia-Romagna, Umbria and Lazio (Cherubini, 1981). In Modern Times, the alimentary diet of the mountain and rural populations deteriorated considerably; chestnut tree cultivation was further intensified; chestnuts and chestnut flour often represented indispensable aids to the survival of entire generations of mountain people unable to eat cereals and meat (Adua, 1997).

Between the 16th and 19th centuries, two very relevant phenomena were determined:

- "International on poverty and the chestnut" which ideally reunited hundreds of thousands of mountain people whose survival, especially during the winter, was almost exclusively based on the consumption of chestnuts (Le Roy Ladurie, 1984);

"Chestnut tree civilization" which had developed in many Alpine and Apennine areas, where the chestnut tree represented the foundation of social and economic, alimentary and judicial-cultural life of the mountain population (Cento, 1997).

During our present age and having finally surpassed the archaic contraindications and preconceptions of official science, that considered the chestnuts detrimental to health, chestnuts are being more and more characterised as food for poor and common people, even if they have slowly entered into a process of refined dishes, the fame of marrons has crossed the ocean and the French pastry industry has developed the production, trade and exportation of "marrons glacés" (Adua, 1998). Besides food, chestnut trees have always furnished wood used in the most varied ways: to burn, to produce charcoal, to extract tannin, timber and wood for poles; from building to handicrafts, from agriculture to the designing of objects for daily life and furniture; the wood from chestnut trees has been distributed and exploited throughout Italy and in Europe (Brenni, 1927). During the 1800s, the survival of hundreds of thousands of farmers and mountain folk still depended a great deal on fresh, dried or pulverised chestnuts; chestnut trees were generally cultivated and trimmed well to obtain more fruit, while a better selection was made between the early and late varieties, for flour or marrons, respectively (Adua, 1998). Besides farmers, also woodsmen, furniture makers, craftsmen, tannin industrialists and others were very interested in the chestnut tree; while the farmers tried to defend "the bread tree" to harvest its fruit, other economic parties were more interested in cutting the plants and entire chestnut-wood grown for fruit, sometimes recklessly and universally (Vigiani, 1943). Forestry legislation did not manage to resolve the rise of continuous conflicts, although the indiscriminate felling had already caused marked damage such as, landslides, floods, etc., actually due to the absence of the chestnut tree which is an important element in hydrologic and geological retention and the control of hilly and mountainous terrain (Piccioli, 1922). Chestnut trees also had to fight against some grave parasites, *Phytophtora cambivora* (Petri) Buis and *Cryphonectria parassitica* (Murr.) Barr., which, starting in the mid-1800s and continuing into the first half of the 1900s, greatly reduced its substantial population. The great vitality of this species, the alimentary needs of the mountain people and the economic inference of fruit and wood production allowed the chestnut tree to overcome the difficulties and reach the highest level of fruit production in its history in 1911 (Figure 1): 8 290 000 quintals (the quintal = 100 kg) harvested (ISTAT), from 652 000 hectares (Ministry of Agriculture).

But by this time the decline of the chestnut tree and chestnuts had already begun: the depopulation of the mountains and hills, internal and external emigration, urbanisation, different alimentary needs, the introduction of new cultural models, growing industrialisation, and mechanised farming had converged with the felling of numerous chestnut trees, serious parasitic attacks, the forsaking of substantial chestnut tree cultivation areas, a considerable reduction of the total production and even more, a strong decrease of the actual harvest. Nonetheless, considerable commercial interest has always been maintained in chestnut wood and chestnuts which, for the most part, flowed into mills while the best quality products, especially marrons, nourished flourishing exportation towards central European countries and North America.

The statistical ISTAT data say that :

- in 1929 nut production exceeded 5 million quintals, but then dropped to under 4 million during the 30s;
- during the decade from 1941 to 1950, the nut average production was 2.7 million quintals; in 1956 and for the last time, over 2 million quintals of chestnuts were harvested, whereas, in 1964, the harvest was just over 1 million quintals;
- during the 70s, the average annual nut production was 650 000 quintals which dropped to 580 000 in the 80s and rose to about 700 000 in the 90s.

Recently, though, the harvest shows a resumption, keeping apace with a renewed interest in a very special, unique forestry plant.

The chesnut tree in the world

Data published annually by the FAO, although not always precise and updated, allows for the observation of the evolution of worldwide chestnut cultivation; the most recent information available is relative to all surface areas and production surveyed in 1997. The cultivation of fruit-bearing chestnut trees is concentrated in Europe and Asia (Table 1); there are only very small such areas in America (USA and Chile), Oceania (Australia and New Zealand) and

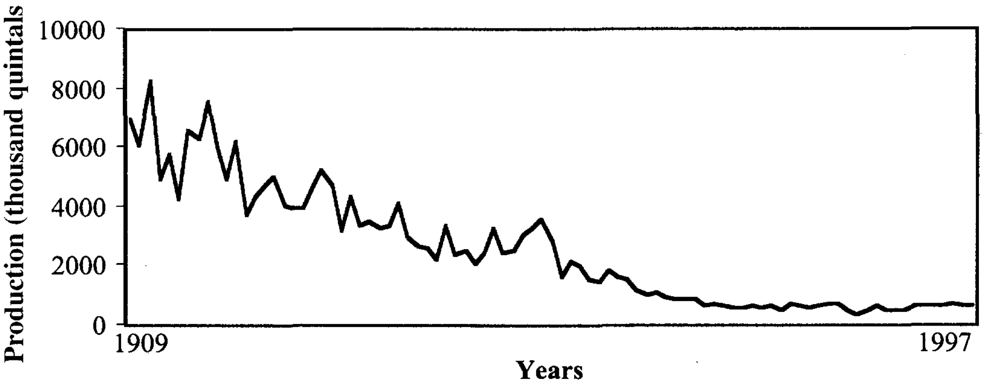

Figure 1. Chesnut and marron nut production in Italy 1909-1997 historical series (quantity in thousand quintals). Source: ISTAT

	Nut productions							
	Average 1969-1971	%	Average 1979-1981	%	1988	%	1997	%
China	**144 667**	**28.1**	**198 333**	**34.3**	**95 000**	**20.9**	**112 000**	**21.7**
Japan	**48 933**	**9.5**	**57 133**	**9.9**	**48 000**	**10.5**	**32 900**	**6.4**
South Korea	**-**	**-**	**76 117**	**13.2**	**70 000**	**15.4**	**129 673**	**25.1**
Turkey*	**47 167**	**9.2**	**54 500**	**9.4**	**92 000**	**20.2**	**60 000**	**11.6**
Other countries of Asia	**6 252**	**1.2**	**5 500**	**1.0**	**12 000**	**2.6**	**7 500**	**1.5**
ASIA	**247 019**	**48.0**	**391 583**	**67.8**	**317 000**	**69.6**	**342 073**	**66.3**
France	**52 570**	**10.2**	**34 726**	**6.0**	**17 202**	**3.8**	**11 000**	**2.1**
Italy	**66 871**	**13.0**	**67 195**	**11.6**	**50 000**	**11.0**	**68 704**	**13.3**
Portugal	**37 800**	**7.3**	**20 216**	**3.5**	**14 400**	**3.2**	**20 000**	**3.9**
Spain	**79 567**	**15.5**	**27 530**	**4.8**	**20 000**	**4.4**	**23 000**	**4.5**
Other countries of Europa	**19 111**	**3.7**	**21 445**	**3.7**	**15 717**	**3.4**	**26 890**	**5.2**
EUROPE**	**255 919**	**49.7**	**171 112**	**29.6**	**117 319**	**25.8**	**149 594**	**29.0**
Other countries of World	**11 777**	**2.3**	**15 064**	**2.6**	**21 200**	**4.6**	**24 470**	**4.7**
WORLD	**514 715**	**100.0**	**577 759**	**100.0**	**455 519**	**100.0**	**516 137**	**100.0**

Table 1. World chestnut nut production, 1969-1997 (quantity in tons). Source: FAO

* Turkey including its European part

** USSR and present Russia are not included. Europe not including the European part of Turkey

Africa (Cameroon and Malawi). The largest surface areas of chestnut trees are located in China (445 000 hectares), South Korea (430 000 hectares), Turkey (392 000 hectares) and Japan (283 000 hectares); in Europe, Italy comes first with 235 000 hectares according to the FAO, but according to ISTAT the surface area is 275 000 hectares.

About 70% of the nut production comes from Asia; in 1997 South Korea harvested 130 000 tons, exceeding China which produced 112 000 tons, as estimated by the FAO. Italian production which reached 69 000 tons in 1997 is higher than both Japan and Turkey. An analysis of FAO data, as far as average yields are concerned, shows the best results achieved by South Korea (3.0 quintals per hectare), Italy (2.9 quintals per hectare) and China (2.5 quintals per hectare). Over the last thirty years, while Asian chestnut tree cultivation has shown a continuous trend towards a quantitative increase in production and equipment specialisation, Europe has had a continuous drop both in surface area as well as nut production.

The cultivation of fruit-bearing chesnut trees in Europe

During the 60s, there was an actual collapse in nut production, especially in France and Italy, that suffered a harvest decrease of about 40%. Portugal, on the other hand, had an increase of about 50% (FAO). Using the average harvest in the main, European chestnut-producing countries as a reference, during the three years from 1969 to 1971 (Table 2) the same marked drop in nut production can be seen as in the 70s, especially in France, Spain, Portugal and Greece, while production remained stable in Italy (FAO). During the 80s, there was a general drop which also hit Italy; in the 90s, a relative resumption was recorded in Italy as well as Spain and Portugal. At the moment (Table 3), greater attention is also being paid to chestnut tree cultivation in Switzerland, the North-central European countries (Hungary, Bulgaria and Slovakia) and in the Balkans (Slovenia, Bosnia and Albania); in each interested European country, the cultivation of chestnut trees is being restructured and located in suitable areas, where chestnut-trees play a significant social-economic role. The figures of Italian chestnut tree cultivation are the most meaningful and represent about half of both the European area and production; Spain and Portugal follow at a distance, while France has assumed an increasingly more marginal position, even though it boasts ancient traditions (i.e. marrons glacés) and produces excellent varieties of chestnuts and marrons as well as Euro-Japanese hybrids.

FAO data and the analysis of the average yields, collected in 1997, show that the highest production per hectare, at 4.0 quintals, comes from Slovenia where the chestnut wood surface area is only 1 250 hectares. Among the main countries cultivating chestnut trees, the best yields are obtained in Spain and Italy, respectively, with 3.3 and 2.9 quintals per hectare, while the lowest productions are recorded in France and Portugal, with 1.6 and 1.0 quintals per hectare. The increase in surface area and nut production, recorded during the period 1990-1997, will hopefully lead to an increase of European chestnut cultivation.

The Italian situation

Data published by ISTAT, in Italy, after the negative peak recorded in 1983 with a production of only 388 000 quintals, both the total surface area of high chestnut forests, around 276 000 hectares, of which 209 000 were fruit-bearing trees, as well as the annual nut production harvest stabilised at about 700 000 quintals. Data regarding areas and nut production are derived from estimates made by local stations of the Italian Corps of Foresters and refer to the areas pertaining to chestnut trees and the total quantity of common chestnuts and marrons harvested both in groves as well as in chestnut tree woods outside forests. Nut production refers only to the harvested quantity, i.e. removed from the trees and the ground beneath them. The findings, especially for chestnuts, are remarkably less than the total produced by the trees; the variation in percentage of the two productions of other arboreal cultivation is rather slight, but that of chestnut trees is considerable. In vast abandoned or semi-abandoned areas of chestnut tree arbors, the harvest, in former times called "chestnut harvest", is carried out sporadically. On the contrary, areas that are cultivated or simply trimmed are often quickly harvested, without passing over it again, every few days, at least 3-4 times across the same ground, as it was usually done during the 50s. According to personal estimates, the belief is that at least 50-60% of the total nut production remains on the ground; based on such an evaluation the total Italian nut production oscillates between 1.1 and 1.4 million quintals. Therefore, it would be the same, if not higher, than that of South Korea and China where harvests are almost complete.

	Nut production				
Country	1961-1965	1969-1971	1979-1981	1989-1991	1995-1997
France	86 026	52 570	34 726	12 620	10 938
Greece	14 273	16 685	13 545	10 961	11 967
Italy	105 660	66 871	67195	49 944	69 776
Portugal	25 260	37 800	20 216	18 348	19 865
Spain	84 600	79 567	27 530	27 868	22 333

Table 2. Chestnut nut production in the main European chestnut producers, 1961 – 1997 (quantity in tons). Source: FAO

	1990					**1997**				
	Surface		**Nut production**			**Surface**		**Nut production**		
Country	**Total**	**%**	**Harvest**	**%**	**Yields**	**Total**	**%**	**Harvest**	**%**	Yields
France	124 000	18.0	13 560	10.1	1.1	70 000	9.8	11 000	7.4	1.6
Italy	190 000	27.6	49 559	37.0	2.6	235 000	32.8	68 704	45.9	2.9
Spain	70 000	10.2	23 605	17.6	3.4	70 000	9.8	23 000	15.4	3.3
Portugal	152 000	22.1	20 405	15.2	1.4	200 000	28.0	20 000	13.4	1.0
URSS	48 000	7.0	12 000	9.0	2.5	-	-	-	-	-
Russia	-	-	-	-	-	47 000	6.5	12 000	8.0	2.6
Greece	88 000	12.8	10 882	8.1	1.3	80 000	11.2	11 000	7.4	1.4
Hungary	3 800	0.6	869	0.7	2.3	3 800	0.5	1 040	0.7	2.7
Yugos. SFR	13 000	1.9	3 000	2.3	2.3	-	-	-	-	-
Yugoslavia	-	-	-	-	-	6 000	0.8	1 400	0.9	2.3
Slovenia	-	-	-	-	-	1 250	0.2	500	0.3	4.0
Bosnia	..	-	-	-	-	2 900	0.4	400	0.3	1.4
Bulgaria	-	..	21	..	..	..	..	350	0.2	..
Switzerland	-	-	-	-	-	..	..	200	0.1	..
Other countries of Europe										
EUROPE *	688 800	100.0	133 901	100.0	2.0	715 950	100.0	149 594	100.0	2.1

Table 3. Surface and european chestnut nut production, 1990 – 1997 (surface in hectares, quantity in tons, yields in quintals. Source: FAO. * Europe not including the European part of Turkey

The situation until the 20s was quite different. At that time the entire nut production was harvested, even the bad fruit designated for animal fodder; thereafter, free access was allowed into the chestnut groves for the "scraping", which consisted of gathering the chestnuts still lying on the ground free of charge; finally, animals (horses, sheep, goats and cows) were allowed to graze freely on the land, thereby completely cleaning the woods of the remaining fruit. The general Census of Agriculture is the only total, statistical survey that also surveyed the areas with fruit-bearing chestnut groves included in the agricultural farms. These areas are submitted to normal cultivation operations and the harvesting of the product; on the contrary, the area of other chestnut tree groves is included among the forests, in the "broadleaf high forest" group. Thus it is possible to point out a drop, both in agricultural farms as well as surface areas, that continued until the Census of 1990. This Census surveyed a total surface area of 108 000 hectares allocated to chestnut-bearing trees present in 98 000 agricultural farms (ISTAT).

By comparing the 1990 Census data with similar data from 1970, a decline of 38 000 agricultural farms and 37 000 hectares occurred in those 20 years. Also in 1990, 68.7% of the agricultural farms with 67.3%

of the surface area was in the mountains, while 29.8% of the agricultural farms and 31.1% of the surface area were located in the hills; only 1 457 agricultural farms with 1 784 hectares of chestnut groves were located on the plains (ISTAT). This data also confirms that the chestnut tree has always been prevalently a mountain plant and has therefore been labelled "queen of the mountain". Taking into account the Union European observation field" that includes agricultural farms with over 1 hectare of Used Agricultural Surface or those that have sold agricultural products for over one million lire in 1990, there were 83 000 chestnut agricultural farms with 104 000 hectares of chestnut groves surveyed in the last census. The above data can be compared with similar information collected by a ISTAT sample survey on the structure and production of agricultural farms that indicated the presence of 67 000 hectares of chestnut groves in 47 000 agricultural farms in 1996. The enormous decline of 43% recorded in agricultural farms and 35% of surface area is at least partially clear when considering that the survey on the structure excludes the surface areas of fruit-bearing trees of exclusively forestry agricultural farms. However, sample statistics certainly emphasize a further drop in the cultivation of chestnut-bearing trees unlike other indicators that show renewed interest in chestnut trees and the recovery of previously abandoned chestnut groves. On the contrary, data collected by the Italian Corps of Foresters annually estimate both the total surface area of high forest chestnut trees and groves of chestnut-bearing trees regardless of the number of agricultural farms. These are the most detailed data currently available and provide information about chestnut production (Table 4) and the calculation of their economic value (Table 5).

A future revision of the forestry statistics on chestnut trees is expected. This will be an exhaustive survey on the entire "chestnut matrix", following in the footsteps of the great survey carried out for ISTAT in 1934-36 (Polacco, 1938). It can be assumed that, although surface areas and nut production remain stable as a whole, during recent years surface areas of chestnut trees directly cultivated by agricultural farms have probably diminished. This has occurred even though some regions, provinces and mountain communes are working to recover and develop the chestnut tree, and is also based on community laws in force that are relative to sustainable integrated territorial development (Reg. 2080/92, Leader initiatives, Local action groups and Life Program).

Italy is divided in three geographical areas:

the North, that includes the regions of Piemonte, Valle d'Aosta, Lombardia, Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia, Liguria and Emilia-Romagna;

the Center, that includes the regions of Toscana, Marche, Umbria and Lazio;

the South, that includes the regions of Abruzzo, Molise, Campania, Basilicata, Puglia, Calabria, Sicilia and Sardegna.

Statistical forestry data of ISTAT show that 70.5% of surface areas are in central-northern Italian regions, although 55.5% of the production is harvested in the South.

The result is a progressive development of the chestnut cultivation in the South which represents the natural return to the great tree in Magna Grecia, where it arrived over 2 000 years ago from the Hellenic peninsula and then spread into Italy and Europe, thanks to the Roman Empire.

Often in the North it is not advantageous to produce chestnut trees, except for marrons and some valued varieties mainly in Piemonte, Emilia-Romagna and Toscana. In the Centre, chestnut cultivation is still a relevant, economic activity, especially in Lazio. In the South, mainly in Campania but also in Calabria, despite low prices (in 1998 only about 600-700 lire for the best fruit), chestnuts are still generally harvested.

The development of chestnut tree cultivation in the South emphasises even more how chestnuts are one of the products typical for nourishment and the Mediterranean gastronomy. With a high, nutritional value, chestnuts unite typical tastes and countless uses in cooking and sweets, both as fresh or Red fruit, as flour or purée, or even as jam or candied. Considering the total surface area of chestnut woods, the principal chestnut-growing areas are in Toscana, which comprises over 80 000 hectares or 29.1% of the national surface area, followed by Calabria, with 47 977 hectares or 17.4%, Piemonte, with 38 215 hectares or 13.9%, and Liguria, with 28 972 hectares or 10.5%. It is interesting to note that the nut production is not proportional to cultivated surface , but depends rather on the type of cultivation and care being practised. It is interesting to compare Emilia-Romagna and Campania: these two regions possess about the same surface area, both in high forest

Region	**Chestnut-groves (*)**				**Nut productions (**)**	
	Total surface		**of wich fruit bearing trees**			
	area	**%**	**area**	**%**	**quantity**	**%**
Piemonte	38 215	13.9	16 382	7.8	80 456	11.7
Valle d'Aosta	1 371	0.5	1 108	0.5	308	0.0
Lombardia	9 099	3.3	6 436	3.1	9 329	1.4
Trentino-A. Adige	5	0.0	0	0.0	7 537	1.1
Veneto	2 753	1.0	1 904	0.9	3 726	0.5
Friuli V. G.	1 761	0.6	1 111	0.5	734	0.1
Liguria	28 972	10.5	14 597	7.0	2 617	0.4
Emilia-Romagna	22 980	8.3	19 399	9.3	15 375	2.2
Toscana	80 063	29.1	75 161	35.9	59 258	8.6
Umbria	997	0.4	424	0.2	6 550	1.0
Marche	2 416	0.9	2 306	1.1	2 155	0.3
Lazio	9 421	3.4	8 668	4.1	117 487	17.1
Abruzzo	2 801	1.0	2 307	1.1	1 057	0.2
Molise	48	0.0	43	0.0	20	0.0
Campania	23 150	8.4	20 978	10.0	252 775	36.8
Abruzzo	42	0.0	4	0.0	30	0.0
Basilicata	1 764	0.6	596	0.3	7 690	1.1
Calabria	47 977	17.4	37 356	17.9	111 163	16,2
Sicilia	1 157	0.4	318	0.2	4 611	0.7
Sardegna	484	0.2	15	0.0	3 660	0.5
ITALY	275 476	100.0	209 113	100.0	686 538	100.0
North-Centre	198 053	71.9	147 496	70.5	305 532	44.5
South	77 423	28.1	61 617	29.5	381 006	55.5

Table 4. Surface of chenut groves and chesnut and marrons nut production in Italy, 1996 (surface in hectares, nut productions in quintals). Source ISTAT; (*) Chesnuts groves include high chesnut forets and fruit-bearing chesnut-groves; (**) Nut productions includes chesnuts and marrons harvested

Region	Value of nut production		Average price
	total	%	per kg
Piemonte	8 836 700	8.2	1.10
Valle d'Aosta	261 800	0.2	8.50
Lombardia	1 878 202	1.7	2.01
Trentino-A. Adige	504 926	0.5	0.67
Veneto	830 689	0.8	2.23
Friuli V. G.	156 578	0.1	2.13
Liguria	256 826	0.2	0.98
Emilia-Romagna	4 891 080	4.5	3.18
Toscana	9 877 519	9.2	1.67
Umbria	1 907 848	1.8	2.91
Marche	479 705	0.4	2.23
Lazio	20 658 797	19.2	1.76
Abruzzo	89 630	0.1	0.85
Molise	400	0.0	0.20
Campania	45 354 200	42.1	1.79
Apulia	3 000	0.0	1.00
Basilicata	1 153 500	1.1	1.50
Calabria	9 282 007	8.6	0.83
Sicilia	556 200	0.5	1.21
Sardegna	808 400	0.7	2.21
ITALY	107 788 007	100.0	1.57
North-Centre	50 540 670	46.9	1.65
South	57 247 337	53.1	1.50

Table 5. Value of the nut production of chesnuts and marron in Italy, 1996 (value in thousand lires). Source ISTAT

chestnut groves and chestnut woods, and yet Campania produces a harvest about 17 times more than Emilia-Romagna.

In 1995, 1996 and 1997, the nut production was substantially stable, even if there was a slight decline, at 720 000, 687 000 and 728 000 quintals, respectively, while the three year average was 711 000 quintals (ISTAT). Statistical data collected do not allow for a division of chestnuts between common chestnuts and marrons; based on personal assessments, marrons represent about 10-12% of the Italian nut production, or 70 000- 85 000 quintals. An analysis of the most recent, available information relative to 1996 shows that over 80% of the nut production is harvested in only 4 regions, Campania (36.8%), Lazio (17.1%), Calabria (16.2%) and Piemonte (11.7%), even though chestnuts are grown in all of the Italian regions, including the Islands (ISTAT).

By calculating the average yields per region, based on the total surface area cultivated with high forest chestnut trees, it ensues that the best productions are obtained in Lazio and Campania, where yields are 12.5 and 10.9 quintals per hectare, respectively. The lowest nut productions are recorded in Liguria where they only reach 0.1 quintal per hectare. These data show a significant and serious crisis of abandonment that chestnut tree cultivation has been suffering for some time in Liguria. In former times, this region was so overrun by chestnut trees that they reached all the way to the seashore and the word "tree" was synonymous with chestnut.

Even in regions with average, low yields, there are many very active chestnut groves with very high average yields, even over 20-25 quintals per hectare. During a period in which alimentary consumption is at a standstill, final purchasers are more interested in quality than quantity, as well as the identification and value-added connected to each alimentary product. Italian common chestnuts and marrons are generally of good quality, even if they could be further improved in their organoleptic, commercial and technological characteristics to display themselves to final consumers with more value-added. The total value of national nut production was 107.8 billion lire in 1996 and 128.1 billion in 1997; an analysis of regional data relative to 1996 emphasizes how the South represents 53.1% of the total value against the remaining 46.9% achieved in north-central Italy where the average price paid per kilo to producers is 151 lire higher than the price paid to southern chestnut cultivators, which is 1 503 lire (ISTAT).

This difference in price depends on various factors, such as:

the greatest unit value of marrons grown exclusively in central-northern Italy;

the practice of often harvesting only the best chestnuts;

the existence of a more efficient harvesting, processing and product distribution network;

the highest purchasing power on the consumer side.

Campania alone represents 42.1% of the amount of the national chestnut fruit cultivation, achieving a production of 36.8%, harvested from 8.4% of the total chestnut surface area. Lazio attains even better results, thanks to a better average yield: 9 400 hectares of high forest chestnut trees have a harvest of 117 000 quintals, at a value of 20.7 billion lire. The total revaluation of the chestnut tree will bring about a considerable increase in the economic value of chestnut products and other by-products

Destination and use of the nut production

The destination and the use of the nut production is analysed with information of experts of the chestnut sector. Over the course of time, both the type of use and the final destination of chestnuts and marrons have been modified. During the Middle Ages and Modern Times, in the mountains there were drying areas or rooms, where the chestnuts were dried by means of a slow smoking process which lasted from 20 to 40 days between the end of autumn and during winter depending on the seasonal conditions; in the valleys, along rivers and streams, numerous mills arose with special, stone grinding wheels to mill the dried, shelled and skinned chestnuts. The drying process (Figure 2) is currently used on only 5-10% of the harvest, although in Italy excellent dried chestnuts and valuable, sweet flour are produced, especially in Toscana (Lucca, Pistoia, Arezzo and Massa Carrara), Piemonte (Cuneo) and Emilia-Romagna (Modena). Scraps from the harvest and processing have always represented an excellent by-product used as animal fodder; this use has diminished recently (5-10% of

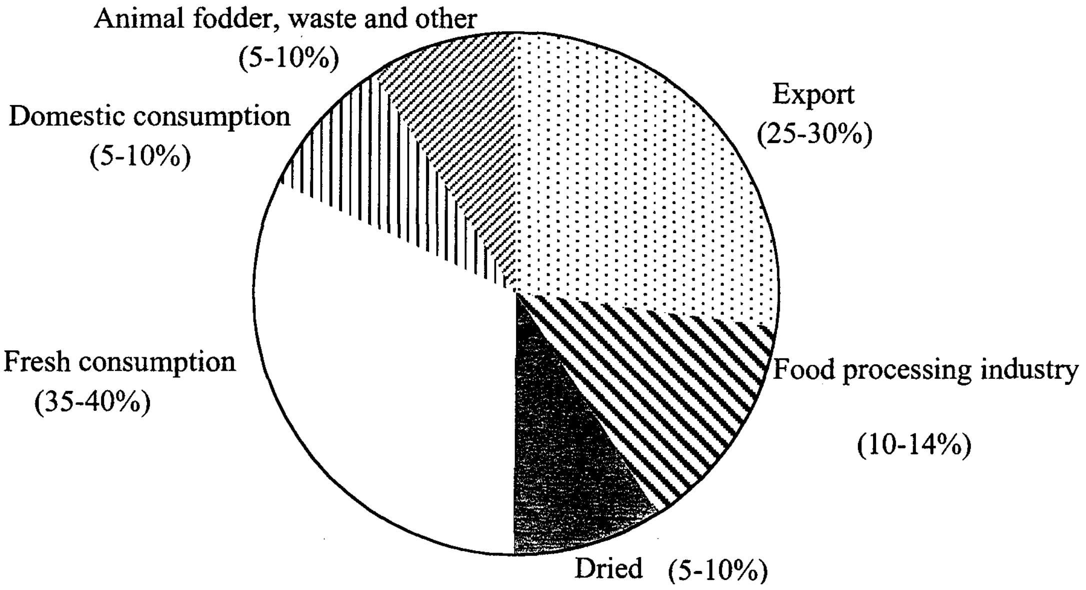

Figure 2. Use of common chestnuts and marrons in Italy 1998; Source Experts ot the sector

national production), except in Calabria where it comprises 30-40% of the entire harvest. Fresh fruit, including domestic consumption and export represent 65-80% of the final destination of common chestnuts and marrons, while 10-14% are bought by alimentary industries to be transformed into "marrons glacés", candied fruit or syrups, jams, purées and other products. Marrons (Figure 3) are much appreciated by both consumers and food industry that absorb about 35-40%, whereas 40-45% are used fresh, for domestic consumption and exported; only a limited amount of marrons is dried, comprising about 1-2% of the harvest. The annual chestnut consumption in Italy amounts to about half a million quintals, or about 1 kilo per person. It is important to stress how the use and final destination of the product, particularly that of fresh consumption and flour depend on the quality of the chestnut and their content in value-added, represented by their history, culture, gastronomy, alimentary value and biological richness, as well as on industrial processing.

International trade of nut production

In ancient times, Greeks, Phoenicians, Jews and Romans transported fresh and dried or milled chestnuts by sea from one Mediterranean country to the other. This trade continued during the period of sea-faring cities and reached as far as north-central European countries, especially during Modern Times. During recent history, following the growing Italian emigration towards the United States, chestnuts followed the emigrants and there was a constant flow of "treated" fruit export, i.e. first the fruit was kept wet for a few days, in order to prevent it being attacked by mildew and fungous growths, then it was dried and packed in barrels or wooden chests carried on steamships or merchant ships. This trade continues today, even if wooden chests and merchant ships have been substituted for the most part by refrigerated containers and cargo planes. Since 1933 the statistical data of international trade were collected by Economic Ministry; after, by ISTAT. The highest export of the nut product, 35 000 tons, occurred in 1913, whereas,

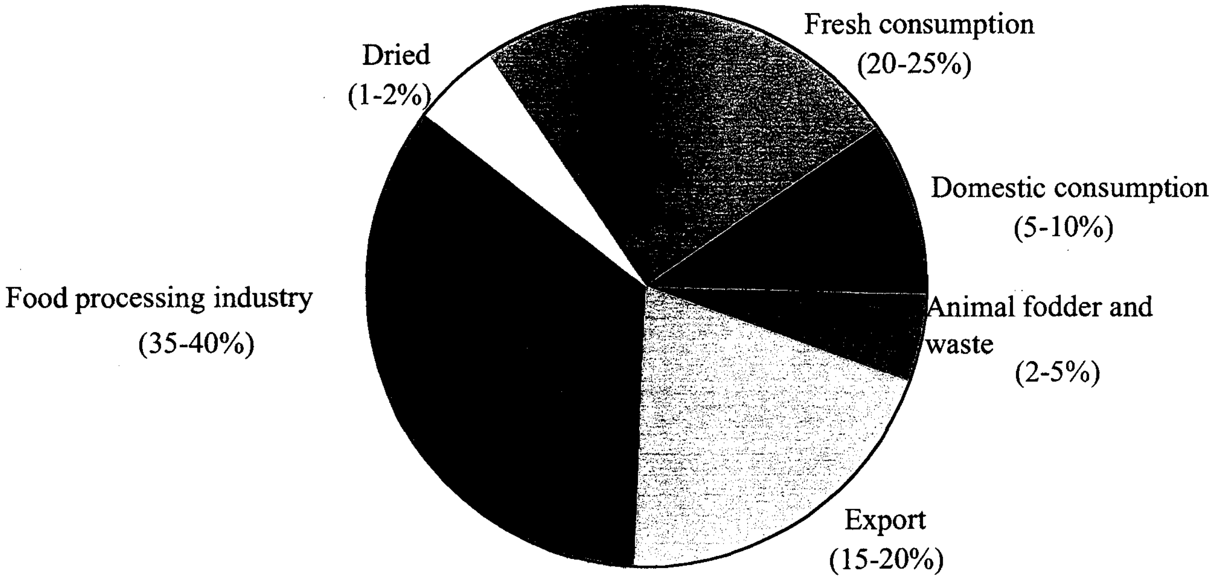

Figure 3. Use of marrons in Italy 1998; Source Experts of the sectors

in 1938 exportation had sunk to 26 000 tons. This century, following the wars, reconstruction and fresh outbreaks of parasites, common chestnuts and marrons exports dropped to 24 000 tons during the 50s and 21000 tons during the 60s. During the 70s and 80s, Italian export decreased further to 18 000 and 16 000 tons, respectively. Over the course of the last decade, in line with production recovery and a growing interest in chestnut trees, international trade has also increased; in 1992, 17 000 tons were exported, while in 1997, the quantity rose to 20 000 tons, or about 30% of the harvest that year. No direct correlation exists between cultivated areas and harvests, the same applies to the correlation between nut production and export: exports are generally more stable compared to harvests. In 1997 (Table 6), 46.7% of exports were sent to European Union countries, while the remaining 53.3% was mainly distributed to America and Asia. In Europe, the main countries importing Italian products are France, Switzerland and Germany. In 1997, their respective import was 3 800, 3 500 and 2 200 tons. North America had a total import of 3 500 tons; in Asia, chestnut export towards Japan, Taiwan, Singapore and Hong Kong is expanding and reached 2 000 tons, or 10% of the total export, in 1997. Current exports are already growing but can improve their position and win new market shares with better quality and higher value-added.

Other European productions, such as that of Turkey, do not seem able to compete with the Italian products. Chestnuts from South-east Asia have very different organoleptic and technological characteristics compared to European fruit, thus they deal with a different type of consumer who also appears to appreciate Italian chestnuts. Italian importation is rather limited; it reached its peak in the latter part of the 80s at 7 000 tons. Thereafter, in the early 90s, imports declined and fell to 1 600 tons in 1997. These data are also consistent with the resumption of production of the "good giant" in the 80s and which began to be more consistently visible in the last few years. In 1997, the trade balance was positive and equal to 183 000 quintals and 71.6 billion lire. International trade is feeling the negative effect of the instructions issued by ICE (Institute for Italian Foreign Trade) a few decades ago have had a negative impact on international trade. These provisions need to be adjusted to the times.

These provisions should consider the evolution which occurred over the last few years, both on the

Countries	Imports				Exports			
	quantity		value		quantity		value	
	Total	%	Total	%	Total	%	Total	%
France	109 933	6.8	335 496	7.2	3 787 712	19.0	10 721 591	14.1
Benelux	-	-	-	-	407 862	2.0	843 866	1.1
The Netherlands	-	-	-	-	118 094	0.6	339 756	0.4
Germany	7 494	0.5	57 431	1.2	2 164 673	10.9	6 334 123	8.3
United Kingdom	-	-	-	-	589 356	3.0	2 620 711	3.4
Ireland	-	-	-	-	250	..	978	..
Denmark	-	-	-	-	56 837	0.3	172 873	0.2
Greece	-	-	-	-	394	..	1 428	..
Portugal	135 650	8.4	440 972	9.5	-	-	-	-
Spain	596 621	36.8	1 567 494	33.6	141 577	0.7	488 478	0.6
Norway	-	-	-	-	710	..	3 037	..
Sweden	-	-	-	-	60 993	0.3	200 098	0.3
Austria	56	..	1 345	..	1 970 243	9.9	6 977 988	9.1
Switzerland	40 120	2.5	181 234	3.9	3 500 638	17.6	14 459 218	19.0
Malta	-	-	-	-	64 015	0.3	241 753	0.3
Czech Republic	-	-	-	-	67 456	0.3	132 913	0.2
Slovakia	-	-	-	-	22 092	0.1	51 852	0.1
Hungary	-	-	-	-	940 560	4.7	839 202	1.1
Romania	1 000	0.1	2 317	..	-	-	-	-
Bulgaria	3 600	0.2	3 420	0.1	-	-	-	-
Albania	65 723	4.1	51 898	1.1	-	-	-	-
Slovenia	-	-	-	-	56 784	0.3	155 300	0.2
Croatia	-	-	-	-	73 855	0.4	108 698	0.1
Yugoslavia F. R.	23 790	1.5	25 631	0.5	23 000	0.1	25 750	..
Cyprus	-	-	-	-	138 584	0.7	284 799	0.4
Tunisia	-	-	-	-	2 000	..	10 600	..
United States	-	-	-	-	2 340 710	11.7	10 750 643	14.1
Canada	11 075	0.7	62 762	1.3	1 182 420	5.9	4 457 243	5.8
Dominican Rep.	-	-	-	-	2 000	..	11 800	..
Venezuela	-	-	-	-	75 490	0.4	273 350	0.4
Brazil	-	-	-	-	177 240	0.9	654 156	0.9
Turkey	589 365	36.3	1 791 757	38.4	-	-	-	-
Malaysia	-	-	-	-	72 000	0.4	446 831	0.6
Singapore	-	-	-	-	261 550	1.3	1 631 218	2.1
China	17 690	1.1	21 762	0.5	-	-	-	-
South Korea	-	-	-	-	21 900	0.1	92 396	0.1
Japan	19 700	1.2	118 700	2.5	827 528	4.2	8 168 967	10.7
Taiwan	-	-	-	-	621 784	3.1	3 795 117	5.0
Hong Kong	-	-	-	-	160 500	0.8	966 428	1.3
TOTAL	1 621 817	100.0	4 662 224	100.0	19 930 807	100.0	76 263 161	100.0
European Union	849 754	52.4	2 402 738	51.5	9 297 991	46.7	28 701 890	37.6
Other countries	772 063	47.6	2 259 486	48.5	10 632 816	53.3	47 561 271	62.4

Table 6. Italian chestnut and marron* imports and exports, 1997 (quantity in kilo, value in thousand lire), Source ISTAT. * Data refer to fresh or dried chestnuts and marrons of the "Castanea spp" variety

production as well as quality, guarantee and specificity of the exported product; this refers to the marron and chestnut trade which has already obtained the classification of Protected Geographical Indication of the European Union.

A quality product

Common chestnuts and marrons are generally genuine, natural fruits from grafted or wild trees, or through the aid of an extremely simple, agronomical technique. Due to the environment in which it flourishes (mainly high, hilly land and mountains, at average heights of 400-1 000 meters) and the cultural and agricultural evolution it has gone through, chemical manure or synthesised antiparasitic products are never used in chestnut tree cultivation. A system of non-treatment of the terrain or minimum plant cultivation is adopted for the bread tree, more through necessity than choice. Tractors are seldom used in chestnut groves, the earth is rarely turned and the harvest is generally done by hand. The "largest " agricultural intervention often only consists of the multiannual pruning or annual cleaning of the underbrush; treatment of the earth with manure is only practised on a limited surface area of chestnut groves and treatment with antiparasitics is lesser still.

Hundreds and hundreds of varieties of chestnuts flourish or survive in Italy; one particular group of cultivars are marrons that certainly represent the best Italian and European chestnut production; the following cultivars should be mentioned: the "Marrone di Chiusa Pesio" and the "Marrone della Val Susa" in Piemonte, the "Marrone di Castel del Rio" in Emilia-Romagna, the "Marrone Buono di Marradi" and the "Marron Fiorentino" in Toscana. Each variety is present and rooted in a set territory and represents the interactive results of the plant with the environment and the work of men over the centuries. It is easy to understand how chestnuts are included in recent Community laws on the denomination of origin of agricultural products that award, qualify, guarantee and protect typical alimentary productions obtained in a set environment and connected to history and the work of man in that same territory. When a product is made in one territory only, the European Union (EU) confers the Protected Denomination of Origin (PDO). When the transformation is totally or partially made in a territory other than that of the production, the Protected Geographical Indication (PGI) is granted. The Community recognition certifies the quality, typicality and origin of a product that is distinctive, rich in value-added (origin, history, the work of man. It promotes and develops protected production.

Almost all varieties of Italian chestnuts could obtain European recognition; until today, the PGI has only been granted to three varieties (Table 7): the "Castagna di Montella" (Campania), the "Marrone di Castel del Rio" (Emilia-Romagna) and the "Marrone del Mugello" (Toscana); other 10 varieties are still waiting for the European Union decision. Chestnuts usually represent a product that is included in the Community regulation on biological agriculture in every respect; for this reason, it is possible to obtain the European certification of controlled Biological Product from the official bodies. Integrated Production is another recognition that can be issued by regions. For example, cultivators have already been doing this for some time in Emilia-Romagna, based on compliance with technical and agronomic rules in a specific handbook. Unions and cooperatives can further qualify and better identify the product by specifying the exact place of origin and using typical denominations and suitable, identification brand names. The maximum quality recognition for the European Union should be aimed, that is the PDO for common chestnuts and marrons. This can be accomplished by developing both the production and subsequent transformation activities in the most suitable areas. PGI and PDO should also be aimed at not only for fresh fruit but also for dried chestnuts, chestnut flour and jam.

Since the age of mass consumption is over, the future will be in winning a greater market share as well as the certification and qualification of a highly valued alimentary product, not to mention the many gastronomic and other uses.

Chesnut wood

Chestnut wood has always been in great use. Primitive man used it to make pile-dwellings and canoes. Romans used it for cabinet-making and building. During the Middle Ages, also known as the Age of Wood, chestnut wood was massively used in construction, carpentry, handicrafts, agriculture, heating, etc. During Modern Times, due to its combustibility, chestnut wood also provided for the functioning of iron-works and the production of charcoal; during present-day times, factories that extract tannin have been the main contributors to the marked impoverishment of chestnut groves and copses. The production of wood is divided into:
timber, including saw logs, plywood, split timber, timber hardboard, posts, poles and pillars, other; wood as a combustible, including firewood and wood for coal and charcoal slack. Cut wood basically comes from chestnut copses, cultivated in rotation, according to the requested product (thin, fine, medium and thick posts, etc.). Fell of fruit-bearing chestnut groves is seldom made, as well as of high chestnut groves for cabinet-making and the furniture industry.

Products that were already granted the European Union PGI

Product designation	Production Region
Castagna di Montella	Campania
Marrone di Castel del Rio	Emilia Romagna
Marrone del Mugello	Toscana

Product waiting to be granted the European Union PGI

Product designation	Production Region
Marrone di Segnino	Lazio
Castagna di Vallerano	Lazio
Castagna di Serino	Campania
Marrone Fiorentino	Toscana
Castagna del Trentino	Trentino
Marrone di Cuneo	Piemonte
Marrone della Val di Susa	Piemonte
Castagna Melosa delle Alpi Provenzali	Piemonte

Table 7. Italian chestnuts and marrons with Protected Geographical Indication (PGI), 1998. Source European Union and Italian Regions

The limits of large-sized wood are often represented by the defect of the "ring shake", which hinders its current use in cabinet-making and furniture manufacturing. Italian copses are able to completely satisfy the national demand for posts, poles and pillars but wood for valuable works, quality and well-seasoned products must often be imported from France and other European countries. Chestnut wood is used in the most varied ways, even if its use has declined over the last few years.

All statistical data of chestnut wood are ISTAT source. The cubic meter production per year of wood for working is (Table 8):

650 000 from 1975-1979;
590 000, from 1986-1990;
580 000 from 1991-1995;
only 514 000 in 1996.

The reduction in wood production is due to the abandoning of the mountains and the subsequent decline or interruption in forestry practices in copses as well as the increasing substitution of chestnut posts and poles with other non-wood products such as plastic, iron and light, alloyed metals. The chestnut tree continues to play an important role in the production of timber a sector which is second only to the poplar; in 1996, among broadleaf trees, out of 3.4 million cubic meters of timber, 0.5 million were chestnut and 1.5 million were poplar. 55.2% of the total production of timber is in the Central-north and the remaining 44.8% in the South; posts and poles, both fine (189 000 cubic meters) and thick (115 000 cubic meters) are the most produced item. The main wood-producing regions are Toscana, Lazio, Campania and Calabria which produced 431 000 quintals or 8.4% of national production in 1996. Still in 1996, chestnut wood for fuel was only 329 000 cubic meters out of 4.5 million among broadleaf trees. Fire-wood, coal and charcoal slack mainly come from Lombardia, Toscana, Emilia-Romagna, Calabria and Campania, and represent two-thirds of the Italian production. Both timber and wood are mainly produced in Central-north Italy; only 15.2% is cut in the South. At the present time, posts, polesand split timber are among the various types of timber use which may have interesting new markets. The use of timber to extract tannin has greatly declined, especially since the chemical industry began producing synthetic tannin which has largely substituted natural tannin. If chestnut wood is not well-seasoned, consumers find it less pleasing than oak, although it is used and marketed locally, for stoves rather than fireplaces.

Among wood production from copses, the chestnut holds an important place, but the future of chestnut wood cultivation is in the advantageous use of the various sorts of wood, beginning, as with chestnut

Type	1986-1990	1991-1995	1996
Saw logs[1]	50.0	48.5	40.3
Split timber	6.9	7.2	11.1
Hardboard wood	47.4	33.8	32.6
Poles and post[2]	323.0	328.8	304.4
Other[3]	163.1	162.1	125.9
TOTAL	590.4	580.4	514.3

Table 8. Chestnut wood products by type in Italy, 1986-1996 (quantity in thousand of cubic meters), Source: ISTAT

[1] Plywood is included

[2] Poles, posts, pilings and pillars are included

[3] Includes wood for sleepers, tannin, staves logs and other

fruit, with the role they have played in history, agriculture, building, handicrafts and the daily lives of mountain populations. This entails a re-evaluation of chestnut side activities, such as the handicraft production of small objects (utensils, chests, barrels, vats). The chestnut tree should be used again for making doors and windows, thereby promoting a more massive use in furniture manufacturing. A major use of chestnut wood calls for the sufficient establishment and care of suitable, specialised chestnut groves.

The increasing use of natural products may benefit the use of chestnut timber for fences and recreational installations instead of other types of non-wood materials, since it is particularly water-resistant. The use of chestnut wood for tannin extraction and the production of vegetable coal are also activities to be promoted, thus increasing the value-added based both on history and the use of natural materials as compared to chemical alternatives or minerals that are more dangerous to the health and the environment.

CONCLUSIONS

Data published by ISTAT, having overcome the critical phase of parasitic attacks, after the negative peak in 1983 with a harvest of only 388 000 quintals and chestnut production of 728 000 quintals in 1997, there has been a resumption in production in the 90s. A stability of 711 000 quintals per annum was seen in the 3-year period from 1995-1997 (Table 9).

The total chestnut grove surface has remained almost the same over the last few years at 276 000 hectares in 1997, 209 000 of which are fruit-bearing trees (ISTAT). During the 90s there was a significant resumption in exportations of chestnut both to America (USA and Canada) as well as to Europe (France, Switzerland, Germany, Hungary) and Asia (Japan, Taiwan, Singapore and Hong Kong); in 1997 total exportations reached 200 000 quintals, whereas the trade balance was positive and equal to 183 000 quintals and 71.6 billion lire, respectively (ISTAT). On the average, the alimentary industry absorbs 10-14% of the nut production, while the consumption of fresh fruit, including domestic consumption and exportation, is 65-80% (experts of the chestnut sector). The awarding of the Indication of Geographic Protection, the recognition of Biological Product and that of Integrated Production open new trade markets, especially for the best varieties of fresh fruit for consumption. Italian Wood production in 1996 (ISTAT data) which amounted to 514 000 cubic meters of timber and 329 000 cubic meters of wood for fuel, presents good prospective for split timber and posts, although there was a decline compared to previous years.

A return to the use of natural materials favours the utilisation of chestnut timber, due to its considerable resistance compared to plastics and metals. Like wheat and olives, the chestnut tree represents a true, multifunctional "tree of civilization", which is able to both satisfy the multiple and variable demands of society as well as carry out useful, differing roles according to the place and time. Knowledge of the history, culture and anthropology connected to the chestnut tree represents the basic starting point for approaching the great tree of life with full knowledge of the facts, and understanding its past evolution, actual potential and future development. Therefore, relenting chestnut tree cultivation must begin at a historical-cultural level and base itself on the rediscovery and re-evaluation of the ancient "Chestnut

	Surface of chestnut groves		Nut production	Value	
Year	**total**	**with fruit**	**harvest**	**total**	**average per kilo**
1995	275 476	209 113	719 709	116 033 400	1 611
1996	275 499	209 109	686 538	107 787 900	1 569
1997	275 560	209 102	727 817	134 102 789	1 843
Average 1995 - 1997	275 512	209 108	711 355	119 308 030	1 677

Year	Imports		Exports	
	quantity	**value**	**quantity**	**value**
1995	37 104	8 606 400	198 176	74 954 700
1996	57 440	12 752 100	221 312	72 650 400
1997	16 218	4 662 300	199 308	76 263 300
Average 1995 - 1997	36 921	8 673 600	206 265	74 622 900

Table 9. Outline of fruit-bearing chestnut groves in Italy, 1995-1997, source ISTAT. Surface in hectares, nut production quantity in quintals, value in thousand lire, imports and exports quantity in quintals, imports and exports value in thousand lire.

civilization" which really has very interesting characteristics. It is able to contribute to the development of agricultural-territorial relations, the defence of the hydrologic, geological and forestry landscape, man-environment, food-nourishment, quality-style of life, employment-income and culture-tourism.

In this way, it will be easier to find the new scenarios in which the chestnut tree will play its own role in the XXI century; new markets for chestnut tree cultivation, other than the production of fruit and wood, will be: products of value, dietetics, herb-based goods, cosmetics, pharmaceuticals, cabinet-making, handicrafts, farm holidays, recreation, sports, gastronomy, culture, history, etc. The chestnut tree and chestnuts can further contribute to the improvement of the quality of life, perceptibly affecting the environment, landscape, social-economic activities, hydrological and geological defence and favour the stay of population in the territory. All this can and could be translated into employment, income and contribution to the local stay of the remaining mountain populations. For the chestnut tree to follow its path and still accompany human history, it is indispensable for each person to play his part. A significant, long-range contribution is expected from the State and the Regions, Provinces, Chamber of Commerce and the Mountain Community, as well as the European Union and Professional Associations.

In conclusion, with the aim of concretely favouring chestnut tree development and for each of its products, an increase should be made on the value-added, represented not only by market characteristics, technological and organoleptics, but also by the richness of the history, culture, quality and typicality.

REFERENCES

Adua M., 1989. *Tante castagne per un sorriso.* Tipografia Don Bosco, Roma. 80 p.

Adua M., 1996. Storia, cultura ed antropologia del castagno. In: *II giornata di studio "Discorso sulla castagna", economia-ambiente-cultura nella Valle Roveto.* Canistro, 26 Ottobre 1996. Comune di Canistro, Avezzano. pp. 33-61.

Adua M., 1997. Indagine sulla "Filiera castagno". *In: Documenti ISTAT*, N° 6/1997. 55 p.

Adua M., 1998. *Storia del castagno dal Miocene ai nostri giorni, Il castagno risorsa per le aree interne, Atti del convegno*, Sersale, 5 dicembre 1997. Gal Valle del Crocchio, Catanzaro. pp. 15-25.

Autori vari, 1990. *Castagno 2000 – Atti convegno.* Pianfei, Cuneo 9 Novembre 1990. CCIAA, Cuneo. 276 p.

Bassi R., 1990. *La coltivazione del castagno.* Informatore agrario editore, Verona. 74 p.

Bignami R., Salsotto A., 1983. *La civiltà del castagno.* L'Arciere, Cuneo. 126 p.

Bourgois C., 1992. *Le chataignier: un arbre, un bois.* Idf, Paris. 367 p.

Brenni G. C., 1927. *L'importanza economica del castagno nel Canton Ticino e nell'Italia settentrionale.* Ed. Stucchi, Mendrisio. 148 p.

Bruneton Governatori A., 1991. *Chatagnes e marrons.* Messiador, Paris. 108 p.

Buccianti M., 1994. *Il castagno in provincia di Lucca storie,strutture,economia.* Ed. San Marco, Lucca. 132 p.

Cavalli G., 1982. *La castagna, Studi lunigianesi.* Anno 12-13, pp. 53-80.

Cento A., 1997. *La civiltà del castagno in Lunigiana.Cronaca e storia della Val di Magra*, anno VI°, *pp. 61-88.*

Cherubini G., 1981. *La Civiltà del castagno alla fine del Medio Evo. Archeologia medievale* – anno VIII°, pp. 247-280.

Ente Autonomo Fiera di Verona, 1997. *Guida ai prodotti tipici d'Italia.* Verona. 149 p.

FAO, 1987. Estadisticas agropecuarias mundiales, 1948-1985. Roma.

FAO, 1998. Productions, Yearbook 1997. Roma.

Fenaroli L., 1945. *Il castagno – Trattato di agricoltura.* Reda editore, Roma. 222 p.

Gargiulli G., Tip. Bartoli, 1833. *Della coltivazione dei castagni. Calendario lunese per l'anno 1834.* Fivizzano. 68 p.

ISTAT, 1958. *Sommario di statistiche storiche italiane 1861-1955.* Roma. 233 p.

ISTAT, 1972. *Il Censimento generale della Agricoltura, 1970.* Roma.

ISTAT, 1992. *IV Censimento generale della Agricoltura, 1990.* Roma.

ISTAT, 1980-1994. *Statistiche forestali.* Roma.

ISTAT, 1990-1997. *Statistica del Commercio con l'estero.* Roma.

ISTAT, 1998. *Struttura e produzioni delle aziende agricole anno 1996.* Roma. 190 p.

ISTAT, 1998. *Coltivazioni agricole e foreste anni 1995-1996.* Roma 109 p.

ISTAT, 1998. *Bollettino mensile di statistica. N. 10/1998.* Roma. 195 p.

Le Roy Ladurie E., 1984. *I contadini di Linguadoca.* Laterza, Bari. 412 p.

Livi Bacci M., 1997. *Popolazione e alimentazione.* Il Mulino, Bologna. 173 p.

Malandrino N., 1983. *Il legno di castagno una ricchezza nazionale.* Roma, Assolegno. 30 p.

Meriana G., 1985. *L'ulivo e il castagno.* Sagep editore, Genova. 65 p.

Merz F., 1919. *Il castagno: sua importanza economica, coltivazione e trattamento.* Berna. 71 p.

Montanari M., 1993. *La fame e l'abbondanza, storia dell'alimentazione in Europa.* Laterza, Bari. 262 p.

Paglietta R. e Bounous G., 1979. *Il castagno da frutto.* Edagricole editore, Bologna. 189 p.

Palenzona M., 1995. *Il castagneto da frutto. Tutela e conservazione.* Savona Provincia n. 4/95. Provincia di Savona, Savona. 110 p.

Piccioli L., 1922. *Monografia sul castagno.* Ed. Spinelli, Firenze. 178 p.

Pitte J.R., 1986. *Terres de castanide.* Fayard, Paris. 479 p.

Polacco F. (a cura di), 1938. *Indagine sulla coltivazione del castagno da frutto in Italia. Bollettino mensile di statistica agraria e forestale.* aprile 1938. Roma, Istat - pp. 340-359.

Quaini M., 1979. *Per la storia del paesaggio agrario in Liguria.* Cciaa, Savona. 120 p.

Savio F. & Pronzati V., 1996. *E Rostie.* Il golfo, Genova. 112 p.

Silvestri F., 1992. *Civiltà del castagno in Montagna Pistoiese.* Pugliese Editore, Firenze. 236 p.

Slicher Van Bath B. H., 1970. *Storia agraria dell'Europa Occidentale.* Einaudi, Torino. 212 p.

Tani A. & Canciani L., 1993. *Il recupero produttivo dei castagneti da frutto.* Arf Emilia-Romagna, Bologna. 45 p.

Turchetti T., Gemignani P. & Cappelletti A., 1995. *Le principali avversità del castagno e la difesa biologica contro il cancro della corteccia.* Comunità Montana del Monte Amiata-Cnr, Castel del Piano. 40 p.

Valli D., 1991. *I metati nel carpinetano.* Edizioni Tecnograf, Reggio Emilia. 85 p.

Vigiani D., 1943. *La coltivazione del castagno.* Dante Alighieri editore, Città di Castello. 132 p.

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Biomass, litterfall and productivity in chestnut coppices of various age at Monte Amiata (Central Italy)

Biomasse, production de litière et productivité au sein des taillis de châtaigniers d'ages différents sur le Mont Amiata (Italie Centrale)

Andrea CUTINI

Istituto Sperimentale per la Selvicoltura, Viale S. Margherita 80, I-52100 Arezzo, Italy.
Tel. ++39 0575 353021, Fax ++39 0575 353490, e-mail: issar@ats.it

ABSTRACT

The effects of longer rotation periods and thinning practice on bio-ecological processes and indexes such as biomass, litterfall, leaf area index (LAI) and productivity have been analysed in thinned and unthinned permanent plots in a chestnut (*Castanea sativa* Mill.) coppices under traditional system (11 yrs.) and under long rotation (35 yrs.). Plots were established in a large chestnut vegetation area (Monte Amiata - Tuscany) in order to evaluate the sustainability of management options alternative to the traditional intensive exploitation. Both traditional and long rotation coppices showed high productivity (aboveground biomass 108.4 Mg ha^{-1} and 239.5 Mg ha^{-1} respectively), high LAI (6.5 m^2 m^{-2} and 5.1 m^2 m^{-2}) and annual litterfall values (6.28 Mg ha^{-1} and 5.60 Mg ha^{-1}). The applied thinning (one third of basal area removal) affected stocking, stand growth and efficiency. Chestnut coppices, namely those under traditional rotation, showed however a good aptitude to re-build an homogeneous canopy cover a few years after thinning occurrence. Results concur to positively evaluate, not only from an economic point of view but also from a bio-ecological one, the adoption of management systems based upon long rotation period and on a less intensive exploitation of chestnut coppice.

Key-words : *Castanea sativa*, forest litter, leaf area index, silvicultural systems, thinning

RESUME

Les effets de différents types d'aménagement sur le fonctionnement des taillis de châtaigner (*Castanea sativa* Mill.) ont été analysés sur deux types de formation largement présentes sur le Monte Amiata (Italie centrale) : un taillis à courte rotation âgé de 11 ans et un taillis à longue rotation de 35 ans. Dans les deux cas, des observations ont été éffectuées sur la biomasse épigée totale, la production de litière, l'indice de surface foliaire (LAI) sur des aires permanentes, l'une éclaircie et l'autre non traitée (contrôle). Les résultats ont montré la bonne productivité aussi bien du jeune taillis que du taillis âgé (biomasse épigée de 108.4 Mg ha^{-1} et 239.5 Mg ha^{-1}), de fortes valeurs du LAI (6.5 m^2 m^{-2} et 5.1 m^2 m^{-2}) et de la production annuelle de litière (6.28 Mg ha^{-1} et 5.60 Mg ha^{-1}). Malgré l'intensité de l'éclaircie (à peu près un tiers de la surface terrière prélevée), les peuplements examinés ont montré une forte production et récupération du couvert forestier. Les résultats justifient le choix du traitement appliqué, aussi bien du point de vue économique que bioécologique et fonctionnel et plus généralement l'adoption de modèles d'aménagement basés sur une exploitation moins intensive du taillis de châtaigner, par rapport à la gestion traditionelle.

Mots-clés : *Castanea sativa*, production de litière, indice foliaire, aménagement, éclaircie

RIASSUNTO

Sono stati analizzati gli effetti di diverse forme di gestione sulla funzionalità di cedui di castagno (*Castanea sativa* Mill.) prendendo in esame due tipologie strutturali ampiamente diffuse sul Monte Amiata (Italia centrale): un ceduo a turno breve di 11 anni e un ceduo a turno lungo di 35 anni d'età. In entrambe le tipologie e all'interno di aree di saggio permanenti, di cui una diradata e l'altra non trattata (controllo), sono state condotte osservazioni su biomassa epigea totale, produzione di lettiera, indice di area fogliare (LAI) e calcolati alcuni indicatori della funzionalità del popolamento. I risultati hanno messo in evidenza l'elevata produttività sia del ceduo a turno breve che di quello a turno lungo (biomassa epigea rispettivamente di 108.4 Mg ha^{-1} e 239.5 Mg ha^{-1}) e gli elevati valori di LAI (6.5 m^2 m^{-2} e 5.1 m^2 m^{-2}) e di produzione annuale di lettiera (6.28 Mg ha^{-1} a^{-1} e 5.60 Mg ha^{-1} a^{-1}). Nonostante l'intensità del diradamento (circa un terzo dell'area basimetrica rimossa) i soprassuoli studiati hano dimostrato una notevole capacità di risposta produttiva e di ripristino della copertura forestale. I risultati sembrano avvalorare, non solo sotto il profilo economico ma anche bio-ecologico e funzionale, la scelta del trattamento applicato e più in generale l'adozione di modelli di gestione informati a uno sfruttamento meno intensivo del ceduo di castagno rispetto a quelli tradizionali.

Parole-chiave : *Castanea sativa*, lettiera, indice di area fogliare, trattamento selcicolturale, diradamento

INTRODUCTION

Chestnut (*Castanea sativa* Miller) is still an important resource for many mountainous areas of Italy. The major part of chestnut woods is made up of simple coppices, generally managed under short rotation period. Although the abandonment is progressively concerning large areas, especially the less accessible and favourable, coppicing is still a diffuse practice in some regions, namely of central and southern Italy.

The large presence of both abandoned and traditionally exploited coppice stands on one hand, and the reclamation issued from the new equilibria between the respect of natural ecological processes and the needs of human socio-economical systems on the other, set a lot of questions about the management of chestnut woods. It has been demonstrated that both intensive exploitation and complete abandonment produce dysfunction at different levels such as bio-geochemical cycles, biological diversity and landscape patterns (Romane & Houssard, 1995). Thus, one of the main question is whether, how and where it is possible to pursue the double objective both of a progressive increase of functional status of chestnut stands, strongly reduced by a long-time overexploitation, and of continuing their exploitation. The latter, of course, should be pursued taking into duly account concerns such as on natural and forest resources management issued from Rio Declaration (Anonymous, 1992; Lust, 1995).

Recently, besides the traditional coppice system with short rotation periods, new management systems for chestnut coppices, mainly based on longer rotation periods or on conversion into high forest, have been proposed for delimited areas characterized by good site conditions (Amorini *et al.*, 1998). In order of preliminary evaluating the suitability from an ecological point of view of such management, tree above-ground biomass, litter production, leaf area index (LAI), and productivity were measured and their pattern compared in thinned and unthinned stands both under traditional system and long rotation. Such variables have been taken into account not only as biological indexes, able to describe structural properties and «quality» of a forest ecosystem, but as indicators useful to evaluate its ecological and functional status and to assess responses to different management options as well (Romane, 1995). Indeed, they are key elements in analysing forest ecosystem's productivity (Bray & Gorham, 1964) and functioning being involved, besides others, in many important processes such as light and rain interception (Hewelett, 1982; Running *et al.*, 1989), evapotranspiration (Grier & Running, 1977), stand structure (Waring, 1983), and biogeochemical cycles (Rapp, 1969). On the other hand, they are strongly affected by silvicultural practice, which modify, according to different goals, spatial distribution of trees, aboveground biomass and canopy cover.

MATERIAL AND METHODS

Monte Amiata (1 738 m a.s.l., south-western Tuscany), is an important chestnut vegetation area where, in the past, woods were traditionally coppiced every 8-10 years to obtain poles and posts for mining activity. The study area is located at S. Lorenzo, near Abbadia S. Salvadore (Siena, 42°53' N, 11° 40' W) on the eastern slope of Monte Amiata at 850 m a.s.l., south exposure and gentle slope. The climate is mountain-Mediterranean: mean annual rainfall and temperature are 1 547 mm (maximum concentration in autumn and winter) and 10.0°C (hottest month 18.5°C, coldest month 1.8°C); the dry period is 18 days only (Amorini & Manetti, 1997). According to Thornthwaite (1948) the climatic type is A B'_1 r b'_4. Chestnut stands, generally pure, are spread between 850 and 1 100 m a.s.l. on brown soils and andosols. According to Schmid (1963), the area is included in the *Quercus-Tilia-Acer* vegetation belt.

At present, the normal rotation period is 18-24 years, even though coppices aged over 30 are quite frequent. Thus, the study considered stands managed under a rotation period of 18 (traditional system, TS) and stands managed under long rotation (LR), aged respectively 11 and 35 at the beginning of study. Stands under long rotation underwent a light thinning at the age of 17.

Two 1 500 m^2 and two 5 000 m^2 permanent plots were established in coppice under traditional system

(1993) and in coppice under long rotation (1994) respectively. A complete mensurational inventory concerned each plot (Amorini *et al.*, 1997). Each tree was labelled and numbered and its diameter at breast (1.30m) height measured. Tree height measurements were carried out on a sample made up by 50% of total tree number, chosen according to size and social rank. The same measurements were repeated two years later in order to calculate trees and stand growth and increments. Afterwards, both in the coppice under normal and long rotation, one plot was subjected to low heavy (one third of basal area removal) thinning, whereas no silvicultural operations was carried out in the other plot (control).

Stand volume and tree aboveground biomass (total, stem and branches) were estimated using data from plot inventory and allometric equations (Amorini & Manetti, 1997; Cutini & Fabbio, 1998) elaborated respectively on the basis of 231 and 81 sample trees of different social rank (Table 1).

Data have been processed according the model

$$y = a + b D^2 H$$

with y = dry weight (kg) or volume (dm^3) of each tree, D = diameter (cm) of the tree at breast height (1.30 m), H = height of the tree (m), a and b regression coefficients. For estimating volume of coppice under traditional rotation a

$$y = aD + bD^2 + cD^2H + dDH$$

model was adopted.

Nine to twelve (depending on plot area and stand structure homogeneity) 0.25 m^2 litter-traps were positioned systematically in each plot to estimate the total annual litter production (dry biomass) and its main components (leaves, woody parts, catkins, and fruits). Since 1993 and 1994 for TS and LR respectively to 1997, litter was collected every fifteen days during fall and once a month during the other seasons, sorted in the main components and then dried in a forced air stove at 85°C ±2 till constant dry weight. LAI (one-sided projected area) was estimated using the specific leaf area (SLA, leaf area for 1g of leaf dry weight) calculated each year on a leaves sub-sample chosen systematically. At each litter collection, all the undamaged leaves, collected from a trap at rotation, were sampled up to a total of 200 leaves for each plot. Leaves were measured before drying with a leaf area meter (Delta T Devices, Burwell, UK) and weighted after drying for 24 hours at 85°C±2. Mean SLA value was used to estimate LAI from leaf litter component. LAI values were corrected using a shrinkage coefficient, previously calculated on a sub-sample of green leaves, in order to avoid underestimates due to a SLA calculated from partly shrunk fallen leaves (Vanseveren, 1969). Data collected were used to calculate indexes commonly used in growth analysis (Evans, 1972; Chiarello *et al.*, 1989) such as mean annual increment and leaf weight ratio (LWR, ratio of leaf biomass to total standing aboveground biomass), and to compare the effects of the different management system on stand functional status. In each typology a t-test for paired samples was used to verify the significance of difference between the means of litter and leaf-litter production of control and thinned plot.

RESULTS

The studied coppices are pure chestnut stands characterised by one storeyed canopy layer and homogeneous cover. Long rotation stand showed a less regularly shaped cover due to natural selective process and to silvicultural practices. The analysis of stand characteristics such as basal area, dominant height, stand volume and aboveground biomass, showed, besides the similarity of the experimental plots in each typology, the good productivity and the sustained growth of the coppice stands both under traditional system and long rotation (Table 2 and Table 3). This aspect is much more evident by comparing performances of Monte Amiata stands with data on standing biomass from other chestnut coppice stands located in Italy (La Marca, 1984; Leonardi *et al.*, 1996a), France (Bédéneau, 1988; Ranger *et al.*, 1990) and Spain (Leonardi *et al.*, 1996b) (Figure 1).

Mean annual volume and biomass increment were respectively 17.8 m^3 ha^{-1} and 10.0 Mg ha^{-1} in the coppice under traditional system and 12.8 m^3 ha^{-1} and 6.9 Mg ha^{-1} in the coppice under long rotation. Branch biomass in coppice under long rotation was twice the value of the coppice under traditional system, although the ratio to total standing biomass was practically the same.

Component	range	number of observations	coefficients	R^2	SEE
TS - stem volume	3<D<19 cm; 6<H<18 m	32	a=-0.0589 b=-0.1046 c=0.0408 d=0.0657	0,99	3,5
LR - stem volume	8<D<34 cm; 12<H<26 m	231	a=4.6092 b=0.0368	0,95	3,9
TS&LR - tree biomass	3<D<34 cm; 6<H<26 m	81	a=2.2607 b=0.0197	0,99	13,64
TS&LR - stem biomass	3<D<34 cm; 6<H<26 m	81	a=1.8898 b=0.0177	0,99	13,49
LR - coarse branches biom.	8<D<34 cm; 12<H<26 m	49	a=-5.1140 b=0.0014	0,51	8,24
TS&LR - fine branches biom.	8<D<34 cm; 12<H<26 m	49	a=0.9902 b=0.0008	0,66	3,61

D: diameter at breast height (1.30m);
H: total tree height; coarse and fine branches, branches with a maximum diameter > and < 3cm

Table 1 Regression analysis and forecast models of tree volume and above-ground biomass (total and main components) for Monte Amiata chestnut coppices under traditional system (TS) and under long rotation (LR). See text for data source and details.

Data on annual litter production and LAI were considerably high, in accordance with those on biomass and mean annual increment (Table 4). Coppice under traditional system showed LAI and litter production higher than coppice under long rotation. The importance of leaf biomass decreases with age: leaf-litter was 64.4% and 56.4% in the coppice under traditional system and long rotation, respectively. This result was consistent with the values of the leaf weight ratio (LWR) which decreased from 3.0% (traditional system) to 1.2% (long rotation).

The intensity of applied thinning was practically the same for coppice under traditional system and coppice under long rotation. The amount of removed trees, much more consistent in the coppice under traditional system due to the younger age, induced marked changes in stand structure and stocking both in normal (Table 2) and long rotation (Table 3) coppice stands. Although stocking was higher in the control plot, growth rates were similar. In coppice under traditional system, mean annual increments of stand volume (volume removed by thinning included) were 18.4 m^3 ha^{-1} and 17.9 m^3 ha^{-1} in control and thinned plot, respectively. The ratio thinned to control plot growing stock increased from 70%, immediately after thinning, up to 75% of the control one at the end of study. In coppice under long rotation, mean annual increments of stand volume were 12.9 m^3 ha^{-1} and 12.6 m^3 ha^{-1} in control and thinned plot, respectively, with the ratio thinned to control plot growing stock practically the same.

Thinning affected canopy characteristics too, as highlighted by the lower values of litter (Figure 2) and leaf-litter (Figure 3) production the year immediately after cutting occurrence. Differences between control and thinned plot were more evident in the coppice under traditional system, especially in litter production values.

In coppice under long rotation the difference between litter production in control and thinned plot was statistically significant ($p<0.05$). On the other hand, differences were not statistically significant for leaf-litter production. Thinned and control plot showed practically the same values in coppice under long rotation, whilst, in coppice under traditional system, thinned plot had higher ones (Figure 3). Changes in amount of leaf biomass and tree above ground biomass at stand level due to age and thinning, induced remarkable differences in leaf weight ratio. In coppice under traditional system it was 3.0% and 4.3% in control and thinned plot, respectively, whilst it was 1.2% and 1.7% in coppice under long rotation.

	num. of stems	basal area	mean dbh	top height	volume	biomass		
						stem	branches	total
	n ha^{-1}	m^{2} ha^{-1}	cm	m	m^{3} ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}
1st inventory								
control plot	3493	30,45	9,7	14,15	194,0	97,2	11,5	108,8
thinned plot								
before thin.	3547	29,74	9,2	13,95	192,1	96,6	11,5	108,0
after thin.	1487	20,56	11,2	14,04	138,6	68,5	8,0	76,5
% removal	58,1	30,9			27,8	29,0	30,4	29,2
2nd inventory								
control plot	3313	36,69	10,9	14,46	239,0	118,8	14,0	132,8
thinned plot	1480	26,11	12,8	14,48	179,0	88,1	10,2	98,3

Table 2. Stand characteristics and aboveground biomass of control and thinned plot in chestnut coppices under traditional system

	num. of stems	basal area	mean dbh	top height	volume	biomass			
						stem	br. >3*	br. <3*	total
	n ha^{-1}	m^{2} ha^{-1}	cm	m	m^{3}ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}
1st inventory									
control plot	1215	46,90	22,2	20,93	447,5	215,0	13,7	10,8	239,5
thinned plot									
before thin.	948	46,49	25,0	21,00	447,2	215,0	13,9	10,6	239,4
after thin.	508	30,86	28,1	21,00	300,0	144,3	9,4	7,0	160,6
% removal	*46,4*	*33,6*			*32,9*				*32,9*
2nd inventory									
control plot	1215	47,57	22,3	20,94	465,0	227,5	14,5	11,4	253,4
thinned plot	508	31,48	28,1	21,01	307,6	147,9	9,7	7,2	164,7

* br.>3 and br.<3 = branches with a diameter > and < 3cm, respectively

Table 3. Stand characteristics and aboveground biomass of control and thinned plot in chestnut coppices under long rotation

	leaves Mg ha^{-1}	woody parts Mg ha^{-1}	catkins Mg ha^{-1}	fruits Mg ha^{-1}	total Mg ha^{-1}	LAI m^{2} m-^{2}
control plot						
trad. system	4,0±0,3	0,97±0,71	0,46±0,26	0,81±1,02	6,28±0,46	6,5±0,2
long rotation	3,2±0,4	0,97±0,68	0,65±0,33	0,82±0,33	5,60±1,39	5,1±0,7
thinned plot						
trad. system	4,19±1,04	0,62±0,49	0,55±0,27	0,63±0,44	6,00±1,58	6,7±1,7
long rotation	2,79±0,30	0,68±0,48	0,53±0,30	0,54±0,29	4,54±1,08	4,5±0,5

Table 4. Mean ± standard deviation of litter production and leaf area index (LAI) in chestnut coppice stands of Monte Amiata under normal and long rotation period

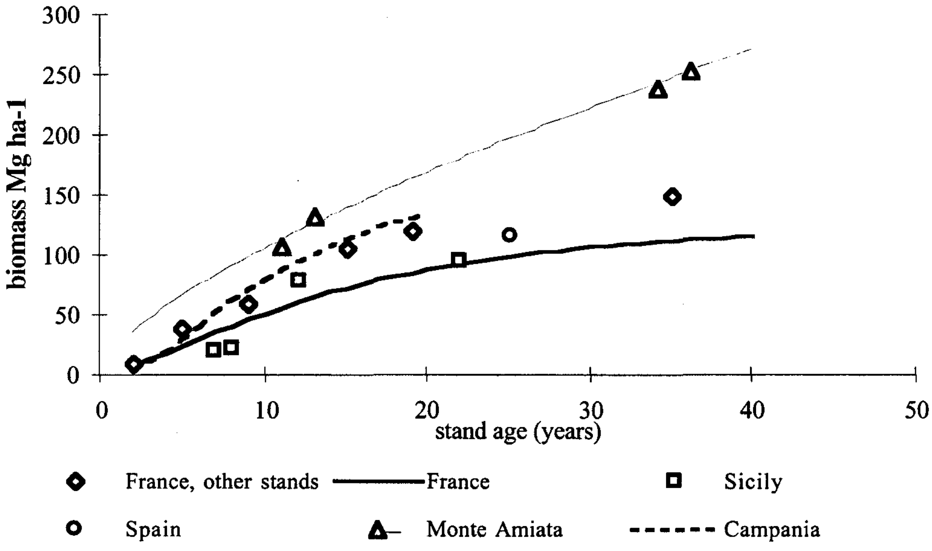

Figure 1. Aboveground stand biomass vs. stand age in chestnut coppices. Comparison among data from different sites (from Leonardi *et al.* 1996, modified). See text for data source

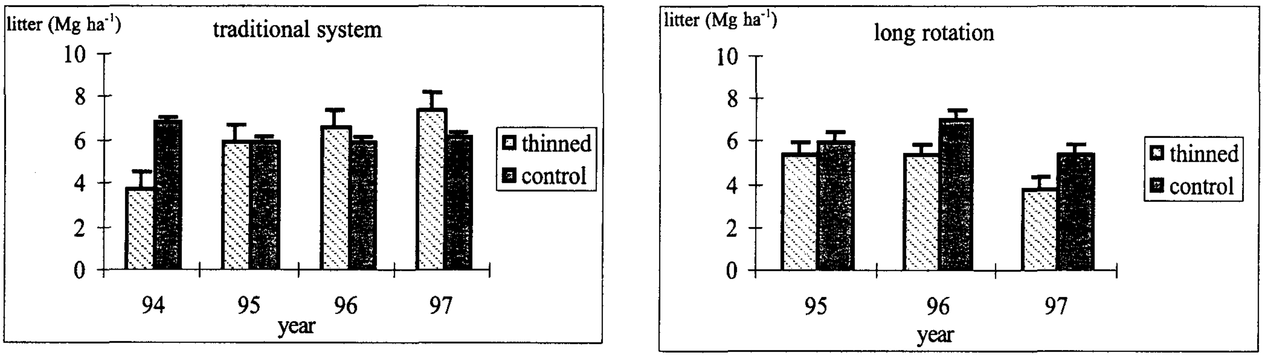

Figure 2. Means (±1se) of yearly litter production in thinned and control plot of chestnut coppices under different management systems.

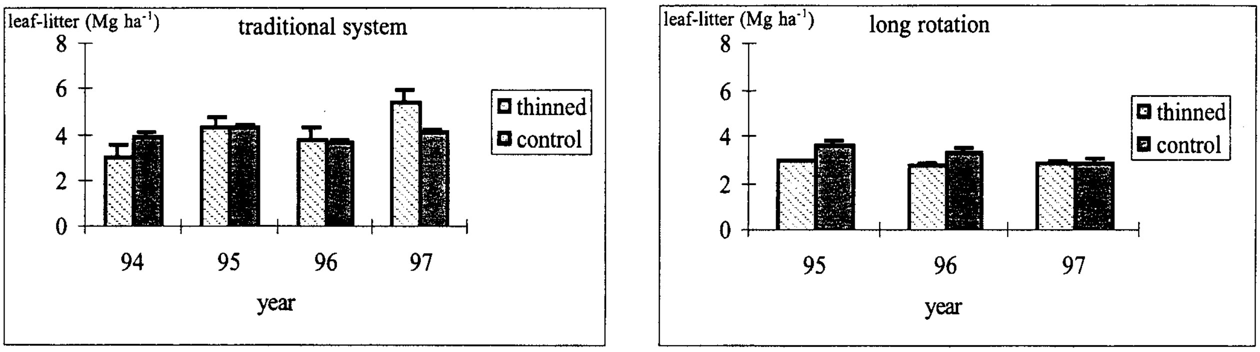

Figure 3. Means (± 1se) of leaf-litter production in thinned and control plot of chestnut coppices under different management systems

DISCUSSION

The investigated chestnut coppice stands are characterised by high productivity values beyond that of other chestnut coppice stands in southern Europe. This is due both to climatic conditions - importance of annual rainfall and summer dry period practically inexistent - and to soil properties and origin (acid and deep soils from volcanic parent material).

LAI and litter production values are consistent with productivity. Both coppices under traditional system and long rotation show mean annual litter production and LAI over 5 Mg ha^{-1} and 5 m^2 m^2, which are values similar to those reported for other chestnut coppice stands characterised by good productivity. More in detail, coppice under traditional system show values of litter production and LAI over 6 Mg ha^{-1} and 6 m^2 m^2, respectively, which are high in comparison with the current results in literature (Gallardo *et al.*, 1995; Leonardi, 1996a).

Such results confirm chestnut as a fast growing species able to maintain high growth rate long time after the traditional rotation periods, that in the past were fixed often only on the basis of physiocratic criteria. Growth rate deserves to be emphasised because good productivity is one of the main requisite in order to evaluate the opportunity of adopting management systems based on long rotation periods (Amorini *et al.*, 1998).,

As regards to the effects of a management based on longer rotation period on functional status of chestnut coppice stands, growth analysis shows that rotation lengthening doesn't imply an immediate and considerable decreasing of growth rate. Even decreasing with stand age, it maintains considerable values for a long time after the present rotation periods. In stand under long rotation, despite the previous thinning, mean annual increment of stand volume and biomass were higher than 12 m^3 ha^{-1} and 6 Mg ha^{-1}, respectively. These figures correspond to 70% of mean annual increment measured in the stands under traditional system, which can be reasonably classified as stands close to the stage of maximum productivity.

In addition to the observation on productivity, some further positive concerns, about the lengthening of rotation period, can be pointed out from changes in the ratio live-to-dead biomass. Decreases of leaf-litter component and leaf weight ratio from coppice under traditional system to coppice under long rotation, account for a rapid and positive evolution of stand structure (Kira & Shidei, 1967) after the traditional exploitation age.

Another aspect, to be duly considered, is the increase of branch biomass in the coppice under long rotation. In addition to the advantages issued from a less frequent clearfelling, a major branch biomass can effectively concur to avoid a progressive loss of fertility. If not exploited at the end of the rotation period, as it usually happens, branch biomass, together with litter, represent the main source of nutrients return to the soil, with a positive influence on biogeochemical cycles.

As regards to thinnings, the short observation period allows only preliminary evaluations which need to be duly analysed with further investigations. Although the applied thinning affected considerably stand structure and canopy cover, changes in LAI and litter production after thinning seem to account for a rapid and positive response to silvicultural practices. On the other hand, the observed increases of leaf biomass to total standing aboveground biomass ratio (LWR) and leaf-litter in thinned plots account for a positive influence of thinning on stand efficiency and functionality (Bjorkman, 1983). The response was more evident in coppice under traditional system, probably as a consequence of age and stand structure.

Although the need of further investigations for providing a more accurate analysis of the effects due to the adoption of new management systems on ecological and functional status of chestnut coppice stands is evident, results issued from this study account for a positive evaluation of them. Both lengthening of rotation period and conversion into high forest meet positive relapses from a bioecological point of view, such as the maintenance of a high stand productivity anyway, the improvement of stand structure and functionality and a low impact on ecosystem equilibria. It seems so possible that these management systems can address the reclamation for a more suitable equilibrium between the exploitation of a natural resource as chestnut coppice stands and the local communities and socio-economical needs as a whole.

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REFERENCES

Amorini E., Bruschini S. & Manetti M.C., 1998. La sostenibilità della produzione legnosa di qualità dal ceduo di castagno: modello alternativo al ceduo a turno breve. *In:* Comunità montana delle Prealpi Trevigiane (ed), *Proceedings of the «Convegno nazionale sul castagno»*, Cison di Valmarino (Tv), 23-25 Ottobre 1997: 217-230.

Amorini, E., Cutini, A., Fabbio, G. & Manetti, M.C., 1997. Analysis of different silvicultural systems in chestnut coppices. Criteria to define a sustainable management. *In*: Romane F. (ed.) "*Dynamics and function of chestnut forest ecosystems in Mediterranean Europe. A biological approach for a sustainable development" (CAST)*, cont. EV5V-CT94-0427. Final report of the UE DG XII project (unpublished).

Amorini E. & Manetti M.C., 1997. Le «fustaie da legno» di castagno del Monte Amiata. *Ann. Ist. Sper. Selv.*, Arezzo, 28 : 53-61.

Anonymous, 1992. *United Nations Conference on Environment and Development (UNCED): Agenda 21, Rio declaration, Forest Principles.* U.N. publications, Geneva.

Bédéneau M., 1988. Croissance des taillis de châtaignier en France : premiers résultats. *Ann. Sci. For.*, 45: 265-274.

Bray J.R. & Gorham E., 1964. Litter production in forest of the world. *Adv. Ecol. Res.* 2 : 101-157

Bjorkman O., 1983. Responses to different quantum flux densities. *In*: Lange O.L. *et al.* (eds) , *Physiological plant ecology*, Encyclopedy of Plant Physiology, vol. 12D, Springer Verlag, Berlin.

Chiarello N.R., Mooney H.A. & Williams K., 1989. Growth, carbon allocation and cost of plant tissue. *In*: Pearcy R.W. *et al.* (eds), *Plant physiological ecology.* Chapman and Hall, London: 327-365.

Cutini A. & Fabbio G., 1998. Impatto della gestione selvicolturale sulla funzionalità di cedui di castagno. *In:* Comunità montana delle Prealpi Trevigiane (ed), *Proceedings of the «Convegno nazionale sul castagno»*, Cison di Valmarino (Tv), 23-25 Ottobre 1997: 245-257.

Evans G.C., 1972. *The quantitative analysis of plant growth,* Blackwell Scientific Publications, Oxford.

Gallardo-Lancho J.F., Egido J.A., Gonzales M.I., Rico M., Santa Regina I., Martin H., Menendez I., Moreno G., Schneider K., Turrion B. & Saavedra J., 1995. Nutrient cycles in chestnut ecosystem of Sierra de Gata (Western-Central Spain). *In*: Romane F. (ed.), *Sustainability of Mediterranean ecosystems. Case study of the chestnut forest.* European Commission, Brussels, Ecosystem research report n. 19: 23-44.

Grier C.C. & Running S.W., 1977. Leaf-area of mature northwestern coniferous forests: relation to site water balance. *Ecology*, 58: 893-899.

Hewelett J.D., 1982. *Principles of forest hydrology.* University of Georgia Press.

Kira T. & Shidei, T., 1967. Primary production and turnover of organic matter in different forest ecosystems of the western Pacific. *Jpn. J. Ecol.*, 17 : 70-87.

La Marca O., 1984. *Ricerche sulla biomassa dei cedui di castagno (Castanea sativa Mill.) della valle dell'Irno (Av e Sa).* Università degli Studi, Istituto di Assestamento Forestale, Firenze. Ricerche sperimentali di dendrometria e di auxometria, VIII, 63-79.

Leonardi S., Rapp M., Failla M. & Guarnaccia D. 1996a. Biomasse, productivité et transferts de matière organique dans une séquence altitudinale de peuplements de *Castanea sativa* Mill. de l'Etna. *Ann. Sci. For.*, 53: 1031-1048.

Leonardi S., Santa Regina I., Rapp M., Gallego H.A. & Rico M., 1996b. Biomass, litterfall and nutrient content in Castanea sativa coppice stands of southern Europe. *Ann. Sci. For.*, 53: 1071-1081.

Lust N., 1995. Elements of sustainable forest management. *Silva Gandavensis*, 60: 1-20.

Ranger J., Félix C., Bouchon J., Nys C. & Ravart M., 1990. Dynamique d'incorporation du carbone et des éléments nutritifs dans un taillis simple de châtaignier (*Castanea sativa* Miller). *Ann. Sci. For.*, 47: 413-433.

Rapp M., 1969. Production de litière et apport au sol d'éléments minéraux dans deux écosystèmes méditerranéens. La forêt de *Quercus ilex* L. et la garrigue de *Quercus coccifera* L. *Oecol. Plant.*, 4: 377-410.

Romane F., 1995. Introduction and objectives *In*: Romane F. (ed.), *Sustainability of Mediterranean ecosystems. Case study of the chestnut forest.* European Commission, Brussels, Ecosystem research report n. 19: 1-5.

Romane F. & Houssard C., 1995. The sustainability of chestnut ecosystem. *In*: Romane F. (ed.), *Sustainability of Mediterranean ecosystems. Case study of the chestnut forest.* European Commission, Brussels, Ecosystem research report n. 19: 173-176.

Running S.W., Ramakrishna R.N., Peterson D.L., Band L.E., Potts D.F., Pierce L.L. & Spanner M.A., 1989. Mapping regional forest evapotranspiration and photosynthesis by coupling satellite data with ecosystem simulation. *Ecology* 70, : 1090-1101.

Schmid E., 1963. Fondamenti della distribuzione naturale della vegetazione mediterranea. *Arch. Bot. e Biogeog. Ital.*, 39: 1-39.

Vanseveren J.P., 1969. Recherches sur l'écosystème forêt. Série B: La chênaie mélangée calcicole de Virelles-Blaimont. Contribution n. 30: L'index foliaire et sa mesure par photoplanimétrie. *Bull. Soc. Roy. Bot. Belg.,* 102: 373-385.

Thornthwaite C.V., 1948. An approach toward a natural classification of climate. *Geogr. Rew.*, 38: 55-94.

Waring R.H., 1983. Estimating forest growth and efficiency in relation to canopy leaf area. *Adv. Ecol. Res.*, 13 327-354.

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The Ecology of bryophytes in the chestnut forests of Mount Etna (Sicily, Italy)

Ecologie des bryophytes des châtaigneraies de l'Etna (Sicile, Italie)

Maria PRIVITERA & Marta PUGLISI

Dipartimento di Botanica, Università di Catania, I – 95125 Catania, Italy

ABSTRACT

A floristic and ecological survey of the epiphytic bryophytes of the chestnut woods (*Castanea sativa* Mill.) of Mt. Etna has been conducted. An analysis of ecological indices has revealed a bryophyte flora which is, overall, acidophilous, xerophilous, and increasingly thermophilous along a decreasing altitudinal gradient. Indices of biodiversity increase with altitude, because air pollution is lower at higher altitudes, despite conspicuous emissions of phytotoxic gases from the volcano.

Key-words: bryophytes, epiphytes, chestnut woods, *Castanea sativa*, Mt. Etna, ecological indices, biodiversity.

RESUME

Une étude floristique et écologique des bryophytes épiphytes de boisements de châtaigniers (*Castanea sativa* Mill.) de l'Etna a été effectuée. L'analyse des indices écologiques a mis en évidence, en général, une flore bryophytique acidophile, xérophile et par ailleurs, plus thermophile selon un gradient décroissant d'altitude. L'indice de biodiversité est plus élevé dans les plus hautes stations, moins exposées à la pollution atmosphérique, malgré les émissions importantes de gaz phytotoxiques dégagés par le volcan.

Mots-clés: bryophytes, épiphytes, châtaigneraies, *Castanea sativa*, Etna, indices écologiques, biodiversité.

INTRODUCTION

In this paper we report the results of a study of the epiphytic bryophyte flora of the chestnut woods of Mt. Etna, which are located mostly on its eastern and southern slopes between 600 m and 1 600 m in altitude. These woodland formations have been investigated previously from a vegetational point of view (Ronsisvalle & Signorello, 1979) and, more recently, through ecological surveys dealing with productivity, living matter flow, rainfall interception, and nutrient content (Leonardi *et al.*, 1993, 1996). No data about the epiphytic bryophytes of these chestnut woods, either floristic or vegetational, have previously been reported.

On Mt. Etna *Castanea sativa* Mill. behaves as a sub-montane or montane mesophilous species preferring deep and mature soil; it usually forms monospecific woods, but is sometimes mixed together with *Quercus dalechampii* Ten., *Quercus congesta* Presl and *Pinus laricio* Poiret.

Chestnut finds its optimum habitat between 1 000 m and 1 400 m. However, it extends to lower altitudes in the foothills, where woodland formations characterised by *Quercus ilex* L. occur. On the south-western slopes, it spreads over the upper montane region where it reaches its highest altitude.

As is well known, bryophyte flora vary both quantitatively and qualitatively in relation to various environmental parameters (Richards, 1932; Smith, 1982). Different environmental conditions are associated with different degrees of both biodiversity and floristic abundance in the composition of the flora. In the case of epiphytes, biodiversity may also provide a mechanism for the assessment of air pollution in a given area (Badin & Nimis, 1996; Giordano *et al.*, 1999).

We have therefore conducted an ecological survey of the epiphytic bryophytes of the chestnut woods of Mt. Etna. Our objective was to gather further information about air quality and the environment, so that improved management plans might be prepared for these woodland formations.

MATERIALS AND METHODS

Environmental overview

We have investigated 13 stations located on different slopes at various altitudes (Figure 1, Table 1). These stands are present on volcanic substrata formed of andesitic lavas and basalts. pH values have been reported from soil (20 cm deep) at a number of stations (Fossa La Nave: 6.7; Balilla: 6.4; Piano Porcheria: 6.6; Mt. Crisimo: 6.5) (Leonardi *et al.*, 1996).

In addition, rainfall, throughfall, stem flow and interception values (Table 2) and nutrient input values (Table 3) have been reported for the stations at Piano Porcheria and Fossa La Nave (Leonardi *et al.*, 1993).

Stations	Localisation	Altitude	Slope	Longitude	Latitude
Station 1	Mt Crisimo	1 200-1 300 m	NE	E 15°05'28"	N 37°47'45"
Station 2	Piano Porcheria	1 000 m	NE	E 15°06'35"	N 37°40'05"
Station 3	Contrada Giarrita	1 400-1 450 m	E	E 15°04'50"	N 37°46'05"
Station 4	Puntalazzo	600 m	E	E 15°08'18"	N 37°45'15"
Station 5	S. Alfio	700 m	E	E 15°07'40"	N 37°44'55"
Station 6	Road S. alfio-Milo	780 m	E	E 15°07'10"	N 37°44'35"
Station 7	Fornazzo	830-850 m	E	E 15°07'39"	N 37°44'25"
Station 8	Contrada Cassone	1 200 m	E	E 15°04'51"	N 37°42'15"
Station 9	Piano del Vescovo	1 200 m	SE	E 15°05'30"	N 37°41'25"
Station 10	Emmaus	780-800 m	E	E 15°05'25"	N 37°41'08"
Station 11	Milia	1 400 m	S	E 14°57'28"	N 37°41'03"
Station 12	Fossa La Nave	1 600 m	SW	E 14°58'28"	N 37°41'12"
Station 13	Balilla	1 400 m	SW	E 14°57'25"	N 37°40'45"

Table 1. Main topographical characteristics of the 13 studied stations

Stations	**Rainfall**	**Throughfall**		**Stem flow**		**Interception**	
	mm	**mm**	**%**	**mm**	**%**	**mm**	**%**
Piano Porcheria	963.7	663.5	68.8	60.9	6.3	239.3	24.8
Fossa La Nave	667.5	526.1	78.8	18.4	2.8	123.0	18.4

Table 2. Rainfall, throughfall, stem flow and interception values in mm and % recorded over one year at the stations at Piano Porcheria and Fossa La Nave (from Leonardi *et al.*, 1993)

Stations	**Chloride**	**Calcium**	**Magnesium**	**Sulphur**	**Phosphorus**	**Nitrogen**
Piano Porcheria	113.2	27.3	12.7	18.6	8.2	23.2
Fossa La Nave	81.5	21.0	12.7	15.7	5.4	12.6

Table 3. Nutrient input to soil through rainfall and canopy leaching of *Castanea sativa* stands at Piano Porcheria and Fossa La Nave during twelve consecutive months. Results expressed in kg ha^{-1} year $^{-1}$ (from Leonardi *et al.*, 1993)

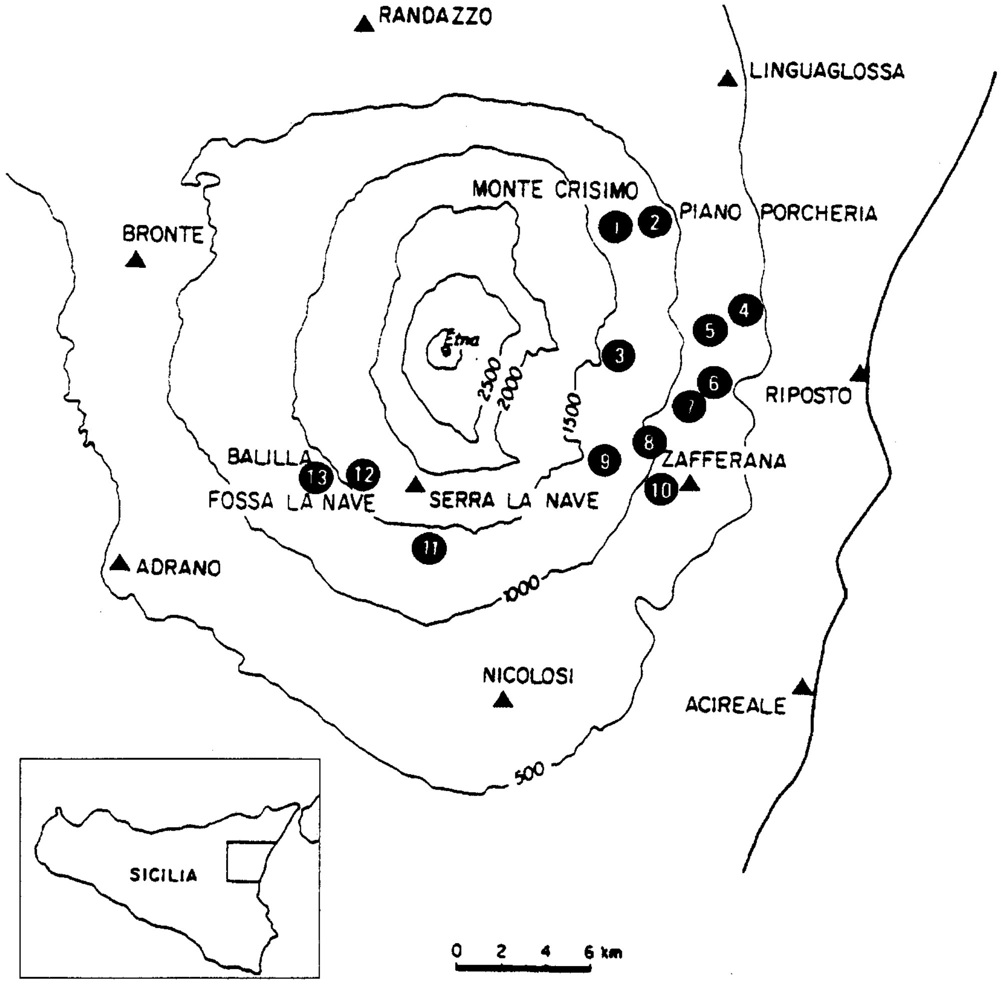

Figure 1. Location of the stations. 1: Mt. Crisimo; 2: Piano Porcheria; 3: Contrada Giarrita; 4: Puntalazzo; 5: S. Alfio; 6: Road S. Alfio-Milo; 7: Fornazzo; 8: Contrada Cassone; 9: Piano del Vescovo; 10: Emmaus; 11: Milia; 12: Fossa La Nave; 13: Balilla.

In these localities the climate is typically Mediterranean, with maximum rainfall during the autumn and winter months and characteristically dry weather during the summer. In particular, the weather stations at Linguaglossa (560 m a.s.l.) and Zafferana Etnea (590 m a.s.l.) are relevant to the sampling stations located on the eastern slopes of the mountain; the annual rainfall is 1 130 mm and 1 354 mm, and the average temperature 14° and 16°C, respectively. According to Rivas Martinez *et al.*'s method (1991), such data are associated with the lower humid ombrotype of the median Mesomediterranean bioclimate at the station at Linguaglossa, and with the upper humid ombrotype of the lower Mesomediterranean bioclimate at the station at Zafferana Etnea. The station at Casa Cantoniera (1882 m a.s.l.) is relevant to the southern and south-western sampling stations, which are mainly located at quite high altitudes. This station is characterised by annual rainfall of 1 250 mm and an average temperature of 7.4°C. These data are associated with the lower humid ombrotype of the lower Oromediterranean bioclimate.

The chestnut woods located at altitudes between 600 m and 850 m are regarded as low-altitude woods, those located between 1 000 m and 1 300 m as mid-altitude chestnut woods, and those between 1 400 m and 1 600 m as high-altitude chestnut woods.

Data analysis

Bryophytes were collected both from bark and tree bases in spring 1995 and in autumn-winter 1997. Ecological indicator values for each species were defined according to Düll (1991): indices were evaluated for pH levels, and for hygrophily and thermophily. Each index was assigned a scale of values from 1 to 9 (classes), designating, respectively, increasing requirements for pH, humidity and temperature. In order for a single value for each index to be allocated to an individual station, the absolute frequency of each class in the range of values was multiplied by the value attached to that class. The sum total of the values thus obtained was then divided by the number of species growing in a given station. It should be noted, however, that such values are simply tentative indicators, as the ecological indices possess a purely qualitative value, rather than a quantitative one.

In order to estimate the index of bryophyte biodiversity, the method of Badin & Nimis (1996) for lichens was followed; it was deemed to be equally viable for application to bryophytes. Relevés were carried out using a grid of 30x50 cm subdivided into 10 rectangles of 10x15 cm each. The centre of the grid was positioned over the part of the tree with the greatest bryophyte cover. A relevé listed all species found within the grid. The species frequency was estimated by computing the number of rectangles in which each species occurred. The sum total of frequency values for all species from the same relevé provided the biodiversity index for each relevé. The average values of biodiversity indices from all the relevés at each station provided the biodiversity index of that station.

RESULTS

The total number of bryophytes collected was 35, a substantial number if one takes into account the climatic characteristics of this territory and the nature of the substratum, which is difficult to colonise. The ratio of liverworts to mosses is low (3/32), as is usually the case in the Mediterranean region (Lo Giudice *et al.*, 1997).

The bryophyte flora consists of strictly epiphytic species, such as *Orthotrichum* spp., *Hypnum cupressiforme* subsp. *resupinatum*, *Tortula laevipila*, and *Zygodon rupestris*; facultative epiphytic species, such as *Hypnum cupressiforme*, *Homalothecium sericeum*, *Pterogonium gracile*, *Dicranoweisia cirrata*, etc.; and finally non-epiphytic species. The strictly epiphytic species grow over the middle and upper parts of the bark; the other species are mostly to be found about tree bases.

The most widespread species are *Hypnum cupressiforme*, *H. cupressiforme* subsp. *resupinatum*, *Ceratodon purpureus*, *Bryum capillare*, *Grimmia pulvinata*, *Homalothecium sericeum*, *Orthotrichum striatum* and *Tortula ruralis*. Acrocarpous mosses (72%) dominate. *Orthotrichaceae* (25% of the whole flora), *Brachytheciaceae* (16.7%) and *Grimmiaceae* (11.1%) are the most important families. *Bryaceae* (11.1%) and *Pottiaceae* (8.3%) have been found over the most polluted areas. *Polytrichaceae* and *Hypnaceae* represent only 5.5% each, and the other families represent only 2.8%.

Ecological indices

For the ecological investigation, indices of pH, humidity and temperature were evaluated. The average values for pH indices at each station mostly ranged between 4.2 and 5.8 (Table 4). Such average values indicate high acidity of the bark. The lowest value was measured at the station of Piano del Vescovo (3.7), where a large number of species are found which are associated with high acidity (*Ceratodon purpureus*, *Racomitrium heterostichum*, *Coscinodon cribrosus*, *Polytrichum piliferum*). The average values for the indices of hygrophily varied from 2.8 to 4. Quite low average indices were found for the flora of the chestnut woods located on the north-eastern, southern and south-western slopes. Slightly higher values were found in some stations on the eastern slope, for example, in the environs of S. Alfio (station 5) and Emmaus (station 10). The average values for the indices of thermophily were found to be higher at lower altitudes, with a peak of 6 in the environs of Puntalazzo (station 4) and S. Alfio (station 5) (Figure 2). The average values of the indices in mid-altitude chestnut woods ranged from 4.1 to 4.8, which are between those observed on the bryoflora of low-altitude chestnut woods and those at high altitude. The latter exhibit lower values, with minimum peaks of 3.7 and 3.8. Among the most significant indicators of cold conditions, *Coscinodon cribrosus* and the epiphytes *Orthotrichum speciosum* and *O. pallens* should be mentioned.

Biodiversity

In Table 5, three groups of relevés have been distinguished corresponding to the samples collected from low, mid and high altitude chestnut woods. A number of species are common to all woodland formations (*Hypnum cupressiforme*, *H. cupressiforme* subsp. *resupinatum*, and *Bryum capillare*). Other species, such as *Ceratodon purpureus*, *Grimmia pulvinata*, *Orthotrichum striatum*, are mostly found in mid- and high altitude chestnut woods. Finally, *Cephaloziella divaricata, Lophocolea heterophylla, Dicranoweisia cirrata*, *Tortula laevipila* and *Pterogonium gracile* are only found in low altitude chestnut woods, and *Orthotrichum tenellum, O. pallens* and *O. speciosum* only in high altitude chestnut woods.

A different floristic composition is observed in chestnut woods at low altitudes when compared with those at medium and high altitudes; the mid- and high altitude woods otherwise show remarkable affinity. The bryoflora of low altitude woodland formations mostly consists of facultative epiphytic species, some accidental species, and a few obligate epiphytes. The bryoflora of mid- and high altitude chestnut woods features an increased number of obligate epiphytic species with higher abundance-dominance values.

Stations	Index of pH levels	Index of hygrophily	Index of thermophily
Station 1	4.40	2.84	4.10
Station 2	4.60	3.50	4.30
Station 3	4.20	3.00	3.70
Station 4	5.00	3.00	6.00
Station 5	5.00	4.00	6.00
Station 6	4.75	3.50	5.00
Station 7	5.80	3.30	5.00
Station 8	4.90	3.60	4.80
Station 9	3.70	3.10	4.75
Station 10	4.40	3.70	5.60
Station 11	5.80	3.50	3.80
Station 12	4.30	3.30	3.80
Station 13	5.70	3.50	4.40

Table 4. Ecological indices of the investigated stations

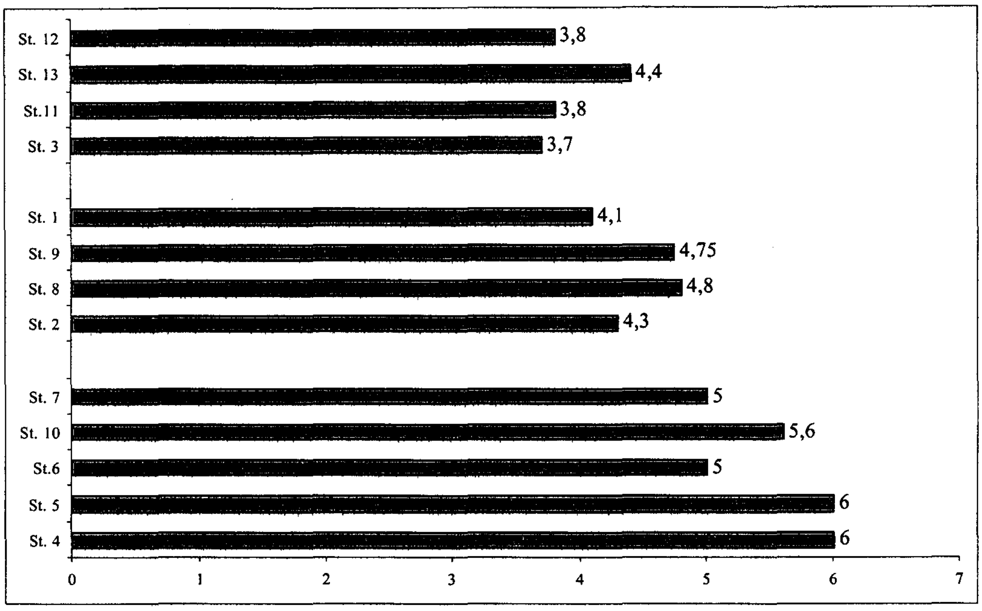

Figure 2. Thermophytism index of the stations in relation to increasing altitude

Stations	4	4	5	5	6	6	10	10	7	7	2	2	2	8	8	9	9	9	1	1	1	1	3	11	11	13	13	13	12	12	12
Number of the species	5	3	4	4	4	2	4	4	4	4	4	5	4	5	4	5	4	5	5	6	6	6	6	5	6	6	5	5	6	6	7
Hypnum cupressiforme ssp. resupinatum	.	.	4	4	.	.	.	.	3	3	3	3	.	.	4	.	.	4	5	5	.	.	3	.	.	.	.	.	.	3	.
Bryum capillare	1	2	.	2	.	.	.	.	1	2	3	3	1	2	.	.	.	.	.	.	2	.	3	.	2	.	.	.	2	.	3
Grimmia pulvinata	.	.	.	.	.	.	.	.	.	2	3	.	.	.	3	.	.	.	4	.	2	3	4	.	3	.	.	2	.	2	2
Orthotrichum striatum	.	.	.	.	.	.	.	.	4	.	3	.	.	.	3	.	.	.	3	.	3	4	.	.	3	.	5	5	3	3	.
Hypnum cupressiforme	4	3	.	.	.	.	.	2	.	.	.	.	3	1	.	.	.	.	.	.	5	5	.	6	.	6	5	.	3	.	.
Ceratodon purpureus	1	.	.	.	.	.	.	.	.	.	.	3	.	2	.	.	3	2	.	.	.	.	2	.	.	.	.	.	2	3	2
Tortula ruralis	1	.	.	.	.	.	.	1	2	.	.	.	.	.	.	1	.	.	.	3	.	.	.	2	3	3	.	2	.	.	.
Homalothecium sericeum	2	3	3	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	3	2	.	4	.	4	.	.	.	.	.
Orthotrichum speciosum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	5	4	5	2	.	3
Brachythecium olympicum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	1	.	.	.	.	.	.	.	.	5	.	.	.	.
Orthotrichum affine	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	5	5	.	.	.	2	.	.	.	.	.
Lophocoloea heterophylla	.	.	.	.	1	3	3	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Coscinodon cribrosus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	2	1	.	.	.	.	.	.	3	.
Brachythecium velutinum	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	3	3	.	.	.	.	.	.	.
Racomitrium heterostichum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	3	3	.	.	.	.	.	3	.	.	.	.	.
Polytrichum piliferum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	3	.	3	.	.	.	.	.	.	2	.	.	.	3
Scleropodium touretii	.	.	.	.	3	.	.	2	.	.	.	.	.	4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cephaloziella divaricata	.	.	.	.	2	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Grimmia laevigata	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.
Zygodon rupestris	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.
Orthotrichum tenellum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	2
Eurhynchium praelongum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3	2	.	.	.	.	.	.	.	.	.	.	.	.	.
Tortula subulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.
Pohlia nutans	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bryum laevipilum	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthotrichum pallens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.
Bryum argenteum	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2
Brachythecium salebrosum	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pogonatum aloides	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranoweisia cirrhata	.	.	.	1	.	.	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pterogonium gracile	.	.	2	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tortula laevipila	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthotrichum lyellii	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Orthotrichum rupestre var. sturmii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4	.	.	.	.	.	.	.
Frullania dilatata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2	.	.	.	.	.	.	.	.	.	.	.

Table 5. Frequency of the species in the relevés of the investigated stations. The first column groups the relevés of low-altitude stations, the second of mid-altitude stations, the third of high-altitude stations

From the indices of bryophyte biodiversity it can be concluded that such values increase with altitude (Figure 3). Biodiversity indices have ranged between 6 and 10 at low altitude stands; between 10.3 and 19.7 at mid-altitude ones; between 16 and 20.6 at high altitude ones. In the group of mid-altitude relevés, the biodiversity index for the station at Mt. Crisimo is remarkably high. Here the chestnut wood is rather productive, with biomass values close to chestnut woods in France (Leonardi *et al.*, 1996).

Biodiversity indices provide a reliable indication of air quality. It is well known that epiphytes are more sensitive to air pollutants than saxicolous and terricolous bryophytes. Indicators of air quality include floristic abundance, species frequency, vegetative and reproductive condition, and life form (i.e. LeBlanc & De Sloover, 1970; Sergio, 1981; Rao, 1982; Privitera & Puglisi, 1995; Lo Giudice *et al.*, 1997).

Biodiversity indices are lower across low altitude chestnut woods. The species are sterile and generally lack sporophytes; the only two species with sporophytes are *Orthotrichum striatum* and *Grimmia pulvinata*. The prevailing life form is the "short tuft", representing 50% of the bryoflora, followed by the "mat" form (25%).

Higher biodiversity indices over mid- and high altitude chestnut woods testify to a lower pollution rate. Here are found a large number of sensitive species belonging to the family *Orthotrichaceae*. The prevailing life form is the "cushion", represented by 36% and 47.3% in mid- and high altitude chestnut woods respectively. The "weft" life form is quite conspicuous (22.7% in mid-altitude chestnut woods and 10.5% in high altitude chestnut woods, respectively). The "short tuft" and "mat" life forms are less prevalent (18.2% "short tuft" and 18.2% "mat" over mid-altitude chestnut woods, and 26% "short tuft" and 15% "mat" over high altitude chestnut woods).

DISCUSSION

The bryophyte flora of the chestnut woods of Mt. Etna shows a low ratio of liverworts to mosses. The sparse occurrence of liverworts must be ascribed to the severe Mediterranean climate, which does not favour epiphyte colonisation, particularly of liverworts, which are more demanding of air humidity.

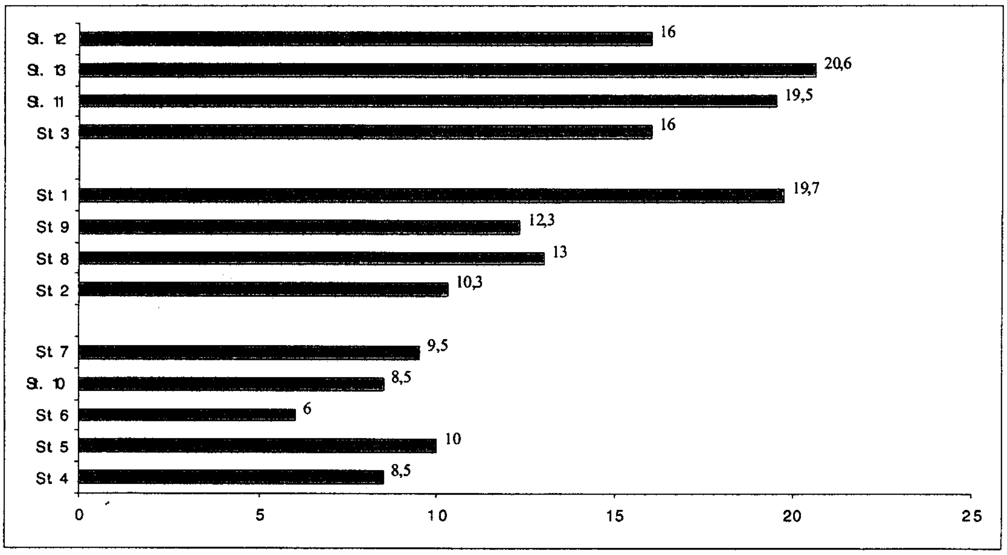

Figure 3. Bryophytic biodiversity index of the stations in relation to increasing altitude

The pH indices reveal, overall, an acidophilous bryophyte flora, in accordance with the acid pH of chestnut bark (Barkman, 1958). Higher acidophilous requirements are recorded in the bryoflora about tree bases and on the lower bark, where the effects of stem flow are strongly felt.

The bryoflora is, overall, xerophilous. No noticeable difference can be detected in the bryoflora of chestnut woods growing on different slopes of the volcano, although the highest values are recorded on the eastern slope, the most humid of the volcano.

Examination of the indices of thermophily shows that there is a correlation between temperature and the composition of the bryophyte flora. These indices decrease from the lowest to the highest stands, where low values are found. At altitudes higher than 1 200 m some cool indicator species are found, such as *Coscinodon cribrosus* and *Polytrichum piliferum*, with obligate epiphytes such as *Orthotrichum speciosum, O. pallens* and *O. rupestre* var. *sturmii.* Conversely, species with higher temperature requirements, such as *Pterogonium gracile*, *Dicranoweisia cirrata* and *Tortula laevipila,* are only found in low altitude chestnut woods.

Examination of the bryophyte vegetation has shown that biodiversity increases with altitude. The species collected at low altitude are sterile, with some rare exceptions, and are mainly characterised by the "short tuft" and "mat" life forms, more resistant to air pollutants (Gilbert, 1970; Lo Giudice *et al.*, 1997).

The bryophyte flora of mid- and high altitude chestnut woods consists of a large number of species sensitive to pollutants. The rate of sexual reproduction is high, although the copious presence of vegetative buds in several species, such as *Zygodon rupestris* and *Orthotrichum lyellii*, suggests that they may also reproduce vegetatively. The "short tuft" type of life form diminishes, while the "cushion" type, more sensitive to air pollutants, becomes prevalent.

From the above observations, it is apparent that low altitude chestnut woods, close to towns or busy highways, suffer more severely from higher pollution rates than mid- and high altitude chestnut woods. This conclusion may not appear to be very convincing at first, since high altitude chestnut woods are more subject to emissions of phytotoxic gases from the volcano. Mt. Etna emits large amounts of magnesium and sulphur, as is evidenced by the conspicuous presence of *Ceratodon purpureus*, a species very resistant to SO_2 pollution (Rao, 1982). Despite these huge emissions, much larger than from other volcanoes, these gases are dispersed across very wide areas (Romano, in Leonardi *et al.*, 1993), and do not have a very serious effect on the vegetation. This has been corroborated by relatively low stem flow values at the stations at Fossa La Nave and Piano Porcheria; such values are within the limits recorded for other species of trees. Similarly, sulphur concentration, although quite high, notably at Piano Porcheria, is within the minimum limits of western European regions subject to sulphur pollution (Leonardi *et al.*, 1993). This station, subject to more conspicuous gaseous emissions, shows a lower biodiversity index as compared with other stations at the same altitude.

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REFERENCES

Aleffi M. & Schumacker R., 1995. Check-list and red-list of the liverworts (Marchantiophyta) and hornworts (Anthocerophyta) of Italy. *Fl. Medit.* 5: 73-161.

Badin G. & Nimis P. L., 1996. Biodiversity of epiphytic lichens and air quality in the province of Gorizia (NE Italy). *Studia Geobot.* 15 : 73-89.

Barkman J. J., 1958. *Phytosociology and ecology of Cryptogamic epiphytes.* Van Gorcum & Comp. N. V., Assen, 595 p.

Cortini Pedrotti C., 1992. Check list of the Mosses of Italy. *Fl. Medit.* 2: 119-221.

Düll R., 1991. Indicator values of Mosses and Liverworts. *In*: Ellenberg H., Weber H. E., Düll R., Wirth V.. Werner W. & Paulißen D., *Indicator values of plants in Central Europe.* Göttingen: 175-214.

Gilbert O. L., 1970. Further studies on the effect of sulphur dioxide on lichens and bryophytes. *New Phytol.,* 69: 605-627.

Giordano S., Sorbo S., Basile A., Castaldo Cobianchi R. & Nimis P. L. 1999. Briofite epifite come bioindicatori della qualità dell'aria: indici ecologici a confronto. Atti 94° Congresso della Società Botanica Italiana (Ferrara 22-25 settembre 1999): 123.

LeBlanc F & De Sloover J., 1970. Relation between industrialization and the distribution and growth of epiphytic lichens and mosses in Montreal. *Can. J. Bot.*, 48: 1485-1496.

Leonardi S., Rapp M., Failla M & Guarnaccia D., 1993. Interception of rainfall, input and leaching of nutrients within two *Castanea sativa* Mill. stands at the Etna volcano. *Oecologia montana,* 2: 7-12.

Leonardi S., Rapp M., Failla M. & Guarnaccia D., 1996. Biomasse, productivité et transferts de matière organique dans une séquence altitudinale de peuplements de *Castanea sativa* Mill. de l'Etna. *Ann. Sci. For.*, 53: 1031-1048.

Lo Giudice R., Mazimpaka V. & Lara F., 1997. The urban bryophyte flora of the city of Enna (Sicily, Italy). *Nova Hedwigia*, 64: 249-265.

Mägdefrau K., 1982. Life forms of Bryophytes. *In*: Smith A. J. E. (ed.), *Bryophyte Ecology*, Chapman & Hall, London: 45-58.

Privitera M. & Puglisi M., 1995. Bryological flora and air pollution in some areas of Messina territory (NE Sicily). *Arch. Geobot.*, 1 : 135-142.

Rao D. N., 1982. Responses of Bryophytes to air pollution. *In*: Smith A. J. E. (ed.), *Bryophyte Ecology*. Chapman & Hall, London: 445-471.

Richards P. W., 1932. Ecology. *In*: Manual of Bryology (Verdoorn F. ed.) pp. 367-395, Nijhoff, The Hague.

Rivas Martinez S., Bascones J. C., Diaz T. E., Fernandez-Gonzalez F. & Loidi J., 1991. Vegetacion del Pirineo occidental y Navarra. *Itinera Geobot.*, 5: 5-546.

Romane F., Hauter S. & Valerino L., 1995. Factors affecting biodiversity in chestnut (*Castanea sativa* Miller) ecosystems along a gradient from coppice to orchard in the Cévennes Mountains (Southern France). *In*: Romane F. (ed.), Sustainibility of Mediterranean ecosystems. Case study of the chestnut forest. Brussels: 103-108.

Ronsisvalle G. S. & Signorello P., 1979. Contributo allo studio fitosociologico dei castagneti dell'Etna. *Boll. Acc. Gioenia Sci. Nat. Catania*, 4: 29-41.

Sergio C., 1981. Alterações da flora briológica epifítica na área urbana de Lisboa, nos últimos 140 anos. *Bol. Soc. Brot.*, ser. 2, 54: 313-331.

Smith A. J. E., 1982. *Bryophyte Ecology*. Chapman and Hall, London, 509 p.

FLORISTIC APPENDIX

Cortini Pedrotti's work (1992) has been referred to for nomenclature and Authors' names of mosses, and Aleffi & Schumacker (1995) for the liverworts. The terminology of life forms has been taken from Mägdefrau (1982). The ecological indicator values (R: reaction number, T: temperature number, M: moisture number) and the life forms (Ma: mat, St: short turf, Ht: High turf, Cu: cushion, De: dendroid We: weft) are reported for each taxon.

Liverworts

Cephaloziella divaricata (Sm.) Schiffn. – R: 4, M: 2, Lf: We.
Frullania dilatata (L.) Dumort. - R: 5, T: 3, M: 4, Lf: Ma.
Lophocolea heterophylla (Schrad.) Dumort. - R: 3, T: 3, M: 4, Lf: Ma.

Mosses

Brachythecium olympicum Jur. - R: 6, T: 7, M: 4, Lf: We.
Brachythecium salebrosum (Weber & D. Mohr) Bruch *& al.* - R: 5, T: 4, M: 4, Lf: We.
Brachythecium velutinum (Hedw.) Bruch *& al.* - R: 6, T: 3, M: 4, Lf: We.
Bryum argenteum Hedw. - R: 6, Lf: St.
Bryum capillare Hedw. - R: 6, M: 5, Lf: St.
Bryum subelegans Kindb. - R: 6, T: 5, M: 5, Lf: St.
Ceratodon purpureus (Hedw.) Brid. - R: 2, M: 2, Lf: St.
Coscinodon cribrosus (Hedw.) Spruce - R: 1, T: 2, M: 1, Lf: Cu.
Dicranoweisia cirrata (Hedw.) Lindb. ex Milde - R: 5, T: 6, M: 5, Lf: St.
Eurhynchium praelongum (Hedw.) Bruch *& al.* - R: 5, T: 4, M:6, Lf: We.
Grimmia laevigata (Brid.) Brid. - R: 5, T: 6, M: 1, Lf: Cu.
Grimmia pulvinata (Hedw.) Sm. - R: 7, T: 5, M: 1, Lf: Cu.
Hypnum cupressiforme Hedw. - R: 4, M: 4, Lf: Ma.
Hypnum cupressiforme Hedw. subsp. *resupinatum* (Taylor ex Spruce) C. Hartm. - R: 3, T: 5, M: 5, Lf: Ma.
Homalothecium sericeum (Hedw.) Bruch *& al.* – R:7, T: 3, M:2, Lf: Ma.
Orthotrichum affine Brid. – R: 6, T: 4, M:4, Lf: Cu.
Orthotrichum lyellii Hook. & Taylor – R: 5, T:4, M: 4, Lf: Cu.
Orthotrichum pallens Bruch ex Brid. – R: 5, T: 2, M:4, Lf: Cu.
Orthotrichum rupestre Schleich. ex Schwägr. var. *sturmii* (Hoppe et Hornsch.) Jur. – R: 6, T: 2, M:3, Lf: Cu.
Orthotrichum speciosum Nees ex Sturm – R: 5, T: 2, M: 5, Lf: Cu.
Orthotrichum striatum Hedw. – R: 6, T: 3, M: 5, Lf: Cu.
Orthotrichum tenellum Bruch ex Brid. – R: 6, T: 6, M: 3, Lf: Cu.
Pogonatum aloides (Hedw.) Beauvais – R: 3, T: 3, M: 6, Lf: Ht.
Pohlia nutans (Hedw.) Lindb. – R.: 2, M: 4, Lf: Ht.
Polytrichum piliferum Hedw. – R.: 2, T: 2, M: 2, Lf: Ht.
Pterogonium gracile (Hedw.) Sm. – R: 3, T: 5, M: 4, Lf: De.
Racomitrium heterostichum (Hedw.) Brid. – R: 1, T: 3, M: 5, Lf: Cu.
Scleropodium touretii (Brid.) L. F. Koch – R: 6, T: 7, M: 3, Lf: We.
Tortula laevipila (Brid.) Schwägr. – R: 6, T: 5, M: 3, Lf: St.
Tortula ruralis (Hedw.) P. Gaertn. *& al.* – R: 6, T: 9, M: 2, Lf: St.
Tortula subulata Hedw. – R: 5, T: 6, M: 4, Lf: St.
Zygodon rupestris Schimp. ex Lorentz – R: 7, T: 6, M: 5, Lf: Cu.

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Some ecological aspects of a chestnut coppice located at the *Sierra de Gata* mountains (Western Spain) and its relationship with a sustainable management

Effets du dépressage sur la croissance d'un taillis de châtaigniers du massif '*Sierra de Gata*' (Espagne de l'ouest) ; implications pour la gestion durable

Juan Fernando GALLARDO[1], Mercedes RICO[1] (✝) & Maria Isabel GONZALEZ[2]

[1]*C.S.I.C.*, Aptado. 257, Salamanca 37071 (Spain). E-mail: jgallard@gugu.usal.es
[2]Area de Edafología, Facultad de Farmacia. Salamanca 37080 (Spain).

ABSTRACT

A chestnut coppice located on the Southern face of the '*Sierra de Gata*' mountains (province of Cáceres, Western Spain) was studied:The soil of the chestnut ecosystem is *humic Cambisol* (deep, on weathered granite), the annual rainfall is about 1 160 l m^{-2} yr^{-1}, the altitude 940 m a.s.l., the slope near 45 %, the orientation NW, and the annual mean temperature is about 14 °C. A initial felling of the chestnut coppice was made and few years after it underwent a thinning to leave around 5 dominant shoots per stump. This traditional thinning is recommended, because yields a good growth and optimum leaf area index; more intense thinning resulted in stronger growth, but the total biomass was very low; on the other hand, the control (no thinning) yielded a very high total biomass but with very low growth. The mean growth of the wood volume was 16.6 m^3 ha^{-1} yr^{-1} during the first 25 yr at the traditionally managed coppice; this means growth of wood volume decreased to then 12.5 m^3 ha^{-1} yr^{-1}.

Key-words: *Castanea sativa*, coppice, biomass, leaf area index, D.B.H., thinning, growth.

RESUME

Cette étude concerne un taillis de châtaigniers situé sur le versant sud de la chaîne de montagnes '*Sierra de Gata*' (province de Cáceres, Espagne de l'ouest). Les sols de cet écosystème à châtaigniers sont de type *Cambisol humique* (sols profonds sur granite altéré). Les précipitations annuelles moyennes avoisinent les 1 150 mm.an^{-1}, l'altitude est de 940m, la pente est de 45 % avec une orientation au nord-ouest et la température moyenne annuelle tourne autour de 14,1°C.
Une coupe initiale du taillis de châtaigniers a été réalisée, suivie quelques années plus tard d'un dépressage (5 brins dominants conservés par souche). Ce dépressage traditionnel est recommandé car il permet une croissance élevée et conduit à un indice de surface foliaire optimal. Un dépressage plus sévère conduit à une croissance plus forte, mais pour une biomasse totale plus réduite, tandis qu'une non-intervention (placette de contrôle) entraîne une forte production en biomasse totale couplée à une très faible croissance. Dans le cas d'une gestion traditionnelle des taillis, la production moyenne de bois correspond à 10 m^{3}ha^{-1}an^{-1} durant les 25 premières années, puis diminue ensuite à 5 m^{3}ha^{-1}an^{-1}.

Mots-clés : *Castanea sativa*, taillis, biomasse, indice de surface foliaire, Diamètre à hauteur de poitrine., dépressage, croissance.

INTRODUCTION

Most chestnut forests in Spain grow at elevation between 600 and 1 500 m above sea level in sheltered but humid situations (although they resist the winter cold well) with annual rainfalls generally above 1 000 mm (Berrocal *et al.*, 1998); they tolerate soil acidity well but not active limestone. In mature stages, these trees reach heights of 22 metres (in any case they may surpass 20 m).

Chestnuts are moderately heliophile and have a strong root system that reaches some meters in depth, although they also develop surface roots as vertical growth decreases. Chestnuts multiply by the production of numerous shoots from stumps (with sufficient radiation); they may therefore be used as coppices with short periods between felling owing to their easy regeneration (Berrocal *et al.*, 1998).

Chestnut trees were of considerable economic importance for their fruit and wood (Elorrieta, 1949) and now are still important in some countries like Portugal (Pires *et al.*, 1994). Loss of interest in the fruit as food together with problems of ring shake in the wood (limiting its use as timber) have led to these forests, being virtually abandoned in Spain, especially as regards of their fruit production (Berrocal *et al.*, 1998). However, there are still important extensions of chestnut forest in Western Spain used as coppices in short rotation periods of 20-40 yr.

The existence in Europe of large areas of marginal (from the point of view of agriculture) lands, especially in Mediterranean countries, propitiates their possible reutilization. In this context, it is necessary to define what is understood by 'sustainable development' since despite the sociological connotations of the term, technical details must also be taken into account. Thus, knowledge of such environments is crucial (Leonardi *et al.*, 1994).

In chestnut-bearing coppices, one of the techniques most commonly used in management is thinning (Evans, 1984). The intensity with which thinning is carried out alters the competition of the coppice, both as regards of shoots from the same stump and among the different stumps. Although, in view of the timber yields obtained, traditional thinning techniques seem to provide satisfactory results regarding exploitation (Meson & Montoya, 1993). It is interesting to consider the results that would be obtained if no intervention were made or if different systematic controlled thinning procedures (Ducrey & Toth, 1992) were implemented to compare these with the results obtained with the traditional thinning method. This could be used to select the best management option for sustainable development (Amorini, 1996), seeking a balance between utilization and conservation.

The aim of the work was therefore to determine the effect of thinning intensity on the growth of the shoots remaining from each stumps (and final biomass) with a view to drawing conclusions about the most suitable methodology for the exploitation and conservation of these forests (increasing timber production within the perspective of sustainable development of the area). Additionally, an estimation of the yield of these chestnut coppice was also made.

From the results obtained, we offer recommendations for the management of these chestnut coppices according to sustainable development considerations.

MATERIALS AND METHODS

The duration of the work was limited by the European Project supporting this research (1992-97).

Situation

The forest ecosystem chosen for the present work was a chestnut (*Castanea sativa* Mill.) coppice located at the site known as *El Soto*' (close to 75 ha), within the municipality of *San Martín de Trevejo* (Figure 1) on the South face of the *Sierra de Gata*' mountains (province of Cáceres, Spanish Central range, Spain). The geographic coordinates of the location are 40° 2' 40'' N and 3° 0' 50'' W. The general characteristics of the area have been described in sufficient depth and published under the auspices of the same Project (Gallardo Lancho *et al.*, 1995).

The climate of the area is characterized by rainy winters and hot summers. Elias & Ruiz (1977) have classified the area as temperate Mediterranean, equivalent to humid mesothermal, without aridness. In short, the annual rainfall is about 1 160 mm yr^{-1} and the mean annual temperature is 14.2 °C.

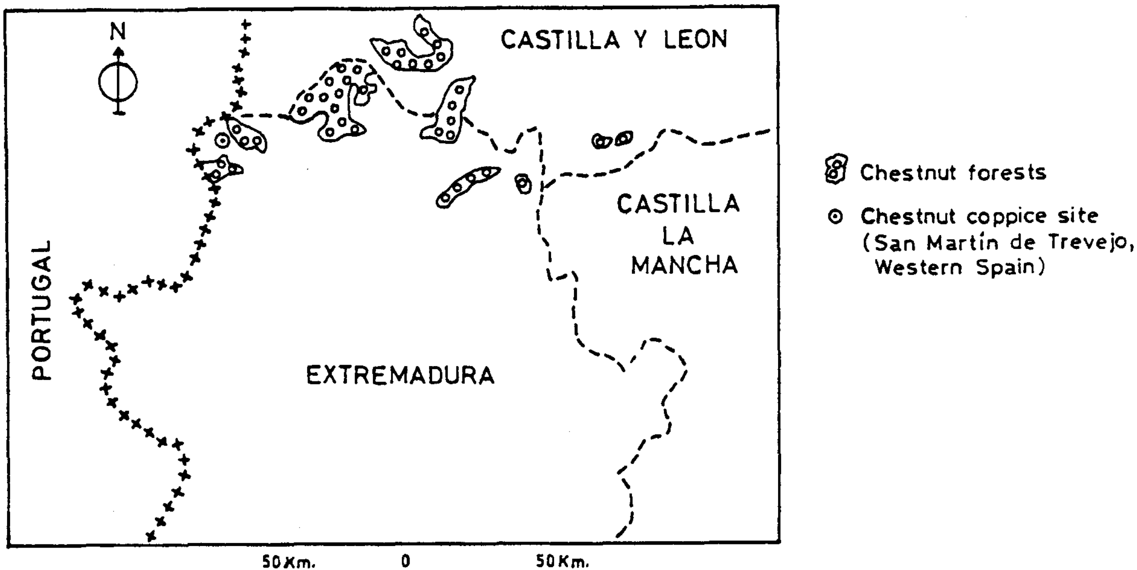

Figure 1. Situation of the studied chestnut coppice stand studied (Spanish Central System)

The topography of the area is a slope (near 45 %) with a general W orientation and the mean altitude is 940 m a.s.l..

The characteristics of this ecosystem and those of the plots used in this study have been described in depth elsewhere (Gallego *et al.*, 1993; Gallardo Lancho *et al.*, 1995). The subplots studied had a strong slope (45 %) and occupied an intermediate position on the hillside such that conditions of leaching or nutrient accumulation are similar at all points of the subplots.

Table 1 summarises some of the general characteristics of this experimental chestnut coppice stand.

Figure 2 shows the annual distribution of the rainfall in Navasfrías (1990-93); although Navasfrías is wetter (1550 mm yr^{-1}) than San Martín, the annual distribution is similar, taken in account the short distance between the first site and the chestnut stand (about 12 km).

Soil characteristics

The soil characteristics have also been described and discussed in depth in earlier work (Gallardo Lancho *et al.*, 1995; Martins *et al.*, 1995; Turrion *et al.*, 1997 among others). In general, *humic Cambisols* associated with *umbric Regosols* developed on granitic sands predominate (Gallardo Lancho *et al.*, 1995). An association of *Leptsosol-humic Cambisol* could be considered as cartography unit.

Table 2 offers the most important physical, physicochemical, and biochemical data of a typical soil. From these it may be inferred that the soils are acid, with a high content in organic matter and total N and a moderate C/N ratio at the surface (about 18), corresponding to an acid forest *Mull.* The contents in available bioelements are high for P (locally, in agreement with the history of the different forest plots) and medium for Ca and K. P fertilisation in this coppice had no effect on tree growth (Turrion *et al.*, 1997). The epipedon has a high cation capacity (T) but both the sum of bases (S) and the percentage of base saturation (V) are low. Textures range between sandy-silty to loamy. The soil humidity regime can be considered *ustic-xeric* (Gallardo Lancho *et al.*, 1995) and soil temperature as *mesic.*

Methodology

The chestnut coppice studied here was clearfelled (to stub level) in January 1987 on the lower part and in January 1988 on the upper part (Figure 3) of the chestnut forest area.

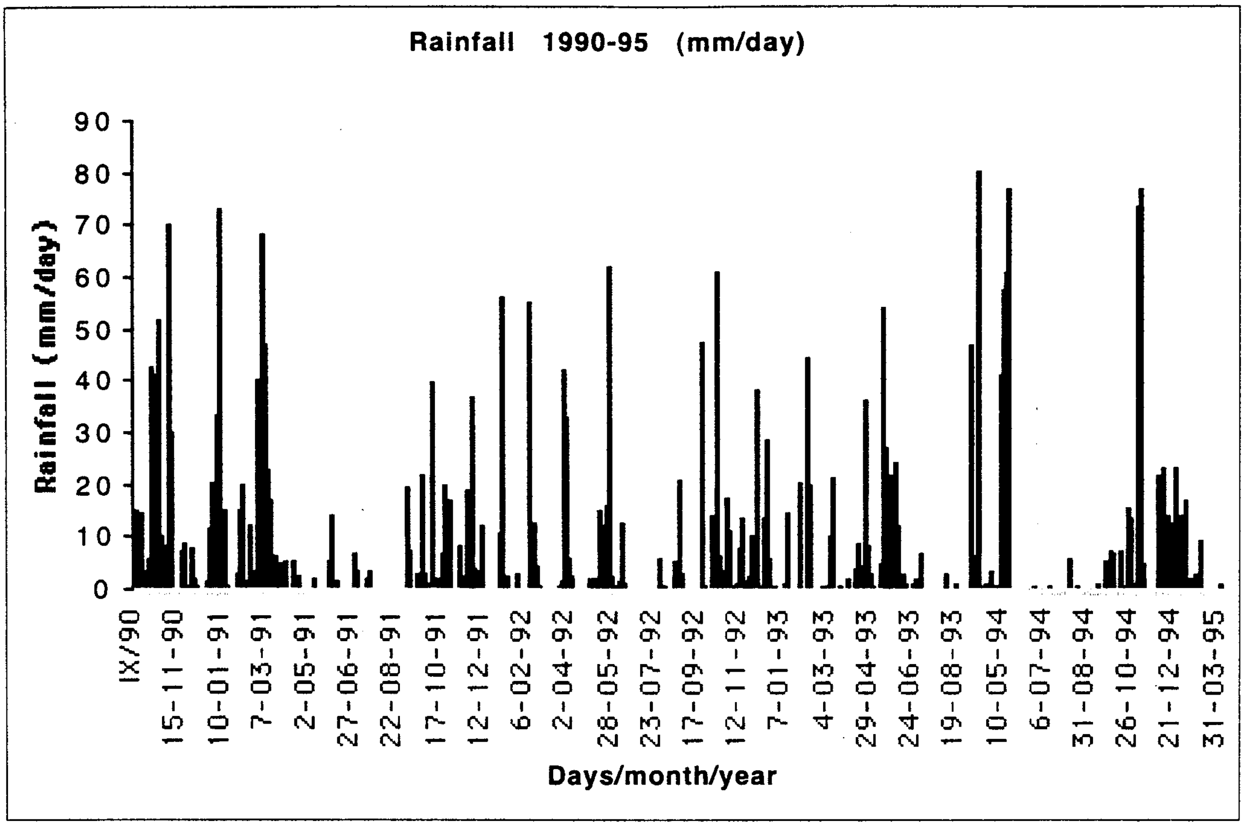

Figure 2. Annual rainfall in Navasfrías (western Spain) from 1990 to 1995

CHARACTERISTICS OF THE CHESTNUT PLOT	San Martín de Trevejo
Mean annual rainfall (mm/yr)	1152
Mean winter rainfall (mm)	430
Mean summer rainfall (mm)	60
Mean annual temperature (°C)	14,2
Actual evapotranspiration (mm/yr)	853
Altitude (m a. s. l.)	940
Slope (%)	45
Slope orientation	NW
Canopy surface (1991, %)	85
Leaf area index (1991, m2/m2)	3,72

Table 1. General characteristics of the chestnut coppice stand of *San Martín de Trevejo*

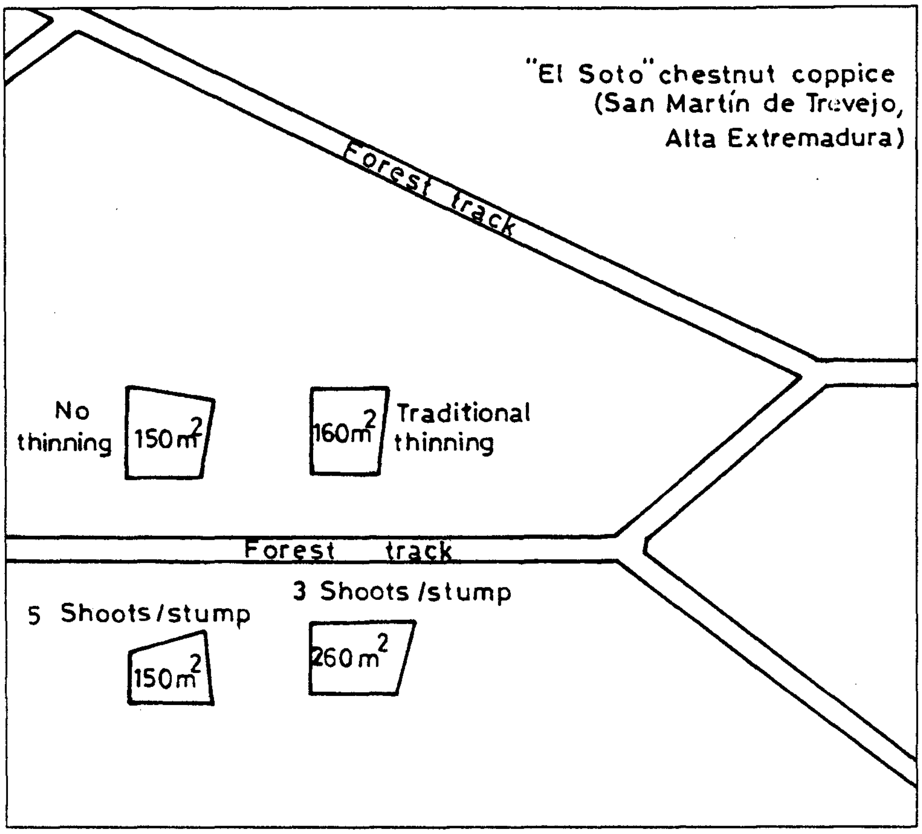

Figure 3. Location of subplots with different thinnings at the chestnut coppice stand of *San Martin de Trevejo*

Soil horizons	Sd[a]	St[b]	Cy[c]	SOM[d]	pH[e]	CEC[f]	Ca^{2+}	Mg^{2+}	K^+	Na^+	S[g]	V[h]
		(%)						($cmol_c$ kg^{-1})				(%)
A_{h1}	58	19	13	7.8	5.1	20.3	1.0	0.8	0.2	t	2.0	9.9
A_{h2}	59	21	15	5.9	4.7	17.0	0.1	t	0.3	t	0.4	2.4
AB_w	62	26	10	3.1	4.9	14.1	0.2	t	0.4	t	0.6	4.3
C	59	22	14	1.2	4.4	19.5	2.0	1.5	0.3	t	3.8	20

Soil horizons	Depth	C	N	C/N	P*	Ca*	K*
	(cm)	(Mg ha^{-1})			(kg ha^{-1})		
A_{h1}	0-20	70.3	3.94	18	75	470	320
A_{h2}	20-50	73.0	3.98	21	38	110	190
AB_w	50-85	51.7	3.09	17	32	230	190
C	85-115	19.2	1.61	12	30	570	30

*Available.

Table 2 . Soil physical, physicochemical, and biochemical properties of the chestnut coppice stand
[a] sand; [b] silt; [c] clay; [d] soil organic matter; [e] in water, [f] total cation exchange capacity, [g] sum of bases, [h] saturation percentage

Experiments were carried out on four subplots, all of which were larger than 100 m^2 (Figure 3). Thus, in January 1992, we performed three different thinnings on selected plots of the coppice resulting from spontaneous growth of the chestnut coppice after felling. One plot was left unthinned.

On the lower part of the coppice systematic thinnings on two selected plots of 260 m^2 (22 stumps) and 150 m^2 (14 stumps) was performed, leaving 3 (66 shoots by plot) and 5 (67 shoots by plot) shoots per stump, respectively. On the upper part, we followed traditional guidelines to thin a plot of 160 m^2 (14 stumps, with 76 shoots by plot) while on another of 150 m^2 (23 stumps), as mentioned above, no thinning was carried out (182 shoots by plot).

Therefore, two pairs of coppice subplots were selected; an unthinned plot (T) and a subplot thinned following traditional procedures (At); another plot with 5 shoots per stump (Am, which *a priori* was believed to resemble the traditional method), and a last plot with three shoots per stump (Ai, strongly thinned). We followed up all these plots as from January 1992 until December 1996 that is 5 yr. It should be noted that whereas the coppice of the two systematically thinned plots was 9 yr old in 1996 after thinning, the other two plots (unthinned and thinned traditionally) were 8 yr old in 1996.

On these subplots, we measured increases in growth (DBH, trunk diameter at 1.3 m) in each new shoot, first annually (1992 and 1993) and then each semester (as from 1994), also taking into account other population aspects (mortality, number of new shoots, height, *etc.*). During the last years of the Project (1995 and 1996), a more detailed study was conducted, carrying out 10 controls of DBH and searching for differences among the different subplots as regards increases in height.

In the last years of the experimental period, 10 litter collectors were randomly installed on each plot, using production boxes of 0.24 m^2 surface area and 30 cm height. Samples were weighed monthly and separated into different fractions, and the corresponding dry weights were obtained.

The leaf area indices (LAI) corresponding to the years 1995 and 1996 were also calculated. At the end of November 1996 the biomass resulting from each of the treatments applied was calculated by felling and later weighing a representative number of trees per treatment (corresponding to 5 stumps).

In order to learn the final wood yield/timber production of these coppices, another chestnut coppice plot, which is rectangular and covers an area of 0.33 ha, was selected at the same site (*'El Soto'*). This coppice stand was 30 yr old in 1997 since it was clearfelled towards the end of 1967. Thus, in 1997 the felling rotation period is therefore a little longer (i.e., usually from 22 to 25 yr at this site). This coppice stand has been inventoried twice. The first time was in May 1991, just before the beginning of the CAST Project. A second inventory was carried out in August 1995, towards the theoretical end of the Project (the CAST Project was later extended).

RESULTS AND DISCUSSION

Effects of thinning on chestnut aboveground productivity

Table 3 shows that, before thinning (December, 1991), there were more than 12 000 shoots ha^{-1} (T), those clearfalled at the beginning of 1987 having a DBH between 4.4 to 4.8 cm (basal area between 18 to 22 m^2 ha^{-1}), and those clear cut at the beginning of 1988, a DBH between 3.8 to 4.0 cm (basal area between 14 to 15 m^2 ha^{-1}). This means that one year yields approximately 4 m^2 ha^{-1} yr^{-1} of basal area (G).

Two of the thinnings (At and Am) reduced this number to 4 800 shoots ha^{-1} at the beginning of 1992 (G was decreased to 6 m^2 ha^{-1}) and to 2 550 shoots ha^{-1} in the case of the intense thinnings (Ai, a G of only 5 m^2 ha^{-1} remaining). The control subplot (T) underwent a self thinning process, decrasing the number of shoots to 8 900 shoots per ha (G was 14 m^2 ha^{-1}). On the four subplots, mean DBH was between 3.8 to 4.8 cm (Table 3) at the beginning of the experimental period (January, 1992). Tree growth depended of both the distribution of rainfall and the total annual rainfalls (Figure 2). Also, the annual water-content evolution of the *Ah* horizon of the similar (*cambic Umbrisol*) soil of Navasfrias is given in Figure 4. Furthermore, the big tree growth happened before July (Figure 5); according to these observations, rains falling in the May-June period are the main factor for tree growth.

SUBPLOTS	Subplot	Number of old stumps		December, 1991				January, 1992	
	Surface area			Shoots (1987/88)	Basal area	Mean DBH	Mean increment	Shoots	Basal area
	(m2)	(by subplot)	(N/ha)	(N/ha)	G (m2/ha)	(cm)	(cm/yr)	(N/ha)	(m2/ha)
T	150	24	1600	12100	14	3.80±0.09	0.95±0.03	8900	14
At	160	14	875	12100	15	3.99±0.08	1.0±0.03	4750	6
Am	150	14	1000	12100	18	4.41±0.10	0.88±0.02	4800	7
Ai	260	22	846	12100	22	4.81±0.11	0.96±0.03	2550	5

SUBPLOTS	December, 1996			Annual increment DBH					
	Basal area	Mean DBH	Mean increment	(cm/yr)					
	G (m2/ha)	(cm)	(cm/yr)	1992	1993	1994	1995	1996	Mean
T	22	5.60±0.17	0.62±0.02	0.40±0.02	0.29±0.02	0.22±0.02	0.29±0.02	0.25±0.02	0.29±0.02
At	13	5.93±0.16	0.65±0.02	0.44±0.02	0.45±0.02	0.29±0.02	0.40±0.02	0.36±0.02	0.39±0.02
Am	16	6.57±0.18	0.66±0.02	0.48±0.03	0.47±0.03	0.38±0.02	0.39±0.02	0.43±0.03	0.43±0.02
Ai	13	7.91±0.20	0.79±0.02	0.67±0.03	0.69±0.03	0.59±0.02	0.55±0.02	0.61±0.02	0.62±0.02

SUBPLOTS	December, 1996			Mean total above ground biomass November, 1996 Ba (per stump)				Total aboveground biomass November, 1996 Ba (per shoots)	
	Age	Mean heigth	Mean increment	Dominants	Dominants	News	Total	Mean	Total
	(yr)	(m)	(cm/yr)	(kg/stump)	(Mg/ha)	(Mg/ha)	(Mg/ha)	(kg/shoot)	(Mg/ha)
T	9	4.4±0.28	48	53 ± 8	84,86	0,32	85,17	6.8 ± 0.9	60,52
At	9	4.7±0.19	52	40 ± 5	34,96	1,29	36,26	9.1 ± 1.0	43,13
Am	10	6.1±0.15	61	52 ± 4	52,10	2,79	54,89	10 ± 1	49,87
Ai	10	5.5±0.26	55	34 ± 4	29,08	4,58	33,66	12 ± 2	29,08

SUBPLOTS	Total litter production			Leaf litter production			Leaf area index (LAI)		
	1995	1996	Mean	1995	1996	Mean	1995	1996	Mean
	(Mg/ha, yr)	(Mg/ha, yr)	(Mg/ha, yr)	(Mg/ha, yr)	(Mg/ha, yr)	(Mg/ha, yr)	(m2/m2)	(m2/m2)	(m2/m2)
T	4,42	4,50	4,46	3,23	3,85	3,54	5,82	6,94	6,38
At	3,74	3,50	3,62	2,89	3,31	3,10	3,34	3,84	3,59
Am	3,13	2,55	2,84	2,75	2,24	2,49	5,59	4,50	5,04
Ai	3,53	2,30	2,91	2,68	2,05	2,37	4,07	3,12	3,59

Table 3. Characteristics and results of the experimental subplots (± standard error)

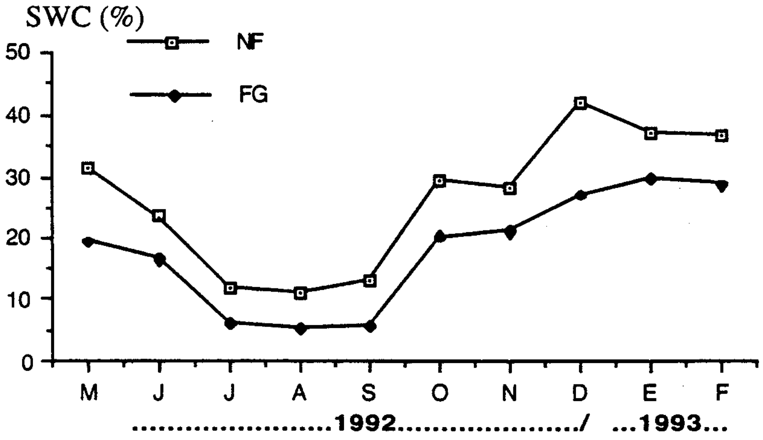

Figure 4. Evolution of the soil water content (SWC, in % vol./vol.) in the *Ah* soil horizons during 1992-93. NF is Navasfrías (mean annual rainfall 1550 mm yr^{-1}) and FG is Fuenteguinaldo (720 mm yr^{-1}); adapted from Martín *et al.*, 1997)

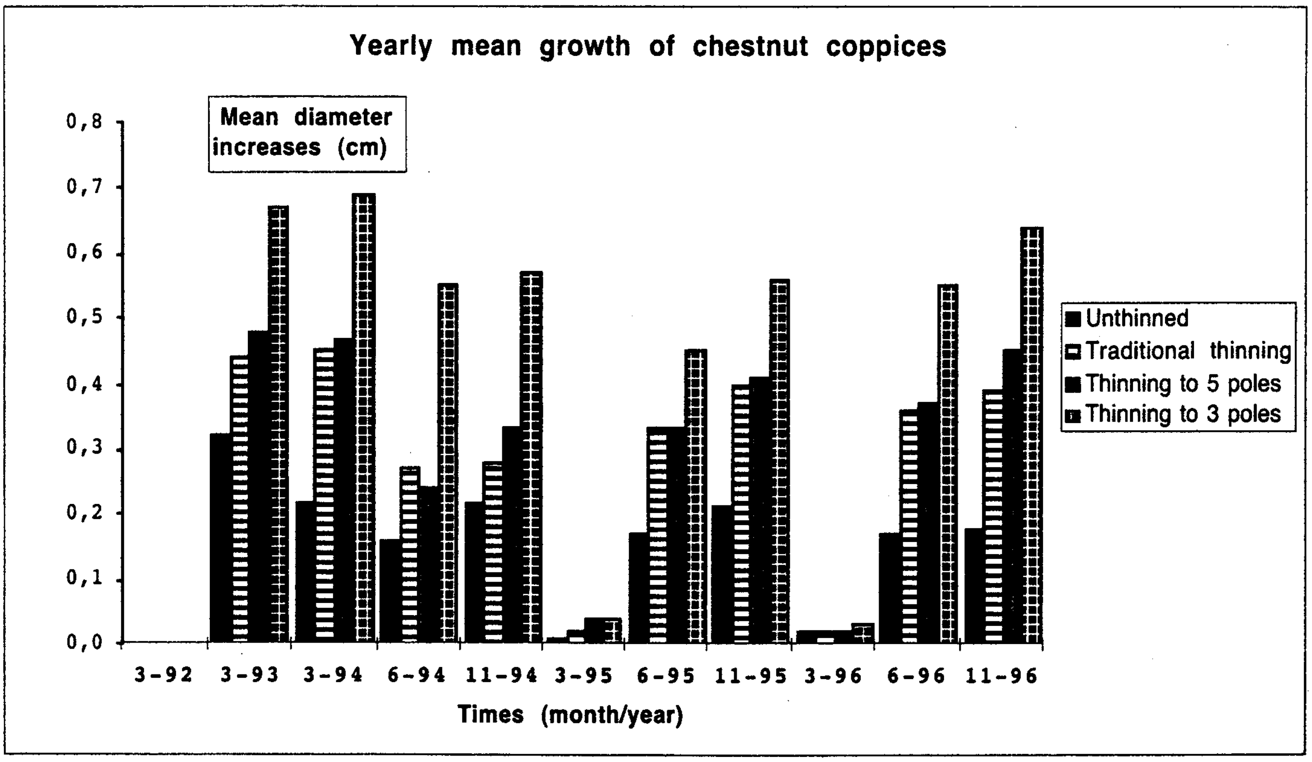

Figure 5. Yearly mean growth of the subplots of the chesnut coppice (jan: January; nov: November)

The increases in DBH (December, 1991 to December, 1996) ranged from about 1.8 cm on the unthinned subplot to 3.1 cm on the most intensely thinned subplot (Table 3) during the period 1992-96. Mean annual growth was thus affected by thinning intensity; Figure 6 shows the detailed growth (mean DBH) of selected shoots belonging to the four subplots during four years (1993-96).

The observed differences between figures of mean DBH growth from 1991 to 1996, mainly in the unthinned subplot, are according if we include all the poles (alive and death, 1.4 cm in 5 yr) or we do not include the death poles produced by the self thinning (1.8 cm in 5 yr).

The DBH on the unthinned subplot (T) had increased a mean increase of 3 mm yr^{-1}, but a self thinning ocurred (approximately 26 %; Table 3 and Figure 7) because of the death of the trees producing the dominant shoots, due in turn to competition for light. Both, At and Am thinnings had a mean DBH increase close to 4 mm yr^{-1}; Am also underwent self thinning (Figure 8; see tree death-roll); nevertherless, in broad stumps, At thinning did not imply shoot dead (Figure 9). In Ai thinning the diameter increase was 6 mm yr^{-1}; obviously in this case the low tree density did not produce a self thinning at all (Figure 10). Elorrieta (1949) affirmed that a DBH increase of more than 4.5 mm yr^{-1} is considered high and between 4.2 to 4.5 mm yr^{-1} would be considered moderate (in coppices 6-12 yr old).

Thus, thinning improves the wood production, but also affects self thinning (Ducrey, 1996).

In the four subplots an increase in G of about 8 m^2 ha^{-1} was observed over the 5 yr of the experimental period (Table 3) almost independently of the treatment applied. However, it should be noted that after this time, on the thinned plots the starting G value of 1991 was not reached, above all on the Ai subplot (13 *versus* 22 m^2 ha^{-1}). The 28 yr old chestnut coppice at *San Martín de Trevejo* that had undergone traditional thinning (see below) had a mean DBH of 10 cm and a G of about 30 m^2 ha^{-1}.

Towards the end of the experimental period, the greatest mean increase in height (H_m) was observed in the Am subplot (6 m), followed by Ai (5.5 m), affording growths of 61 cm yr^{-1} in Am, close to 55 cm yr^{-1} in At and Ai, and only 48 cm yr^{-1} in the T subplot (Table 3). The shoot mortality (light competition) at the Am subplot (Figure 8) could explain this similarity in H_m growths. Elorrieta (1949) stated that a H_m increase of more than 50 cm yr^{-1} is considered high and between 40 to 50 cm yr^{-1}, moderate (in coppices 6-12 yr old). In this sense, thinning also improved the wood production.

With respect to total aboveground biomass (B_a, calculated from the mean biomass per shoot) results showed that on the unthinned subplot (T) each shoot weighted 7 kg; this was 9 kg for the At, and 10.4 kg for Am; finally, this value was 11.5 kg for Ai (mean values obtained weighting 39, 22, 29, and 22 shoots, respectively). Multiplication of these values by the number of shoots per ha gave a B_a (attained at the end of the experimental period) of 61 Mg ha^{-1} on T, 43 on At, 50 on Am, and only 29 Mg ha^{-1} on Ai (Table 3). Total B_a was much higher when the coppice was unthinned (T) than when it was intensely thinned (Ai). The results obtained when the calculations of B_a were based on stumps (5 per subplot, randomly selected) were very similar even though the number of stumps per ha varied (from 14 to 24 stumps per subplot). Thus, the B_a obtained following this methodology was 85, 36, 55, and 34 Mg ha^{-1} (Table 3). The differences found between both methods (B_a calculated by to shoots or by stumps) when the values are compared are due to this spatial variability, since the number of shoots (7 or 5 dominant shoots) per stump is not always the same, owing to the different sizes of stumps and competition among shoots. However, on the Ai subplot had almost always the same number of shoots (39) with a high DBH (mean 7.9 cm), such that in both cases the values obtained are quite similar. In principle, the results of B_a obtained from using the shoot as unit would be expected to be more reliable since other parameters point to a similarity between At and Am thinnings. Total litter production (P_L) of the chestnut coppices varies according the annual precipitation; P_L corresponding to 1995 and 1996 were estimated (Table 3), together with their means. In this way, Figure 2 shows the high variation of the annual total rainfall and its distribution in the nearby site of Navasfrías. Mean P_L was much higher on T subplot, with 4.5 Mg ha^{-1} yr^{-1}; on At, P_L fell to 3.6 Mg ha^{-1} yr^{-1}. Am and Ai had even lower P_L (between 2.8 to 2.9 Mg ha^{-1} yr^{-1}).

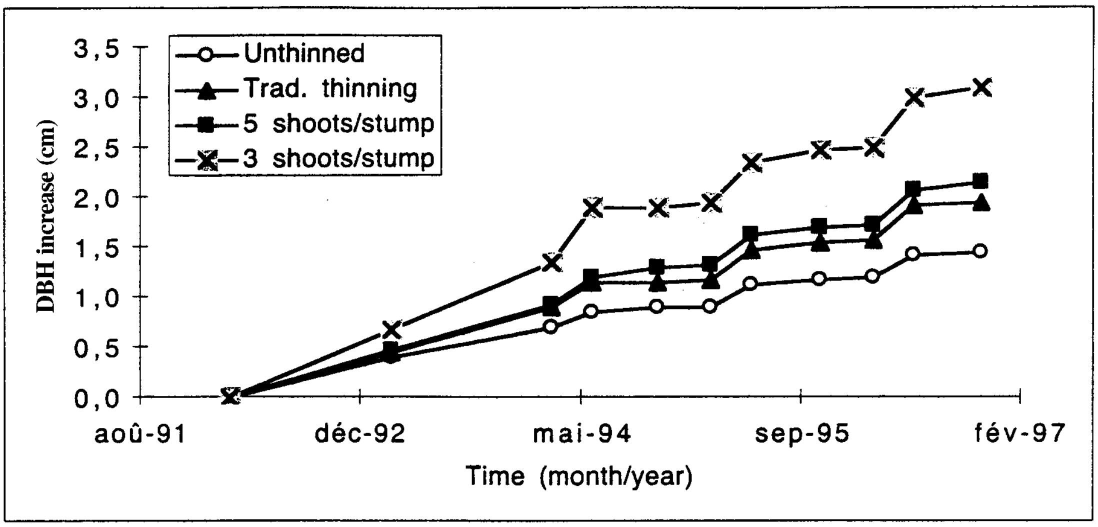

Figure 6. Accumulative mean growth of each thinned subplot of the chestnut coppice

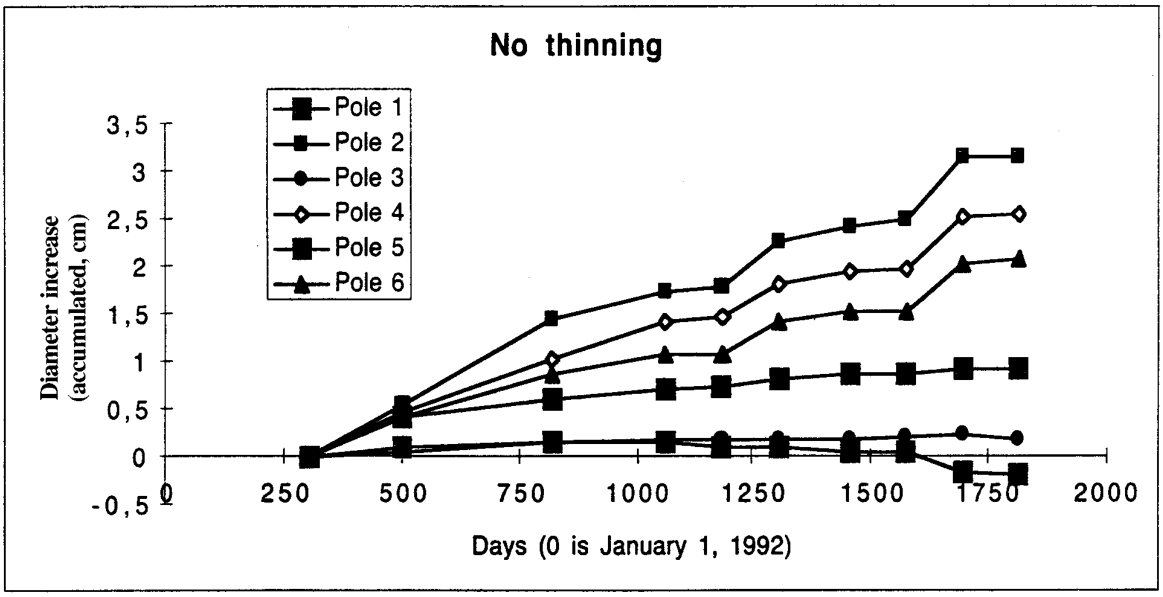

Figure 7. Growth of shoots on a stump selected from a unthinned subplot of the coppice

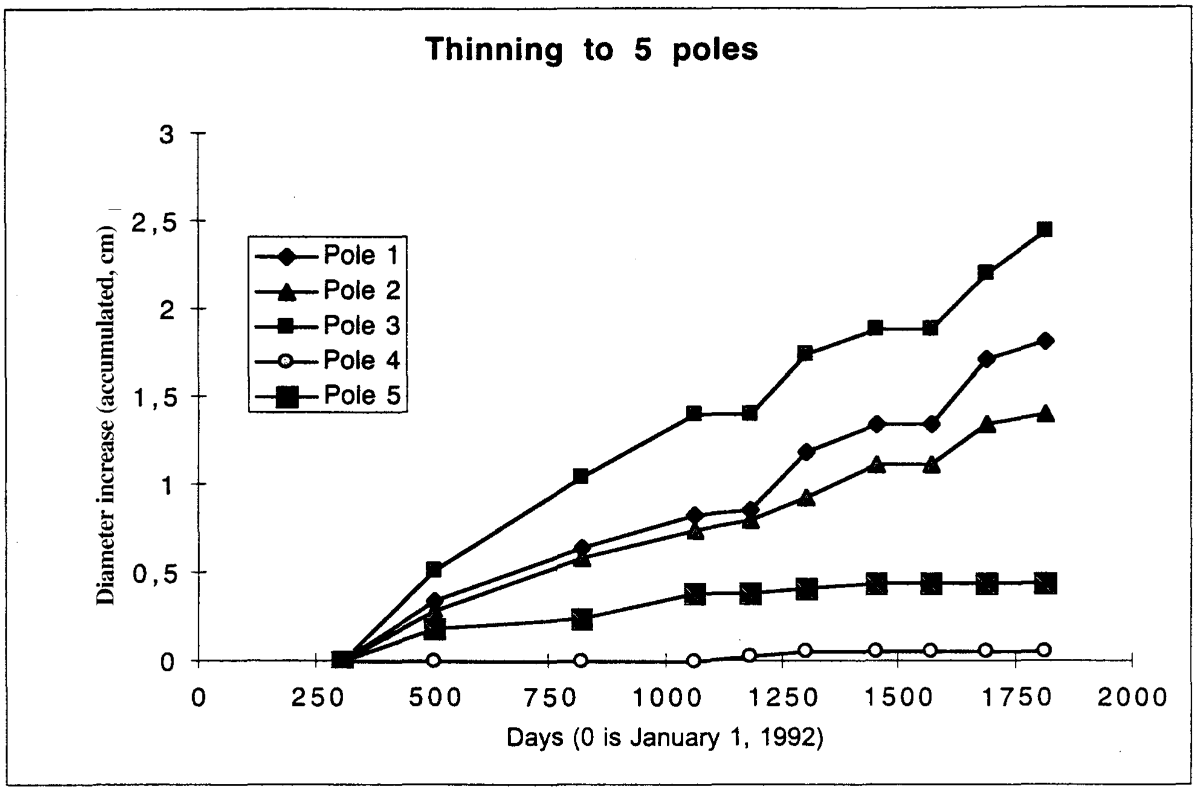

Figure 8. Growth of shoots on a stump selected from a subplot thinned to 5 poles of the coppice

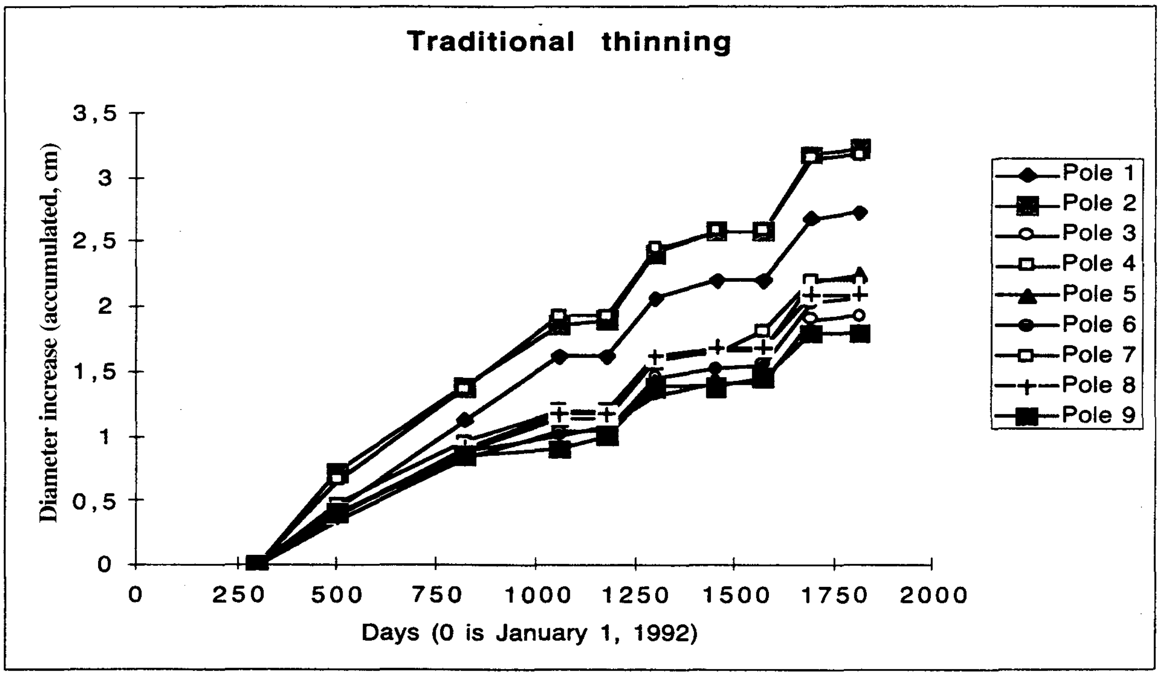

Figure 9. Growth of shoots on a stump selected from a traditional thinned subplot of the coppice

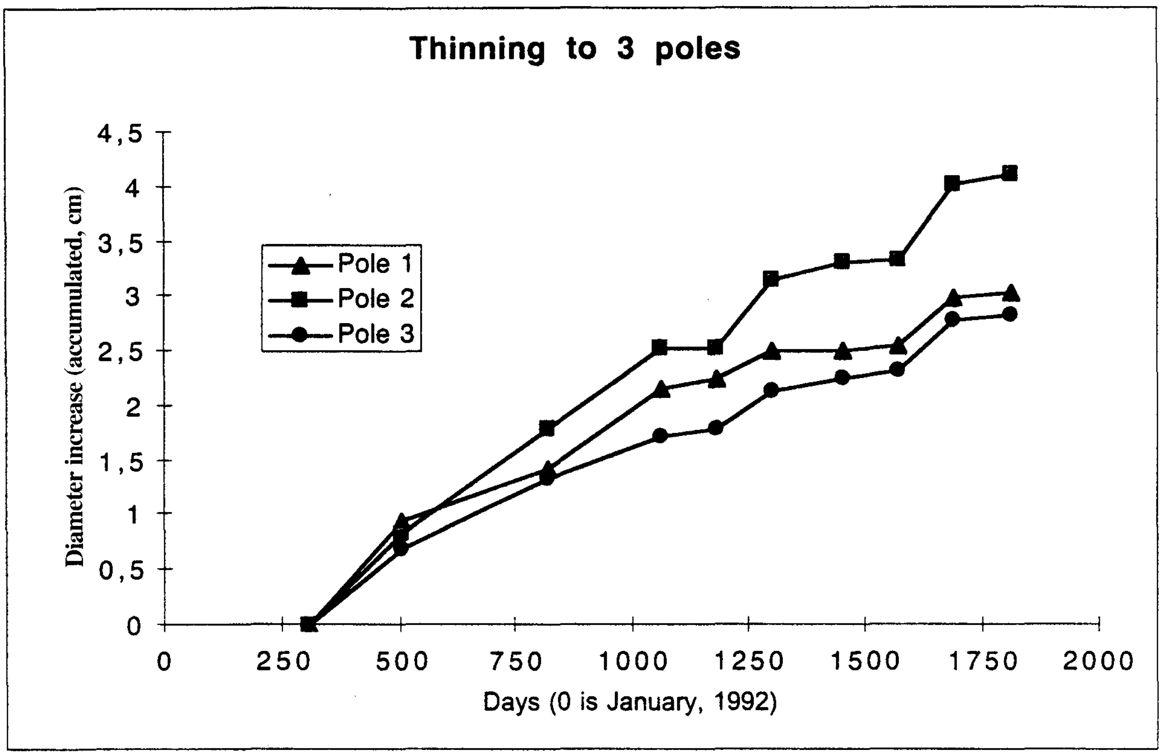

Figure 10. Growth of shoots on a stump selected from a subplot thinned to 3 poles of the coppice

Organ fractions were also separated (within P_L), although more than 80 % of this P_L was found to correspond to leaves, but this percentage varies from one year to the next because the amount of this fraction also depends on climatic factors (Table 3). In an old chestnut orchard of the *'Sierra de Béjar'* converted into a coppice (15 yr old) Santa Regina & Gallardo (1995) found a lower mean P_L (only 0.6 Mg ha^{-1} yr^{-1}), with leaf contribution reaching 52 %. Gallardo Lancho *et al.* (1995) found a mean P_L of 5.3 Mg ha^{-1} yr^{-1} (and a leaf litter production of 3.4 Mg ha^{-1} yr^{-1}) in the 25 yr old coppice of *San Martín de Trevejo* (see below).

The leaf area index (LAI) was calculated for 1995 and 1996. LAI values are affected by leaf production and unit leaf area (ULA), and therefore also vary from one year to another (Table 3). The At and Ai subplots gave the lowest LAI; this low value of LAI in the At subplot apparently due to a higher canopy surface, as we have observed before. Higher LAI seems to be directly related with a higher B_a.

Despite this, the ULA (Table 4) of the T subplot (21 cm^2 per leaf) was significantly lower than that of the thinned subplots; this means that higher the number of leaves, the lower the ULA.

The Am subplot had a little higher LAI than the other two thinnings (At and Ai; Table 3) apparently due to the effect of the ULA. Thus, both LAI and ULA area also seem to be affected by thinning. Note (see below) that the LAI of a 25 yr old chestnut coppice at the same site was 3.7 m^2 m^{-2}; this means that the LAI should diminish with the age of the chestnut coppice (increase of the canopy coverage).

The dead mass (tree necromass) resulting from this was measured (Table 4) at the end of the experimental period. 3.1 Mg ha^{-1} of dry organic matter was collected from the unthinned subplot, while on the rest of the subplots tree necromass remained below 0.6 Mg ha^{-1}, except the one with traditional thinning (At), which obviously gave the lowest tree necromass (below 0.4 Mg ha^{-1}).

Finally, the amount of soil litter (humus necromass) decreased over each year (Table 5), from

5.8 to 2.9 Mg ha^{-1} on the unthinned subplot (T) in 1995 due to the effect of litter decomposition (Gallardo Lancho *et al.*, 1995); this means an annual decomposition rate of 50 %. Santa Regina & Gallardo (1995) reported leaf decomposition values (*k*) of 0.33 in a chestnut coppice of the '*Sierra de Béjar*'; on a 25 yr old chestnut stand Gallardo Lancho *et al.* (1995) found a leaf *k* value of 0.42. These high decomposition constants justify the decrease in the amount of the soil litter along the year. The same decreases in soil litter was observed on the other subplots, although there was a lower initial amount of humus necromass, given the lower P_L (Table 5). It should be recalled that the highest fraction in soil litter comes from leaves. However, the amount of humus necromass was greater on the thinned plots towards the end of each year, which suggests a slower decomposition rate (above all on the intensely thinned subplot). Then, litter decomposition was found to decrease as the intensity of thinning increased. Working in subtropical forests Aceñolaza & Gallardo (1995) found that self thinning (which produced a decrease of canopy coverage) increases soil dryness, thus slowing down litter decomposition. That higher P_L in the T subplot, in addition to a higher production of tree necromass, increases the risk of forest fires in this subplot in relation to the other thinned subplots. From the above data, it is possible to calculate the rate of decomposition (*k*, Jenny *et al.*, 1949). The results (Table 6) point to a logically faster rate of decomposition for the leaf litter (*k*) than for the total litter (higher *K*, except for the unthinned subplot, which had almost the same value; this last fact is contradictory, since the total litter has other recalcitrant fractions; the result may then come an error of the methodology. The calculated mean residence times (Table 6) of the total litter on the soil (1/*K*) ranged from 4 yr (for Ai subplot, with lower *k*) to 1.8 yr (T, unthinned subplot); canopy coverage seems then to affect the time of decomposition, because of its influence on the microclimate. The chestnut coppice studied here emerges as a productive ecosystem, the dead leaves acting as the main vector of bioelement return to the soil (Martins *et al.*, 1995 and 1997).

Timber production of the chestnut coppice as managed in a traditional way

Table 7 shows the most important data concerning the dasometric characteristics of a chestnut coppice traditionnally thinned and clearfelled in 1967. In 1995, the index of leaf coverage was 85 % (Table 2). Thus, the fact that the tree cover of the chestnut forest was not completely closed led to the continuous appearance of new trees (Table 7). The consequence of this is dual: on one hand, the density of the forest continued to increase (from 3 970 trees ha^{-1} in 1991 to 4 573 trees ha^{-1} in 1995) while, on the other, mean height decreased (from 13 to 11 m in the same years) despite the continuous increase in the dominant height (from 15 to 19 m). It should be noted that if no previous thinning had been carried out the number of chestnut trees after felling would be no less than 12 000 trees ha^{-1} (see above) and stabilisation could be reached about 5 000 trees ha^{-1}; this means that in unthinned chestnut coppice more than 50 % of shoots die owing to self thinning. The LAI depends on annual leaf production (Table 7) but may reach 3.72 m^{2} m^{-2} (1991) or fall to 3.07 m^{2} m^{-2} in dry years (1995); this means that LAI is also influenced by annual climatic changes. Regarding basal area *G* (an index reflecting productivity) was found to increase from 28.6 to 32.8 m^{2} ha^{-1} (1991 and 1995, respectively; Table 7); that is, over the 4 yr elapsed it increased by 4.2 m^{2} ha^{-1}. This means that there was a mean *G* increase of 1 m^{2} ha^{-1} yr^{-1} when this chestnut coppice surpassed an age of 20 yr. This increase was slightly higher during the first 24 yr (1.2 m^{2} ha^{-1} yr^{-1}); note that the mean annual increase in *G* for a coppice of 5 yr old was approximately 4 m^{2} ha^{-1} yr^{-1} (see above) and for an unthinned coppice of 9 yr, 2.5 m^{2} ha^{-1} yr^{-1}; furthermore, a mean annual increase of *G* of approximately 1.5 m^{2} ha^{-1} yr^{-1} was calculated for the thinned subplots. Using the data of *G* (in m^{2} ha^{-1}) and H_m (in m) of the stand (Table 7), the final volume (V_f, in m^{3} ha^{-1}) is obtained according the formula: $V_f\,(m^3\,ha^{-1}) = G{*}H_m{*}f$

being *f* a factor depending from the trunk shape (we assume a value of 0.7 for the chestnut coppice). Then, the resulting final volume is 260 m^{3} ha^{-1} for 1991 and 259 m^{3} ha^{-1} for 1995. Dividing this volume by 25 yr, we obtain a yearly yield of 10 m^{3} ha^{-1} yr^{-1}, implying a strong mean annual growth.

SUBPLOTS (November, 1996)	MEAN UNIT LEAF AREA (cm2/leaf) ± SE	ABOVEGROUND NECROMASS Per stump ± SE (kg/stump)	ABOVEGROUND NECROMASS Per ha (Mg/ha)
T	21 ± 2	2.0±0.8	3,1
At	26± 2	0.36±0.04	0,31
Am	28 ± 3	0.6±0.1	0,56
Ai	27 ± 2	0.7±0.2	0,60

Table 4. Unit leaf area and tree necromass (death due to competition) of the chestnut subplots (± SE: Standard error)

SOIL NECROMASS (Mg/ha)	UNTHINNED (T)					TRADITIONAL THINNING (At)				
	1995			1996		1995			1996	
	March	June	November	March	November	March	June	November	March	November
Leaves	5,79	2,88	2,90	2,58	3,84	5,54	3,14	2,66	3,03	2,91
Branches	3,68	1,11	0,45	0,31	0,59	4,98	2,38	2,90	2,28	2,85
TOTAL	9,47	3,99	3,35	2,89	4,43	10,52	5,52	5,56	5,32	5,76

SOIL NECROMASS (Mg/ha)	THINNED 5 SHOOTS PER STUMP (Am)					THINNED 3 SHOOTS PER STUMP (Ai)				
	1995			1996		1995			1996	
	March	June	November	March	November	March	June	November	March	November
Leaves	4,34	2,90	3,31	3,00	36,58	4,79	3,16	4,73	3,51	4,31
Branches	3,45	0,71	1,72	1,76	1,07	3,22	1,74	5,18	1,57	1,21
TOTAL	7,79	3,61	5,02	4,76	37,65	8,01	4,90	9,91	5,08	5,52

Table 5. Necromass on the floor of the chestnut subplots (on five dates)

SUBPLOTS (Year 1995)	Leaf or total litter production A (Mg/ha, yr)	Leaf or total litter accumulation L (Mg/ha)	k or K A/(A+L) (1/yr)	Mean residence time tr (yr)
Leaf litter				
T	3,23	2,90	0,53	1,9
At	2,89	2,66	0,52	1,9
Am	2,75	3,31	0,45	2,2
Ai	2,68	4,73	0,36	2,8
Total litter				
T	4,42	3,50	0,56	1,8
At	3,74	6,09	0,38	2,6
Am	3,13	5,39	0,37	2,7
Ai	3,53	10,3	0,26	3,9

Table 6. Decomposition constants of leaf (*k*) and total (*K*) litter, and mean times of residence (tr)

DATES Month, year	Tree density (Tree/ha)	Leaf litter production (Mg/ha, yr)	Total litter production (Mg/ha, yr)	Mean D.B.H. (cm)	Mean heigth (m)	Dominant heigth (m)	LAI (m2/m2)	Basal area (m2/ha)
May, 1991	3970	3,20	4,79	9,2	13,0	15,0	3,72	28,58
August, 1995	4573	3,95	5.25*	9,6	11,3	19,0	3,07	32,76

* Mean of three years (1991-94).

Table 7. Evolution of some characteristics of the chestnut stand (*San Martin de Trevejo*)

But, if the following equation, reported by Gallego *et al.* (1993) is used:

V_f (m^3 ha^{-1}) = 0.079*$DBH^{2.514}$ *(number of trees/δ_{wood})

where δ_{wood} is the density of the chestnut wood (we assumes is 0.92 Mg m^{-3}), we obtain 90 and 116 m^3 ha^{-1} for 1991 and 1996, respectively.These figures seems to be very low and, hence, this equation is only useful to know the weight (in kg) for each individual tree.

Moreover, if we use the following relationship (Berrocal *et al.*, 1998):

H_m(m) =0.86*DBH(cm)+ 2.02

for calculating directly the final volume of the wood, we obtain 240 and 260 m^3 ha^{-1} for 1991 and 1995, respectively (also a f = 0.7 was used), values too close to those obtained using the first formula. The difference between these two values divided by 4 yr (1991-1995) gives the mean periodic growth (or annual growth of the volume of wood), estimated in 5 m^3 ha^{-1} yr^{-1}; anyway, this figures should be taken with criticism, because the methodological errors.

In the recent years price of every chestnut pole *in situ* has increased from 150 Spanish pesetas (0.85 euros) to 200 Spanish pesetas (1.1 euros). Given that the tree density is about 4000 poles ha^{-1}, this means that the price of 1 ha of chestnut coppice (about 25 yr old) is 800 000 pesetas (more than 4 200 euros). Hence, the net benefit of this coppice is about 170 euros ha^{-1} yr^{-1}, which is an important input for marginal lands (mushroom recovery and hunting of wild boars are not included in this estimation), but not enough for economic development of the area (except public chestnut forests or private, large landowners)

CONCLUSIONS

Taking into account the parameters studied here, it may be concluded that At or Am thinning on chestnut coppices is the most recommendable procedure even though the control plot (T) had a higher total biomass, but with thin shoots and weak growth. By contrast, intense thinning (Ai) led to strong growth, although starting out from a very low initial total biomass. Accordingly, leaving approximately 5 shoots per stump in thinning (or performing the traditional thinning to 7-4 dominant shoots per stump) affords an intermediate starting biomass, an optimum LAI, and good growth. The high density at the unthinned plot (T) led to spontaneous thinning, with many of the trees subsequently diyng (up to 25 % of the initial trees). Then, thinning improve the wood production, but also afects spontaneous thinning.

Total litter production was much higher on the unthinned coppice (T) than on the thinned coppices. This fact and the existence of tree necromass in unthinned coppices give an undesirable increasing of the fire risk at these. Furthermore, the thinning of chestnut coppices affords a greater unit leaf area.

The amount of litter necromass in the soil decreased throughout the year, being more evident in the unthinned coppice (T) because a faster litter decomposition due to an effect of the litter humidity. Mean residence time of the soil litter is about 3 yr.

The traditional technique of clearfelling at around 22-25 yr can be said to be successful (with a thinning at around 5 yr, leaving about 5 dominant shoots per stump) in the sense that as from that age the annual yield in timber decreases, apart from other problems such as the development of ring shake in the trunk or the appearance or chancre (*Endothia parasitica*), which can be controlled by treatment aimed at delaying its onset.

Tree growth is mainly controled by the amount of rainfall in May and June, whereas the price of chestnut wood limits coppice management for sustainable development, in spite of high timber production of these coppices.

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REFERENCES

Aceñolaza P. & Gallardo J.F. 1995. Influencia de la edad del bosque en la evolución de la pérdida de peso seco en hojarasca de *Alnus acuminata* en alisedas de la provincia de Tucumán (R. Argentina). *Inv. Agr.: Sist. Recur. For.*, 4:177-188.

Amorini E. 1996. Analysis of different silvicultural systems in chestnut coppices. Criteria to define a sustainable management. In: F. Romane (Ed.). *Second Annual Report of the CAST/ENVIRONMENT Project.* C.E.F.E./C.N.R.S., Montpellier. 71-75.

Berrocal M., Gallardo J.F., & Cardeñoso J.M. 1998. *El castaño*. Mundi-Prensa, Madrid.

Ducrey M. 1996. Dynamic of shoot populations: stool resprouting, evolution of stand structure and competition processes. In: R. Morandini (Ed.). *Consolidate Progress Report of the MEDCOP/AIR Project.* Istituto Sperimentale per la Selvicoltura, Arezzo.

Ducrey M. & Toth J. 1992. Effect of cleaning and thinning on height growth and girth increment in holm oak coppices. *Vegetatio*, 99-100 : 365-376.

Elías F. & Ruiz L. 1977. *Agroclimatologia de España.* I.N.I.A., Madrid.

Elorrieta J. 1949. *El castaño en España.* I.F.I.E., Madrid.

Evans J. 1984. *Silviculture of broadleaved woodland.* Forestry Comission, London. 73-81.

Gallardo Lancho J.F. & col. 1995. Nutrient cycles in chestnut ecosystems of Sierra de Gata. In: F. Romane (Ed.). *Sustainability of Mediderranean ecosystems: case study of the chestnut forest.* European Commission, Luxemburgo. 23-44.

Gallego H.A., Rico M., & Santa Regina I. 1993. : Biomass equations and nutrients content for a *Castanea sativa* Mill. forest. In: E. Antognozzi (Ed.). *International Congress on chestnut.* Istituto coltivazioni arboree, Spoleto. 409-412.

Jenny H., Gessel S.P., & Bingham F.T. 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. *Soil Sci.*, 68: 419-432.

Leonardi S., Rapp M., Izzo R., Failla M., Guarnaccia D. & De Santis C. 1994. Chestnut ecosystem function: nutrient cycle processes within several stands in relation to age and altitude on the Etna Volcano. In: Final Report of the Project *'Biological criteria for sustainable development in natural degenerate forests of Mediterranean Europe: A case study of chestnut ecosystems.* In: F. Romane (Ed.). *C.N.R.S.*, Montpellier. 45-61.

Martíns A., Gallardo J.F., & Santa Regina, I. 1995. Interaction between litter and soil epipedons in forest ecosystems of the *'Sierra de Gata'* mountains, province of Salamanca, Spain. *Arid Soil Res. Rehabil.*, 9: 299-305.

Martíns A., Gallardo J.F., & Santa Regina, I. 1997. Long term decomposition process of leaf litter from *Quercus pyrenaica* forests across a rainfall gradient (Spanish Central System). *Ann. Sci. For.*, 54: 189-200.

Mesón M. & Montoya M. 1993. *Silvicultura mediterránea.* Mundi-Prensa, Madrid.

Pires A.L., Portela E., & Martins A. (1994) : Nutrient cycling in chestnut groves in the Tras-Os-Montes region. In: F. Romane (Ed.). *Final Report of the Project 'Biological criteria for sustainable development in natural degenerate forests of Mediterranean Europe: A case study of chestnut ecosystems'. C.N.R.S.*, Montpellier. 9-22.

Turrión B.; Gallardo J.F., & González M. 1997. Nutrient availability in forest soils as measured with anion-exchange membranes. *Geomicrobiol. J.*, 14: 51-64.

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Organic matter and foliar nutrient dynamics in *Castanea sativa* Mill. coppice stands of southern Europe

Matière organique et dynamique des éléments minéraux de la nappe foliaire dans des taillis de *Castanea sativa* Mill. du sud de l'Europe

I. SANTA REGINA[1], S. LEONARDI[2] & M. RAPP[3]

1. IRNA-C.S.I.C., Cordel de Merinas 40, 37071 Salamanca, Spain
2. Università di Catania, Istituto Chimico, Facoltà di Ingegneria, viale A. Doria, I-95125 Catania, Italy
3. CEFE-CNRS, 1919, Route de Mende, B.P. 5051, 34293 Montpellier Cedex 5, France

ABSTRACT

Organic matter, chemical and biological aspects of aboveground biomass, nutrient content, linked to seasonal foliar nutrient dynamics and nutrient-use efficiency, are of basic importance for sustainability of forest ecosystems. These parameters have been studied in four *Castanea sativa* Mill forests near Salamanca (Spain), Catania (Italy) and Montpellier (France). Best regression equations for the aboveground tree biomass were obtained by applying the allometric : (tree biomass) = a $(\mathrm{DBH})^b$ method and the following regression equations were calculated:

Italian stands : biomass (Kg) = $0.137\ (\mathrm{DBH\ cm})^{2.247}$
Spanish stand : biomass (Kg) = $0.066\ (\mathrm{DBH\ cm})^{2.628}$
French stand : biomass (Kg) = $0.118\ (\mathrm{DBH\ cm})^{2.336}$

The relation between litterfall and stand age was very significant: in the two younger coppices of Fossa la Nave and Piano Porcheria (Italy), the amounts of yearly litterfall were: 2640 kg $\mathrm{ha^{-1}\ yr^{-1}}$ and 1709 kg $\mathrm{ha^{-1}\ yr^{-1}}$ respectively; whereas in the two older stands litterfall amounted 5245 kg $\mathrm{ha^{-1}\ yr^{-1}}$ in San Martín (Spain) and 5334 kg $\mathrm{ha^{-1}\ yr^{-1}}$ in Le Vernet (France). The N and P translocation patterns, from leaves to perennial organs followed the same relationship that the nutrient inmobilization in biomass, the K translocation differs in the French stand, whereas for Ca, the pattern differed for the two Italian stands. Mg don't followed any pattern. The nutrient-use efficiency index values (proportional resorption) as applied to the four stands suggest that Le Vernet stand translocated less amounts of K and Mg, Fossa la Nave of N, Piano Porcheria of Ca and San Martín of P.

Key-words: Aboveground biomass, nutrient translocation, forest ecosystems, *Castanea sativa* Mill.

RESUME

La matière organique et les éléments minéraux accumulés dans la biomasse aérienne et leurs relations avec la dynamique de la nappe foliaire, de sa minéralomasse, ainsi que de l'efficience de l'utilisation des nutriments sont d'une importance primordiale pour la gestion durable des systèmes forestiers. Ces paramètres ont été étudiés dans quatre taillis de *Castanea sativa* Mill localisés aux alentours de Salamanca (Espagne), Catania (Italie) et Montpellier (France).

Les biomasses aériennes des arbres ont été établies en utilisant des calculs de régression entre la biomasse aérienne et le diamètre du tronc à 1,30m. Les régressions de puissance, de type: Biomasse aérienne de l'arbre = a $(D_{1,30})^b$ donnent les meilleurs résultats, avec respectivement les équations suivantes:

Italie biomasse(kg) = $0{,}137(D_{1{,}30\mathrm{m}}\mathrm{cm})^{2.247}$
Espagne biomasse(kg) = $0{,}066(D_{1{,}30\mathrm{m}}\mathrm{cm})^{2.628}$
France biomasse(kg) = $0{,}118\ (D_{1{,}30\mathrm{m}}\mathrm{cm})^{2.336}$

La relation entre l'âge des peuplements et les retombées de litière sont significatives. Dans les deux stations les plus jeunes (Fossa la Nave et de Piano Porcheria, Italie), les retombées annuelles de litière sont respectivement de 2640 et 1709 kg $\mathrm{ha^{-1}\ an^{-1}}$. Dans les deux stations plus âgées, la production de litière s'élève à 5245 kg $\mathrm{ha^{-1}\ an^{-1}}$ à San Martín (Espagne) et 5334 kg $\mathrm{ha^{-1}\ an^{-1}}$ au Vernet (France). Les translocations de N et de P, de la nappe foliaire vers les organes pérennes étaient directement liées à leur immobilisation dans la biomasse. La translocation de K était différente dans la station française par rapport aux trois autres, alors que pour Ca, ce sont les deux taillis italiens que diffèrent des deux autres. Pour le Mg, aucune relation entre les quatre stations n'a été observée. L'indice d'efficience d'utilisation des nutriments appliqué aux quatre peuplements indique les plus faibles translocations de K et de Mg au Vernet, de N à Fossa la Nave, de Ca à Piano Porcheria et de P à San Martín.

Mots-clés : écosystèmes forestiers, biomasse aérienne, retombée de litière, translocation de nutriments, *Castanea sativa* Mill.

INTRODUCTION

Aboveground litter plays a fundamental role in the nutrient turnover and in the transfer of energy between plants and soil, being the source of the nutrient accumulated in the uppermost layers of the soil. This is particularly important in the nutrient budgets of forest ecosystems on nutrient-poor soils, where the vegetation depends in large part on the recycling of the nutrients contained in the plant detritus (Singh, 1978).

The adaptations of perennial plants to different levels of nutrients in soils are often studied in terms of the efficiency of nutrient use, where efficiency is the relationship between biomass production and the loss of nutrients through litterfall (Gray, 1983; Boerner, 1984; Pastor *et al.*, 1984). The withdrawal of nutrients from senescing leaves and their storage in the perennial parts of trees is a common phenomenon (Ryan & Bormann, 1982). This retranslocation of nutrients may satisfy a significant proportion of demand for nutrients for the production of new biomass (Sollins *et al.*, 1980; Chapin & Kedrowski, 1983; Meier *et al.*,1985; Lim & Cousens, 1986). Similarly, retranslocation is a beneficial process because the tree is less subject to fluctuations of nutrient pool in the soil.

Sweet chestnut (*Castanea sativa* Mill) stands are very common all around the western Mediterranean Basin. Formerly managed as coppices, these stands were regularly clear-cut every 15-25 years, according to their productivity under various local conditions.

Castanea sativa coppice management is now more or less forsaken. Fruit production occurs mostly in orchards and the wood is only used for barrels or fuel. Nevertheless, chestnut coppices cover large areas in the Mediterranean mountains of France, Italy and Spain. The role of these forests is not limited only to aboveground production, but aesthetical and landscape safeguard aspects are also important. Nevertheless this century has been characterised by a progressive decrease in the chestnut area. Ink and blight diseases, forest fires, changes in alimentary customs, low markets for high quality timber, etc., are some of the main causes of this decline. Over the last years, social interest in forest conservation has increased. Efforts have been made to save and improve existing chestnut stands; in this line, research has played a significant role in improving contributions to health aspects, nut quality and production, vegetative propagation, genetic improvement, economical and other cultivation aspects of the chestnuts. Data concerning ecological parameters of these forests are rare. It is thus necessary to conduct new research on the ecological role of chestnut species (*C. sativa, C. crenata*, etc.) and the use of these forests as resources for sustainables development.The main aim of the present work was to make a comparison of organic matter dynamics and its nutrient content in several *Castanea sativa* forests, under Mediterranean climate, in Spain, Italy and France.

MATERIALS AND METHODS

Study sites

In Italy, two *Castanea sativa* stands were selected around the Etna volcano. One was situated at 1600 m above sea level (Fossa la Nave) on the southern side of the volcano, while the other one (Piano Porcheria) was on the eastern slope at 1000 m above sea level. The two stands were even-aged young coppices, with a density of 1895 and 5668 trees ha^{-1} respectively. Their DBH distribution classes are shown in Figure 1. The basal area was 26.0 m^2 for Fossa la Nave and 28.1 m^2 for Piano Porcheria.

The Spanish stand of San Martín was located in the Sierra de Gata (Cáceres Province), West of Salamanca, at 940 m elevation, with a density of 3970 trees ha^{-1} and 26.0 m^2 basal area.

The French stand of Le Vernet was located at 800 m elevation, in the Cevennes mountains, on the southern part of the Massif Central, about 100 Km North of Montpellier, with a density of 2706 trees ha^{-1}. Basal area amounted 33.5 m^2. Soils at the study sites were very different: humic leached brown soils in Spain, acid brown soils in France (cambisol) and volcanic andosols at Etna Volcano (F.A.O. 1973) The general climate, parent material, forest data and others structural characteristics are indicated in Table 1.

Biomass determination

The diameter at breast height (DBH) of all trees, include in 1 ha area, at each experimental plot were measured and their distributions in diameter classes were calculated for the Italian, French and Spanish

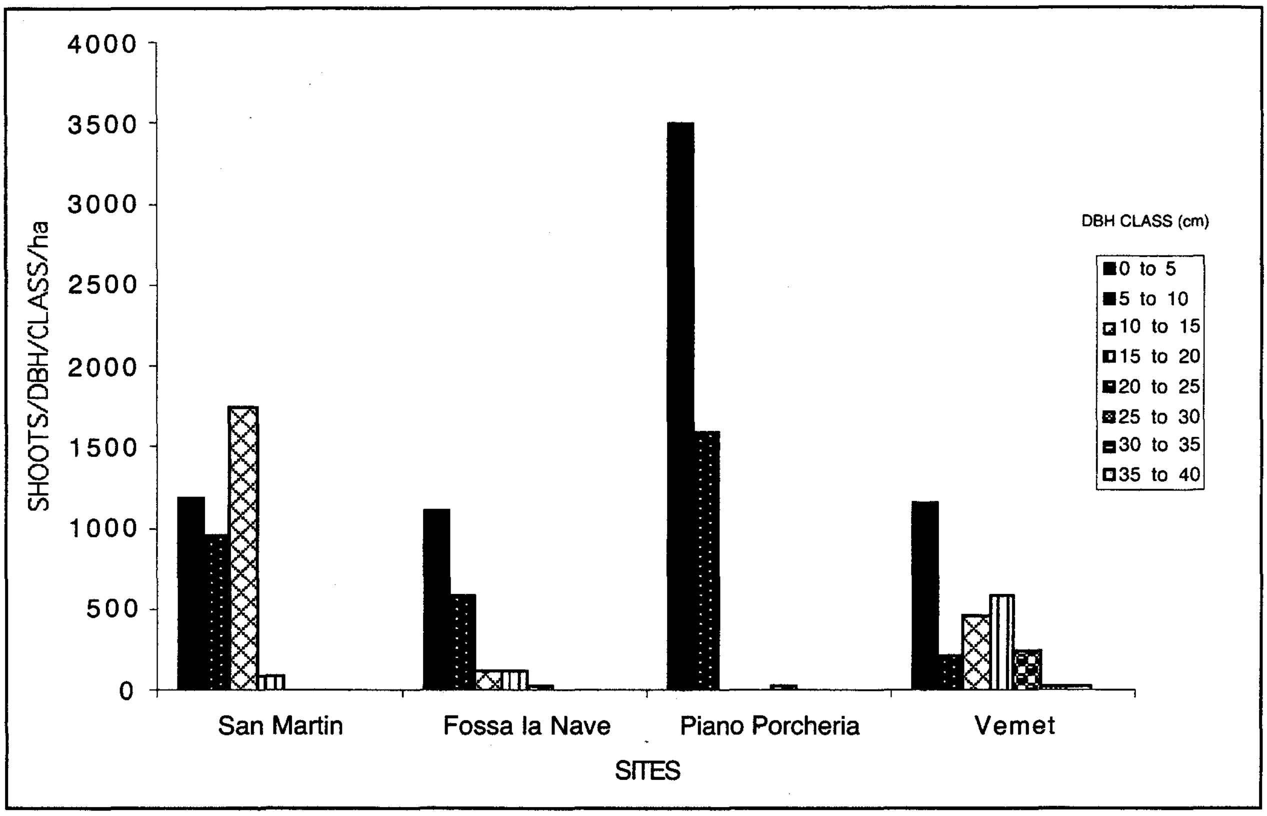

Figure 1. Diameter at breast height (DBH) class distribution in the four chesnut forests

Site	Altitude (m)	Mean Temp. (°C)	Rainfall (mmy^{-1})	Parent Material	Soil	Trees ha^{-1}	Age Years	Basal area (m^2)	DBH (cm)
Piano Porcheria	1000	13.3	1180	Volcanic ash & lava	Andosol	5668	7	28.1	4.9
Fossa la Nave	1600	7.5	1110	Volcanic ash &lava	Andolol	1895	8	26.0	7.5
San Martín	940	14.2	1180	Granite	Cambisol	3970	25	26.0	10.0
Le Vernet	800	12.7	690	Schist	Cambisol	2706	>30	33.5	10.0

Table 1. Site and forest characteristics for the four experimental plots

sites (Figure 1). Forty-two representative trees of the different diameter classes were felled to establish their aboveground biomass: 31 in Italy, 8 in Spain and 10 in France.

Each harvested tree was divided into sections (trunk, branches and leaves), according to their height (from 0-1.3 m, 1.3-3 m, 3-5 m, 5-7 m, and so on), and each section of the tree was weighed in the field. Subsamples were brought to the laboratory for further analysis: moisture content, after drying to constant weight at 80°C, for trunk, branch and leaf samples.

For each tree, the trunk, branch and leaf weights and total biomass were correlated with DBH using regression analysis. Various regression equations, calculated for the 49 studied trees, indicated the following determination coefficient values:

- logarithmic regression = 0.445
- exponential regression = 0.772
- linear regression = 0.445
- power regression = 0.908

Consequently, the power regression equations: Biomass = a $(DBH)^b$ were selected.

Litterfall determination

Thirty litter traps, with a 0.25 m^2 collection area each one were distributed randomly at the Spanish and French sites and forty at the Italian sites. Samples of litter were collected monthly or each two weeks during the period of high litterfall; at other times the collections were less frequent (Santa Regina & Gallardo, 1985). In the laboratory, the samples were separated into leaves, twigs, fruits, bark, inflorescences, etc. The components were then air-dried, grounded, homogenised and expressed on a surface area basis.

Seasonal variation of nutrients within leaf biomass

Monthly leaf samples were collected during a vegetative cycle at three tree heights, from several representative trees of different DBH classes of each stand. The samples were taken to the laboratory, dried at 80°C. Mean leaf dry weight for each sampling time was also determined.

Laboratory procedures

Representative biomass and litter samples were ground, then used for chemical analysis, according to the procedure proposed by Chapman & Pratt (1979). After plant digestion Ca, Mg and K were determined using atomic absorption spectrophotometry or flame photometry. P was determined, colorimetrically using metavanadate (Chapman & Pratt, 1979) and N by the Kjeldahl method or directly with a macro-N Heraeus device. The chemical results, expressed as percentage of the plant tissue, were applied to the biomass or litterfall values to determine the amounts of nutrients in the biomass or litter on a surface area basis.Data were subjected to a one - factor statistical analysis of variance algorithm (ANOVA). The regression curves were also established according to the best r^2.

RESULTS AND DISCUSSION

Aboveground tree biomass

From all the felled, measured and weighed trees, wood and leaf biomass were determined relative to DBH of the trunk for each tree using the allometric equations: $Y = aX^b$

were Y is the total aboveground biomass (dry weight), X is the tree's DBH. The following regression equations for total aboveground biomass (Kg), expressed in terms of DBH (cm) were calculated for each country:

Italian trees biomass 0.137 (DBH) r = 0.955
Spanish trees biomass 0.066 $(DBH)^{2.628}$ r = 0.996
French trees biomass 0.118 $(DBH)^{2.336}$ r = 0.936

Table 2 summarises the aboveground stand biomass for trunk, branches and leaves from the three sites. The available data had been determined previously (Gallego *et al.,* 1994, Leonardi *et al.,* 1995) using the specific regression for each country and the number of trees ha^{-1}, distributed in DBH classes. The total biomass amounts were as follow : Fossa la Nave 22.0 Mg ha^{-1}; Piano Porcheria 24.1 Mg ha^{-1}, San Martín 120.4 Mg ha^{-1}, Le Vernet 153.4 Mg ha^{-1} (Table 2). In the old stands, with trees aged from 25 to more than 30 years, the biomass values were directly related to the stand age. The mean yearly increment amounted 2.8 Mg ha^{-1} at Fossa la Nave, 3.4 at Piano Porcheria, 4.8 at San Martín and more than 5.0 Mg ha^{-1} at Le Vernet (data not show). Similarly, the

Site	Age (years)	Trunk	%	Branches	%	Wood	%	Leaves	%	Total
Piano Porcheria	7	$18386^{\pm 884}$	76.3	$4208^{\pm 252}$	19.1	$22594^{\pm 1236}$	95.4	$1488^{\pm 88}$	4.6	$24082^{\pm 1428}$
Fossa la Nave	8	$16689^{\pm 903}$	75.7	$3741^{\pm 226}$	17.0	$20430^{\pm 1182}$	92.7	$1607^{\pm 90}$	7.3	$22037^{\pm 1346}$
San Martín	25	$104702^{\pm 2140}$	86.9	$11807^{\pm 683}$	9.8	$11650\ 9^{\pm 5390}$	96.7	$3910^{\pm 203}$	3.3	$120419^{\pm 5480}$
Le Vernet	> 30	$118233^{\pm 2350}$	77.1	$31533^{\pm 1240}$	20.6	$149766^{\pm 6460}$	97.7	$3606^{\pm 236}$	2.3	$153372^{\pm 6825}$

Table 2. Aboveground biomass for the four sites (Kg ha^{-1})

Site	Total litterfall	Leaf litterfall	N	P	K	Ca	Mg	Total Nutrients
Piano Porcheria	$1709^{\pm 163}$	$1230^{\pm 72.0}$	$10.4^{\pm 0.6}$	$1.8^{\pm 0.2}$	$7.7^{\pm 0.6}$	$10.7^{\pm 1.2}$	$6.4^{\pm 0.8}$	$37.0^{\pm 2.3}$
Fossa la Nave	$2640^{\pm 198}$	$1353^{\pm 51.3}$	$10.3^{\pm 0.6}$	$1.9^{\pm 0.2}$	$6.9^{\pm 0.5}$	$15.0^{\pm 1.1}$	$6.5^{\pm 0.7}$	$40.6^{\pm 2.3}$
San Martín	$5245^{\pm 302}$	$3429^{\pm 65.4}$	$41.5^{\pm 2.3}$	$6.8^{\pm 0.9}$	$15.4^{\pm 1.1}$	$18.5^{\pm 1.5}$	$11.0^{\pm 1.1}$	$93.2^{\pm 6.8}$
Le Vernet	$5334^{\pm 315}$	$3457^{\pm 64.8}$	$43.7^{\pm 2.4}$	-	$17.3^{\pm 1.3}$	$10.4^{\pm 1.3}$	$5.0^{\pm 0.5}$	$76.4^{\pm 5.9}$

Table 3. Yearly leaf litterfall and amounts of nutrients returning to the soil (Kg ha^{-1} yr^{-1})

Site	Leaf biomass	N	P	K	Ca	Mg	Total Nutrients
Piano Porcheria	$1500^{\pm 88}$	$19.8^{\pm 1.7}$	$3.4^{\pm 0.3}$	$14.8^{\pm 1.4}$	$15.6^{\pm 1.8}$	$6.4^{\pm 0.7}$	$60.0^{\pm 5.3}$
Fossa la Nave	$1600^{\pm 90}$	$21.9^{\pm 1.8}$	$3.6^{\pm 0.2}$	$16.8^{\pm 1.5}$	$18.0^{\pm 2.2}$	$5.5^{\pm 0.6}$	$65.8^{\pm 5.4}$
San Martín	$3900^{\pm 203}$	$59.7^{\pm 3.6}$	$9.8^{\pm 0.6}$	$35.9^{\pm 2.5}$	$12.9^{\pm 1.7}$	$9.8^{\pm 1.1}$	$128.1^{\pm 12.1}$
Le Vernet	$4100^{\pm 236}$	$67.0^{\pm 4.1}$	-	$24.0^{\pm 2.1}$	$14.0^{\pm 1.9}$	$8.0^{\pm 0.9}$	$113.0^{\pm 12.0}$

Table 4. Leaf biomass and leaf nutrient content in biomass (Kg ha^{-1})

proportion of leaves to perennial biomass was 7.3 %, 4.6 %, 3.3 % and 2.3 % respectively (Table 2) for the four same chestnut stands.

The aboveground biomass values for the four studied stands in the Western Mediterranean area were in range of data reported for other *Castanea sativa* stands. Ranger *et al.* (1990 a, b) indicated aboveground biomass values of 9.7, 39.7, 60-5, 107.2 and 119.9 Mg ha^{-1} for chestnut coppices aged respectively, to 2, 5, 9, and 15 years. Berthier (1984) found that aboveground biomass amounted, to 25.2, 37.8 and 67.8 Mg ha^{-1}, 5, 8 and 11 years after clear-cut. In contrast, La Marca (1984) determined much higher biomass values, 107 Mg ha^{-1} for a 13 year old stand.

Litterfall amounts

A strong seasonality can be observed with litterfall occurring between October and December (data not show). The amount of yearly litterfall is indicated in Table 3. The relation between litterfall and stand age was very significant: in the two younger coppices of Fossa la Nave and Piano Porcheria, the amount of organic matter were: 2640 kg ha^{-1} yr^{-1} and 1709 kg ha^{-1} yr^{-1} respectively; whereas in the two older stands litterfall amounted was 5.245 kg ha^{-1} yr^{-1} in San Martín and 5334 kg ha^{-1} yr^{-1} in Le Vernet. The reason for such differences in the litterfall could be related to soil properties. In all cases, these values are more or less coincidents with the results in other stands.

Anderson (1973) calculated 3.9 Mg ha^{-1} y^{-1}, whereas O'Neill & DeAngelis (1981) reported 5.2 Mg ha^{-1} yr^{-1} or Santa Regina (1987) in *Castanea sativa* stand in the Sierra de Béjar estimated 6.3 Mg ha^{-1} yr^{-1}.

Foliar nutrient dynamics

From all felled, measured and weighed trees, integrating all samples from the four study sites the following regression equation between the DBH and the leaf biomass was calculated.

Leaf biomass$_{(Kg)}$ = 0.004 (DBH$_{cm}$)$^{2.296}$

Table 4 summarises the leaf biomass values from the four sites. The young stands had much lower biomass values: Fossa la Nave 1600 kg ha^{-1} and Piano Porcheria 1500 kg ha^{-1}. The leaf mass increased in the two older stands, 3900 kg ha^{-1} and 4100 kg ha^{-1} for San Martín and Le Vernet respectively.

The total amount of nutrients content in leaf biomass are also given in Table 4. For all sites the decreasing relationship between the five nutrients was as follows: N>K>Ca>Mg>P. The amounts of N,P,K, and Mg are lower in the young stands with respect to the old stands; whereas the Ca amounts were higher in Fossa la Nave and Piano Porcheria.

In the younger stands, which trees aged from 12 to more than 25 years, the leaf biomass values were directly related to the stand age. The proportion of leaves to perennial biomass are 7.3 % at Fossa la Nave, 4.6 % at Piano Porcheria, 3.3 % at San Martín and 2.3 % at Le Vernet (Table II). The Spanish value was closely correlated with the high productivity of that stand. For Le Vernet, the low percentage of leaves compared to the perennial aboveground biomass results probably from the high mortality indicated by the remaining standing dead trunks.

The amounts of nutrients stored in the leaves depends above all on the leaf biomass. Consequently the main differences for the five analysed nutrients were found between the two old stands (San Martín and Le Vernet) and the younger Italian stands (Fossa la Nave and Piano Porcheria) (Table 4). Concerning N and P, the amounts were three times greater in the older stands; K only twice greater. Ca contents of the Italian stands seemed higher than that of the two old plots.

The amounts of yearly leaf-litter and the restitution of nutrients to the soil are indicated in Table 3. Leaf litter production was very similar at Fossa la Nave and Piano Porcheria and lower than at the older stands of San Martín and Le Vernet, indicating a relation between leaf litterfall and stand age. In the two younger coppices of Fossa la Nave and Piano Porcheria leaf litter amounted to only 1353 and 1230 kg ha^{-1} yr^{-1} respectively, whereas in the two older stands leaf litter observed was near the same: 3429 kg ha^{-1} yr^{-1} in San Martín and 3457 kg ha^{-1} yr^{-1} in Le Vernet. Similar values are reported by Leonardi *et al.* (1995) and Martín (1995).

As a result, the rhythm of leaf fall may to a large extent respond to the succession of phenophases regulated by internal biological processes with a strong genetic dependence (Lee & Correl, 1978).

Concerning nutrients, the results were similar to those of nutrient accumulation in the leaf biomass (Table 3). Also there were significant differences in the amounts between younger and older stands. For N the relationship was: Le Vernet > San Martín > Piano Porcheria = Fossa la Nave; for P: San Martín > Fossa la Nave = Piano Porcheria; for K: Le Vernet > San Martín > Piano Porcheria > Fossa la Nave and for Ca and Mg: San Martín > Fossa la Nave > Piano Porcheria > Le Vernet.The annual litterfall is the main source for the annual return of nutrients to the soil. The root contribution to the potential bioelement return is not taken in account in this study. Khanna & Ulrich (1991) indicated that root decay represents about 20 % ot the total potential return of mineral elements. According with these authors we estimate that litter is responsible of about 80 % of the total amount of bioelement returning to the soil. Because of differences in nutrient concentrations among the leaf litter compartments, the distribution of nutrients did not always follows the pattern established for leaf mass. *Castanea sativa* leaf litter from the Etna volcano contained less N, P and K than those from de San Martin and Le Vernet, and it was the opposite for Ca and Mg between the Italian plots and Le Vernet.The rotation coefficient: nutrients in leaf litterfall x 100/nutrients in leaf biomass, indicated interesting values for the four chestnut stands (Table 5). In the two Italian stands N, P and Mg are recycled in the same proportion. In contrast, the K is recycled slowly in Fossa la Nave and Ca in Piano Porcheria. Except K, the other four bioelements are recycled faster in San Martín than in Le Vernet site. Generally, the nutrients are recycled faster in the old stands.

Stand	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Piano Porcheria	52.5	52.9	52.0	68.6	100.0
Fossa la Nave	47.0	52.7	41.1	83.3	100.0
San Martín	69.5	69.4	42.9	100.0	100.0
Le Vernet	62.5	-	72.1	74.3	62.5

Table 5. Leaf rotation coefficients between the three four forest stands = nutrients in litterall x 100/nutrients in biomass

It appears that nutrient management is related to its availability in the soil. Nutrients which are in lower amounts in volcanic soils are recycled through the plant-soil system in much higher proportions than other nutrients available in higher quantities in these soils (Leonardi *et al.*, 1996). Table 6 shows the monthly evolution of the dry weight and the mineral element concentrations in leaves during a vegetative cycle. The dry weight of current leaves varied annually. The current leaves had lighter weight in the first months, in the two Italian stands (data not show). Dry weight increased significantly during all the growing season. Seasonal increases in mass of current foliage was reported for Woodwell *et al.* (1975) and Helmisaari (1990). Different patterns were found for the nutrients studied. Concentrations decrease in the case of N, P and K for all the four stands; the Mg showed an invariable pattern, Ca increased in concentration during the vegetative cycle. The vegetative cycle of deciduous forests leaves is subject to three stages of development: rapid growth, maturation and senescence. During the first period relative concentrations of mobile and basic biological macronutrients, N, P, K were the highest, then decreased even the foliar abscision in all the studied plots (Table 6). The decrease would occur because the increase in dry weight of the recently matured leaves was faster than the translocation of nutrients into the leaves (Helmisaari, 1990). These changes have been attributed to resorption of nutrients from the foliage into perennial tissues (Luxmoore *et al.*, 1981; Ostman & Weaver, 1982; Ryan & Bormann, 1982; Boerner, 1985; Tyrrell & Boerner, 1987). During the spring, growth is accompanied by an intense mitotic activity due to cellular growth and a strong demand for nutrients, in particular N (Ryan & Bormann, 1982). Thereafter, the contents of this element decrease throughout the vegetative cycle and above all during the period of senescence (autumn). It is therefore evident that retranslocation to perennial tissues occurs before total abscission. The low variation in the concentration of these organs masks more important absolute variations when considering the relative mass of leaves. The transfer of N to the perennial parts of the tree may represent 30-50 % of the amount required for the biomass production of the following cicle (Helmisaari, 1992). The concentration of Ca, considered to be an immobile element, increases until leaf abscision, resulting perhaps from lignification of the tissues. Similar pattern was reported by Santa Regina (1987). The concentration of Mg remains constant during the vegetative cycle in the all considered sites (Table 6). The fact that the amounts of retranslocated elements from the leaves are more related to their individual concentrations in plant organs than to their availability in soil highlights the indirect nature of the effect of the substrate in this context. The small amount of nutrients present during foliar senescence are attributed both to retranslocation and leaching from the leaves. The translocation from leaves to perennial parts are given in Table 7. Nitrogen and phosphorus follow the same trend that the leaf nutrient content in aboveground biomass. The K changed in Le Vernet. For Ca the pattern differed for the two Italian stands, and the Mg did not followed any pattern. The relation: Nutrients in leaf biomass - Nutrients in leaf litterfall = Translocation to perennial parts, allows to relate the leaf compartment to the leaf litterfall flux (Table 7). Leaf translocation may apply to both the aboveground parts of the *Castanea sativa* stands and to root mass.

Stand	Date	Leaf dry weight (g)	N	P	K	Ca	Mg
Piano Porcheria	28.05	$0.03^{\pm 0.03}$	$2.08^{\pm 0.3}$	$0.54^{\pm 0.05}$	$1.50^{\pm 0.2}$	$0.78^{\pm 0.1}$	$0.44^{\pm 0.05}$
	21.06	$0.15^{\pm 0.02}$	$1.37^{\pm 0.1}$	$0.24^{\pm 0.02}$	$1.03^{\pm 0.1}$	$0.90^{\pm 0.1}$	$0.41^{\pm 0.05}$
	29.08	$0.19^{\pm 0.02}$	$1.04^{\pm 0.1}$	$0.16^{\pm 0.02}$	$0.82^{\pm 0.1}$	$1.16^{\pm 0.2}$	$0.48^{\pm 0.05}$
	15.09	$0.19^{\pm 0.02}$	$0.98^{\pm 0.1}$	$0.17^{\pm 0.02}$	$0.93^{\pm 0.1}$	$1.16^{\pm 0.2}$	$0.47^{\pm 0.06}$
	24.10	-	$0.88^{\pm 0.1}$	$0.22^{\pm 0.03}$	$0.91^{\pm 0.1}$	$1.22^{\pm 0.3}$	$0.43^{\pm 0.05}$
Fossa la Nave	18.06	$0.13^{\pm 0.01}$	$1.77^{\pm 0.2}$	$0.35^{\pm 0.04}$	$1.56^{\pm 0.2}$	$0.86^{\pm 0.1}$	$0.39^{\pm 0.04}$
	06.07	$0.24^{\pm 0.02}$	$1.59^{\pm 0.2}$	$0.23^{\pm 0.03}$	$1.15^{\pm 0.1}$	$0.92^{\pm 0.2}$	$0.36^{\pm 0.04}$
	03.09	$0.39^{\pm 0.04}$	$1.31^{\pm 0.1}$	$0.22^{\pm 0.03}$	$1.01^{\pm 0.1}$	$1.08^{\pm 0.2}$	$0.33^{\pm 0.04}$
	18.09	$0.31^{\pm 0.03}$	$1.28^{\pm 0.1}$	$0.26^{\pm 0.03}$	$1.19^{\pm 0.1}$	$1.16^{\pm 0.2}$	$0.34^{\pm 0.04}$
	29.10	$0.28^{\pm 0.03}$	$0.92^{\pm 0.1}$	$0.28^{\pm 0.03}$	$0.90^{\pm 0.1}$	$1.72^{\pm 0.3}$	$0.39^{\pm 0.04}$
San Martín	28.04	$0.13^{\pm 0.01}$	$2.85^{\pm 0.4}$	$0.28^{\pm 0.03}$	$1.21^{\pm 0.2}$	$0.19^{\pm 0.02}$	$0.27^{\pm 0.03}$
	25.05	$0.13^{\pm 0.01}$	$2.65^{\pm 0.4}$	$0.31^{\pm 0.04}$	$1.24^{\pm 0.2}$	$0.28^{\pm 0.03}$	$0.30^{\pm 0.03}$
	28.06	$0.23^{\pm 0.02}$	$2.20^{\pm 0.3}$	$0.21^{\pm 0.02}$	$1.10^{\pm 0.1}$	$0.31^{\pm 0.04}$	$0.24^{\pm 0.02}$
	27.07	$0.34^{\pm 0.03}$	$2.01^{\pm 0.3}$	$0.24^{\pm 0.03}$	$1.08^{\pm 0.1}$	$0.25^{\pm 0.03}$	$0.27^{\pm 0.03}$
	25.08	$0.40^{\pm 0.04}$	$1.96^{\pm 0.3}$	$0.24^{\pm 0.03}$	$1.00^{\pm 0.1}$	$0.33^{\pm 0.04}$	$0.29^{\pm 0.03}$
	28.09	$0.40^{\pm 0.04}$	$1.59^{\pm 0.2}$	$0.26^{\pm 0.03}$	$1.01^{\pm 0.1}$	$0.34^{\pm 0.04}$	$0.27^{\pm 0.03}$
	02.11	$0.43^{\pm 0.05}$	$0.82^{\pm 0.2}$	$0.24^{\pm 0.03}$	$0.58^{\pm 0.1}$	$0.40^{\pm 0.05}$	$0.27^{\pm 0.03}$
Le Vernet	21.04	$0.08^{\pm 0.01}$	$2.43^{\pm 0.4}$	-	$0.75^{\pm 0.1}$	$0.25^{\pm 0.03}$	$0.20^{\pm 0.02}$
	06.05	$0.11^{\pm 0.01}$	$2.43^{\pm 0.4}$	-	$0.75^{\pm 0.1}$	$0.25^{\pm 0.03}$	$0.22^{\pm 0.03}$
	07.06	$0.21^{\pm 0.02}$	$1.47^{\pm 0.2}$	-	$0.55^{\pm 0.1}$	$0.30^{\pm 0.04}$	$0.20^{\pm 0.02}$
	01.07	$0.27^{\pm 0.03}$	$1.65^{\pm 0.3}$	-	$0.60^{\pm 0.1}$	$0.35^{\pm 0.05}$	$0.21^{\pm 0.02}$
	27.07	$0.33^{\pm 0.03}$	$1.19^{\pm 0.2}$	-	$0.65^{\pm 0.1}$	$0.30^{\pm 0.04}$	$0.20^{\pm 0.02}$
	07.09	$0.39^{\pm 0.04}$	$1.46^{\pm 0.4}$	-	$0.65^{\pm 0.1}$	$0.45^{\pm 0.06}$	$0.20^{\pm 0.02}$

Table 6. Variation of chemical composition (%) of the leaves during a year.

Stand	N	P	K	Ca	Mg
Piano Porchería	$9.4^{\pm 0.6}$	$1.6^{\pm 0.3}$	$7.1^{\pm 1.0}$	$4.9^{\pm 1.1}$	$-1^{\pm 0.2}$
Fossa la Nave	$11.6^{\pm 0.7}$	$1.7^{\pm 0.2}$	$9.9^{\pm 0.8}$	$3.0^{\pm 0.8}$	0
San Martín	$18.2^{\pm 1.2}$	$3.0^{\pm 0.7}$	$20.5^{\pm 2.3}$	$-5.6^{\pm 1.3}$	$-1.2^{\pm 0.3}$
Le Vernet	$23.3^{\pm 1.6}$	-	$6.7^{\pm 0.5}$	$3.6^{\pm 1.0}$	$3^{\pm 0.9}$

Table 7. Nutrient translocation to perennial parts = nutrients in leaf biomass-nutrient in leaf litterfall (Kg ha^{-1})

Stand	N	P	K	Ca	Mg
Piano Porcheria	0.58	0.69	0.45	0.36	0.15
Fossa la Nave	0.48	0.37	0.42	0.50	0.15
San Martín	0.71	0.32	0.53	0.53	0.20
Le Vernet	0.51	-	0.27	0.44	0.09

Table 8. Nutrient-use efficiency index applied to the four studied stands

For that reason, we are not able, at the present stage, to determine the amount of the required nutrients, recycling through the forest stand.

Efficient retranslocation of the most essential nutrients is a typical characteristic of the climax phase of any forest ecosystem (Whittaker *et al.*, 1979; Staaf & Berg, 1981; Prescott *et al.*, 1989). Translocated P and N could supply during the following cycle most of the demand for these nutrients for production of new leaves. This retranslocation, accompanied by a reduction in the nutrient restitution through leaf litter and requirements, allows the ecosystem to have a certain independence versus the soil and the possibility of optimal management of the available elements (Melillo, 1981).

Various approaches have been employed to define nutrient use efficiency index of forest species (Bockheim & Leide, 1991). A commonly used indicator is the proportion of foliar resorption, which is estimated as the difference between the maximum and minimum foliar nutrient contents divided by the maximum foliar nutrient content (Chapin & Kedrowski, 1983). This relation ignores any canopy leaching or dry-fall impaction that would occur during leaf maturation.

San Martín plot reabsorbed greater amounts of the five nutrients considered, except for P, where the greater amounts were observed in Piano Porcheria (Table 8). Le Vernet reabsorbed similar proportions of N that Fossa la Nave and considerably lower proportions of Mg and K that the others three stands. The two Italian stands resorbed the same proportions of K and Mg. Fossa la Nave resorbed a greater proportion of Ca than Piano Porcheria and lower proportion of P.

The nutrient-use efficiency index applied to the four stands suggest that Le Vernet stand translocated less amounts of K and Mg, Fossa la Nave of N, Piano Porcheria of Ca and San Martín for P (Table 8). The *Castanea sativa* stands, according to their various soils, conserve nutrients by having a lower nutrient requirement, investing lower amounts of nutrients in foliage and woody tissues, retaining greater proportions of nutrientes in perennial production and returning lower amounts of nutrients in litterfall and fine-root turnover. Similar conclusions were showed by Bockheim & Leide (1991).

CONCLUSIONS

Differences in aboveground stand biomass resulted mainly from variations in stand density of individual trees and their repartition between DBH classes. The results were similar for litterfall especially in evenaged stands, with variations being closely related to the age of the coppices.

Aboveground nutrient concentrations in leaves, as well as biomass and litterfall quantities, varied between the Spanish and Italian stands specially for N, K and P. This indicates a correlation between nutrient uptake and availability in the soil. The Spanish site is located on cambisol, and the Italian ones on volcanic substrata of the Etna volcano.

The rotation coefficients were higher for N, P and Ca in the Spain site, for K in the French stand and similar in the Spanish and Italian plots for Mg.

The monthly evolution of mineral element concentrations in leaves during a vegetative cycle indicates different patterns for the nutrients studied. Concentration decrease in the case of N, P and K for all the four stand; the Mg showed an invariable pattern, Ca increased in concentration during the vegetative cycle.

The nutrient use efficience index values showed that San Martín plot reabsorbed greater amounts of the N, K, Ca and Mg, and Piano Porcheria of the P.

Le Vernet reabsorbed similar proportions of N that Fossa la Nave and considerably lower proportions of Mg and K than the other three stands. The two Italian stands reabsorbed the same proportions of K and Mg, Fossa la Nave a greater proportion of Ca than Piano Porcheria and lower proportion of P.

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REFERENCES

Anderson J.M., 1973. Stand structure and litter fall of a coppice beech *Fagus sylvatica* and sweet chestnut *Castanea sativa* woodland. *Oikos*, 24 : 128-135.

Berthier B. 1984. Fonctionnement d'un écosystéme forestier. Croissance biomasse et productivité du compartment ligneux épigé des taillis de châtaignier *Castanea sativa* Mill du sud sud-est de la France. Thèse Univ. Sci. et Méd. de Grenoble, France, 62 p.

Bockheim J.G. & Leide J.E. 1991. Foliar nutrient dynamics and nutrient-use efficiency of oak and pine on a low-fertility soil in Wisconsin. *Can. J. For. Res.*, 21, : 925-934.

Boerner R.E.J. 1984. Foliar nutrient dynamics and nitrogen use efficiency of four deciduous tree species in relation to site fertility. *J. Appl. Ecol.*, 21 : 1029-1040.

Boerner R.E.J. 1985. Foliar nutrient dynamics, growth and nutrient use efficiency of *Hammamelis virginiana* in three forest microsites. *Can. J. Bot.*, 63 : 1476-1481.

Chapin F.S. & Kedrowski R.A. 1983. Seasonal changes in nitrogen and phosphorus fractions and autumn retranslocation in evergreen and deciduous taiga trees. *Ecology*, 64 : 376-391.

Chapman H.D. & Pratt P.F. 1979. *Métodos de análisis para suelos, plantas y aguas.* Trillas, México. 195 p.

F.A.O. 1973. The legend F.A.O./U.N.E.S.C.O. : Soil map of the world. F.A.O., Roma. 63 p.

Gallego H.A., Rico M. & Santa Regina I. 1994. Biomass equations and nutrient content for a *Castanea sativa* Mill forest. *Proceeding of the International Congress on Chestnut*, Spoleto, Italy, 1 : 409-413.

Gray J.T. 1983. Nutrient use by evergreen and deciduous shrubs in Southern California, I. Community nutrient cycling and nutrient-use efficiency. *J. Ecol.*, 71 : 21-41.

Helmisaari H.S. 1990. Temporal variation in nutrient concentrations of *Pinus sylvestris* needles. Scand.*J.For. Res.*, 5 : 177-193.

Helmisaari H.S. 1992. Nutrient retranslocation within foliage of *Pinus sylvestris*. *Tree Physiol.*, 10 : 45-58.

Khanna P.K. & Ulrich B. 1991. Ecochemistry of temperate deciduous forests. *In* : Röhrig E. & Ulrich B. (eds), *Ecosystems of the world. 7. Temperate deciduous forests.* Elsevier, Amsterdam : 121-163.

La Marca O. 1984. Ricerche sulla biomassa dei cedui di catagno (*Castanea sativa* Mill.) della Valle dell'Irno (AV e SA). *Ricerche Spèrimentali di dendrometria e di Auxomatria,* 8 : 63-79.

Lee K.E. & Correl R.L. 1978. Litter fall and its relationship to nutrient cycling in a south Australian dry sclerophyll forest. *Aust. J. Ecol.*, 3 : 243-252.

Leonardi S., Rapp M., Izzo R., Failla M., Guarnaccia D. & De Santis C. 1995. Chestnut ecosystem function: nutrient cycle processes within several stands in relation to age and altitude on the Etna Volcano. *In* : Romane F. (ed), Sustainability of Mediterranean Ecosystems; *Case Study of the Chestnut Forest* Eur Comm 63-70.

Leonardi S., Santa Regina I., Rapp M., Gallego H.A., & Rico M. 1996. Biomass. Litterfall and nutrient content in *Castanea sativa* coppice stands of southern Europe. *Ann. Sci. For.*, 53 : 1071-1081.

Lim M.T. & Cousens J.E. 1986. The internal transfer of nutrients in a Scots pine stand. 2. The patterns of transfer and the effects of nitrogen availability *Forestry,* 59 : 17-27.

Luxmoore R.J., Grizzard T. & Strand R.H. 1981. Nutrient translocation in the outer canopy and understory of an eastern deciduous forest. *For. Sci.*, 27 : 505-518.

Martín A. 1995. Reciclado de bioelementos a través de la hojarasca en ecosistemas forestales de la Sierra de Gata (Sistema Central Español). Thesis Univ. Salamanca, Spain. 356 p.

Meier C.E., Grier, C.C. & Cole, D.W. 1985. Below and aboveground N and P use by *Abies amabilis* stands. *Ecology,* 66 : 1928-1942.

Melillo J.M. 1981. Nitrogen cycling in deciduous forests. In: Clark F.E. & Rosswall T. (Eds) Terrestrial Nitrogen Cycles. *Ecol. Bull.* (Stockholm). 33 : 405-426.

O'Neilll R.V. & DeAngelis D.L. 1981. Comparative productivity and biomass relations of forest ecosystems. *In*: Reichle D.E. (Ed), *Dynamic properties of forest ecosystems.* Cambridge Univ. Press, London : 411-449.

Ostman N.L. & Weaver G.T. 1982. Autumnal nutrient transfer by retranslocation, leaching, and litter fall in a chestnut oak forest in southern Illinois. *Can. J. For. Res.*, 12 : 40-51.

Pastor J. Aber J.D., McClaugherty C.A. & Melillo, J.M. 1984. Aboveground production and N and P cycling along a nitrogen mineralisation gradient on Blackhawk Island. *Wisconsin Ecology,* 65 : 256-258.

Prescott C.C., Corbin J.P. & Parkison D. 1989. Biomass, productivity, and nutrient-use efficiency of aboveground vegetation in four Rocky Mountain coniferous forests. *Can. J. For. Res.*, 19 : 309-317.

Ranger J., Felix C., Bouchon J., Nys C. & Ravart M. 1990a. Dynamique d'incorporation du carbone et des éléments nutritifs dans un taillis simple de châtaigner (*Castanea sativa*). *Ann. Sci. For.*, 47 : 413-433.

Ranger J., Nys C. & Bouchon J. 1990b. Les relations entre la fertilité du sol, la production et l'utilisation d'éléments nutritifs dans les taillis de châtaigniers. *Acta Oecol.*, 11 : 487-501.

Ryan D.F. & Bormann F.H. 1982. Nutrient resorption in northern hard-wood forests. *Bioscience*, 32 : 29-32.

Santa Regina I. 1987. Contribución al estudio de la dinámica de la materia orgánica y bioelementos en bosques de la Sierra de Béjar. Tesis doctoral. Univ. Salamanca., Spain. 464 p.

Santa Regina I. & Gallardo J.F. 1985. Retorno al suelo de bioelementos en tres ecosistemas forestales de la Cuenca de Candelario (Salamanca). *Rev. Ecol. Biol. Sol,* 22 : 407-417.

Singh K.P. 1978. Litter production and nutrient turnover in deciduous forest of Varanasi. *Proc. Symp. Rec. Adv. Trop. Ecol* : 655-665.

Sollins P., Grier C.C., McCorison F.M., Cromack Jr.K. & Fogel R. 1980. The internal element cycles of an old-growth Douglas-fir ecosystem in Western Oregon. *Ecol. Monogr.*, 50 : 261-285.

Staaf H. & Berg B. 1981. Plant litter input to soil. *In* : Clark, F.E. & Rosswall T. (Eds), *Terrestrial Nitrogen Cycles*. 33 : 147-162.

Tyrrell L.E. & Boerner R.E.J. 1987. *Larix laricina* and *Picea mariana*: relationships among leaf life-span, foliar nutrient patterns, nutrient conservation, and growth efficiency. *Can. J. Bot.,* 65 : 1570-1577.

Whittaker R.H., Likens G.E. & Bormann F.H., Eaton J.S.& Siccama T.G. 1979. The Hubbard Brook study: nutrient cycling and element behaviour. *Ecology,* 60 : 203-220.

Woodwell G.M., Whittaker R.H. & Hougton R.A. 1975. Nutrient concentrations in plants in the Brookhaven oak-pine forest. *Ecology,* 56 : 318-332.

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Nitrogen management contribution to sustainability of *Castanea sativa* Mill. coppice stands on mount Etna (Sicily, Italy)

Bilan azoté et développement des taillis de *Castanea sativa* Mill. du mont Etna (Sicile, Italie)

Salvatore LEONARDI*, Maurice RAPP**, Giuseppe SIRACUSA* , Maria FAILLA* & Giuseppe SCIACCA*

*Universita di Catania, Dipartimento di Metodologie Fisiche e Chimiche per l'Ingegneria, Facoltà di Ingegneria, Viale A. Doria, I-95125 Catania, Italy
**CNRS – CEFE. 1919 route de Mende, F-34293 Montpellier, cedex 5, France

ABSTRACT

Nitrogen is the main nutrient missing on volcanic substrates. This resource is built up through a succession of nutrient cycles, occurring progressively with the colonization of lava or volcanic ash by an increasingly extensive vegetation cover, ultimately resulting in the formation of woodlands and forests. Under these conditions, forest ecosystems have to sparingly manage the nitrogen pool to ensure sustainable development of such formations in volcanic areas. The present study involved quantification of the nitrogen cycle in four *Castanea sativa* Mill. coppice stands on the Mount Etna volcano. The stands differed in terms of age (two young and two older stands) and elevation on mount Etna (1000 m and 1600 m above sea level).The main nitrogen cycle compartments and fluxes in the four stands were estimated. Yearly mineral nitrogen production in the soil (ammonia and nitrate nitrogen production), i.e. the main source of this nutrient for chestnut trees, was also determined. Finally, variations in nitrogen mineralization relative to age and stand location, or period during the year are discussed, along with the forest sustainability implications.

Key- words : Nitrogen cycle, nitrogen mineralization, ammonia nitrogen, nitrate nitrogen, volcanic soils

RESUME

L'azote, élément essentiel de la nutrition végétale, est pratiquement absent dans les roches volcaniques. La disponibilité de la ressource azotée résulte essentiellement des cycles biogéochimiques qui se sont succédés, au fur et à mesure de la colonisation des laves et des cendres volcaniques par des tapis végétaux de plus en plus importants, aboutissant finalement à des formations forestières. Dans ces conditions, les écosystèmes forestiers sont tributaires du stock d'azote accumulé dans le sol pour assurer le développement durable et continu de ces formations sur substrat volcanique. Le présent travail consiste à quantifier les principaux paramètres du cycle de l'azote dans différents compartiments de quatre taillis de *Castanea sativa* Mill. de l'Etna. Les stations diffèrent par leur âge (deux taillis jeunes et deux plus âgés) et leur localisation altitudinale dans le volcan (autour de1000 et de 1600 m au-dessus du niveau de la mer, respectivement). L'essentiel des compartiments et des flux d'azote de ces quatre stations ont été estimés. La production d'azote minéral (ammoniacal et nitrique) dans le sol, qui est la principale source d'azote pour les châtaigniers, a également été déterminée. Finalement les différences de production d'azote minéral en fonction de l'âge des peuplements, de la localisation des stations et au cours de l'année, sont discutées en même temps que leurs implications sur le développement durable de ces forêts.

Mots-clés : cycle de l'azote, minéralisation de l'azote, azote ammoniacal, azote nitrique, sols volcaniques

INTRODUCTION

Nitrogen is an essential nutrient for biomass production. This nutrient makes up almost three-quarters of the atmosphere but is almost completely absent in rocks and the geological substratum, when plant nitrogen needs are mainly met by nitrate uptake from the soil through the roots. Soil nitrogen supplies, in organic or mineral form (ammonia and nitrate nitrogen), are primarily the result of biological atmospheric nitrogen fixation by microorganisms, followed by a series of biogeochemical cycles that occur as the soil is colonized by increasingly complex forms of vegetation (i.e. from herbaceous plants to trees).

Forest ecosystems usually develop by using a more or less constant nitrogen pool, essentially immobilized in the biomass and in the soil organic matter and recycled permanently through the ecosystem. Efficient nitrogen management is thus essential to maintain supplies of this nutrient for trees and enhance the sustainability of forest ecosystems. Apart from stands with mycorrhizae, forest ecosystems are maintained by exploiting a relatively constant nitrogen pool, immobilized in the soil organic matter and continuously recycled through the ecosystem. This mechanism involves a succession of processes (mainly biological), including:

- Soil nitrogen uptake by trees, mainly as nitrate.
- Nitrogen assimilation and relatively long-term immobilization in the perennial and annual biomass, mostly as protein nitrogen.
- Return of part of this nutrient to the soil via litterfall.
- Above-ground litter decomposition processes allow the conversion of small quantities of organic nitrogen back into ammonia or nitrate nitrogen (mineral form), while a major portion of the litter nitrogen is reorganized as specific and relatively stable organic compounds within soil organic matter.
- Mineralization of the latter fraction, which occurs mainly in the upper organic soil layers via the action of soil microflora. It leads to the production of ammonia and nitrate nitrogen that is available for uptake by trees.

The sustainability of forest stands within a development framework therefore depends on management of nitrogen resources in the stand, especially in the soil compartment, and on the temporal stability of these resource. This theoretically closed system is open to abiotic, atmospheric and hydrogeological inputs or outputs. Nitrogen losses can occur as a result of physical factors, through leaching of soil nitrates into the ground water, biological factors, subsequent to denitrification processes with the release of nitrogen into the atmosphere, and anthropogenic factors, with the export of nutrients out of the system by harvesting trees. Otherwise the capacity of some soil microorganisms for fixing atmospheric nitrogen can lead to nitrogen gains within the ecosystem. In addition, there are sometimes substantial inputs associated with rainfall or leaching during stormy periods of dry and wet deposits on the canopy. In the present study, we investigated the nitrogen cycle in four chestnut stands growing on the slopes of Mount Etna (Sicily) on nitrogen-free volcanic sand and lava. Our aim was to investigate actual parameters concerning the nitrogen cycle in long-established stands, rather than analyzing or quantifying nitrogen acquisition processes, which can result from very long-term colonization of the volcanic substratum by successive vegetation covers. Locally, the role of the endemic leguminous *Genista aetnensis* as pioneer species, enriching the environment, is well known. We focused specifically on organic nitrogen mineralization processes, which enhance nitrogen resources available for trees. Potential stand losses of nitrogen via leaching are also discussed. The sustainability of these coppice stands is dependent on the minimization of these losses and the compensation of nitrogen fixation within the perennial biomass, by atmospheric inputs, which is presently the main nitrogen source for these stands. This study is based on studies carried out in different earlier publications (Leonardi *et al.*, 1993, 1995, 1996,a,b,c,d), that led to the quantification of a number of nutrient fluxes and compartments at these sites.

SITE DESCRIPTION

Study area

The four coppice stands are located along an elevation gradient (Figure 1). The two highest sites are on the southern slopes of Mount Etna between 1400 m and 1600 m above sea level, with the Fossa la Nave stand on a 30% slope and the Balilla stand on a 10% slope. The Monte Crisimo stand, which is growing on old terraces, and the Piano Porcheria stand are located on the eastern slopes of the volcano at an elevation of 1000 to 1200 m, typical of the more productive low-elevation chestnut stands. At each elevation, we compared a mature stand (not clearcut for over 20 years) with a young, recently clearcut stand (7 or 8 years ago) in the reforestation process.

Soil

The four stands are on 2000 to 200000 year-old basaltic volcanic lava and ash. The soils are quite similar at all four stands, i.e. 40-60 cm deep humified andosols, subdivided into two horizons: A_1, 1-15 cm depth, with high organic matter content; A_1B, 15-60 cm depth, with less organic matter but with high ash and degraded lava content and extensive root colonization. At deeper horizons (below 60-70 cm depth), there is only sand, cinders and blocks of volcanic lava.

The chemical characteristics of the four soils are summarized in Table 1.

Climate

The climate type is xerothermic mesomediterranean at the lower elevations (Piano Porcheria and Monte Crisimo). Fossa la Nave, and to lesser extent Balilla, have a typical mountain climate, with cold winters, regular snowfall and less rainfall. There are 3 months of summer drought at all four sites. The temperature and mean monthly rainfall patterns, as recorded at the weather stations in the vicinity of the studied stands, are shown in Figure 2.

Vegetation

Chestnut coppice stands have been growing for many years on Mount Etna, occupying the natural habitat of mesomediterranean deciduous oak (Ronsisvalle & Signorello, 1979; Poli *et al.*, 1981), thus explaining the absence of specific associations with respect to these stands. The stands have a monospecific tree layer, mainly consisting of *Castanea sativa* stump shoots. Some features of these stands are given in Table 2, while the chestnut tree diameter distributions are classified in Figure 3. There are very few species in the herbaceous layer, i.e. mostly *Pteridium aquilinum*.

METHODS

Biomass

Biomass (Leonardi *et al.,* 1996a) was determined by correlating an easy to measure dendrometric parameter, i.e. trunk diameter at breast height (DBH), measured at 1.30 m height and the dry weights of a number of felled trees or of their respective organs.

This technique is recommended and used by many forestry scientists, and was described in detail by Bouchon *et al.* (1985) and more recently by Hanchi (1994). Issued from all four stands, 36 trees, with a DBH range of 0.5 to 35.3 cm, were cut, separated into trunks and branches. 22 trees were cut in winter and 14 during the vegetation period to determine the leaf biomass.

After determining the age of the felled trees and the dry weight of the trunks, branches and leaves, regression equations were calculated between DBH and partial and total weights of each tree.

Power regressions, $Y = a \times X^b$, where Y = trunk, branch or leaf weights, with X = DBH in cm and a and b = constants, give the best results (Baskerville, 1965).

The three following regressions were used for total and partial biomass determinations: wood = $96.771 \times X^{2.318}$ (n = 36, r = 0.981); leaves= $3.023 \times X^{2.414}$ (n = 14, r = 0.967); biomass = $102.000 \times X^{2.314}$ (n = 36, r = 0.982).

These regression equations, applied to different DBH classes for all trees from each stand and multiplied by the number of trees for each class, enabled to determine the biomass of different stand components.

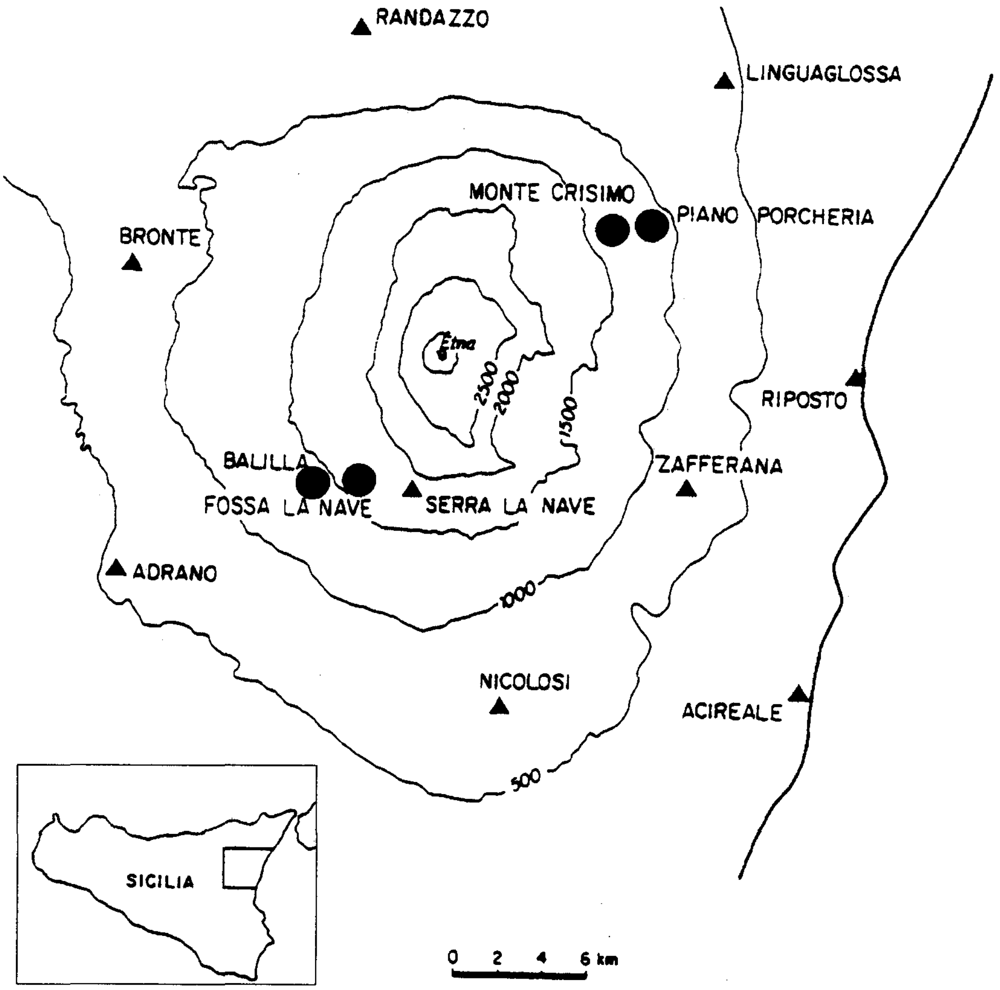

Figure 1. Location of the four *Castanea sativa* stands (filled circles) on the Etna volcano

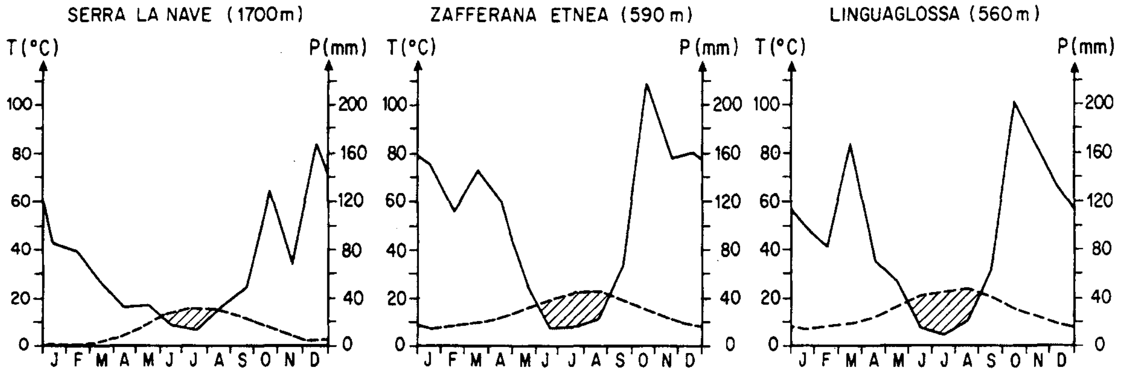

Figure 2. Climatic data (rainfall and mean monthly temperature) at three meteorological stations near the *Castanea sativa* stands

	Fossa la Nave		Balilla		Piano Porcheria		Monte Crisimo	
Soil depth	20	50	20	50	20	50	20	50
PH	6.7	6.7	6.4	6.5	6.6	6.6	6.5	6.5
C %	2.52	2.18	2.85	2.27	1.94	1.90	2.14	1.94
N %	0.18	0.18	0.19	0.16	0.15	0.17	0.19	0.16
C / N	14	13	15	14	13	11	11	13
O. M. %	4.33	3.75	4.90	3.90	3.34	3.27	3.68	3.34
CEC meq % sol	13.7	15.2	13.3	12.2	9.2	10.1	10.7	11.2
Ca	7.50	8.00	7.50	6.90	4.90	4.60	4.60	4.30
Na	0.09	0.11	0.09	0.09	0.06	0.06	0.08	0.06
Mg	1.82	1.79	1.78	1.46	1.14	1.24	1.38	1.19
K	0.59	0.56	0.51	0.51	0.28	0.32	0.35	0.30
S / T %	73	69	74	73	61	62	60	52
Total nutrients %								
Ca	5.64	5.53	5.62	5.66	5.77	5.48	5.25	4.98
Mg	2.03	1.89	2.01	2.00	2.02	1.95	1.91	1.70
K	1.20	1.11	1.21	1.23	1.25	1.24	1.23	1.16
Na	2.44	2.42	2.46	2.51	2.64	2.56	2.57	2.48
P	0.64	0.64	0.62	0.63	0.61	0.61	0.61	0.66
S	0.04	0.04	0.07	0.04	0.07	0.10	0.07	0.06

Table 1. Chemical characteristics of soils in the four stands studied

Stand	Elevation m	Stumps ha^{-1}	Shoots	Shoots per stump	Basal area M^2 ha^{-1}	Mean diameter of trunks at 1.30m cm
Fossa la Nave	1600	238	1895	8	8.4	7.5
Balilla	1400	245	1529	6	30.9	16.0
Monte Crisimo	1200	441	5529	12	29.1	8.2
Piano Porcheria	1000	288	5668	20	10.5	4.9

Table 2. Features of the four *Castanea sativa* Mill. stands studied on Mount Etna

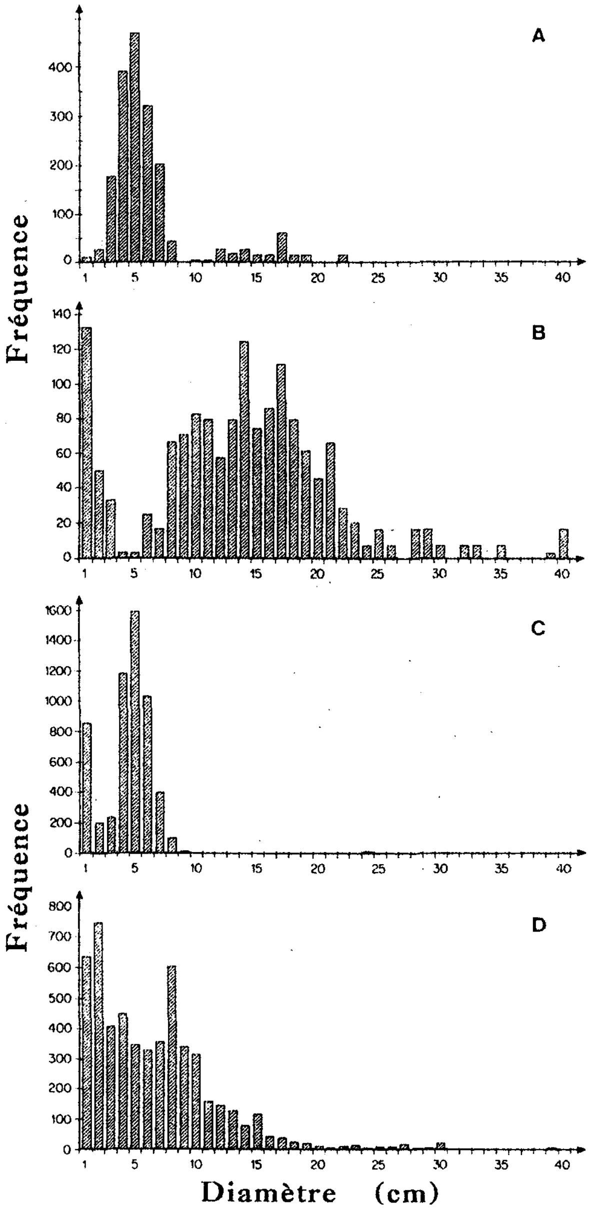

Figure 3. Distribution of *Castanea sativa* trees in relation to the diameter at breast height at : (A) Fossa la Nave; (B) Balilla; (C) Piano Porcheria; (D) Monte Crisimo

Litterfall

Ten litter-traps (0.25 m^2 opening) were distributed randomly at each site (Leonardi *et al.,* 1996a). Litter was collected monthly and more frequently in autumn. The collected litter was subdivided into leaves, wood, flowers, fruit and unidentified material. All the different fractions were dried (85°C) and then weighed. Based on these measurements, extrapolations were made on a per-hectare scale.

Above-ground litter

Ten above-ground litter samples, 2500 cm^2 each (0.25 m^2), were collected at each site. Each sample was then subdivided into leaves, reproductive organs (mainly chestnuts and husks) and wood. Some sub-samples were incinerated at 550°C and the resulting ash was weighed. This allows to determine organic material by eliminating all soil contamination and particle fallout, which is very common in active volcanic environments.

Litter decomposition

In each stand, 10 g dried leaf samples were put in 2 mm-mesh litterbags and placed within the litter layer in the stand. For 2 consecutive years, three litterbags were collected at each site at 2-month intervals — the material was dried and weighed. This technique was initially described by Burges (1956) and Bocock & Gilbert (1957) and has been widely used since.

Nitrogen determination in plant tissues

Total nitrogen in all plant samples, dried at 85°C and ground to 0.5 mm particle size, was determined using Kjeldahl's technique.

Nitrogen in rainfall and throughfall

Precipitation levels were determined with rain gauges set in clearings outside of the stands. In the two young coppice stands, 10 rain gauges similar to those set in the clearings were placed randomly under the canopy to collect throughfall precipitation (Leonardi *et al.*, 1993). In each stand, precipitation collectors were attached to 6 trees representative of all DBH classes to determine stemflow. The collectors were monitored weekly, or after storms, to determine precipitation volumes. These precipitation volumes were easily transformed into incident precipitation and throughfall precipitation in mm, on the basis of the rain gauge openings. Stemflow precipitation was more difficult to calculate. Stemflow precipitation volumes were estimated using a regression equation, with DBH of the trees to which the rain gauges are attached and precipitation volumes after each rainfall as variables. This equation was applied to each DBH class and multiplied by the number of trees in each class to determine total stemflow precipitation volumes (l/ha) and thus the stemflow precipitation in mm. Aliquotes for each type of precipitation and each sampling were analyzed by Kjeldahl's technique to measure total nitrogen, by colorimetry with Nessler's reagent to determine ammonia nitrogen, and by distillation and titration with 0.01N H_2SO_4 in the presence of Dewarda's alloy to assess nitrate nitrogen.

Mineral, ammonia and nitrate nitrogen production in the soil

Nitrogen mineralization was studied in the field under semi-natural conditions using the method described by Rapp *et al.* (1979) and whose efficiency was confirmed by Raison *et al.* (1987).

Over a 2-year period, soil samples were incubated at each of the four sites for a series of 6-week periods, except in winter or under hard environmental conditions (snow, difficult access to sites) when the incubation periods were longer. The samples were incubated in aluminium cans with a horizontal surface of 127.4 cm^2, closed at the top, opened at the bottom and perforated on the sides. They were forced into the soil to 7 cm and 15 cm depth. By this method, the soil moisture content is the same inside and outside of the cans. Moreover, it prevents also input of nitrogen by rain and leaching of mineralized nitrogen during storms, as well as nutrient uptake by the roots of the chestnut trees throughout the incubation period. At each sampling, the fine earth was separated from the volcanic cinders, weighed and expressed on the basis of unit area (127.4 cm^2) and depth (7 and 15 cm). Total nitrogen, ammonia and nitrate nitrogen were determined at the beginning and end of each incubation period. Determinations were performed in triplicate for each depth and station to estimate (per surface area and for 7 and 15 cm soil depths) the quantity of ammonia and nitrate nitrogen produced during the incubation period (final ammonia or nitrate nitrogen - initial ammonia or nitrate nitrogen), therefore the soil organic nitrogen mineralization. This enabled us to calculate the mean daily mineral nitrogen production by dividing the quantity of ammonia or nitrate nitrogen produced during the incubation period by the number of incubation days. It was also possible to determine monthly nitrogen mineralization levels, but these were means for incubation periods that were sometimes much longer than 1 month (during winter). These mineralization results were also expressed on a per unit area basis for the purposes of comparisons with other nitrogen cycle compartments and flows at the four study sites.

Total nitrogen was further determined by Kjeldahl's technique. For mineral nitrogen determination, a 25 g sample of fine earth was agitated with 100 cc K_2SO_4 for one hour, followed by extraction. After filtration, the extraction liquid was adjusted to 100 cc for ammonia nitrogen determination. After adding MgO, a drop of phenolphthalein and three drops of NaOH, the extract was distilled and the distillate was recovered in boric acid up to a volume of 75 cc. This solution was then titrated with 0.1N H_2SO_4. After cooling the initial extract, nitrate nitrogen was converted into ammonia nitrogen with Dewarda's alloy (selenium mixture) as catalyst and the distillation process described above was again applied to measure the converted ammonia nitrogen.

RESULTS AND DISCUSSION

Above ground nitrogen compartments and fluxes

Nitrogen in above ground biomass and litter fall

The aerial biomasses, calculated by the regression equations reported above, and applied to the population of the four sites, are respectively : 22.0 and 24.1 Mg ha^{-1} on the recent clearcutt sites (Fossa la Nave and Piano Porcheria), 83.2 Mg ha^{-1} and 99.5 Mg ha^{-1} on the older stands of Monte Crisimo and Balilla (Leonardi *et al.*, 1996a).

Theses values are similar to the 107 Mg ha^{-1} aerial biomass obtained by La Marca (1984) for a 13 year old chestnut wood in Italy, and to those of Berthier (1984) in France. This latter obtained perennial biomass (trunk and branches) values of 25.2 to 67.8 Mg ha^{-1} at sites respectively 5 and 11 years old.

The nitrogen immobilized within the above ground biomass amounted 42.8 to 216.7 kg ha^{-1} for the four sites (Leonardi *et al.*, 1996b). Distributed between leaves and wood, the amounts of nitrogen are given in Table 3.

Dividing the perennial biomass values by the age of each stand we can estimate the increment of the above ground perennial biomass (Table 4).

Multiplying theses values by the mean nitrogen composition of trunk and branch wood from each site, the yearly immobilization of nitrogen within the increasing biomass was: 4.2 kg ha^{-1} year^{-1} (Fossa la Nave), 4,2 (Piano Porcheria), 5.1 (Monte Crisimo), and 5 (Balilla).

Mean yearly litter fall during three consecutive years amounted 2640 and 1709 kg ha^{-1} in the youngest stands (Fossa la Nave and Piano Porcheria) and respectively 5093 and 5822 kg ha^{-1} in the two oldest sites of Monte Crisimo and Balilla (Leonardi *et al.*, 1995). Total nitrogen restitution to the soil by litter fall amounted: 24.0 kg ha^{-1} at Fossa la Nave, 15.4 kg ha^{-1} at Piano Porcheria, 47.8 kg ha^{-1} at Monte Crisimo and 53.7 kg ha^{-1} at Balilla.

	Leaves (kg ha^{-1})	Wood (kg ha^{-1})	Total (kg ha^{-1})
Fossa la Nave	30.5	35.0	65.5
Piano Porcheria	20.5	22.3	42.8
Monte Crisimo	55.9	77.2	133.1
Balilla	65.8	150.9	216.7

Table 3. Amounts of nitrogen distributed between leaves and wood

	Trunk (Mg ha^{-1} year^{-1})	Branches (Mg ha^{-1} year^{-1})	Total (Mg ha^{-1} year^{-1})
Fossa la Nave	2.0	0.4	2.4
Piano Porcheria	3.6	0.8	4.4
Monte Crisimo	4.4	1.0	5.4
Balilla	2.7	0.6	3.3

Table 4. Estimation of the increment of the above ground perennial biomass

Nitrogen input by rainfall, throughfall and stemflow

Input of nitrogen to the forest by rainfall and to the soil after canopy leaching and stemflow has been studied during 12 consecutive months at Fossa la Nave and Piano Porcheria (Leonardi *et al.*, 1993). Their is greater input through rainwater at Piano Porcheria (963.7 mm) then at Fossa la Nave (667.5 mm). But interception is also higher at Piano Porcheria (239.3 mm) then at Fossa la Nave (123 mm). Throughfall amounted respectively 663.5 and 526.1 mm at the two stands, and stemflow 60.9 and 18.4 mm. So the differences of water supply were not so significantly different for the amounts of water reaching the soil. Concerning nitrogen, the amounts are the followings (Table 5). As the two older stands are respectively at the same altitude and in the vicinity of the two studied sites, it appears that the sites located at the eastern slope of the volcano, and at lover altitude, benefits of a higher input of nitrogen by rain then the sites at higher elevation on the southern part of the volcano.

If the ecosystem benefits of a perceptible nitrogen input, it is not the case for the soil. We see that several kg ha^{-1} of nitrogen are immobilized during throughfall. Nitrogen losses as rainwater passes through the canopy has been reported for many years by Carlisle et al. (1966, 1967). Indeed, nitrogen is absorbed and used by the epiphytes and microorganisms (algae and fungi) living on bark and trunks of trees (Benzing, 1990).

	Fossa la Nave	Piano Porcheria
Rainfall	12.6	23.2
Throughfall	10.2	16.6
Stemflow	0.5	0.8
Total under canopy	10.7	17.4
Immobilization within canopy	-1.9	-5.8

Table 5. Amounts of nitrogen input by rainfall, throughfall and stemflow (kg ha^{-1} year$^{-1)}$

Nitrogen immobilization in the above ground litter layer

From each of the ten 0.25m^2 above ground soil litter samples the following mean amounts of organic matter were determined : 7.3 Mg ha^{-1} at Fossa la Nave, 7.7 Mg ha^{-1} at Piano Porcheria, 7.9 Mg ha^{-1} at Monte Crisimo and 7.4 Mg ha^{-1} at Balilla including respectively 75.6, 68.8, 65.6 and 63.9 kg ha^{-1} nitrogen.

The study of leaf litter decomposition and the loss of nitrogen during two consecutive years using litterbags (Leonardi et al., 1996b), indicate loss of 49% of the initial amount of nitrogen during two years at Fossa la Nave, 60% at Piano Porcheria, 67% at Monte Crisimo and 58% at Balilla. These percentages correspond respectively to a loss of 5.0, 7.0, 17.5, and 16.2 kg ha^{-1} nitrogen from fresh leaf litter during the two first years following litter-fall, with respectively the following annual amounts: Fossa la Nave (first year: 4.7 kg ha^{-1}; second year: 0.3 kg ha^{-1}), Piano Porcheria (first year: 0.0 kg ha^{-1}; second year: 7.0 kg ha^{-1}), Monte Crisimo (first year: 7.7 kg ha^{-1}; second year: 9.8 kg ha^{-1}) and Balilla (first year: 2.6 kg ha^{-1}; second year: 13.6 kg ha^{-1}).

Below ground nitrogen mineralization processes

Nitrogen mineralization throughout the year (Figures 4, 5, 6, 7)

Nitrogen mineralization occurred year-around under our experimental conditions, but there were clear between-season differences. Mineralization rates always peaked between April and September, but the timing varied according to the stand elevation and the thickness of the soil profile investigated. Concerning the month of peak mineralization, there was a significant difference between the surface soil layer (0-7 cm) and the deeper horizons (0-15 cm). In the 0-7 cm layer, microbial activity was markedly faster after the winter season, with peak soil nitrogen mineralization occurring in May in all stands, followed by June for the high elevation stands and July for the two stands on the northeastern slopes of

Mount Etna. In the 0-15 cm layer, peak mineralization occurred in July for three stands and in June for the Fossa la Nave stand, which is located at the highest elevation. These timing lags could be explained by the fact that starting of microbial activity at the soil surface is earlier in relation with better bioclimatic conditions (temperature and humidity) than at deeper horizons.

We also noted a difference between the high-elevation stands on the southern slopes of Mount Etna and the lower stands on the northeastern slopes. At the high-elevation stands, there was very high surface nitrogen mineralization in May and June, followed by a decrease in July and August, i.e. the hottest and driest months. At lower elevations, the delay in the onset of biological activity was offset by the prolongation of intense activity until September-October.

Annual mineral nitrogen production

Table 5 summarizes the annual quantities of ammonia, nitrate and total mineral nitrogen produced per hectare in the four stands during the 2-year study period at 7 and 15 cm soil depths. The results obtained for these 2 years were quite close, with less than 10% difference, except for the surface layer at the Monte Crisimo stand and the 0-15 cm layer at the Piano Porcheria stand, where the between-year differences were around 30%.

As shown in Table 5, mean yearly mineral nitrogen production was similar in the two soil horizons studied (0-7 cm and 7-15 cm). However, there seemed to be more activity in the surface layer. Although this layer only accounted for 48 ± 3% of the mineralized nitrogen in the four soil profiles studied, it represented 6% less in terms of soil volume and weight.

The highest mineralization occurred in the oldest stand (Balilla), followed by Piano Porcheria, Fossa la Nave and Monte Crisimo, with almost identical annual nitrogen mineralization rates noted in the latter three stands.

The mean annual mineral nitrogen production, which is the main source of nitrogen for the trees in the four studied chestnut stands, amounted respectively 27.5 kg ha^{-1} $year^{-1}$ at Fossa la Nave, 31.5 kg ha^{-1} $year^{-1}$ at Piano Porcheria, 25.7 kg ha^{-1} $year^{-1}$ at Monte Crisimo and 41.6 kg ha^{-1} $year^{-1}$ at Balilla.

Nitrogen pool in the top 15 cm soil layer

When the incubation experiments were set up, total soil nitrogen was determined in the control samples. This was useful for estimating potential nitrogen reserves in the 0-7 cm and 0-15 cm soil layers. The means for each stand are the followings: Fossa la Nave (0-7 cm: 365.0 kg ha^{-1}; 0-15 cm: 763.5 kg ha^{-1}), Piano Porcheria (0-7 cm: 430.0 kg ha^{-1}; 0-15 cm: 812.5 kg ha^{-1}), Monte Crisimo (0-7 cm: 284.5 kg ha^{-1}; 0-15 cm: 676.0 kg ha^{-1}) and Balilla (0-7 cm: 285.5 kg ha^{-1}; 0-15 cm: 741.0 kg ha^{-1}).

A few differences can be noted in almost the same soils. The variations were more marked in the surface layer (30%) than in the entire 15 cm profile. In the latter layer, the differences were less than 16% between the most nitrogen-rich soil (Piano Porcheria) and the poorest soil (Monte Crisimo).

In the upper layer, nitrogen quantities were higher in the two recently clearcut stands (365 and 430 kg ha^{-1}) than in the older stands (285 kg ha^{-1}). This could be the result of increased decomposition of the above-ground litter, boosted by the decomposition of residue left after clearcutting. Microclimate changes, induced by opening the canopy, were also likely responsible for intensifying and accelerating the decomposition of accumulated organic material on the soil surface, thus prompting an increase in soil organic matter and nitrogen reserves. The same microclimate changes ensure also the mineralization of the available soil organic matter.

We also noted that the soil in the Piano Porcheria stand, located 1000 m above sea level, had the highest nitrogen content in the 0-7 cm layer. This could be explained by climatic factors. At such elevations, it is known that microbial activity continues until August-September. Above-ground litter decomposers are likely active at the same time, i.e. longer than at Fossa la Nave. As clearcutting was carried out in late spring and early summer, above-ground litter and residues were more decomposed in the Piano Porcheria stand, thus boosting soil organic matter and nitrogen contents.

Nitrogen mineralization rates

Mineralization rates can be calculated on the basis of annual quantities of mineral nitrogen produced and soil nitrogen reserves: annual mineral nitrogen x 100 / Total soil nitrogen.

Table 6 gives the different annual mineralization rates and the mean values for the study period. These rates ranged from 3.2 to 7.1%, indicating high biological activity in these soils (4% is generally considered as a good rate by European foresters). The best biological activity was noted at the oldest stand: Balilla, followed by Monte Crisimo, which is also a mature stand. The two recently clearcut stands had lower mineralization rates, i.e. ranging from 3.5 to 4%, which is still quite suitable. Comparisons of the two soil layers studied highlighted that mineralizing microbial activity was greater in the surface layer, except at Piano Porcheria.

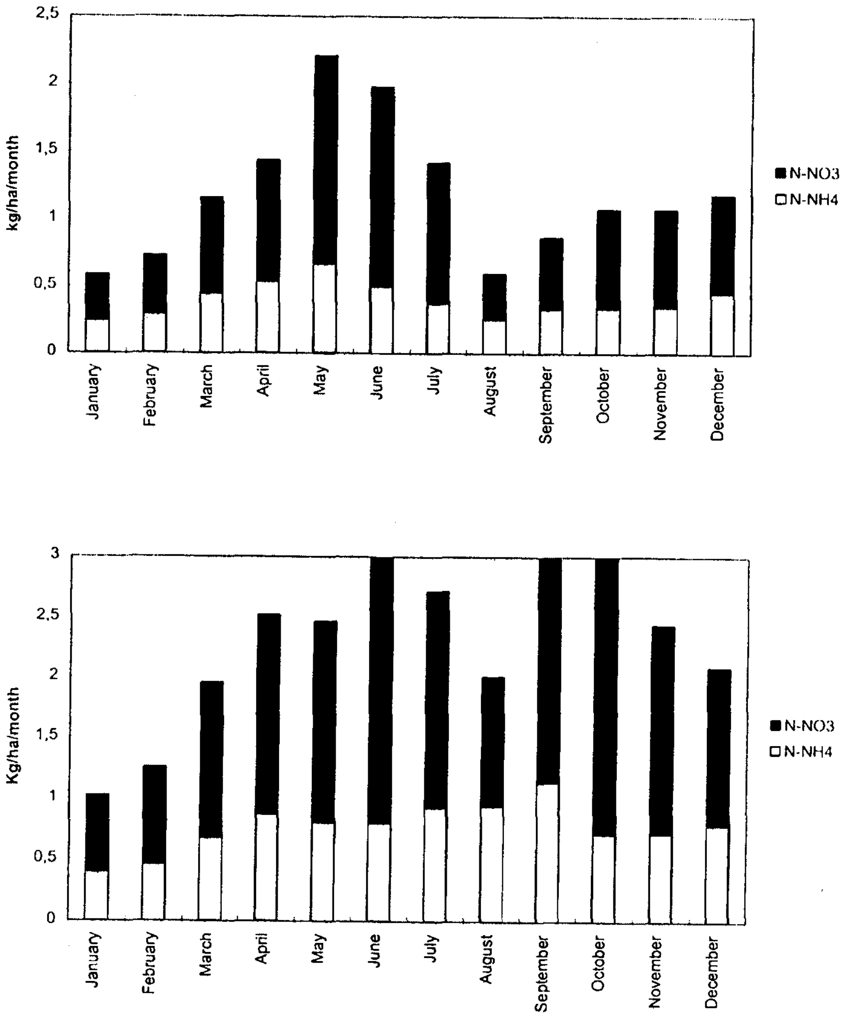

Figure 4. Monthly mineral nitrogen production during two following years at Fossa la Nave

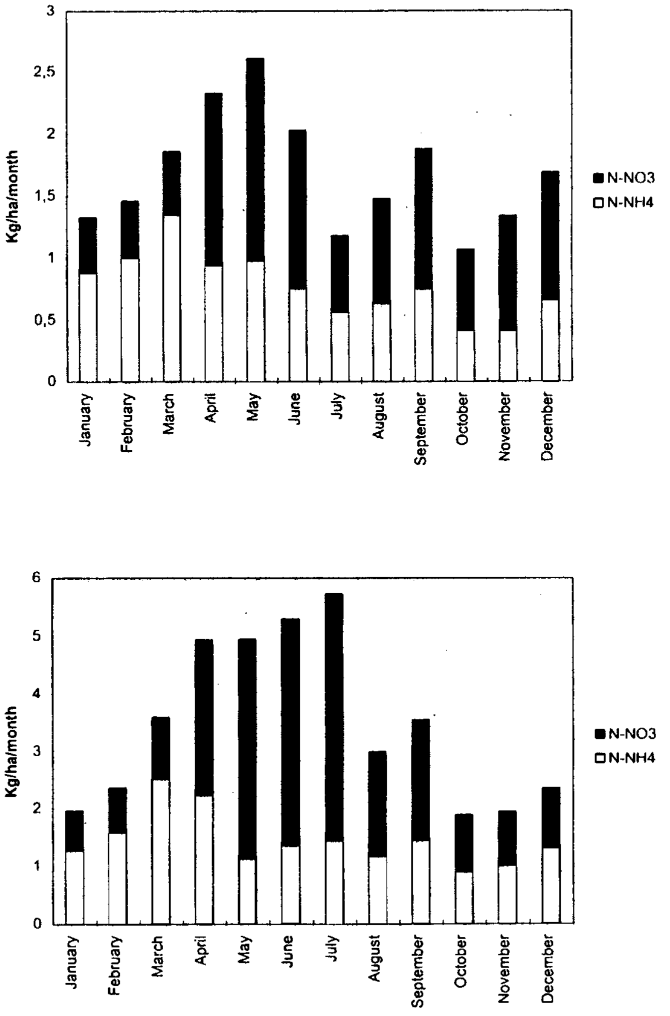

Figure 5. Monthly mineral nitrogen production during two following years at Balilla

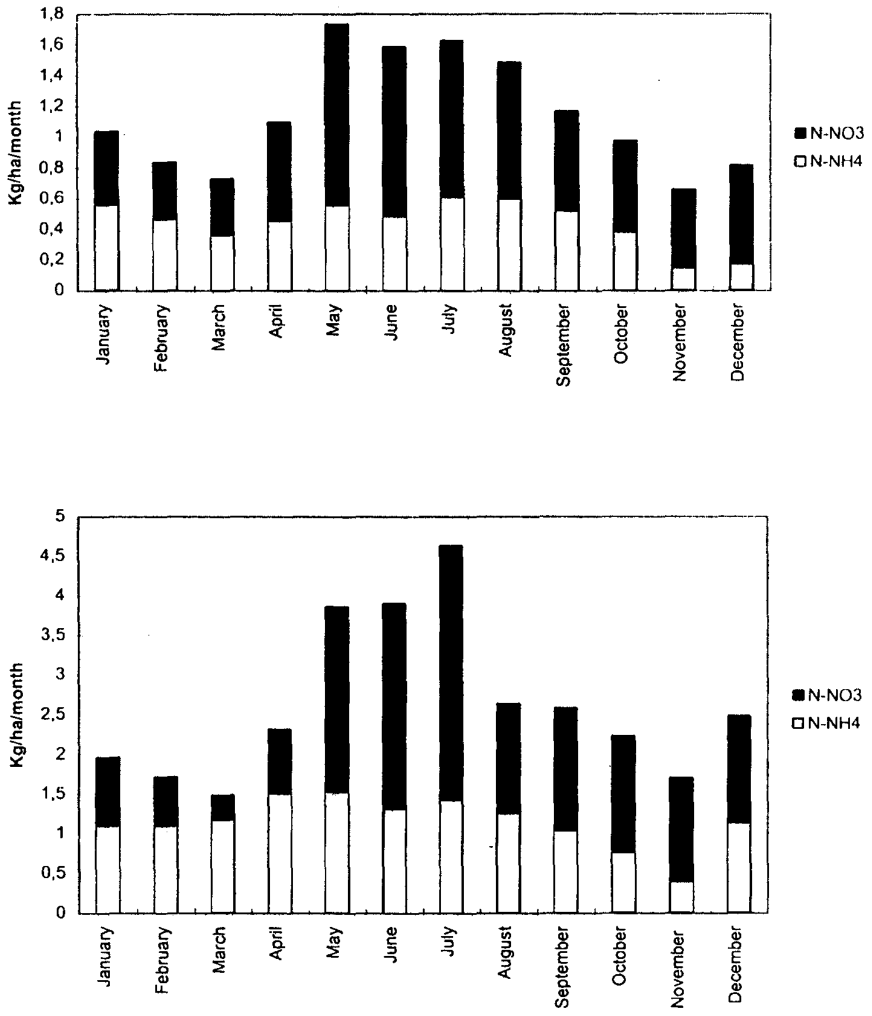

Figure 6. Monthly mineral nitrogen production during two following years at Piano Porcheria

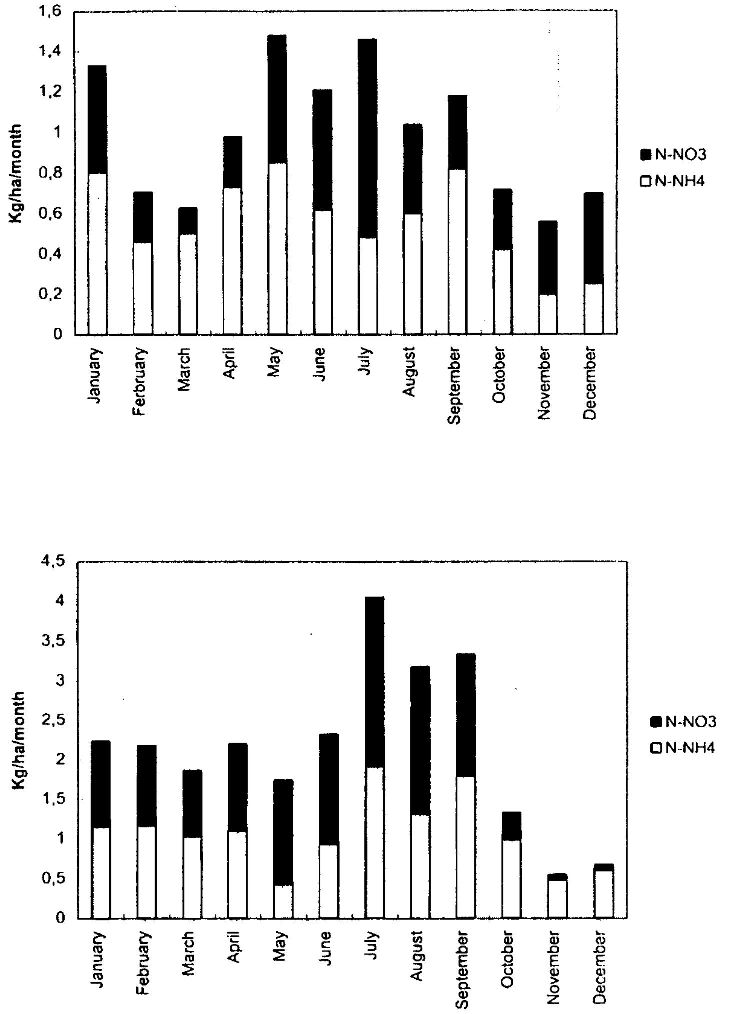

Figure 7. Monthly mineral nitrogen production during two following years at Monte Crisimo

	Depth	Fossa la Nave			Balilla			Piano Porcheria			Monte Crisimo		
	cm	N-NH$_4$	N-NO$_3$	N-min	N-NH$_4$	N-NO$_3$	N-min	N-NH$_4$	N-NO$_3$	N-min	N-NH$_4$	N-NO$_3$	N-min
Year 1	0 - 7	4.9	10.2	15.1	9.8	10.8	20.6	6.4	7.8	14.2	7.6	6.6	14.2
	7 - 15	4.6	7.2	11.8	6.1	17.1	23.2	10.6	12.1	22.7	8.3	8.2	16.5
	0 - 15	9.5	17.4	26.9	15.9	27.9	43.8	17.0	19.9	36.9	15.9	14.8	30.7
Year 2	0 - 7	4.5	9.1	13.6	8.8	1.1	19.9	4.1	9.3	13.4	5.9	3.9	9.8
	7 - 15	4.4	10.0	14.4	9.9	9.5	19.4	6.3	6.4	12.7	5.0	9.0	13.9
	0 - 15	8.9	19.1	28.0	18.7	20.6	39.3	10.4	15.7	26.1	10.9	12.9	23.7
Mean 2 years	0 - 7	4.7	9.6	14.3	9.3	10.9	20.2	5.3	8.5	13.8	6.7	5.3	12.0
	7 - 15	4.5	8.7	13.2	8.0	13.4	21.4	8.4	9.3	17.7	6.2	7.5	13.7
	0 - 15	9.2	18.3	27.5	17.3	24.3	41.6	13.7	17.8	31.5	12.9	12.8	25.7

Table 5. Annual ammonia, nitrate and mineral nitrogen production in kg ha^{-1}, in the three soil horizons studied (0-7 cm, 7-15 cm and 0-15 cm) over 2 consecutive years

	0-7 cm		0-15 cm		Mean	
	1st year	2nd year	1st year	2nd year	0-7 cm	0-15 cm
Fossa la Nave	4.0	3.8	3.4	3.7	3.9	3.6
Balilla	7.2	6.9	5.8	5.4	7.1	5.6
Monte Crisimo	4.8	3.6	4.5	3.5	4.2	3.8
Piano Porcheria	3.2	3.2	4.4	3.3	3.2	3.8

Table 6. Annual mineralization rates (%) and means for soil nitrogen (mineralized nitrogen x 100/total soil nitrogen) in the four stands studied over 2 consecutive years

Nitrogen balance in the *Castanea sativa* coppice stands

Table 7 summarizes the main nitrogen compartments and flows within these four stands. Part of these results were published previously by Leonardi *et al.* (1993; 1996a,b,c,d).

A comparison of the mature stands and young coppices indicated that stand age is a major factor affecting nitrogen cycling and balance.

Despite similar above-ground biomass immobilization rates, i.e. 5 kg ha^{-1} year^{-1} in the mature stands and 4.2 kg ha^{-1} year^{-1} in the young coppices, annual nitrogen requirements and uptake were almost twofold higher in the mature stands (58.7 and 52.9 kg ha^{-1} year^{-1} for Balilla and Monte Crisimo) as compared to the younger coppices (19.6 and 28.2 kg ha^{-1} year^{-1} for Piano Porcheria and Fossa la Nave). The classical requirement, calculated as defined by Duvigneaud (1974) : requirement or uptake or absorption = nutrient returning to the soil via litterfall + nutrient include in the increase of biomass, has been modified to adapt to more important translocation (= nutrient in leaf biomass - nutrient in leaf litter) versus immobilization within annual perennial production. Indeed Leonardi et al. (1996b) indicate that leaf biomass include respectively 30.5, 20.5, 55.9 and 65.8 kg ha^{-1} nitrogen at Fossa la Nave, Piano Porcheria, Monte Crisimo and Balilla, when yearly leaf litter-fall include only 10.3, 10.4, 29.0 and 28.0 kg ha^{-1} of the same nutrient. On the opposite, the yearly increment of the perennial above ground biomass needs only 4.2, 4.2, 5.1 and 5.0 kg ha^{-1} nitrogen. This is due to the twofold increase in leaf mass, and thus in the nitrogen content, in the mature 20-30 year-old stands of Monte Crisimo and Balilla.

In the upper 15cm soil layer, the balance between plant uptake and nitrogen mineralization rates was negative for the two mature stands, close to equilibrium (or slightly negative) for the Fossa la Nave stand and positive (or in slight excess) for Piano Porcheria.

Nitrogen flows between the canopy and the soil, according to the intrasystem cycle described by Waring and Schlesinger (1985), could only be assessed in the two young coppices because throughfall and stemflow chemistry was not studied in the older stands. The results indicated a nitrogen gain in the upper 15cm soil layer, suggesting possible leaching of nitrogen to deeper horizons. This phenomenon was especially marked at Piano Porcheria, mainly as a result of high nitrogen inputs via throughfall and stemflow.

Concerning the intersystem cycle, i.e. the balance between the ecosystem and its atmospheric and geological environment, the inputs of nitrogen by rain are higher for the whole stands as for their soils only (inputs of nitrogen via throughfall and stemflow). This could be explained by the fact that rainwater losses nitrogen during throughfall and stemflow, nitrogen which is absorbed and assimilate by the epiphytes : bacteria, algae, lichens, mosses etc. In the present conditions, this resulted in a soil nitrogen deficit in the mature stands, although this trend was not as marked as on the intrasystem scale. For the young coppice there were higher nitrogen inputs allowing the possibility of substantial potential leaching of this nutrient into the ground water. The canopies in these two stands are not entirely closed, which means that the trees have a minor impact on the water management and cycling processes. As evapotranspiration is lower, there is less nitrogen transfer to the vegetation by massflow and on the opposite higher percolation.

Nitrogen mineralization also had a quantitatively important effect between the two different sites conditions studied. The higher mineralization rates in the mature stands reflected intense mineral nitrogen production, and thus higher availability of this nutrient for the trees.

The sustainability of the chestnut coppices from Mount Etna, in relation with nitrogen availability and management in these woodlands, could be ensured by regular clearcutting, every 15 to 20 years. The clearcutting allows a reduction of nitrogen uptake by regenerating shoots and an acceleration of decomposition and mineralization of the available organic matter, organic matter resulting from the remaining material on the soil surface after clearcutting and harvesting of the trees. In other way the increase of soil organic matter decomposition and mineralization, in relation with microclimate changes in the upper soil layers after clearcutt, could promote availability of mineral nitrogen for absorption by rhe trees, but also induce leaching of ammonium or nitrate nitrogen out the forest ecosystem.

	Old coppices		**Young coppices**	
	Balilla	**Monte Crisimo**	**Fossa la Nave**	**Piano Porcheria**
Intrasystem processes				
Balance on a tree scale				
- Nitrogen in biomass *	216.7	133.1	65.5	42.8
- Absorption **	58.7	52.9	28.2	19.6
- Fixation in perennial biomass**	5.0	5.1	4.2	4.2
- Restitution to the soil **	53.7	47.8	24.0	15.4
Decomposition / Mineralization				
- Nitrogen in above-ground litter *	63.9	65.6	75.6	68.8
- Nitrogen, in 15th first cm of soil *	741.0	676.0	763.5	812.5
- Mineralization **	41.6	25.7	27.5	31.5
Intrasystem balance				
- Balance : Mineralization – Absorption ** = production – uptake	- 17.1	- 27.2	- 0.7	+ 11.9
- Inputs by rain and throughfall **			10.7	17.4
- Potential losses by drainage ** =Excess of mineral nitrogen (Mineralization - Absorption) + inputs by rain and throughfall			10.0	28.3
Intersystem processes				
- Atmospheric inputs of nitrogen **	12.6	23.2	12.6	23.2
- Intersystem balance ** = (Mineralization – Absorption) + Inputs by rainfall - Potential losses by Drainage	- 4.5	- 4.0	+ 1.9	+ 26.4

Table 7. The main nitrogen cycle parameters in the four chestnut stands studied on Mount Etna. The results are given in kg.ha^{-1} (*) and kg.ha^{-1}.year^{-1} (**)

CONCLUSION

Sustainable management of *Castanea sativa* coppice stands is dependent on all biological processes associated with nitrogen mineralization, balance and cycling. Biogeochemical nitrogen cycle imbalances occur in older stands reaching maturity. They can be efficiently overcome by regular clearcutting (every 20-30 years), practice preserving or even boosting the soil nitrogen pool. Nitrogen losses by leaching are only hypothetical and cannot yet be confirmed. It seems that soil nitrogen fertility could be suitably maintained in *Castanea sativa* coppice stands by implementing a relatively short-term clearcutting program, reducing annual nitrogen uptake by the trees, but maintaining normal fixation within the perennial biomass, while accelerating decomposition of above-ground litter and clearcutting residues. In addition, the lower nitrogen uptake by trees for a few years after clearcutting, could compensate, on a long time scale, the nitrogen losses due to the removal of wood from the site at the moment of clearcutt by reducing the immediate needs of nitrogen by the regenerating *Castanea sativa* coppice stands.

REFERENCES

Baskerville G.L., 1965. Estimation of dry weight of tree components and total standing in conifer stands. *Ecology*, 46, 867-869.

Benzingy D.H., 1990. *Vascular epiphytes.* Cambridge Univ. Press, Cambridge.

Bocock K.L. & Gilbert O.J.W., 1957. The disappearance of leaf litter under different woodland conditions. *Plant and Soil*, 9 : 179-185.

Bouchon J., Nys C. & Ranger J. 1985. Cubage, biomasse et minéralomasse: comparaison de trois taillis simples des Ardennes primaires. *Acta. Oecol., Oecol. Plant.*, 6 : 53-72.

Burges A., 1956. The release of cations during the decomposition of forest litter. *C.R. VI C. Int. Sci. Soil.*, Paris, B, 1-2 : 741-745.

Carlisle A., Brown A.H.F. & White E.J., 1966. The organic matter and nutrient elements in the precipitation beneath a sessile oak canopy. *J. Ecol.*, 54 : 87-98.

Carlisle A., Brown A.H.F. & White E.J., 1967. The nutrient content of tree stemflow and ground flora litter and leachates in a sessile oak (*Quercus petraea*) woodland. *J. Ecol.*, 55 : 615-627.

Duvigneaud P., 1974. *La synthèse écologique.* Doin, Paris, 296p.

Hanchi A., 1994. *Cycle de l'eau et des éléments biogènes dans un bassin versant forestier : cas d'une hêtraie au Mont Lozère.* Thèse Univ. Dijon (France), 232 p.

Leonardi S., Rapp M., Failla M. & Guarnaccia D., 1993. Interception of rainfall, input and leaching of nutrients within two *Castanea sativa* Mill. stands at the Etna volcano. *Oecol. Montana*, 2 : 7-12.

Leonardi S., Rapp M., Izzo R., Failla M., Guarnaccia D. & De Santis C., 1995. Chestnut ecosystem function : nutrient cycle processes within several stands in relation to age and altitude on the Etna volcano. *In :* F. Romane (Ed.), Sustainability of mediterranean ecosystems. Case study of the chestnut forest, European Commission, 45-61.

Leonardi S., Rapp M., Failla M. & Guarnaccia D., 1996(a). Biomasse, productivité et transferts de matière organique dans une séquence altitudinale de peuplements de *Castanea sativa* Mill. de l'Etna. *Ann. Sci. For.*, 53 : 1034-1048.

Leonardi S., Rapp M., Izzo R., Failla M. & Guarnaccia D., 1996(b). Les cycles biogéochimiques de différents taillis de *Castanea sativa* Mill. en fonction de leur âge et de l'altitude dans le massif de l'Etna (Sicile). Coll. Phytosociol., XXIV : Fitodinamica - I differenti aspetti della dinamica vegetale, J. Cramer, Berlin-Stuttgart, 505-520.

Leonardi S., Rapp M. & Failla M., 1996(c). Variation de la biomasse, de la minéralomasse et de la surface assimilatrice de la nappe foliaire au cours d'une saison de végétation dans deux peuplements de *Castanea sativa* Mill. *Archivio Geobotanico*, 2, (2), 157-163.

Leonardi S., Santa Regina I., Rapp M., Gallego H.A. & Rico M., 1996(d). Biomass,litter-fall and nutrient content in *Castanea sativa* coppices stands of southern Europe. *Ann. Sci. For.*, 53 : 1071-1081.

Poli E., Maugeri G. & Ronsisvalle G. A., 1981. *Note illustrative della carta della vegetazione dell'Etna. C.N.R., AQ/1/131*, Roma.

Raison R.J., Connel N.J. & Khanna P.K., 1987. Methodology for studying fluxes of soil mineral nitrogen in situ. *Soil Biol. Biochem.*, 19 : 521-530.

Rapp M., Leclerc M. Cl. & Lossaint P., 1979. The nitrogen economy in a *Pinus pinea* L. stand. *For. Ecol. Manag.*, 2 : 221-231.

Ronsisvalle G.A. & Signorello P., 1979. Contributo allo studio fitosociologico dei castagneti dell'Etna. Boll. *Acc. Gioenia Sc. Nat. Catania*, 4 : 29-41.

Waring R.H. & Schlesinger W.H., 1985. *Forest Ecosystems. Concepts and management* Acad. Press, Orlando, San Diego, New York, 340 p.

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Competition and dynamics in abandoned chestnut orchards in southern Switzerland

Compétition et dynamique dans les châtaigneraies abandonnées de Suisse méridionale

Marco CONEDERA[1], Pietro STANGA[1], Christian LISCHER[2] & Veronika STÖCKLI[3]

[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

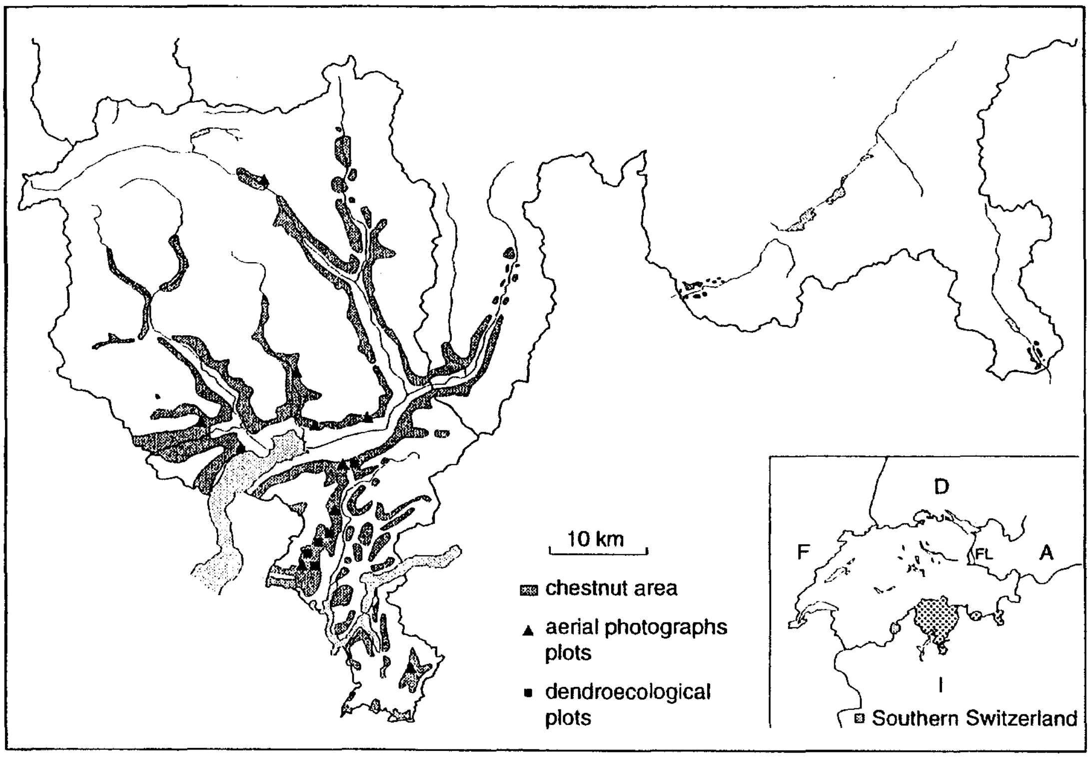

Figure 1: Locations of the study sites in southern Switzerland

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 chesnut 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}, ..., x_{im}). The probability was logarithmically transformed to avoid values exceeding 1, so that the following logistic regression model was obtained (Cox, 1980) :

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

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^{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	
			Orchards		Coppices		High forests					
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	■	■	7.4	23.1	8.3	25.9	6.8	21.2	8.9	27.7
40 - 60%	14.8	100.0	■	■	■	■	2.5	16.9	7	47.3	4.6	31.1
20 - 40%	5.6	100.0	■	■	■	■	■	■	2.6	46.4	2.9	51.8
total	112.3	100.0	■	■	■	■	■	■	■	■	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	■	■	8.5	19.1	0.5	1.1	0.3	0.7
0.4 – 0.6	19.7	100.0	■	■	■	■	0.3	1.5	1.1	5.6
0.2 – 0.4	7.5	100.0	■	■	■	■	■	■	0.6	8.0
<0.2	0.0	-	■	■	■	■	■	■	■	■
total	112.3	100.0	■	■	■	■	■	■	■	■

■ 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
	cover	95	100	95	100	80
Diversity indexes**	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***	*Acer pseudoplatanus*	▯●○	▯●○	▯○	▯○	
	Alnus glutinosa	▯●○				
	Betula pendula	▯○	▯○	▯○	▯●	▯●
	Castanea sativa	▯●○	▯●○	▯●○	▯●○	▯●○
	Fagus sylvatica		▯●○	▯●○		
	Frangula alnus		▯○		▯○	
	Fraxinus excelsior	▯●○	▯○	▯○		
	Pirus malus	▯○				
	Prunus avium	▯●	▯○		▯○	
	Quercus petraea			▯●○		▯○
	Robinia pseudoacacia			▯○		
	Sorbus aria	▯●	▯○	▯○	▯○	
	Sorbus aucuparia		▯●○	▯●	▯●	
	Tilia cordata	▯○	▯●○	▯○		▯●

*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

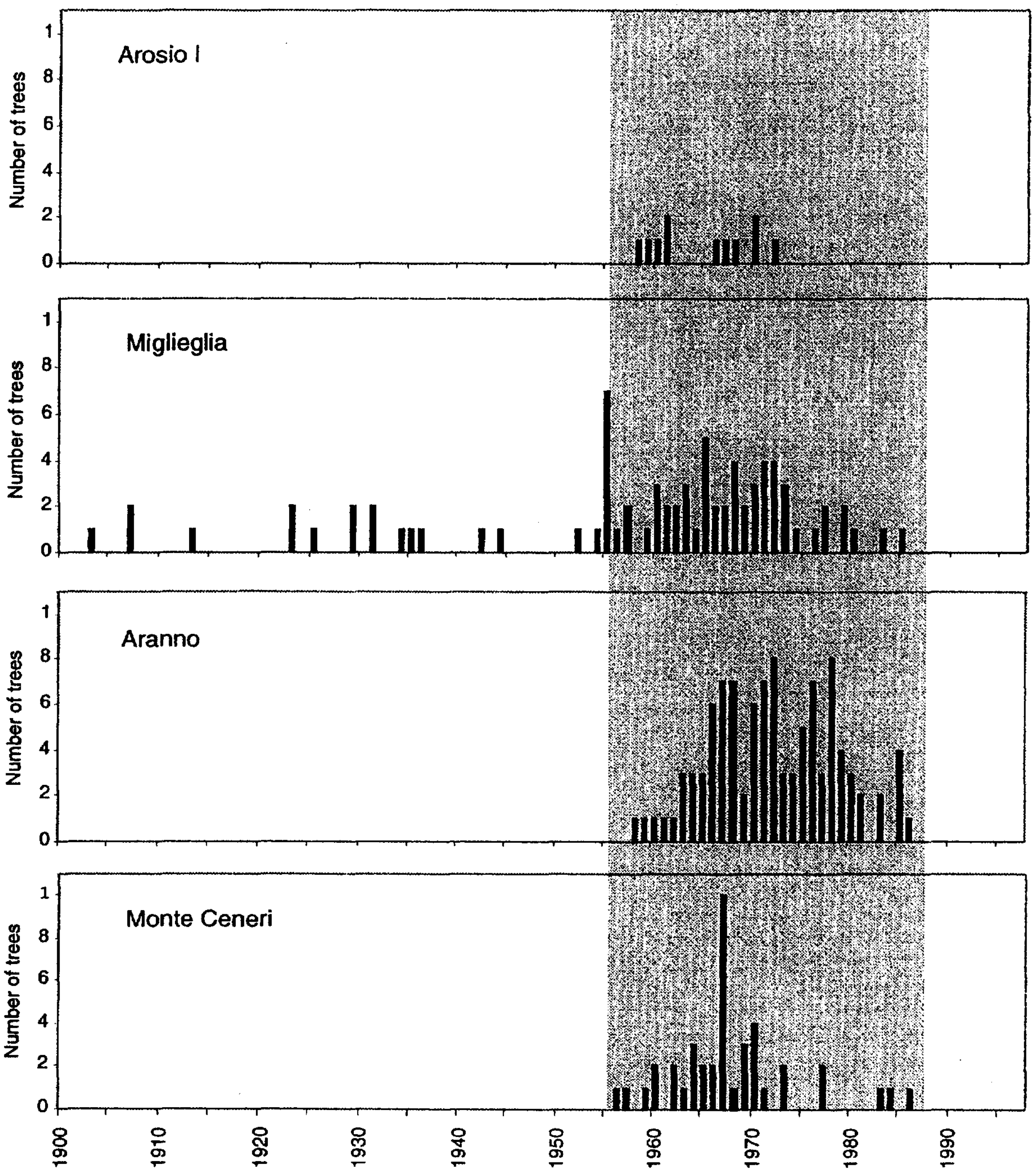

Figure 2. Colonisation year of the invading tree species which reached a height of at least 2 m in 1995

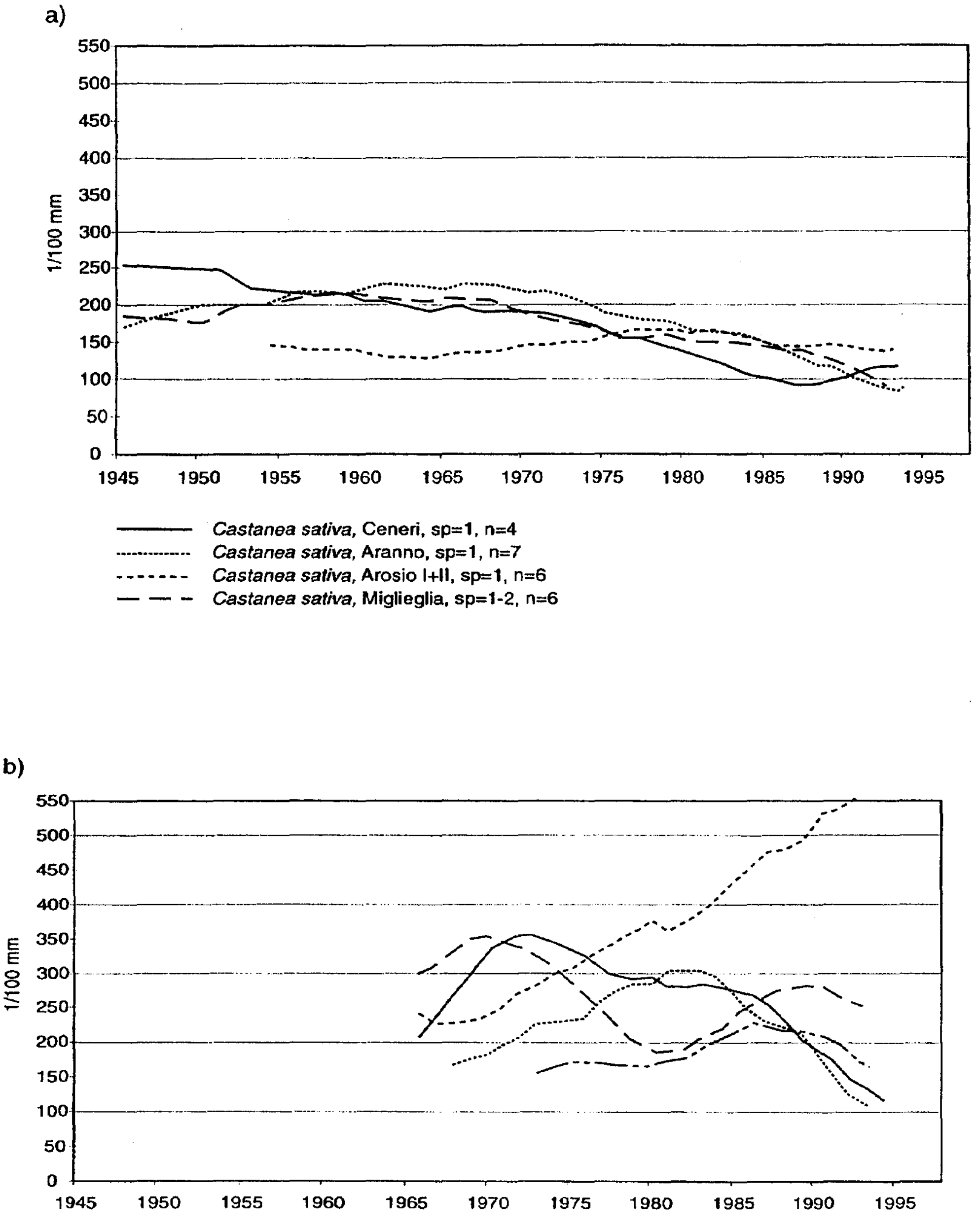

Figure 3. Moving average on 9 years of the radial growth rate of the chestnut-trees (a) and of some invading species (b).
sp = social position (1 = dominant; 2 = codominant, 3 = dominated); n = number of considered trees

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

1 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 particular 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 sylvicultural 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 sylviculturally 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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REFERENCES

Angelini R., 1995. *Dinamismo evolutivo dei castagneti abbandonati in Bassa Valtellina.* Tesi di laurea presso l'Istituto di Selvicoltura dell'Università di Firenze. 98 p.

Arnaud M.T., Chassany J.P., Dejean R., Ribart J., Queno L., 1997. Economic and ecological consequences of the disappearance of traditional practices related to chestnut groves. *Journal of Environmental Management*, 49 : 373-391.

Bacilieri R., Bouchet M.A., Bran D., Grandjanny M., Maistre M., Perret P., & Romane F., 1993. Germination and regeneration mechanisms in Mediterranean degenerate forests. *Journal of Vegetation Science*, 4 : 241-246.

Bernetti G., 1995. *Selvicoltura speciale.* Torino, UTET. 415 p.

Braun-Blanquet J., 1964. *Pflanzensoziologie.* Springer, Wien: 865 p.

Conedera M., Marcozzi M., & Jud B., 1993. Banque de données sur les incendies de forêt au sud des Alpes suisses. *Proceedings of the Symposium "Contribution of European Engineers to Reduction of Natural Disasters"*, Lausanne 29-30 Sept. 1993: 165-171.

Conedera M., Jermini M., & Sassella A., 1997. Nouvelles perspectives pour la culture du châtaignier au sud des Alpes. *Revue suisse Vitic. Arboric. Hortic.*, 29 (6) :1-8.

Conedera M. & Tinner W., 2000. The interaction between forest fires and human activity in southern Switzerland. *In* : Innes J.L., Verstraete M.M., Beniston M. (eds.), *Biomass Burning and its Inter-Relationships with the Climate System.* Kluwer Academic Publishers, "Advances in Global Change Research" (Series Editor: M. Beniston), Dordrecht and Boston: 247-262.

Cox D.R., 1980. *Analysis of binary data.* Chapman and Hall. London: 140 p.

Eccher A. & Piccini C., 1985. Considerazioni sulla tipologia e sull'evoluzione dei cedui lombardi, con approfondimenti su alcune latifoglie di pregio. *Monti e Boschi,* 36 (2) :7-14.

Ewald K.C., 1978. Der Landschaftwandel zur Veränderung schweizerischer Kulturlandschaften im 20. *Jahrhundert. Bericht Schw. Anst.forstl. Vers'wes*, 191, 308 p.

Gouyon P.H., 1990. Invaders and disequilibrium. *In* : di Castri F., Hansen A.J., Debussche M. (eds.), *Biological invasions in Europe and the Mediterranean basin.* Kluwer, Dordrecht: 365-370.

Guidi M., Piussi P. & Lasen C., 1994. Linee di tipologia forestale per il territorio prealpino friulano. *Annali Accademia Italiana di scienze forestali,* 43 : 221-285.

IFRF (Istituto Federale di Ricerche Forestali), 1959: *Carta di distribuzione del castagno.* [16 Fogli CN 1:25'000]. Birmensdorf: 3 p.

Keller W., 1979. Una chiave di feracità auxometrica semplice per i soprassuoli forestali delle regioni al sud delle Alpi. *Mitt. Eidgenöss. Forsch. Anst. Wald Schnee Landsch.,* 55 (2) :181-232.

Landolt E., 1977. Oekologische Zeigerwerte zur Schweizer Flora. *Veröff. Geobot. Inst. Eidg. Techn. Hochsch. Stift. Rübel, Zürich,* 64 : 1-208.

Magini E. & Piussi P. 1966. *Insediamento spontaneo di specie arboree nei castagneti abbandonati: considerazioni sulle conseguenze pratiche del fenomeno.* Atti del convegno internazionale sul castagno. Cuneo, 12-14 ottobre 1966: 293-294.

Magurran A.E., 1991. *Ecological diversity and its measurement.* Chapman and Hall, London: 179 p.

Maltoni A., Paci M., Tani A., 1997. *Modificazioni strutturali e floristiche nei castagneti in seguito all'abbandono.* Atti del convegno nazionale sul castagno. Cison di Valmarino (Treviso), 23-25 ottobre 1997: 109-124.

Merz F., 1919. *Il castagno. Sua importanza economica, coltivazione e trattamento.* Berna: 79 p.

Mondino P.G., 1991. *Caratteristiche dei boschi di sostituzione e loro tendenze evolutive.* Atti del simposio: I boschi italiani. Valori naturalistici e problemi di gestione. Castiglione dei Pepoli (BO), 9 ottobre 1989: 53-61.

Münch, D., 1995. Bestandesdynamik von Naturwaldreservaten: eine Dauerbeobachtung in Luftbildzeitreihen. *Mitt. Forstl. Vers.- Forsch.anst. Baden-Württ.* 5 : 1-105.

Peterken G.F. & Jones E.W., 1989. Forty years of change in Lady Park Wood: the young-growth stands. *Journal of Ecology,* 77 : 401-429.

Pitte J.R., 1986. *Terres de castanide. Hommes et paysages du châtaignier de l'Antiquité à nos jours.* Librairie Arthème Fayard, Paris: 479 p.

Ruffner C.M. & Abrams M.D., 1998. Relating land-use history and climate to the dendroecology of a 326-year-old *Quercus* prinus talus slope forest. *Canadian Journal of Forest Research,* 28 (3) : 347-358.

Schiess H. & Schiess-Bühler C., 1997. Dominanzminderung als ökologisches Prinzip: eine Neubewertung der ursprünglichen Waldnutzungen für den Arten- und Biotopschutz am Beispiel der Tagfalterfauna eines Auenwald in der Nordschweiz. *Mitteilung Eidgenöss. Forsch.anst. Wald Schnee Landsch,* 72 (1) : 3-127.

Southwood T.R.E., 1978. *Ecological Methods.* Chapman and Hall, London: 524 p.

Stanga P., 1997. *Uso delle foto aeree per l'analisi delle dinamiche evolutive nell'areale castanile del Sud delle Alpi.* Dissertation ETH, Zürich: 131 p.

Stierlin H.R., Ulmer U., 1999. Costituzione del bosco. *In* : Brassel, P., Brändli, U.-B. (Red.) *Inventario Forestale Nationale svizzero. Risultati del secondo inventario* 1993-1995. Birmensdorf, Istituto federale di ricerca per la foresta, la neve e il paesaggio. Berna, Ufficio federale dell' ambiente, delle foreste e del paesaggio. Berna, Stoccarda, Vienna, Haupt. 103-150.

Zoller H., 1961. Die Kulturbedingte Entwicklung der insubrischen Kastanienregion seit den Anfängen des Ackerbaus im Neolithikum. *Ber. Geobot. Inst. Eidgenöss. tech. Hochsch., Stift. Rübel,* 32 : 263-279.

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Effects of diseases on chestnut orchards and forest ecosystems

Impacts des maladies du châtaignier au niveau des châtaigneraies et des écosystèmes forestiers

T. TURCHETTI* & G. MARESI**

*Istituto per la Patologia degli Alberi Forestali (IPAF) CNR, P.le Cascine 28, 50144 Firenze, Italy.
Phone : +39 055 3288342, Fax : +39 055 354786, email : Turchetti@ipaf.fi.cnr.it
** U.O. Foreste, Istituto Agrario di S. Michele a/A (Tn), Italy.

ABSTRACT

Chestnut blight and ink disease, the two most destructive diseases of chestnut (*Castanea sativa* Miller), are spreading through European chestnut orchards and stands, playing an important role in their evolution and affecting management. Predominance of hypovirulence was observed in the majority of European countries. Abnormal cankers arising from the action of hypovirulent strains of *Cryphonectria parasitica* were detected in the stands investigated. Blight may be now considered as naturalised and endemic in almost all European chestnut stands but, because of the spread of hypovirulence, damage primarily affects weak and stressed trees. Blight can act as a bio-regulator in chestnut ecosystems. Spread of new virulent lines of the parasite, wildfire and other stress factors can change this favourable situation, but in the chestnut stands visited to date this occurs in limited areas and only for a short time. Sylvicultural management and, if necessary, artificial combined inoculation with selected hypovirulent strains enhances natural biological control of the disease. Ink disease attacks produce severe damage in chestnut stands and influence their evolution towards mixed woods. Monitoring of ink disease foci and control of blight evolution are desirable in chestnut management projects.

Key-words: *Castanea sativa*, chestnut blight, hypovirulence, ink disease, sylvicultural management, biological control

RESUME

Le chancre de l'écorce et la maladie de l'encre constituent les deux phytopathologies les plus virulentes pour le châtaignier (*Castanea sativa* Miller). Ces maladies s'étendent dans les vergers et les châtaigneraies d'Europe, jouant un rôle important dans leur évolution et affectant leur gestion. Une prédominance d'hypovirulence a été observée dans la majorité des pays européens. Des chancres anormaux issus de l'action de souches hypovirulentes de *Cryphonectria parasitica* ont été détectés dans les châtaigneraies inventoriées. Le chancre peut maintenant être considéré comme naturalisé et endémique dans la quasi totalité des châtaigneraies européennes mais, en raison de la diffusion de l'hypovirulence, les dégâts affectent principalement les arbres affaiblis et soumis à des stress écologiques. La maladie peut donc agir comme un bio-régulateur dans les écosystèmes dominés par le châtaignier. L'expansion de nouvelles lignes virulentes du parasite, les incendies et d'autres facteurs de stress peuvent modifier cette situation favorable ; cependant, dans les châtaigneraie suivies jusqu'à présent, ceci se produit dans des zones limitées et seulement durant un temps limité. La gestion sylvicole et, si nécessaire, l'inoculation artificielle de souches hypovirulentes sélectionnées augmente le contrôle biologique naturel de la maladie. La maladie de l'encre engendre des dommages sévères dans les châtaigneraies et influence leur évolution vers des boisements mixtes. Le suivi de la maladie de l'encre et le contrôle de l'évolution du chancre de l'écorce doivent être pris en compte dans les projets de gestion durable des châtaigneraies.

Mots-clés : *Castanea sativa*, chancre de l'écorce, hypovirulence, maladie de l'encre, gestion sylvicole, contrôle biologique

INTRODUCTION

The importance of chestnut (*Castanea sativa* Mill.) ecosystems, where chestnut stands were traditionally grown as orchards for nut production and as coppice for timber and wood, is decreasing although they are still an essential feature of mountain landscapes. Social and economic changes have reduced the disturbance created by man, but concomitantly intensified the activity of constraints such as disease pathogens. Ink disease, caused by endemic *Phytophthora cambivora* (Petri) Buism. and *P. cinnamomi* Rands., as well as the introduced chestnut blight fungus (*Cryphonectria parasitica* Murr. Barr), have spread and caused severe damage with the effect of increasing the number of abandoned stands and orchards.

Investigations carried out in various European chestnut stands (Italy, France, Spain) were undertaken to assess the role of these diseases in the evolution of chestnut ecosystems and to identify sustainable management criteria.

Evolution of chestnut diseases in Europe

Ink disease, which can produce root rot, has long been present in European chestnut orchards and stands, especially in France, Italy, Spain and Portugal (end of the XIX - beginning of XX century). Chestnut root rot and collar rot associated with dieback of branches, gradual decline and death of infected trees are induced both by *Phytophthora cambivora* (Petri) Buism. and *P. cinnamomi* Rands. These parasites are widespread in European countries and cause severe damage, especially in damp sites (Ewin & Ribeiro, 1996).

The effects of ink disease on chestnut stands are highly destructive, as the death of chestnut trees and the resulting stumps scattered throughout coppice areas lead to wide canopy gaps, thereby decreasing soil protection. Other competing hardwoods are then able to invade the infected chestnut stands. Furthermore, ink disease can kill other species such as cherry and walnut, threatening new plantations set up for wood arboricolture.

Severe damage has been caused by chestnut ink disease in Spain. Dead trees were observed in chestnut stands visited in Castilla-Leon. At one Spanish study site (Rioseco) chestnut trees were constrained by ink disease, while blight symptoms were not observed. In other stands both diseases were present (Bembibre, Las Medulas, Ponferrada and Sierra de Gata), but all dead trees had been killed by *Phythophthorae* activity.

In France, ink disease-induced damage was noted at one site of the Cévennes National Park and in other chestnut stands (including a new plantation) located in the Ardèche Region.

Considerable loss of trees (Turchetti & Parrini, 1993) was observed in several Italian chestnut forests affected by this disease in Monte Amiata, Mugello and, recently, Monti Cimini (Anselmi *et al.*, 1996). Investigations in the Mugello area emphasised the presence of the disease not only in valley bottoms but also on slopes and ridges, with a rapid increase in dead trees in the past few years (Turchetti, unpublished). In Italy, *P. cambivora* was described in 1917 (Petri, 1917) while the first isolate of *P. cinnamomi* was obtained in a chestnut stand only in 1985 (Cristinzio, 1986) but was subsequently found only in nurseries (Turchetti & Parrini, 1993).

This reappearance of ink disease in Italy could be partly due to climatic trends over the last 10-15 years, especially the repeated droughts. Furthermore, new and more virulent isolates of the pathogen may have appeared. The presence of both *P. cambivora* and *P. cinnamomi* in several Italian nurseries emphasises the role of commercial chestnut seedlings as a possible source of new infections and epidemics.

The widespread destructiveness of chestnut blight since its appearance after World War II had until recently reduced the importance of ink disease. First noticed in 1938 near Genoa (Biraghi, 1946), blight spread from Italy into adjacent countries. In France, the disease was reported in 1956 (Darpoux *et al.*, 1956) and the parasite was found on Japanese chestnut in Spain as early as 1950, but only later (1972-1974) on European chestnut, as reported by Munoz and Cobos (1991). Since 1950 blight has spread to other European countries (Albania, Austria, Ex-Yugoslavia, Greece, Hungary, Switzerland, Turkey).

As it gradually spread, blight produced severe damage in chestnut stands due to the high mortality of tree branches and stump sprouts. Recurrent attacks often caused dieback of large chestnut trees. In coppice stands up to 90% of 4-5 year-old sprouts were killed within just a few years by this parasitic infection

(Biraghi, 1955). Such a severe disease course was common to all European countries affected by the blight epidemic at the beginning of the 1950s. As a result, some chestnut orchards and coppices were totally destroyed.

Despite its severity, spread of this disease was slower in Europe as compared to the American epidemic. Chestnut blight invaded chestnut stands throughout Italy, including the Italian islands (Sicily and Sardinia), over a period of roughly thirty years after discovery of the disease. Over a twenty-year period *C. parasitica* became established in France and the Northern Regions of Spain. But after the initial dramatic epidemic development, the severity of the disease decreased first in Italy then in Europe (Biraghi, 1968), and the effects of the blight were not so destructive as on American chestnut (Roane *et al.*, 1986). Natural biological control of blight due to spread of hypovirulent strains of the parasite is the main factor which has determined the recovery of many chestnut trees in numerous European stands (Grente & Sauret, 1968; Turchetti, 1988, 1994; Heiniger & Rigling, 1994).

In many chestnut European stands visited (Italy, France, Spain, Switzerland, Slovenia, Croatia, Austria and recently Hungary) several different types of cankers were observed (Turchetti & Maresi, 1990, 1993; Turchetti *et al.*, 1995; Turchetti *et al.*, 1997; Davini *et al.*, 1998).

Initial undifferentiated infections are easily detected in chestnut stands. Although the velocity of spread of hypovirulence varied, the virulent cankers with the characters described by Shear *et al.* (1917), named as **normal,** were easily recognizable in the chestnut stands investigated together with **abnormal cankers**. Two types of abnormal cankers have been observed and defined in chestnut groves:

(i) **healing cankers**, characterised by a reddish-orange area with more or less pronounced swellings. On the surface of the infected bark, a few orange or reddish - brown pycnidia are produced. The reaction of host tissues is active and increases the diameter of the infected area on the branches or sprouts. Some cankers are very long.

(ii) **Healed cankers,** in which the fungus spreads longitudinally over a large vertical portion of the stem; the bark is slightly cracked, has a rough appearance and is dark in colour. Fructifications of *C. parasitica* are not easily detectable.

Characters intermediate between those of the normal and abnormal cankers are found on other cankers, defined as **intermediate cankers**. This type of canker starts as a normal virulent infection and kills the inner bark and the cambium with abundant mycelial mats of fungus. Vigorous wound cork barriers are produced in the reactive swollen zone that encircles the killed area. Epicormic shoots below the canker occur normally along with fructifications of the fungus in the central zone. This type of canker, which began as virulent, becomes a healing canker on the majority of vigorous stems.

Isolates of the parasite have been obtained from abnormal cankers. Such isolates differ in morphological characters and virulence as compared to normal strains (Bonifacio & Turchetti, 1973). The hypovirulence of *C. parasitica* appears related to transmissible dsRNA (double stranded RNA) (Nuss, 1992). These particles, which belong to a family of viruses known as *Hypoviridee* (Hillman *et al.*, 1995), have been detected in almost all European populations of the pathogen, and are able to overcome vegetative incompatibility among strains (Maresi *et al.*, 1995).

The hypovirulence (Table 1) spreading in chestnut forests deserves more detailed investigation. Perithecia and pycnidia are produced on the infected barks of normal cankers, while pycnidia are observed in cracks of the bark during the early development of healing canker. This production is present for one-two years, during which the host reaction takes place and the healing process is eventually completed. However healed cankers may still produce a few pycnidia in some limited sectors of the infected bark.

Conidia containing dsRNA are probably the main source for dissemination of hypovirulence, although mycelial fragments could be involved in this process. Both mucilaginous conidia and mycelium fragments may be disseminated by different vectors.

Rain is the main vector of spread. Tendrils of conidia in the pycnidia are produced mostly during rainy or damp weather in spring or summer but even in autumn. Conidia can be washed down and transported by stem flow along the infected tree or sprout, leading to production of new abnormal cankers on the same stem. Through the action of rain and wind, conidia are also splashed down onto the nearest sprouts in the same stump, so that cankers are produced at the same level on different stems (Davini *et al.*, 1998).

Country	FRCp	HC	HS	dsRNA
Italy	1938	1951	1964	+
Spain	1947	1992	1992	+
Switzerland	1948	1975	1975	+
Croatia	1950	1978	1981	+
France	1956	1964	1964	+
Greece	1964	1975	1984	+
Hungary	1965	1995	1996	+
Turkey	1967	1998	1998	+
Albania	1967	1997	1998	+
Austria	1970	1993	1993	+
Slovakia	1976	ND	ND	ND
Portugal	1989	ND	ND	ND
Germany	1992	1993	1993	+
Slovenia	1950	1995	1999	+

FRCp = First recording of *C. parasitica*
HC = Healing cankers
HS = Hypovirulent strains

\+ = Positive
\- = Negative
ND = Not determined

Table 1. Detection of hypovirulence in some European countries (from Heiniger & Rigling, 1994, updating of data collected by the authors)

Birds are implicated as carriers of *C. parasitica*: inoculum on feathers or feet may be deposited on twigs or limbs, which are highly susceptible to the blight. Mammals are other potential disseminators of the chestnut blight fungus (Sharf & DePalma, 1981) and slugs (*Limax* sp.) have been investigated as agents spreading virulent and hypovirulent *C. parasitica* in Italy (Turchetti & Chelazzi, 1984). The fungus was recovered from slugs collected from cankers and from faecal pellets of slugs that fed on hypovirulent and virulent strains.

Insects may disseminate conidia of hypovirulent and virulent *C. parasitica,* but they are believed to be most important in creating wounds into which new infections may penetrate. Shain (1982) is cautious in regard to insect dissemination of the blight fungus and indicates that the rules for proof of transmission have not been met. Craighead (1916) observed that insects found in association with blight cankers seldom colonised unblighted trees. Ants have also been examined as agents possibly disseminating hypovirulent and virulent strains (Anderson & Babcock, 1913; Studhalter & Ruggles, 1915).

Mites (*Acarina*) are important in disseminating hypovirulent and virulent strains, as they are often fungus feeders and have been found associated with blight fungus (Wendt *et al.*, 1983; Nannelli & Turchetti, 1989). Griffin *et al.* (1984) isolated *C. parasitica* from mites recovered from cankers. Recent research (Nannelli & Turchetti, 1993, 1994) emphasised the role of mites as vectors of hypovirulence. White hypovirulent strains of *C. parasitica,* containing dsRNA, were isolated from the faecal pellets produced by mites collected on healing cankers. It is possible that these Arthropods acquire dsRNA and in their gut transmit dsRNA to virulent strains (Nannelli *et al.,* 1998).

Condition of chestnut ecosystems

Abandoned stands and mixed woods

The majority of chestnut stands and orchards located in the countries visited (France, Spain and Italy) are only partially cultivated or completely abandoned. The impact of blight is revealed by the extensive presence of old completely dry branches which are the result of earlier infections dating from several years ago. Current blight incidence can be evaluated by the presence of wiltings in young branches, which are characterised by the presence of dry leaves remaining on the killed twigs and limbs and are caused by recent virulent infections (Santagada *et al.*, 1996). These symptoms are easily detectable in the green foliage and constitute a practical and effective index of the activity of *C. parasitica* normal or virulent strains. Numerous recent wiltings especially on the large branches are symptomatic of a situation where virulent infections of the blight are still predominant.

Abandoned chestnut trees are in competition with intrusive tree species such as *Quercus pyrenaica* (Willd.) in Spain. In the Cévennes (France) the competitive species were: *Quercus ilex*, *Q. pubescens*, *Pinus halepensis* and *P. pinaster*. In central Italy, *Ostrya carpinifolia, Fraxinus ornus, Q. pubescens* and *Q. ilex* were observed as intrusive species. On both of the two *Quercus* the presence of the blight fungus, *C. parasitica*, was detected in Italy, but the parasite was not recovered on the cited hosts in France or on *Q. pyrenaica* in Spain during preliminary investigations. Chestnut trees may be considered as a component, with varying degree of predominance, of these natural ecosystems in evolution. The result of this natural evolution is often the establishment of mixed broad-leaved woods (Maltoni *et al.*, 1998).

Shading by upper-canopy foliage and competition from neighbouring trees lead to decreased limb vigour of growing chestnut trees. Reduced vigour, along with small stem diameter, may increase the susceptibility of branches, sprouts and smaller, lower limbs to blight. In such conditions, the natural spread of hypovirulence is essential to limit the damage caused by this disease and to permit survival of chestnut. It is not impossible to obtain an equilibrium between host and parasite, as can clearly be seen in many of the stands visited that are located in the natural range of chestnut.

However, further investigation is also desirable to assess the effects of hardwood competition on the development of blighted chestnut trees colonised by abnormal cankers and living on unfavourable sites. Preliminary field observations suggest that blight incidence could increase in such conditions, intensifying competition effects. Thus, further and periodic monitoring is necessary in order to evaluate the stability or evolution of this natural equilibrium in chestnut ecosystems.

Ink disease is capable of destroying chestnut trees, thereby increasing the spread of competitive species which are not susceptible to the parasite. In abandoned chestnut orchards, the presence of these two diseases proved to be the main factor influencing natural evolution towards mixed woods where chestnut has almost completely disappeared.

Orchards

In orchards the effects of human pressure on chestnut ecosystems are evident, as blighted and dead branches are often pruned and dead trees removed. Visible damage can therefore be attributed to recent disease activity.

The mortality level caused by recent blight attacks was limited in most of the stands visited (wiltings of less than 10 % of the tree canopy).

In three Spanish sites located in the Bierzo Region, large branches were still dying as a result of *C. parasitica* canker activity. The same situation was observed in a limited number of chestnut stands in France and Italy, most of which were located at or under 350 m altitude, but a few abnormal cankers were found in all these sites. Throughout the investigations no chestnut trees completely killed by the disease were observed. Most chestnut areas of Spain, France and Italy exhibited vigorous recovery of foliage and spontaneous vegetative regrowth of trees, as an effect of the natural spread of hypovirulence.

In this favourable situation, blight appears as a constraining factor for damage on new grafts, as even hypovirulent strains can cause severe failures (Turchetti, 1978). Thus protection of graft union is needed. Encouraging results were obtained in protecting grafts with a single treatment of a grafting wax containing a biological additive (C.N.R. patented 9406). This biological wax must be applied to all susceptible wound surfaces in order to avoid contact between parasite and tissues (Santagada *et al.*, 1996). Subsequent new infections on grafted trees will be produced by predominantly hypovirulent strains and abnormal cankers will assure their survival.

Ink disease foci were detected in several recovered orchards. Damage level was high due to the death of productive trees. This disease therefore appears as a main constraining factor for the growth and management of these stands.

Coppices

Competitive species were constrained in chestnut coppices by sprouts growth and stumps density.

Blight presence was intensive in most of the chestnut coppices visited in Spain, France and Italy, but some unblighted sites were still found in Spain. Two coppices examined near Las Medulas were unblighted: all sprouts in these study sites had been cut when blight infections appeared and this treatment appeared to have brought temporary benefit to the chestnut coppices, as suggested by Biraghi (1950). New two or three year-old sprouts were still undiseased as well as the youngest seedlings.

Percentage of cankered trees varied greatly among chestnut coppices. In presence of hypovirulence, the percentage of blighted stump sprouts observed in surveys of Switzerland and Italy rose from 37-39% to 55-60% in two years, while the level of mortality due to *C. parasitica* was lower than previously in both areas investigated (Heiniger & Bissegger, 1993; Zambonelli & Zechini D'Aulerio, 1986). In observations carried out in Italian chestnut coppices a similar increase in canker percentage was recorded although the ratio between new infections and active healing cankers was 1:8 (Turchetti & Maresi, 1993). This could be explained by the presence of a high mass of cankers capable of producing a sufficient level of inoculum. Further investigations are required on this subject.

The natural establishment and predominance of hypovirulence has occurred extensively both in cultivated and abandoned chestnut coppices. Recent observations (Turchetti & Maresi, 1990, 1993, 1994) have demonstrated that healing cankers are predominant and the ratio between normal cankers and abnormal cankers is 1:10 (Davini *et al.*, 1998). Of interest for an understanding of the natural spread of hypovirulence is the observation that in younger stands the healing cankers are predominant and active in producing pycnidia and cirri, while in other stands a large proportion of cankers are healed, but the hypovirulent inoculum is maintained by the presence of an adequate number of active healing cankers. In the chestnut stands visited almost all new infections developed into healing cankers within a few years.

Ink disease was recorded in some coppices located in Italy, especially in the Mugello and Monte Amiata areas, where it was causing severe damage. *P. cambivora* was isolated from stems samples collected in the infected plots. Stump deaths have opened up large gaps that can be invaded by other species, modifying the stand composition.

CONCLUSIONS

Chestnut blight is the most common disease in European chestnut woods and is present throughout almost the entire natural range of *C. sativa*. However, the pronounced spread of hypovirulence has greatly reduced the severity of the blight and in most stands the abnormal cankers are clearly predominant.

C. parasitica may now be considered as a naturalised component of European chestnut ecosystems, where its role may be considered as a regulation factor. Suppressed, weak or stressed trees or sprouts with no chance of survival are killed by the chestnut blight fungus. Vigorous trees can easily recover from infections as an effect of the evolution of the phytosanitary situation and the predominance of hypovirulence.

Natural biological control is sustained mainly by the ability of hypovirulent strains to spread and convert the virulent population of *C. parasitica* present in Europe. Biological treatments are efficient to protect chestnut stands and additional artificial inoculations with hypovirulent strains can enhance blight control (Grente & Sauret, 1969; Jaynes & Elliston, 1980; Turchetti & Maresi, 1991; Antonaroli & Maresi, 1995).

The severity of damage and intensity of blight are related to environmental conditions and the effectiveness of management. The predominance of hypovirulence could be modified by the appearance of new genotypes of the parasite or by the action of stress factors such as drought, wildfire and frost. It has been observed that all these factors could be correlated with new foci of blight infection capable of causing severe damage during an early stage, but such phenomena affected limited areas and disappeared within a few years (Davini *et al.*, 1998; Leonardi *et al.*, 1996; Turchetti & Maresi, 1998, 1999). This assessment supports the hypothesis of a stability mechanism in the chestnut-*C. parasitica* pathosystem dominated by hypovirulence, which could be involved in resilience factors of chestnut ecosystems. Further investigations on this interesting subject are desirable. Monitoring of the blight epidemic together with regular surveys of ink disease foci are desirable in all recovery or management projects, in order to plan appropriate treatment.

The availability of effective and cheap biological control methods encourages chestnut regrowth and assures good prospects of keeping blight under control in the future (Turchetti & Maresi, 1991; Antonaroli & Maresi, 1995). In this perspective, abandonment of chestnut wood management due to economic or social evolution and the resulting competition with other tree species appear to be the main factors of chestnut decline. However, the presence of ink disease could constrain the range of natural chestnut woods and represents a strong limitation to revival of chestnut cultivation.

REFERENCES

Anderson P. J. & Babcock D. C., 1913. Field studies on the dissemination and growth of the chestnut blight fungus. *Penn. Chest. Bl. Comm. Bul.*, 3 : 1-32.

Anselmi N., Giordano E., Vannini A., Troiani L., Napoli G & Crivelli L., 1996 Il mal dell'inchiostro del castagno in Italia: una vecchia malattia ritornata attuale. *Linea Ecologica–Economia Montana*, 5 (27) : 39-44.

Antonaroli R. & Maresi G., 1995. Modalità e costi di un intervento di lotta biologica contro il cancro della corteccia del castagno. *Monti e Boschi*, 1 : 41-44.

Biraghi A. 1968. La rinascita del castagno dagli orrori del cancro. *L'Italia Agricola*, 105 : 485-490.

Biraghi A., 1946. Il cancro del castagno causato da *Endothia parasitica*. *L'Italia Agricola*, 7 : 406.

Biraghi A., 1950. Caratteri di resistenza in *Castanea sativa* nei confronti di *Endothia parasitica*. *Bol. Stn. Patol. Veg. Roma*, 7 : 161-171.

Biraghi A., 1955. Il cancro della corteccia ed i suoi riflessi sulla crisi del castagno. *Ital. For. Mont.*, 10 : 1-11.

Bissegger M., Rigling D. & Heineger U., 1997. Population structure and disease development of *Cryphonectria parasitica* in European chestnut forests in the presence of natural hypovirulence. *Phytopathology*, 87 : 50-82.

Bonifacio A. & Turchetti T., 1973. Differenze morfologiche e fisiologiche in isolati di *Endothia parasitica* (Murr.) And. *Ann. Acc. ital. di Scienze Forestali*, 22 : 111-131.

Craighead F. C., 1916. Insects in their relation to the chestnut bark disease. *Science*, 43 : 133-135.

Cristinzio G., 1986. Un nuovo pericolo per la castanicoltura italiana. *In: Atti delle giornate fitopatologiche 1986* : 223-228

Darpoux H., Ridé M. & Bondoux P., 1957. Apparition de foyers d'*Endothia parasitica'* sur châtaigners en France. *CR. Acad. Agric. France*, 43 : 670-674.

Davini G., Gervasini E., Maresi G., Rapella A., Ronchi L Tagliaferri A. & Turchetti T. 1998. *Il castagno in Lombardia: prime indagini fitosanitarie*. Quaderni di Ricerca e sperimentazione, ARF ed.: 108 p.

Elliston J. E., 1978. Pathogenicity and sporulation in normal and diseased strains of *Endothia parasitica* in American chestnut. *In*: MacDonald W. L., F. C. Cech, J Luchok & C. Smith (eds.), *Proceedings of the American Chestnut Symposium*, WV University, Morgantown: 95-100.

Erwin D. C. & Ribeiro O. K., 1996. *Phytophthora. Diseases worldwide*. Aps Press, St. Paul Minnesota: 592 p.

Grente J. & Sauret S., 1969. L'hypovirulence exclusive, phénomène original en pathologie végétale. *C. R Hebd. Séance Acad. Sci.*, 268 : 2347-2350.

Griffin G. J. & Griffin S. L., 1995. Evaluation of superficial canker instability for hypovirulent *Cryphonectria parasitica* inoculated on American chestnut trees. *Eur. J. For. Path.*, 25 : 351-355.

Griffin G. J., 1986. Chestnut blight and its control. *Hort. Rev.*, 8 : 291-335.

Griffin G.J., Wendt R.A. & Elkins J.R., 1984. Association of hypovirulent *Endothia parasitica* with American chestnut in forest clearcut and with mites. *Phytopathology,* 74 : 804.

Heiniger U. & Rigling D., 1994. Biological control of chestnut blight in Europe. *Annu. Rev. Phytopathol.,* 32 : 581-599.

Heiniger U. & Bissegger, M. 1993. Population dynamics of *Cryphonectria parasitica. In*: Antognozzi ed. *Atti del Congresso Internazionale sul castagno*, Spoleto ottobre 1993: 501-504.

Hillman B. L., Fulbright D. W. , Nuss D. L & Van Halfen N. K. 1995. Family Hypoviridae. *Virus Taxonomy* (Murphy, Fauquet, Bishop, Ghabrial, Jarvis, Martelli, Mayo e Summers eds). Springer Verlag, Berlin: 261-264.

Janes R. A. & Elliston J. E., 1980. Pathogenicity and canker control by mixtures of hypovirulent strains of *Endothia parasitica* in American chestnut. *Phytopathology*, 70 : 453-456.

Leonardi S., Guarnaccia D., Failla M., Maresi G & Turchetti T., 1996. Some phytosanitary investigation on chestnut coppices located on the Etna volcano. *Oecologia Montana*, 5 : 27-34.

Maltoni A., Paci M. & Tani A., 1998. Modificazioni strutturali e floristiche nei castagneti in seguito all'abbandono. *In: Atti del Convegno nazionale sul castagno*, Cison di Valmarino, ottobre 1997: 109-124.

Maresi G., Giovannetti L., Ventura S. & Turchetti T., 1995. Transmission of hypovirulence agents among some *Cryphonectria parasitica* strains from Italy. *Eur. J. For. Path.*, 25 : 191-196.

Munoz M. C. & Cobos P., 1991. *Endothia parasitica* (Murrill) Anderson. Sintomatologia a identificacion. Situacion de la enfermidad en los castaneros asturianos. *Bol. San. Veg. Plagas,* 17 : 287-298.

Nannelli R. & Turchetti T., 1989. Osservazioni preliminari sull'associazione di alcune specie di acari corticicoli con *Cryphonectria parasitica* (Murr.) Barr. Redia,, 72 : 581-593.

Nannelli R. & Turchetti T., 1993. Interazioni acari corticicoli-*Cryphonectria parasitica*: probabile ruolo degli acari nella diffusione degli isolati del parassita. *In*: Covassi M. ed. *Atti del convegno "Piante forestali: Avversità biotiche e prospettive di controllo biologico ed integrato"*, Firenze 5 marzo 1992: 157-163.

Nannelli R. & Turchetti T., 1994. The probable role of corticolous mites in the natural spread of *Cryphonectria parasitica*. *In*: M. L Double & W. L. MacDonald eds. *Proceedings of the International Chestnut Conference* Morgantown 1992, WV University Press: 167-168.

Nannelli R., Turchetti T. & Maresi G., 1998. DsRNA and mites: relationships in some Italian strains of *Cryphonectria parasitica*. *Internat. J. Acarol.*, 24 : 237-244.

Nuss D. L., 1992. Biological control of chestnut blight: an example of virus-mediated attenuation of fungal pathogenesis. *Microbiological Rev.*, 56 : 561-576.

Petri L., 1917. *Studi sulla malattia del castagno detta "dell'inchiostro"*. M. Ricci ed., Firenze: 182 p.

Roane M. K., Griffin G. J. & Elkins J. R., 1986. *Chestnut blight, other Endothia diseases and the genus Endothia*. APS monograph series, 53 p.

Santagada A., Maresi G. & Turchetti T., 1996. Alcune indicazioni pratiche sulla difesa dei castagneti. *Sherwood, Foreste ed alberi oggi*, 12 : 18-21.

Shain L., 1982. Strategies for enhancing dissemination of hypovirulence in *Endothia parasitica*. *In*: H. C. Smith e W. L. MacDonald eds. *Proc. U.S. For. Serv. AM. Chestnut Coop. Meet.*, West Virginia Universitary books, Morgantown 1982 : 175-183.

Sharf C. S. & DePalma N. K., 1981. Bird and mammals as vectors of the chestnut blight fungus (*Endothia parasitica*). *Can. J. Zool.*, 59 : 1647-1650.

Shear C. L., Stevens N. F & Tiller E. J., 1917. *Endothia parasitica* and related species. *U.S. Dep. Agr. Bur. Plant Ind. Circ,* 380 p.

Studhalter R. A. & Ruggles A. G., 1915. Insects as carrier of the chestnut blight fungus. *Penn. Dept. For. Bull.*, 12.

Turchetti T., 1978. Attacchi di *Endothia parasitica* (Murr.) Barr su innesti di castagno. *L'Italia Forestale e Montana,* 33 : 135-141.

Turchetti T., 1988. Prospettive di lotta biologica in Patologia Forestale. *In: Atti del "Convegno sulle avversità del bosco e delle specie arboree da legno"*, Firenze, 15-16 ottobre 1987 : 265-276.

Turchetti T. 1994. Some aspects of natural spread of Hypovirulence in Italy. In: M. L Double & W. L. MacDonald eds. *Proceedings of the International Chestnut Conference* Morgantown 1992, WV University Press: 161-164.

Turchetti T. & Chelazzi G., 1984. Possible role of slugs as vectors of the chestnut blight fungus. *Eur. J. For. Pathol.*, 14 : 125-127.

Turchetti T. & Maresi G., 1988. Mixed inoculum for the biological control of chestnut blight. *Bulletin OEPP/EPPO Bulletin*, 18 : 67-72.

Turchetti T. & Maresi G. 1990. Indagini sulla diffusione naturale degli isolati ipovirulenti di *Cryphonectria parasitica* in alcuni cedui di castagno. *In: Atti Giornate Fitopatologiche 1990*, 2 : 89-98.

Turchetti T. & Maresi G., 1991. Inoculation trials with hypovirulent strains of *Cryphonectria parasitica*. *Eur. J. For. Path.*, 21 : 65-70.

Turchetti T., Maresi G. & Santagada .A. 1991. Attacchi di *Cryphonectria parasitica* (Murr.) Barr su differenti ospiti nel Cilento. *Monti e Boschi*, 5 : 54-58.

Turchetti T. & Maresi G., 1993. Natural spread and dsRNA of some hypovirulent Italian strains of *Cryphonectria parasitica. In*: Antognozzi ed. *Atti del Congresso Internazionale sul castagno*, Spoleto ottobre 1993 : 505-508.

Turchetti T. & Maresi G. 1994. Alcune indagini sulla diffusione naturale dei ceppi ipovirulenti di *Cryphonectria parasitica. MiRAAF – Convegno "Innovazioni e prospettive nella difesa fitosanitaria"*, Ferrara 1994 (Coord. A. Quacquarelli) Ed. Ist. Sper. Pat. Veg., Roma: 367-370.

Turchetti T. & Maresi G., 1998. L'influenza del cancro della corteccia e del mal dell'inchiostro sulla castanicoltura in Italia. *In: Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Tv), 23-25 ottobre 1997: 417-435.

Turchetti T. & Maresi G., 1999. Investigations on natural spread of chestnut blight hypovirulence in Italy and other European countries. *In*: G. Salesses ed. *Proc 2nd Int. Symp. on Chestnut, ISHS Acta Hort,* 494 : 509-511.

Turchetti T. & Parrini C., 1993. Indagini preliminari sul "mal dell'inchiostro" del castagno. *Monti e Boschi,* 6 : 34-39.

Turchetti T., Maresi G., Casula G. & Geminiani P. 1995. Phytosanitary investigations on some chestnut forests in the south of France and Italy: preliminary results. *In* Romane F. (ed.) *Ecosystems Research report 19 "Sustainability of Mediterranean Ecosystem: case study of the chestnut forest".* Report EUR 15727: 149-163.

Turchetti T., Maresi G., Aponyi I., Sotonji J. & Hertelendy L. 1997. Biologiai veldekezes szelidgesztenye keregelhalasa ellen. (Biological control : sustainable protection of chestnut trees). *In*: Aponyne I., Olasz Z., Elekes A., Kovacs G. & Nagy G. eds. *"Integralt termesztes a kerteszetben" (17)*, Budapest, 26 novembre 1996: 23 p.

Wendt R.,Weidhaas J., Griffin G. J. & Elkins J. R., 1983. Association of *Endothia parasitica* with mites isolated from cankers on American chestnut trees. *Plant Dis.*, 67 : 757-758.

Zambonelli A. & Zechini D'Aulerio A., 1986. Compatibilita` vegetativa e sessuale di ceppi di *Endothia parasitica* (Murr.) And. isolati in un medesimo castagneto. *Inf. Fitopatologico* 10/87 : 43-48.

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Biological control of *Phytophthora cambivora* (Petri) Buisman in chesnut tree (*Castanea sativa* Mill.)

Contrôle biologique de *Phytophthora cambivora* (Petri) Buisman dans les châtaigneraies (*Castanea sativa* Mill.)

V. A. BOURBOS & I.T. METZIDAKIS

NAGREF, Subtropical Plants and Olive Tree Institute. 73100, Agrokipio–Chania, Crete, Greece

ABSTRACT

"Ink disease" of chestnut tree, caused by *Phytophthora cambivora*, produces serious damages in chestnut orchards in Crete during the last years. Natural environment has been affected and agricultural income has been significantly decreased. The biological control of this pathogen has been studied in this work by the use of the two antagonist fungi *Trichoderma harzianum* Rifai and *T. koningii* Oudem. The commercial biological product "Promot", which contains the above antagonists in concentrations $2x10^7$ and $3x10^7$ respectively, was used. Two strains of the pathogen were tested for the artificial soil infections, which was carried out one week before the chestnut sow. The first strain (*P. cambivora* 1) was isolated by infected chestnut trees from the area of Chania in Crete, while the Benaky Phytopathological Institute in Athens provided the second one (*P. cambivora* 2). Seedlings of "Rodgiano" variety chestnut seeds of *Castanea sativa* were used. Chestnut seeds were soaked into a suspension-dilution of the biological product in the dose of 100 g/hl just before their transplantation. The same dose of suspension-dilution of the biological product was used for root watering of young trees of 10 cm stem height, as well as two months later. The treatment's effect was estimated by the number of the trees with leaf wilting, at the plant tip infection of the root system, and base of the trunk, as well as apoplexia symptoms. Chestnut trees treated with the biological product were protected by the pathogen with efficiency ranged from 98.9 to 100% depending on the evaluation criteria for the strain *P. cambivora* 1 and *P. cambivora* 2 respectively. This efficiency was statistically significantly different from the control.

Key-words : Biological control, *Phytophthora cambivora, Castanea sativa,* antagonistic fungi

RESUME

La maladie de l'encre du châtaignier, causée par *Phytophthora cambivora*, a engendré de sérieux dommages aux châtaigneraies de Crète au cours ces dernières années. L'environnement naturel a été affecté et les revenus agricoles ont diminué de façon significative. Ce travail vise à étudier le contrôle biologique de ce pathogène en utilisant deux espèces de champignons antagonistes *Trichoderma harzianum* Rifai et *T. koningii* Oudem. Le produit commercial biologique "Promot", qui contient les deux espèces antagonistes, aux concentrations respectives de $2x10^7$ et $3x10^7$, a été utilisé. Deux souches de ce pathogène ont été testées en infectant des sols artificiels, une semaine avant l'ensemencement en plantules de châtaignier. La première souche (*P. cambivora* 1) a été isolée à partir de châtaigniers contaminés de la région de Chania (Crète), tandis que l'Institut Phytopathologique d'Athènes a fourni la seconde (*P. cambivora* 2). Des plantules de la variété "Rodgiano" de *Castanea sativa* ont été utilisées ; les graines ont été trempées dans une supsension-dilution du produit biologique "Promot" dosée à 100 g/hl, juste avant leur transplantation. La même dose de suspension-dilution de "Promot" a été utilisée pour humecter les racines de jeunes arbres de 10 cm de haut, et ce traitement a été renouvelé deux mois plus tard. L'effet du traitement a été estimé en considérant le nombre d'arbres ayant des feuilles desséchées, une zone infectée au niveau du système racinaire et à la base du tronc. Les châtaigniers traités avec le produit biologique ont été protégés de l'agent pathogène avec une efficacité de 98,9 à 100% respectivement, selon les souches de *P. cambivora* 1 et *P. cambivora* 2. Cette efficacité est statistiquement significative par rapport au traitement témoin.

Mots-Clés : contrôle biologique, *Phytophthora cambivora, Castanea sativa*, champignons antagonistes

INTRODUCTION

Chestnut tree cultivation is of great interest in some mountain areas in Crete where chestnut cultivation has the first or the second place of the total agricultural income (Skoudridakis & Bourbos, 1990). During the last twenty years it has been observed serious damages in chestnut trees with economical and environmental effects. These dryings are caused by root rot "ink disease" produced by *Phytophthora cambivora* (92%), and by *Armillaria mellea* (Vahl Quel) (8%). There have not been found any attacks from other species of *Phytophthora* in Crete. "Ink disease" of chestnut tree may be caused by *P. cambivora* as well as by *P. cinnamomi* Rands (Zentmyer, 1980), *P. cactorum* (Leb. & Cohn) Shroet. (Goidanich, 1968), *P. megasperma* Drechsl. (Waterhouse, 1963), *P. katsurae* Ko & Chang (Erwin *et al.*, 1983), *P. cryptogea Pethybridge* and Lafferty, *P. syringae* (Kleb.) Kleb (CMI, 1964 and 1966) and *P. citricola* Sawada (Chambers & Scott, 1993). *P. cambivora* has been isolated from host like beech and Norway maple (Hepting, 1971), rhododendron (Koch, 1971), sour cherry (Bielenin & Jone, 1988), almond and cherry (Wicks & Hall, 1988), Apple (Matheron *et al.*, 1988), red rasberry (Duncan & Kennedy, 1989), oak (Jung *et al.*, 1996), and eucalyptus (Shearer *et al.*, 1988).

MATERIAL AND METHODS

Seeds of the local variety "Rogdiano" of *Castanea sativa* were used in the experiment. This variety which produces fruits of excellent quality is mainly cultivated in the area and is characterized by a great susceptibility in *Phytopthora cambivora.*

Two strains of the pathogen were used for the artificial soil inoculation, in which chestnuts were sowed. The first strain, *P. cambivora* 1, was isolated from an infected chestnut tree in the area of Chania in Crete, while the Benaky Phytopathological Institute of Athens provided the second one *P. cambivora* 2. These strains were used as suspension dilution which contained 4.8 x 10^2 propagules/ml.

The chestnut sow was carried out on plastic bags which countained sand loam soil with pH 5.5-6.0.The biological product which was used is known under the commercial name "Promot". This product contains strains of the antagonistic fungi *Trichoderma harzianum* Rifai and *T. koningii* Oudem in concentrations $2x10^7$ and $3x10^7$ spores/g respectively. The soil was infecfed one week before the chestnut sow by watering till field capacity point with the suspension-dilution of both pathogens strains.

Chestnut seeds were soaked into suspension-dilution of the biological product in the dose of 100g/hl just before their sow in plastic bags. The same dose (100g/hl) of suspension-dilution of the biological product was used for root watering of young trees at the stage of 10 cm stem height as well as two months later.

This experiment continued for two years. Each treatment had 10 plastic bags with 5 replicate. The efficiency was estimated by the number of the trees with leaf wilting at the plant tip, apoplexia symptoms, infection of the trunk base and of the root system. The statistical analysis was based on Duncan test (p=0.05).

RESULTS

In the plastic bags where the soil has not been artificially infected by the pathogens strains and the chestnut seeds have not been soaked in the suspension-dilution of the biological product, infection symptoms were not observed. The grow of plants which have been treated with the biological product, two months after chestnut seeds sow, was greater than the control (Table 1).

The seedlings which have been treated with Promot have shown an efficiency ranged from 99.4 to 100% and 99 to 100% depending on the evaluation criteria and the year of the experiment, for the strain *Ph. cam 1.* and *Ph. cam. 2* respectively (Table 2).

These results were not statistically significantly different. In the treatment where the seedlings have been artificially infected by the two pathogen strains, they showed from 22 to 44% apoplexia symptoms and the 94 to 100%, 96 to 98% and 100% infection of the root system and of the trunk base and leaves wilting at the plant tip, respectively.

Treatment	Daily seedling shoot growth in cm	
	1996	1997
Ph. cam 1 + Promot	0.42a	0.41a
Ph. cam 2 + Promot	0.41a	0.41a
Control without infection and without Promot	0.31ab	0.32ab

Table 1. Effect of "Promot" in growth of chestnut seedligs

Treatment	% plants with leaves wilting at the plant tip		% plants with infection to the roots system		% plants with infection to the collar		% plants with apoplexia	
	1996	1997	1996	1997	1996	1997	1996	1997
Ph. cam1 + Promot	4.00	6.00	4.00	6.00	0.00	0.00	0.00	0.00
% Efficiency	99.6	99.4	99.5	99.4	100.0	100.0	100.0	100.0
Ph. cam 2 + Promot	8.00	8.00	8.00	10.00	4.00	0.00	0.00	0.00
% Efficiency	99.2	99.2	99.0	99.0	99.6	100.0	100.0	100.0
Ph. cam 1	100.0	100.0	94.0	96.0	96.0	96.0	28.00	26.0
Ph. Cam 2	100.0	100.0	100.0	100.0	98.0	98.0	36.0	44.0
Control without infection and without Promot	00.0	00.0	00.0	00.0	00.0	00.0	00.0	00.0

Table 2. Efficiency of the biological product "Promot" to the control of *Phytophthora cambivora* in chestnut tree

DISCUSSION

"Ink disease" of chestnut tree, caused by *P. cambivora* threatens from an economical and ecological point of view, the chesnut orchards in the high altitude areas of Crete. The control of this disease with cultural measures and with a use of systemic fungicides faces in the difficulties of their use because of the inaccessibity of these chestnut areas and the possible pollution of the natural environment which might cause their use. Several cultural, chemical, and biological methods, have been developed for the control of the pathogen: the exposure of the affected parts to the sun and after that, their cover with copper (Waterhouse & Waterston, 1996), as well as their flooding (Wilcox & Mircetich, 1985) and the watering of the infected plants in different grooves. Several attempts have been made to face the pathogen with satisfactory results after the arrival of the systemic fungicides metalaxyl and fosethyl-Al in the market (Skoudridakis & Bourbos, 1990; Wicks & Hall, 1988; Wicks, 1988; Bielenin & Jones, 1988). Exceptional success was noted as well, when the phosphorus acid was used in root watering or spraying of the leaves or injection to the trunk (Wicks & Hall, 1988; Wicks & Hall, 1990). The effect of the sodium tetra-thiocarbonate (Matheron & Matejka, 1988) and of the dinotroanaline herbicides oryzalin and pendimethalin with non phytotoxic doses (Wilcox, 1996) were shown *in vitro*. The biological control of the *P. cambivora* was based: a) in the use of Japanese and Chinese rootstooks, *Castanea crenata* (Waterhouse & Waterston, 1996), *C. mollissima* (Bounous & Liu, 1996), resistant to the pathogen; b) in the production of hybrids by the crossing of *C. sativa* and *C. crenata* (Waterhouse & Waterston, 1996), c) by selection of local clonal (Pereira *et al.*; Guidi *et al.*,1997); d) in the use of several competitive fungi including the endotrophic mycorrhixal of the basidiomycetes *Suillus luteus*, *Lactarius deliciosus* and *Leucopazillus cereallus* var. *piceina* (Marx, 1969), and e) in the soil solarization (Wicks, 1998). In Crete, the rootstooks *C.*

crenata, did not show good adaptation to the microclimate of the area and their compatibility to the grafting with the local chestnut trees varieties were not satisfactory (Skoudridakis & Bourbos, 1990). Furthermore, the cultivation of the Japanese edible varieties produced lower quality products. Lately, an effort is being made to collect autochthonous clones, more resistant to the pathogen and to product hybrids with imported Chinese varieties.

The species of the *Trichoderma* genus, known for their specific competitive characteristics in many soil pathogens, have been used to control several species of genus *Phytophthora* (Cook & Baker, 1983). *T. harzianum* Rifai and *T. koningii* Oudem, which help for the growth of the seeds, easily settle to the roots and increase the development of the root system (Windman *et al.*, 1986; Chang *et al.*, 1986). They have been used to control the *Rhizoctonia solani, Sclerotium rolfsii, Pythium* spp. and *Fusarium oxysporum f. sp niveum* (Beltaief *et al.*, 1996).

In chestnut trees, *T. hamatum, T. pseudokoningii* and *Gliocladium virens* controlled satisfactory *P. cinnamoni* and *P. citricola* (Chambers & Scott, 1993). *T. viride* releases antibiotics which stimulate several species of *Phytophthora* in the production of oospores (Brassier, 1975). The effect of homothallyn I and ll of *T. koningii* on *P. cinnamomi* is similar (Sakata & Rickards, 1980).

According to the results of this research, the biological product "Promot", which contains the antagonistics fungi *T. harzianum* and *T. koningii* promises the possibility to control the disease particularly replanting. Both antagonistics fungi restricted the pathogen effect and favour the seedlings development.

The further development of the efficiency of this biological product in the existed plantations is considered as necessary.

REFERENCES

Beltaief A., Bourbos V.A., Skoudridakis M.T. & Nikolaides A., 1996. Biological control of *Fusarium oxysporum f.sp. niveum* on Watermelon. In *«Advances in Biological control of Plant Diseases»*, China Agric. University: 54-55.

Bielenin A. & Jones A., 1988. Prevalence and pathogenicity of *Phytophthora* spp. from sour cherry trees in Michigan. *Plant Disease,* 72 : 473-476.

Bielenin A. & Jones A.L., 1988. Efficacy of sprays of fosethyl Al and drenches of metalaxyl for the control of *Phytophthora* root and crown rot cherry. *Plant Disease*, 72 : 477-480.

Bounous G. & Liu L., 1996. Chestnut production in China. *Riv.di Frt. Ortofl.*, 58 : 41-48.

Brassier C.M., 1975. Stimulation of sex organ formation in *Phytophthora* by antagonistic species of *Trichoderma viride. Nature.* 231 : 283.

Chambers S.M. & Scott E.S., 1993. Biocontrol of Phytophthora root rot of chestnut. *6th Intern.Congr.of Plant Pathology,* Montreal, Canada, 292.

Chang Y.C., Baker R., Kleifeld O. & Chet I., 1986. Increased growth of plants in the presence of the biological control agent *Trichoderma harzianum. Plant Disease*, 70 : 145-148.

CMI, 1964 & 1966. *Descriptions of Pathogenic Fungi and Bacteria*, no 32 : 592 p.

Cook R.J., Baker K.F., 1983. *The nature and practice of biological control of plant pathogens.* Ed. APS: 540 p.

Duncan J.M. & Kennedy D.M., 1989. The effect of waterlogging on *Phytophthora* root rot of red rasberry. *Plant pathology* 38 : 161-168.

Erwin D.C., Bartnicki-Garcia S. & Tsao P.H., 1983. *Phytophthora its biology, taxonomy, ecology, and pathology*. Ed. APS: 392 p.

Goidanich G., 1968, 1975. Manuale di Patologia Vegetale. Ed. Agricole, Bologna, tom I: 456 p and II: 1283 p.

Guidi G., Turchetti T., Benedetto di F. & Benedetto Di F., 1997. Observations on chestnut cultivation in the Piceno area: preliminary investigations on some local chestnut cultivars. *Monti e Boschi.*, 48, 3 : 20-26.

Hepting G.H., 1971. Diseases forest and shade trees of the United States. *US Forest. Serv. Agric. Handb.,* 386, 658 p.

Jung T., Blaschke H. & Neumann P., 1996. Isolation, identification and pathogenisity of *Phytophthora* species from declining oak stands. *European Journal of Forest Pathology*, 26 : 253-272.

Koch J., 1971. Rhododendron blight caused by *Phytophthora cambivora*. *Friesa*, 9 : 418-425.

Marx D.H., 1969. The influence of endotrophic mycorrhizal fungi on the resistance of pine roots to pathogenic infections. I. Antagonism of mycorrhizal fungi to root pathogenic fungi and soil bacteria. *Phytopathology,* 59 : 153-163.

Matheron M.E, & Matejka J.C., 1988. In vitro activity of sodium tetrathiocarbonate on sporulation and growth of six *Phytophthora* species. *Phytopathology*, 78 : 1234-1237.

Matheron M.E., Young J. & Matejka J.C., 1988. Phytophtora root and crown rot in apple trees in Arizona. *Plant Disease*, 72 : 121-126.

Pereira J.G., Valdiviesso T., Abreu de C.P. & Sousa de A.J.T., 1995. Chestnut ink disease. Appraisal of the sensitivity of chestnut clones to ink disease. *Phytoma*, 477 : 50 -52.

Sakata K. & Rickards R.W., 1980. *Synthesis of homothalline II. In 23rd Symp. Chemistry of natural products,* Japan: 165-172.

Shearer B.L., Michaelsen B.J. & Somerford P.J., 1988. Effects of isolate and time of inoculation on invasion secondary phloem of *Eucalyptus* spp. and *Banksia grandis* by *Phytophthora* spp. *Plant Disease,* 72 : 121-126.

Skoudridakis M.T. & Bourbos V.A., 1990. Comparative effectiveness of metalaxyl and phosethyl Al to *Phytophthora cambivora* (Petri) Buism. *Med.fac. Landbouww. Gent,* 55 : 963-966.

Waterhouse G.M., 1963. Key to the species of *Phytophthora* de Bary. *Mycol. Pap.,* 92 : 1-22.

Waterhouse G.M., & Waterston J.M., 1966. *Phytophthora cambivora.* CMI no 112.

Wicks T.J., 1988. Effect of metalaxyl on the control of *Phytophthora* crown rot of almonds. *Australian Journal of Experimental Agriculture* 28 : 547-552.

Wicks T.J., 1988. Effect of solarization on the control of *Phytophthora cambivora* in almond and cherry. *Australian Journal of Experimental Agriculture,* 28 : 539-545.

Wicks T.J. & Hall B. 1990. Evaluation of phosphonic (phosphorus) acid for the control of *Phytophthora cambivora* on almond and cherry in south *Australia.Australian Plant Pathology,* 19 : 132-133.

Wicks T.J. &.Hall B, 1988. Preliminary evaluation of phosphorus acid fosethyl Al and metalaxyl for controlling *Phytophthora cambivora* on almond and cherry. *Crop Protection,* 7: 314-318.

Wilcox W.F., 1996. Influence of dinitroanaline herbicides on growth, sporulation and infectivity of four *Phytophthora* spp. pathogenic to deciduous fruit trees. *Phytopathology,* 86 : 906-913.

Wilcox W.F. & Mircetich S.M., 1985. Effects of flooding duration on the development of *Phytophthora* crown rot of almonds. *Phytopathology,* 75 : 1451-1455.

Windman M.T., Eland Y. & Baker R., 1986. A mecanism for increased plant growth induced by *Trichoderma* spp. *Phytopathology,* 76 : 518-521.

Zentmyer G.A., 1980. *Phytophthora cinnamomi and the Diseases It Causes.* Monogr. 10. APS.: 96 p.

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Soil physical properties and the occurrence of chestnut ink disease: a micromorphological study

Propriétés physiques du sol et occurrence de la maladie de l'encre du châtaignier : étude micromorphologique

V. MARCELINO [1], N. TORRES [2], E. PORTELA [2] & A. MARTINS [2]

[1] Laboratory of Mineralogy, Petrology and Micropedology, Ghent University, Krijgslaan 281/S8, B-9000 Gent, Belgium
[2] Soil Science Department, UTAD, 5001 Vila Real, Portugal

ABSTRACT

Ink disease caused by the fungus *Phytophthora cinnamomi* Rands is a major threat to the sustainability of chestnut ecosystems in northern Portugal. Not only soil factors and host resistance but also management practices can influence the occurrence of this disease. Total soil porosity was measured in chestnut groves affected by the ink disease and in healthy ones, at 2 or 3 depth zones. The orchards were located either in mid-slope position or at the foot of the slope. The purpose of the work was to investigate whether or not the occurrence of ink disease would be related with the presence of a plough pan and with the topographical position of the stand. The areas covered by pores with Ø>30 µm (po30) and by pores with Ø>500 µm (po500) were directly quantified on soil thin sections using micromorphological and image analysis techniques. This method was chosen because routine methods fail to detect soil porosity differences in the soils with a clear plough pan. The results show that low absolute total porosity does not directly influence the health status of the orchards. However, the presence of a layer with reduced porosity at 20-35 cm clearly affects the occurrence of ink disease. This plough pan strongly hinders root development and soil aeration and thus makes the trees more sensitive to the attack of *Phytophthora cinnamomi*. The plough pans observed were more pronounced in the foot-slope than in the mid-slope soils. Former studies have shown that lowland groves are also more intensively affected by ink and that there is a close relationship between the number of tillage operations and the incidence of the disease. This study evidences the relationship between the occurrence of *Phytophthora* root disease and the presence of a plough pan, which in turn depends on the location of the stand on the slope. From a methodological point of view it stresses the importance of micromorphological and image analysis techniques to directly determine total soil porosity and to provide complementary and more accurate data than the indirect methods commonly used for quantifying soil porosity.

Key-words: chestnut ink disease, soil porosity, soil micromorphology, image analysis

RESUME

La maladie de l'encre (*Phytophthora cinnamomi* Rands) constitue une des grandes menaces pour le maintien des châtaigneraies cultivées du Nord du Portugal. L'occurence de cette maladie est influencée par des facteurs pédologiques, la résistance de la plante et les pratiques agricoles. L'objectif principal de l'étude est de vérifier si la présence de la maladie est liée à l'existence d'une semelle de labour dans les sols et/ou à la position topographique de la châtaigneraie. Ainsi, la porosité totale du sol a été mesurée à 2 ou 3 profondeurs dans des châtaigneraies attaquées par le champignon et dans des châtaigneraies saines. Les châtaigneraies étudiées sont localisées en mi-pente ou en bas-fonds. Nous avons directement mesuré, en lames minces de sols par des techniques micromorphologiques et d'analyse d'images, les surfaces couvertes par des pores de diamètre supérieur à 30 µm et par des pores de diamètre supérieur a 500 µm. Cette technique a été choisie car les méthodes de routine n'ont pas permis de détecter des variations de porosité à différentes profondeurs, même dans les sols avec une semelle de labour très prononcée. Les résultats indiquent qu'une porosité totale plus basse n'a pas d'influence directe sur l'état de santé des châtaigneraies. D'autre part, la présence dans les sols d'une couche compactée, entre 20-35 cm de profondeur, est clairement associée à l'occurrence de la maladie. Cette semelle de labour restreint le développement des racines et l'aération du sol ; de ce fait, les arbres deviennent plus sensibles à l'attaque du *Phytophthora*. Les semelles de labour sont plus prononcées dans les sols des châtaigneraies en bas-fonds que dans les sols des châtaigneraies en mi-pente. Des études précédentes ont montré que les châtaigneraies en bas-fonds sont aussi plus fortement attaquées par la maladie de l'encre et qu'il existe une relation directe entre le nombre d'opérations de labour et le taux d'incidence de la maladie. Cette étude met en évidence la relation entre la maladie de l'encre sur des châtaigniers et la présence d'une semelle de labour dans les sols, qui, à son tour est reliée à la position topographique de la châtaigneraie. Sur le plan méthodologique, l'étude souligne l'importance de l'utilisation des techniques micromorphologiques et de l'analyse d'images pour mesurer directement la porosité totale du sol et pour fournir des résultats plus précis que ceux obtenus par les méthodes indirectes de quantification de la porosité du sol.

Mots-clés : maladie de l'encre sur des châtaigniers, porosité du sol, micromorphologie du sol, analyse d'images

INTRODUCTION

The sustainability of chestnut ecosystems strongly depends on the health conditions of the trees. A major problem of widespread occurrence in chestnut stands in northern Portugal is the ink disease (Abreu *et al.*, 1993; Martins et *al.*, 1997), which is caused by the fungus *Phytophthora cinnamomi* Rands. Because the pathogen is a soilborn fungus, the occurrence of the disease is affected not only by host resistance but also by soil factors, which in turn are influenced by agricultural and management practices. The increase in the incidence of the disease has indeed been associated, already in the years 50, to alterations of these practices (Fernandes, 1955; Guerreiro, 1957).

More recently, Portela *et al.* (1997, 1998) have been studying the relationship between the degree of incidence of ink disease and the topographical position and associated management practices in chestnut orchards in the Trás-os-Montes region. They observed that in stands located in south facing slopes the presence of ink was related to deficient rooting and water stress while in lowland groves the occurrence of the disease was associated to soil compaction resulting from the combined effect of excessive tillage and poor soil structure.

The selection of chestnut orchards to be studied was based on these findings of Portela *et al.* (1997, 1998). Macroscopic observation of the selected soil profiles pointed to the existence, in some of them, of a compacted subsurface layer, which was not reflected by porosity data previously obtained with routine methods of soil physical analysis.

The general purpose of this study was to compare the soil porosity of chestnut groves affected by the ink disease with the soil porosity of healthy ones.

Specific objectives were, on one hand, to investigate whether or not the occurrence of ink disease would be related with the presence of a plough pan and with the topographical position of the stand and, on the other hand, to test the use of micromorphological and image analysis techniques to directly quantify soil porosity in thin sections.

MATERIALS AND METHODS

Sampling and sample preparation

Six profiles, four in chestnut groves affected by ink (P20, P22, P29 and P30) and two (P2 and P32) in healthy ones, were selected for this study. Profiles P2, P32, P20 and P29 were located in mid-slope position and profiles P22 and P30 at the foot of the slope. Depending on the stoniness of the soil undisturbed soil samples in Kubiena boxes or undisturbed soil blocks (2-4/depth zone) were taken at 2 or 3 depth zones ($d1<20$ cm, $d2 = 20\text{-}35$ cm, $d3>35$ cm). Depth zone d2 corresponds to the depth at which a plough pan usually occurs.

The samples were impregnated with a polyester resin mixed with a fluorescent dye (Uvitex). After complete drying, two parallel surfaces of each impregnated block were finely polished and photographed under UV light so that the area covered by pores with $Ø> 500$ µm could be quantified.

The same surfaces were viewed with a fluorescence microscope to produce images (6/surface) suited for the measurement of the area occupied by pores with $Ø>30$ µm. The photographs were then digitised using a flat bed scanner.

Image analysis

The quantification of total porosity (area % occupied by pores) in soil thin sections was formerly done by point counting or visual estimation but this has been successfully replaced by more accurate and less time consuming techniques such as the use of imaging software (White *et al.*, 1998).

For this study the areas covered by pores with $Ø>30$ µm (po30) and by pores with $Ø>500$ µm (po500) were measured on the digital images using the public domain UTHSCSA Image Tool software. This programme permits to determine the number of pixels in the pore space (fluorescent zones) and the total number of pixels in the image.

Data analysis

The hypotheses to be tested were: (i) there are no differences among total porosity at the different levels of the factors - health status, depth zone and topographical position -, and (ii) there is no interaction between the factors.

Total porosity data (po30 and po500) were analysed using a mixed model Analysis of Variance (General Linear Model) with soil profile (P20, P22, P29, P30, P2 and P32) as random factor, depth zone (d1, d2, d3) and topographical position (mid-slope, foot-slope) as within fixed factors and health status (ill, healthy) as between fixed factor.

Mean total porosities at the different levels of the health status, depth zone and slope position combinations were estimated from the best fitting model (i.e. the model with only the significant main effects and significant interaction terms, plus possibly the non significant lower order terms included in the latter). Pairwise comparisons between the estimated marginal means were carried out with Bonferroni adjustment.

RESULTS

The descriptive statistics for the total porosity measurements (po30 and po500) are compiled in Table 1.

The results of the statistical analysis are given in Table 2, Table 3 and Figure 1.

As can be seen from Table 2 total porosity is affected by health status, topographical position of the orchard and depth zone and/or their interactions. The effect of depth zone is significant and, more importantly, it is modified by the health status and, for po30, also by the topographical position of the orchard.

Pairwise comparisons in Table 3 show that in healthy chestnut groves the differences between porosities in d1, d2 and d3 are not significant while in affected groves total porosity in d2 is significantly smaller than in d1 and d3. This is well illustrated by the images in Figure 2.

The graphs in Figure 1 again suggest that the effect of depth zone is modified not only by the health status but also by the topographical position.

DISCUSSION

From the data in Table 1 and the graphs in Figure 1 it can be deduced that low absolute total porosity values do not directly influence the health status of the orchards. On the contrary, the presence of a layer with reduced porosity (plough pan) at d2 clearly affects the occurrence of ink disease in chestnut groves (Table 2, Table 3, Figure 1 and Figure 2).

Mean soil porosity values for po30 (Table 1) have in the ink affected orchards larger standard deviations than in the healthy ones. This indicates a high variation of total porosity within the same depth zone and suggests the presence of micro-sites with very low porosities in the soil of ink affected groves.

The plough pan is more pronounced in the foot-slope than in the mid-slope soils as illustrated by the graphs in Figure 1. This is in line with the studies by Portela *et al.* (1998) that show that lowland groves are also more intensively affected by ink and that there is a close relationship between the number of tillage operations and the incidence of the disease. According to these authors the lowland soils have high amounts of fine sand and silt and consequently are submitted to frequent tillage to break up soil crusts.

The plough pan strongly hinders root development and soil aeration and thus makes the trees more sensitive to the attack of *Phytophthora cinnamomi.* Low oxygen availability, even for short periods, may favour *Phytophthora* root disease (Shea & Broadbent, 1983).

This study evidences the relationship between the occurrence of *Phytophthora* root disease and the presence of a plough pan, which in turn depends on the location of the stand on the slope. Attention should thus be focussed on minimising tillage operations in chestnut orchards.

From a methodological point of view it stress the importance of micromorphological and image analysis techniques to directly determine total soil porosity and to provide complementary and more accurate data than the indirect methods commonly used for quantification of soil porosity.

health status	soil profile	depth	area % occupied by pores with ∅>30 μm (po30)			area % occupied by pores with ∅>500 μm (po500)		
			mean	std. dev.	N	mean	std. dev.	N
ink affected	P20 (mid-slope)	d1	14.6	3.7	36	6.1	1.2	4
		d2	14.3	3.6	48	3.4	1.9	4
	P22 (foot-slope)	d1	10.7	3.5	36	3.5	0.8	3
		d2	5.5	2.4	36	1.5	0.7	3
		d3	10.0	2.8	36	4.3	1.0	4
	P29 (mid-slope)	d2	9.1	4.2	24	4.1	1.6	2
		d3	14.5	2.1	12	5.4	-	1
	P30 (foot-slope)	d1	9.7	3.1	36	3.0	0.5	3
		d2	5.7	2.3	36	1.3	1.0	3
healthy	P2 (mid-slope)	d1	7.7	1.8	12	2.3	-	1
		d2	8.0	1.6	12	2.3	-	1
		d3	8.0	2.0	24	1.6	0.1	3
	P32 (mid-slope)	d1	10.5	1.9	24	4.6	0.4	2
		d2	7.0	2.2	12	3.6	-	1
		d3	7.8	1.7	36	3.6	1.4	3

Table 1. Descriptive statistics for the total porosity values

Factor	df	P-values	
		(pore ∅>30 μm)	(pore ∅>500 μm)
health status	1	0.11	0.08
slope position	1	0.13	0.05
depth zone	2	<0.0001	0.05
profile (health status * slope position)	3	<0.0001	0.04
depth zone * slope position	2	<0.0001	-
depth zone * health status	2	<0.0001	0.04

Table 2. Best fitting GLM model and P-values for factors

Health status	Slope position	Comparison	Significance(1)	
			(po30)	(po500)
ill	mid-slope	d1 vs d2	**	*
		d1 vs d3	NS	NS
		d2 vs d3	**	NS
ill	foot-slope	d1 vs d2	**	*
		d1 vs d3	NS	NS
		d2 vs d3	**	**
healthy	mid-slope	d1 vs d2	NS	NS
		d1 vs d3	NS	NS
		d2 vs d3	NS	NS

(1) ** significant at the 1% level; * significant at the 5% level; NS not significant

Table 3. Pairwise comparisons between total porosity at the different depth zones

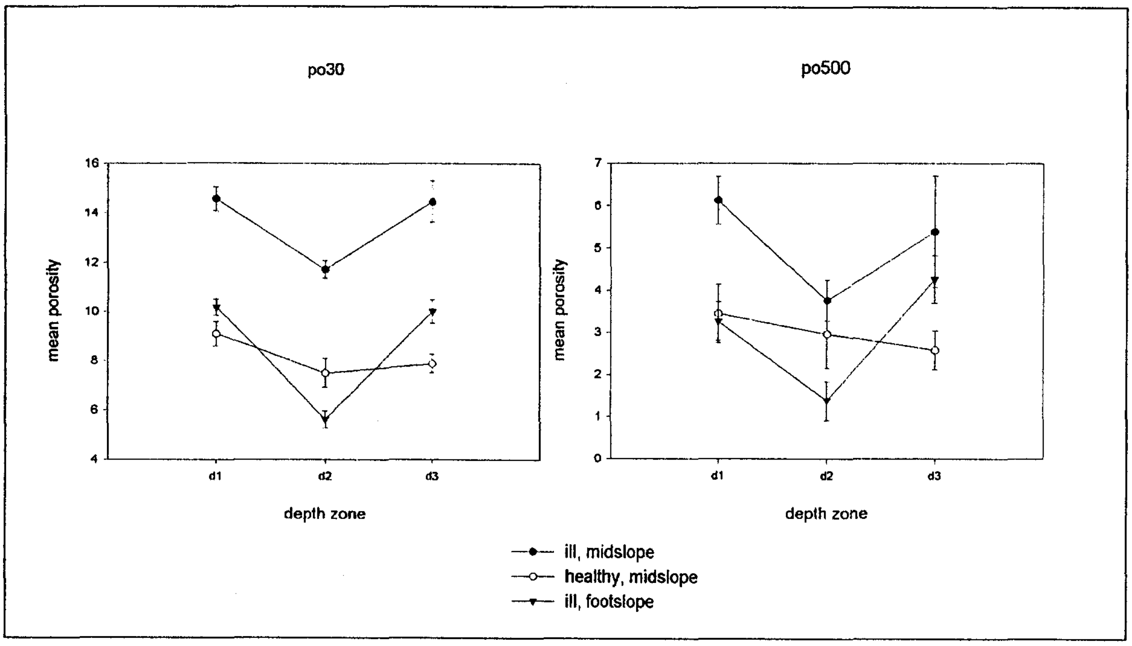

Figure 1. Estimated marginal means for po30 and po500 with error bars (± 1 standard error)

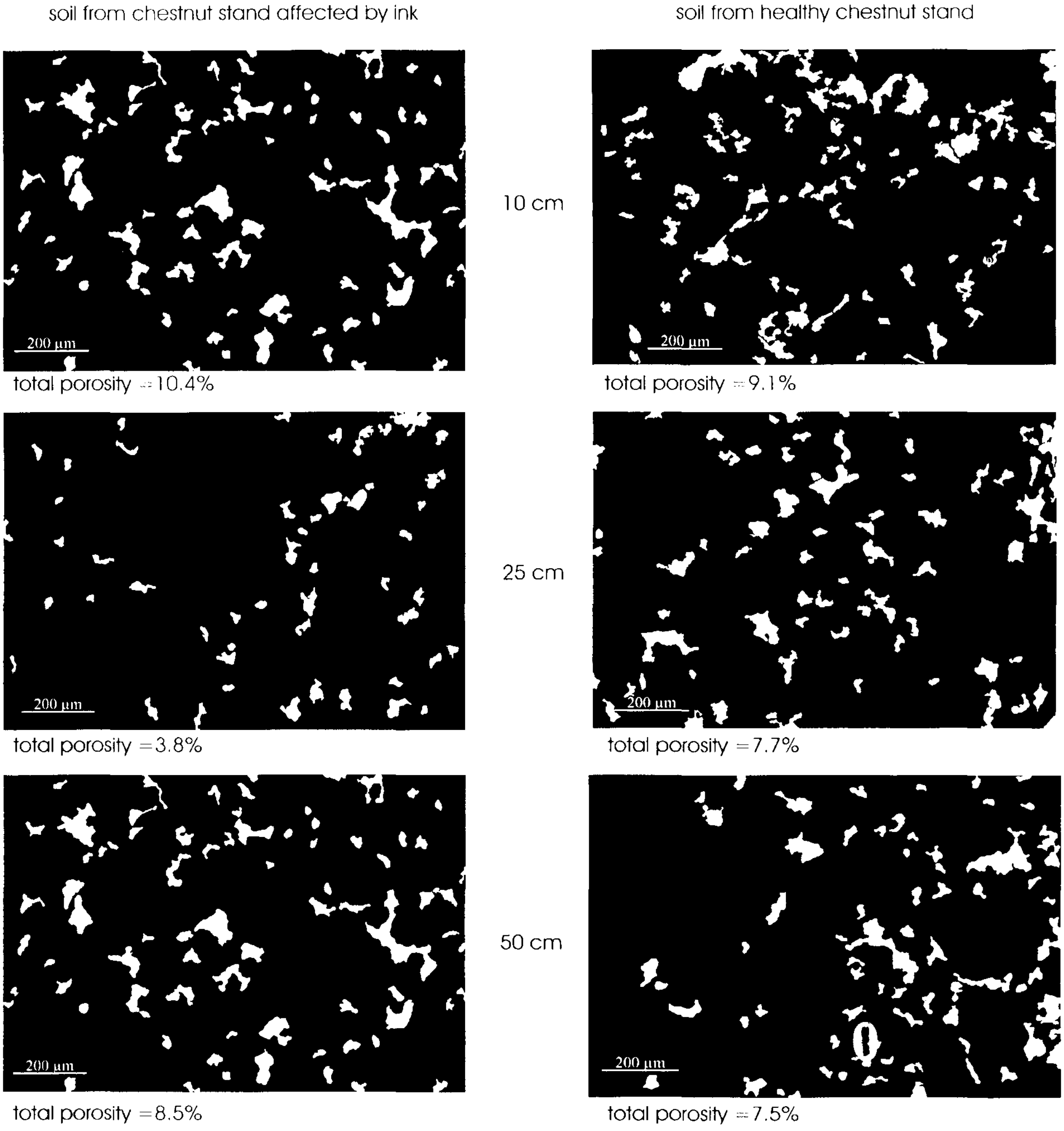

Figure 2. Images of the porosity variation with depth in soils of chestnut groves affected by ink disease and in soils of healthy groves

REFERENCES

Abreu C.A., Marques C.P., Varejão E.S. & Cardoso A.O., 1993. Aplicação da fotografia aérea policromada de infravermelho na detecção da doença da tinta do castanheiro. Proceedings of the *II Encontro de Fitopatologistas portugueses*, Universidade de Coimbra, 2-3 December 1993.

Fernandes C.T., 1955. O papel e importância do castanheiro na Terra Fria do nordeste de Portugal. Separata das *Publicações da Direcção Geral dos Serviços Florestais e Aquícolas*, 22 : 43-51.

Guerreiro M.G., 1957. *Castanheiros - Alguns estudos sobre a sua ecologia e o seu melhoramento genético.* Dissertation at the Instituto Superior de Agronomia. Lisboa.

Martins L.M., Abreu C.G. & Marques C.P., 1997. Evolução do estado sanitário do Castanheiro numa área limitrofe à Serra da Nogueira (Trás-os-Montes). In: Tricas F.P. & Rivas M. (eds.), *Comunicaciones ao I Congreso Florestal Hispano-Luso*, Pamplona, vol. 5: 265-270.

Portela E., Martins A. & Pires A.L., 1997. Edaphic factors and management practices associated with the incidence of ink disease in chestnuts in northern Portugal. In: *Proceedings of the 10th Congress of the Mediterranean Phytopathological Union*, Société Française de Phytopathologie, ORSTOM, Montpellier: 775-780.

Portela E., Martins A. & Pires A.L., 1998. *Práticas culturais de limitação da tinta do castanheiro.* Universidade de Trás-os-Montes e Alto Douro, Vila Real, Portugal. 63 p.

Shea S.R. & Broadbent P., 1983. Developments in cultural and biological control of Phytophthora diseases. *In*: D.C. Erwin, S. Bartniki-Garcia & P.H. Tsao (eds.), *Phytophthora, its Biology, Taxonomy, Ecology, and Pathology.* Am. Phytopathol. Soc., St.Paul: 335-350.

White J.V., Kirkland B.L. & Gournay J.P. 1998. Quantitative porosity determination of thin sections using digitised images. *Journal of Sedimentary Research*, 68A, 220-222.

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Chestnut litter production and nutrient budgets in relation to management over a five year period

Production de la litière de châtaignier et bilan des nutriments en relation avec les pratiques de gestion au cours d'une période de cinq ans

Ana Luisa PIRES* & Ester PORTELA

Dep. Edafologia, Universidade de Trás-os-Montes e Alto Douro, P - 5000 Vila Real, Portugal

* Corresponding author

ABSTRACT

The effect of low and intensive chestnut (*Castanea sativa* Mill.) grove management on the amount of litterfall produced and on litter macro nutrient inputs and outputs was examined during five years in two adjacent 48 year old stands. One, F plot, was fertilized, pruned and tilled 3-4 times each year, while the other, NF plot, was only submitted to 2-3 tillage operations. Total litterfall was similar in both plots, but contribution of each litterfall component to total litter was different. Contribution of leaves to total was higher ($P<0.05$) in NF plot, since it was not pruned. In F plot, the more intense management significantly increased nut production, which was 55% higher, per tree, than in NF plot. In this plot, the biggest proportion of nutrients released by trees was in leaves. In F plot, due to the higher nut production, the amount of N, P, K and S in nuts was larger than in leaves (N, K) or similar (P and S). The amount of P and K exported by nuts collected in F plot was equal to the amount returned to the soil by all the other litterfall components. In addition, F plot was also pruned, removing 6.5 t of DM ha^{-1} in the five years. When pruned biomass was considered, nutrient balance was negative for K and near to zero for N, P and S. The results suggested that a more intense management increased nut production and that a higher fruit export will not impoverish the soil of nutrients. Removal of pruned biomass, however, is not a suitable practice due to the high amount of nutrients exported. The finer material, the richest in nutrients, should at least be left on the soil.

Key -words: sweet chestnut, nutrient balances, *Castanea sativa* Mill.

RESUME

Les effets des gestions intensive et extensive des vergers de châtaignier (*Castanea sativa* Mill.) sur la production de litière et sur les transferts des macro nutriments ont été étudiés durant 5 ans dans deux formations adjacentes, âgées chacune de 48 ans. La première formation (placette F) a été fertilisée, élaguée et taillée 3 ou 4 fois par an, alors que la deuxième (placette NF) a seulement subit 2 ou 3 opérations de taille. L'accumulation de litière est similaire dans les deux placettes, mais la contribution des différents éléments de la litière est différente. La contribution des feuilles est plus élevée ($p>0.05$) dans la placette NF, car elle n'a pas été élaguée. Dans la placette F, la gestion plus intensive augmente significativement la production de châtaignes (55% de plus par arbre que dans la placette NF, où les feuilles produisent par ailleurs la plus forte proportion de nutriments). Dans la placette F, les quantités d'azote et de potassium sont plus importantes dans les châtaignes que dans les feuilles. La quantité de phosphore et de potassium prélevée lors de la cueillette des châtaignes est équivalente à celle retournant au sol à travers les autres composantes de la litière. De plus, la placette F a été élaguée, enlevant 6,5 t. de MS par hectare durant les 5 ans. Quand on considère la biomasse élaguée, la balance des nutriments est négative pour K, et presque égale à zéro pour N, P et S. Les résultats suggèrent qu'une gestion plus intensive augmente la production de châtaignes et qu'une plus forte récolte n'appauvrit pas les sols. Cependant, l'élimination des rémanents n'est pas une pratique favorable car elle entraîne une perte importante de nutriments. Les éléments fins, les plus riches en nutriments, doivent au moins être laissés sur place.

Mots-clés : Châtaigneraies, balance de nutriments, *Castanea sativa* Mill.

INTRODUCTION

In the Trás-os-Montes (region of northern Portugal), chestnut stands occupy 17,000 ha, most for nut production. The fact of being one of the few marketable crops that farmers have, has led to an intensified management, in the last 10 years, including the use of chemical fertilizers, pruning and soil mobilization. As stated by Cole (1995), if farmers want to provide the maximum benefits from the land, they must ensure that productivity and stability are maintained for the future since an intensive management may modify nutrient capital and rate of supply to trees. A major pathway for loss of nutrients is removal of the harvested biomass and possible declines in site productivity may be expected (Pritchett & Fisher, 1987). So, the objectives of this study are to determine the effect of fertilization and pruning on the amount of litterfall produced, and on litter N, P, K, Ca, Mg and S budgets.

MATERIALS AND METHODS

This study was conducted in two adjacent groves, established in 1943 at Carrazedo de Montenegro (41° 35' N, 7° 25'W; altitude: 831 m), northern Portugal. Mean annual temperature is 12.5°C and mean annual precipitation is 1133 mm. On these groves, two plots, each one with 61 trees, were selected. The two plots, NF and F, were submitted to different management practices (Table 1). Other characteristics of the chosen stands are shown in Table 2. On each plot, litterfall traps (27.8 x 47.5 cm plastic boxes) were placed by three trees and in two associated open spaces chosen at random: eight below the canopy of each tree, and four (F plot) or three (NF plot) on each open space. Litterfall was collected from August 1991 to March 1996. After being sorted into leaves, inflorescences, burs, nuts (shell and kernel), twigs and moss-lichens, it was dried at 60°C and weighed. Litter components were then combined by year and the bulk sample was ground to pass a 1-mm screen and analyzed. For K, Ca, Mg and S determinations, it was digested with nitric-perchloric acids being Ca and Mg determined by atomic absorption spectrophotometry, K by flame photometry and S by a turbodimetric method. For N and P analysis, the digestion was with sulfuric acid and their concentration was determined by an autoanalyzer. The soils are sandy loam to loam, derived from mica schists and classified as Humic Cambisols (FAO/UNESCO), with good drainage. Depth of limiting layer is 70 cm and the layer of maximum root density is 20-50 cm depth. Soil chemical properties, determined at the beginning of this study (July 1991) are shown in Table 3. In 1992/93, 1993/94 and 1994/1995, F plot was pruned. Following determination of pruned biomass dry weight, analyses were carried out after separating it into several classes: leaves, burs, inflorescences, twigs and branches. These were separated by diameter: 1-3 cm, 3-5 cm, 5-7 cm and bigger than 7 cm. Branch analysis was carried out after separating the wood from the bark. Analysis of variance and Fisher PLSD mean separation test was calculated using the Stat View program (Abacus Concepts Inc., 1987).

RESULTS AND DISCUSSION

The average amount of litterfall collected in NF and F plots, from 1991 to 1996, is shown in Table 4. Although the purpose of these stands is for nut production, which implies a much smaller tree density ha^{-1} than coppices, total litter produced is comparable to the values reported by Vogh *et al.* (1986) for warm-temperate broadleaf deciduous forest (3.4 to 5.4 t ha^{-1} $year^{-1}$) and by Gallardo *et al.* (1995) for chestnut coppices (4.7 t ha^{-1} $year^{-1}$). The average amount of litterfall collected in both plots was rather similar. However, due to the different grove management (Table 1), contribution of each litter component to total was different. In NF plot, since trees were not pruned, leaf production is higher ($P<0.05$) than in F plot, representing 59.8% of total while in F plot it represented only 38.4%. In this plot, the more intense management significantly increased fruit production, being 56% higher, per tree, than in NF plot. The amount of nutrients that reach the soil (Table 5) and that can potentially be reused by trees was affected by this pattern of litter production. In NF plot the biggest proportion of nutrients released by the trees was in leaves while in F plot, only Ca and Mg were in higher amounts in leaves than in fruits (Table 5). This is due to the very low concentrations of these nutrients in chesnuts (Pires & Portela, 1993). The higher amounts of nutrients exported by fruits were N and K

Management practices	NF plot	F plot
Fertilization	none	300 kg ha^{-1} 7:14:14 (March 1991)[a]
		238 kg ha^{-1} 7:14:14 (March 1992)[a]
		238 kg ha^{-1} $Ca(NO_3)_2$ (March 1993)[b]
		238 kg ha^{-1} 4:16:12 (March 1994)[c]
		178 kg ha^{-1} 4:16:12 (Jan. 1995)[c]
		2078 kg ha^{-1} of organic fertilizer (Jan. 1995)[d]
Soil mobilization	1 plowing (Nov.)	1 plowing (Nov.)
	2 tillages (May, Sept.)	3 tillages (May, July , Sept.)
Pruning	none	each tree every 2 years

a: 7% N, 14% P_2O_5 and K_2O, 10% Ca and S; b: 15%N and 21% Ca; c: 4% N, 16% P_2O_5, 12% K_2O, 16% Ca and 2% Mg; d: 70% OM, 2.5% P_2O_5, 1,6% K_2O, 1.6% Ca, 0.7% Mg and 0.4% S.

Table 1. Management practices in chestnut stands between non fertilized plot (NF) and fertilized plot (F)

	1991		1994	
	NF	F	NF	F
Tree density (trees ha^{-1})	67	85	67	85
Average height (m)	9.9	9.0	10.3	8.9
Average breast height diameter (cm)	40.5	38.6	41.8	39.8
Canopy projection area (%)	80.3	58.4	81.3	57.6
Open space area (%)	19.7	41.6	18.7	42.4

Table 2. Chestnut stand characteristics in 1991 and 1994 between non fertilized plot (NF) and fertilized plot (F)

	0-20 cm		30-50 cm	
	NF plot	F plot	NF plot	F plot
pH (H_2O)	5.3	5.2	5.3	4.9
Organic matter(%)	2.1	1.7	0.3	0.3
Exangeable cations ($cmol_c\ kg^{-1}$)				
Ca	0.72	0.68	0.21	0.22
Mg	0.27	0.20	0.09	0.11
K	0.34	0.35	0.16	0.14
Na	0.09	0.07	0.09	0.07
H+Al	1.38	1.21	1.33	1.91
CECe ($cmol_c\ kg^{-1}$)	2.80	2.51	1.90	2.45
Base saturation (%)	51	52	30	22
Extractable P_2O_5 ($mg\ kg^{-1}$)	60	99	7	7

pH: 1:2.5 soil solution ratio; organic matter: modified Walkly-Black method; exangeable bases: 1N ammonium acetate pH 7; H+Al: KCl method; P_2O_5: Egner-Riehm method.

Table 3. Soil chemical properties of chestnut stands between non fertilized plot (NF) and fertilized plot (F)

Litter components	NF plot	F plot	NF plot	F plot
	---------- $kg\ ha^{-1}\ year^{-1}$	------------------	---------- %	----------------
Leaves	2431.8 a	1704.0 b	59.8	38.4
Inflorescences	171.3 a	214.7 a	4.2	4.8
Burs	566.3 a	760.5 a	13.9	17.1
Fruits	863.6 a	1710.8 b	21.2	38.6
Twigs	30.6 a	40.0 a	0.8	0.9
Moss-lichens	2.0 a	5.5 b	0	0.1
Total	4065.6	4435.5	100.0	100.0

Means followed by the same letter, in each line, are not significantly different ($P<0.05$).

Table 4. Mean yearly dry weight, kg ha^{-1}, and percentage of litter components collected in NF and F plots from 1991/92 to 1995/96, between non fertilized plot (NF) and fertilized plot (F)

	N		P		K	
	NF	F	NF	F	NF	F
Input						
L	17.3 a	13.0 b	5.2 a	2.8 b	14.5 a	9.0 b
I	1.2 a	1.9 a	0.2 a	0.3 a	1.7 a	2.0 a
B	2.8 a	4.5 a	0.5 a	0.8 b	4.8 a	5.3 a
T	0.2 a	0.3 a	0.0 a	0.1 a	0.1 a	0.2 a
M/L	0.0 a	0.1 a	0.0 a	0.0 a	0.0 a	0.0 a
Total	21.5	19.8	5.9	4.0	21.1	16.5
Output						
F	9.5 a	15.0 b	1.6 a	2.7 b	8.6 a	15.4 b
PB	0.2	4.0	0.0	0.7	0.1	3.1
Total	9.7	19.0	1.6	3.4	8.7	18.5
Balance	+11.8	+0.8	+4.3	+0.6	+12.4	-2.0

	Ca		Mg		S	
	NF	F	NF	F	NF	F
Input						
L	15.2 a	11.8 b	5.7 a	3.5 b	1.8 a	1.4 b
I	0.6 a	0.8 a	0.4 a	0.4 a	0.2 a	0.4 a
B	1.8 a	2.6 a	0.8 a	0.9 a	0.2 a	0.4 a
T	0.3 a	0.4 a	0.1 a	0.1 a	0.0 a	0.0 a
M/L	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Total	17.9	15.6	7.0	4.9	2.2	2.2
Output						
F	0.8 a	1.9 b	0.7 a	1.2 b	0.8 a	1.4 b
PB	0.3	6.4	0.0	1.1	0.0	0.7
Total	1.1	8.3	0.7	2.3	0.8	2.1
Balance	+16.8	+7.3	+6.3	+2.6	+1.4	+0.1

L: leaves; I: inflorescences; B: burs; T: twigs; M/L: moss/lichens; F: fruits; PB: pruned biomass and/or broken branches. In each line and within each nutrient, means followed by the same letter are not significantly different ($P<0.05$).

Table 5. Average nutrient litter balance, kg ha^{-1} year^{-1}, between non fertilized plot (NF) and fertilized plot (F) in 1991/96

since these are the nutrients presenting the highest concentrations in nuts. Nevertheless, a higher fruit production in F plot may not impoverish the soil of N, P, K and S since the input due to all the other litter components is higher than nut output (Table 5).

During 1992/1993,1993/1994 and 1994/1995, F plot was pruned removing a total of 6.5 t of DM ha^{-1}: 4.1 t of branch wood, 1.5 t of branch bark and 1.2 t of leaves+burs+inflorescences+twigs. In 1995/96 strong winds broke several branches in both plots. These branches were also taken out of the field by the farmers: 0.1 t of DM ha^{-1} in F plot and 0.4 t of DM ha^{-1} in NF plot. Although the removal of these small quantities of DM did not affect nutrient budget, the removal of an average of 1.3 t DM ha^{-1} $year^{-1}$ exports a larger amount of Ca than fruits (Table 5). When this pruned material was considered, nutrient budgets in F plot were negative for K or near zero for N, P and S. Due to the high Ca concentration in pruned biomass (Pires & Portela, 1993), the amount of Ca exported, in relation to the other nutrients considered, was the largest, followed by N, K, Mg, S and P. Such high output of nutrients could be minimized if the finer pruned material stayed in the field since it was the material richest in nutrients (Pires & Portela, 1993). In relation to Ca, however, it would be difficult to minimize the export because this element is mainly concentrated in the bark, specially in the bark of thicker branches (Pires & Portela, 1993). So, removal of pruned biomass may contribute to a long term decrease in soil fertility, especially in unpolluted areas where natural inputs are low and when nutrients are not added by fertilizers. Such a decrease was not observed in F plot. The results of soil analysis collected in July 1995 are rather similar to the ones obtained in July 1991 (Table 3), since all macronutrients have been applied as fertilizers, although in small amounts (Table 1). In addition, leaching losses were also rather small (Portela & Pires, 1995).

In conclusion, this five years study showed that intensification of management has contributed to an increase of nut production and the low cost of such gains largely justify the inputs. The higher output of fruit did not decrease soil fertility and the low rates of fertilizers added were enough to minimize nutrient export and to minimize nutrient losses by leaching.

Acknowledgments

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REFERENCES

Cole D.W. 1995. Soil nutrient supply in natural and managed forests. *Plant and Soil*: 43-53.

Gallardo-Lancho J.F.,. Egido J.A.,. Gonzalez M.I., Rico M., Santa Regina I., Gallego H., Martin A., Menendez I., Moreno G., Schneider K., Turrion B. & Saavedra J. 1995. Nutrient cycles in chestnut ecosystems of sierra de Gata (western central Spain). *In* Romane, F. (ed.), *Sustainability of Mediterranean Ecosystems*: 23-44.

Pires A.L. & Portela E. 1993. Nutrient balance in low and intensively managed chestnut groves in northern Portugal. *In*: Antognozzi E. (ed.), *Proceedings of the "International Congress on Chestnut"*, Spoleto, Italy, 20-23 Oct. 1993: 397-401.

Portela E. & Pires A.L. 1995. Nutrient deposition and leaching by rainwater in low and intensively managed chestnut groves. *In*: *Proceedings of the Conference on "Erosion and Land Degradation in the Mediterranean"*, Univ. de Aveiro, Portugal, 14-18 June 1995: 307-317.

Pritchett W.L. & Fisher R.F. 1987. *Properties and Management of Forest Soils* (2nd ed.). John Wiley & Sons, New York: 494 p.

Vogt K.A., Grier C.C. & Vogt D.J. 1986. Production, turnover, and nutrient dynamics of above- and belowground detritus of world forests. *Advances in Ecological Research*, 15: 303-377.

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Plant species richness responses to management practices in chestnut (*Castanea sativa* Miller) forests and coppice stands in the Cévennes mountains (southern France)

Changements de richesse spécifique végétale et régimes sylvicoles des forêts et taillis de châtaignier (*Castanea sativa* Miller) dans les Cévennes (sud de la France)

Hélène GONDARD[1], James ARONSON[1], Michel GRANDJANNY[1], Edouard LE FLOC'H[1], Alain RENAUX[1], François ROMANE[1,3] & Zuheir SHATER[1,2]

[1] CNRS-CEFE (UPR 9056), 1919 route de Mende, 34293 MONTPELLIER CEDEX 5, France
[2] Département de foresterie et d'écologie, Faculté d'agronomie de l'Université de Tichrine, Lattaquie, Syrie
[3] Corresponding author (phone +33 4 67613277; fax +33 4 67412138; e-mail romane@cefe.cnrs-mop.fr)

ABSTRACT

We compared plant species diversity in cut (coppiced) and uncut (22 yrs old) chestnut stands of the Cévennes in southern France over a 6-year period by measuring species richness, Shannon-Weaver biodiversity index, Leaf Area Index (LAI), and life form spectra. Species richness increased six-fold immediately after the clear-cut from 5 species in the old coppice stand before the clear-cut to 30 species 2 years after the cut, but subsequently decreased over the 6-year period to reach 15-16 species in a 100 m^2 plot (n = 15). The Shannon-Weaver diversity index behaved like species richness. LAI increased during this period, but there were no statistically significant relationships between the diversity indices and LAI. The life form spectra were also greatly modified after the clear-cut. These changes mainly concerned the number of hemicryptophytes which increased significantly. This behavior is very different from that observed in old field succession where therophytes (annuals) are the first invaders of the open areas. Finally we discuss the consequences of various land use practices on the conservation of plant species diversity in these two types of chestnut dominated ecosystems.

Key-words: *Castanea sativa*, plant diversity, Cévennes, coppice stands, clear-cut, plant species richness, Leaf Area Index, life form

Nomenclature: Flora Europaea (Tutin *et al.*, 1964-1980)

RESUME

Se basant sur des mesures de la diversité végétale (richesse spécifique, index de Shannon et Weaver), nous avons suivi pendant six ans l'évolution de la biodiversité dans un taillis coupé à blanc et dans un peuplement (vieux taillis) âgé de 22 ans, tous deux de châtaignier (*Castanea sativa* Miller). Ces formations sont issues à l'origine de vergers de châtaignier abandonnés il y a plusieurs décennies. La richesse spécifique après la coupe du taillis a été multipliée par 6, passant de 5 espèces dans le vieux taillis à 30 espèces deux ans après la coupe. Six ans après la coupe, cette richesse spécifique, bien qu'ayant diminué très rapidement (15 à 16 espèces), est encore très significativement différente de celle du vieux taillis (5 espèces). La diversité, estimée avec l'index de Shannon et Weaver, se comporte d'une manière très comparable à la richesse spécifique. Bien que les graphiques suggèrent que cette richesse spécifique puisse être liée aux variations de l'indice foliaire, aucune relation statistique n'a pu être mise en évidence. Quant aux spectres biologiques ils sont aussi largement modifiés par la coupe, surtout pour les hémicryptophytes qui augmentent considérablement en nombre après la coupe. Ce comportement est donc assez éloigné des modèles mis en évidence dans les successions végétales après culture où les thérophytes jouent un rôle prépondérant dans les premières années après l'abandon. Les conséquences sur la diversité spécifique végétale de quelques techniques sylvicoles sont ensuite discutées pour des formations à base de châtaignier.

Mots clés : *Castanea sativa*, diversité végétale, Cévennes, taillis, coupe, richesse spécifique végétale, indice foliaire, spectre biologique

INTRODUCTION

Why study biodiversity in managed Mediterranean forests? One reason is that a plant community with a high number of organisms (plant and/or animals), and a correspondingly high diversity of biotic interactions, and fluxes and cycles of energy, water and nutrients, is often thought to be somehow «better» (*i.e.*, higher stability, higher production, *etc.*) than other communities in the same biome with lower levels of biodiversity. This general idea is quite old and appealing (Darwin, 1859; Mc Arthur, 1955 *in* Peterson *et al.*, 1998; Lepart, 1997), and the concept has been largely developed in ecology over the last two decades (di Castri & Younès, 1990 and 1996; di Castri, 1996). Specifically, many scientists have hypothesized that a direct relationship exists between the level or amount of biodiversity of an ecosystem and how «well» it functions long-term (Schulze & Mooney, 1993). However, despite its broad-reaching consequences, this general hypothesis has rarely been tested, largely due to the considerable problems inherent in the design and realization of appropriate tests (Hobbs *et al.*, 1995; Huston, 1997; Peterson *et al.*, 1998; Allison, 1999).

Because it is considerably easier to observe, manipulate and experiment in the absence of trees or tall shrubs, most «biodiversity x ecosystem function» studies in terrestrial ecosystems have concerned herbaceous communities of plants, particularly in old fields following crop abandonment (*e.g.*, Lavorel *et al.*, 1994).

However, the functional aspects of biodiversity changes have also increasingly been studied in southern European forests (*e.g.*, Tatoni & Roche, 1994; Vallauri *et al.*, in press) and, of course, in many other mediterranean-climate regions around the world (*e.g.*, Dell *et al.*, 1986; Davis & Richardson, 1995). In southern Europe, such studies have been stimulated by (i) the hypothesis that it is possible to maintain high plant species diversity when timber production *per annum* is maximized (Kangas & Kuusipalo, 1993; Kuusipalo & Kangas, 1994) and (ii) the growing pressure of the various «Green» parties, and their constituencies, to preserve as much as possible of existing biological diversity in the various ecosystems of this biologically rich region (Gomez Campo, 1985; Blondel & Aronson, 1995, 1999), and to protect them against possible biological invasions of non-native organisms (*e.g.*, Fox & Fox, 1986; Prieur-Richard, 2000).

This problem of biodiversity conservation is particularly critical in forests of protected areas such as the Cévennes National Park of southern France where a large percentage of the often centuries-old chestnut (*Castanea sativa* Miller) groves have been transformed into coppice stands that are now managed for timber production (Romane & Valérino, 1997). An indirect analysis (Gondard *et al.*, accepted) has clearly shown that plant species diversity drastically and significantly decreased when chestnut groves were abandoned. Thus, the question that we addressed here was: is it possible to maintain current levels of plant species diversity with the new kind of management practices of these chestnut ecosystems that are now emerging? If plant species richness changes dramatically in the course of the thinning cycle practiced by land owners and recommended by state foresters, one possible strategy for preserving biodiversity could be to maintain a mosaic - at the landscape scale (Forman & Godron, 1986) - of the various stages of this cycle. This could possibly help managers and foresters to achieve a management and «sustainable» development program presumed to be compatible with biodiversity conservation, even if the details of this concept remain somewhat vague (Shearman, 1990; di Castri, 1998; Wikstrom, 1999).

Thus, to be able to answer, at least for one particular ecosystem, the question just mentioned, our approach was to study the changes of plant species diversity after the clear-cutting of a chestnut coppice stand as compared to an uncut stand nearby. If it is well known that plant species richness initially increases after clear-cutting in such ecosystems (Romane *et al.*, 1994), we sought to elucidate the long-term response of plant species diversity of an ageing chestnut coppice. We hypothesized that the structure of the overstorey - coppiced or uncut - could be a major factor explaining plant species diversity trends and changes (Gilliam *et al.*, 1995).

Changes in canopy structure induce large modifications of understorey light conditions in forests (Federer & Tanner, 1966), and also of the rainfall pattern (Collins & Pickett, 1987), understorey temperature and humidity (Chen *et al.*, 1993), and of the chemical and microbiological soil properties (Likens *et al.*, 1978; Kropp & Albee, 1996).

Thus, an experiment was designed to assess the importance of chestnut canopy structure by measuring the Leaf Area Index (LAI). Any relationships revealed between this component of the forest ecosystem and overall plant diversity should help orient and refine forest management practices and protocols in chestnut forests throughout southern Europe.

The role of plant biodiversity in the functioning of the chestnut forests and coppice ecosystems will be also discussed indirectly, since many authors, *e.g.*, Huston (1997), have underlined the difficulties of a direct analysis. For this purpose we employ the concept of plant life forms first proposed by Raunkiaer (1934), a part of the life history traits which are often used to replace more direct studies of ecosystem functioning. The life form classification proposed by this author is based on the location of regenerating buds, a trait which greatly influences a plant's ability to survive the «worst» or most unfavorable season for growth (generally the winter in mediterranean-type ecosystems).

BIOLOGICAL MODEL AND METHODS

The site

Le Vernet site (44° 08' N; 03° 48' E) is about 80 km north of Montpellier (southern France), with a mean elevation of 700 m a.s.l. Yearly rainfall is about 1 300 mm with a Mediterranean climate pattern (Daget, 1977), that is, however, greatly influenced by the Oceanic climate. Parent bedrock is schist which is relatively unusual in this part of the Mediterranean Basin. The site is in a state forest managed by the French Office National des Forêts (ONF) where the chestnut coppice stand was about 22 years old and 16 m high when it was clear-cut during the winter of 1992-1993. Before the clear-cut, the basal area of chestnuts was about 30 m^2 ha^{-1} with 2 000 shoots ha^{-1} (ONF, pers. comm.).These coppice stands are derived from old chestnut groves. We chose this site because it appeared to be representative of a large part of the forest vegetation in the Cévennes mountains, in the National Park and nearby. The forest managers also questioned insistently about the biodiversity management of this kind of forest stands.

Experimental design

First of all, due to the fact that our team was not able to independently finance an experimental design as we needed, we used an experiment of the Office National des Forêts designed for other objectives. That explains some of the unsatisfactory traits of the design such as the unbalanced number of plots between the cut and uncut areas, the absence of observations the year after clear-cutting, *etc.* The data processing has taken into account these shortcomings.

Our experiment consisted of 20 square plots (10 x 10 m each), 15 of which were in the clear-cut area and 5 in the uncut area. The latter plots represented the «control». The 20 plots were situated along four parallel lines (5 contiguous plots in each line) perpendicular to the slope. Due to topography, the distance was about 5 meters between line 1, line 2 and line 3 and 20 m between line 3 and line 4 (control) to obtain a design as homogeneous as possible.

All plant species present were recorded in each plot. These species were generally understorey species less than 1 m, except *Cytisus scoparius* that could be a little bit higher. The overstorey was exclusively *Castanea sativa*. Total plant cover was estimated by the point quadrat method (Goodall, 1953). We used 100 points along a 10 m line trough each plot (in its middle) and perpendicular to the slope, *i.e,*. one point every 10 cm. Unfortunately, no measurements had been obtained before the clear-cut took place. However, the «control plot» that had not been cut provided a rather good estimation of the flora and vegetation present in the site as a whole before the clear-cut took place. The 15 plots were clear-cut (winter 1992/1993), but we could not monitor the vegetation in 1993 because missing information about the clear-cut). Thus, for species richness and diversity assessments, the plots were monitored each year from 1994, until 1999 in May, June and July, which allowed us to record all, or almost all, the species present (see Appendix). For species abundance, point quadrats were carried out in May or June each year in all 20 plots when the vegetation had reached its «maximum» or peak of growth).

After 5 years, plant species richness had declined and appeared to have stabilized. This suggested to us attempting a chestnut thinning, a practice which has been proposed by foresters as a preferred management practice to complement the role of the clearing. The clearing was realized in the winter 1998-1999, by removing almost a third of the tree shoots, in the 15 plots that have been clear-cut 6 years ago. It was decided not to include a control plot so as to maximize the number of plots available for statistical analysis.

For data processing, the main variables used were species richness (number of taxa in each 100 m^2 plot), diversity and evenness (Pielou, 1975; Magurran, 1988; van der Maarel, 1996). Among the many diversity indices available, we chose the Shannon-Weaver index (H'), which is easy to measure and recommended by Pielou (1975): $H' = - \Sigma_{i=1,n} p_i \log_2(p_i)$ where p_i is the abundance ratio of species (i) along a 10 m line in each plot, and n = species number in the plot. The evenness is defined as $E = H'/H_{max} = H'/\log_2 n$.

To carry out statistical analysis, we first verified normality and homoscedasticity of the data (species richness, diversity index, life forms). If normality and homoscedasticity hypotheses were verified, then a Student t test was carried out to compare the means pairwise. If only one or both hypotheses were not verified, then we used the non-parametric Kruskal-Wallis test to compare means. If there were differences, the means were compared pairwise by the non-parametric Mann-Whitney test (Falissard, 1996). We did not try to transform the data because it would have been difficult to explain the biological meaning of such transformation.

Leaf area index (LAI) was recorded with a LAI-2000^R plant canopy analyzer (LI-COR, 1992) at the center of each plot once a year during the summer time (June or July), *i.e.*, when all species leaves are present. To compare the LAI and plant diversity, we only take into account the species richness recorded along the 10 m transect line in each plot (5 m on either side of the center). We guessed that the point quadrat method that needed a systematic sampling increases the stability of the results; we also reduced by this way the distance of observation from the plot center where the LAI data have been recorded (5 m instead of 7.1 m).

In view of the low number of observed years (Daget, 1976; Falissard, 1996), we compared diversity and LAI, using the Spearman rank correlation coefficient, based each year on the data of all 15 plots of cut coppices.

RESULTS

Species richness, diversity and evenness

Because there were no observations in the 15 plots before the clear-cutting, we considered that observed species richness in the 5 uncut plots (22 years old) provided a good estimation of the initial richness of the clear-cut plots. To absorb annual fluctuations, we used the mean of the six available years (1994-1999) to estimate this initial richness, *i.e.,* 4.7 ± 0.6 plant species (Figure 1). The clear-cut, carried out during the winter of 1992-1993, of the 22-year old coppice stand induced a dramatic increase of plant species richness, *i.e.*, 29.7 ± 5.2 species in 1994. After 1994, however, species richness decreased very quickly (1995 and 1996) and then more slowly (1997-1998). Nevertheless the botanical richness of the uncut area was always significantly less than in the clear-cut area (Tables 1 and 2). In this uncut area, plant species richness was quite low and rather stable since there were no significant differences among years (Table 2). This slower decrease led us to carry out a thinning of the 5-year old coppice stand during the winter of 1998-1999. The results suggested that the plant community reacted rather quickly after this thinning, since the species richness in 1999 (*i.e.*, a few months after the clearing process) was already higher ($p < 0.05$) than in 1998 (Table 2). Trends in biodiversity changes after the clear-cut, according to the Shannon-Weaver index, were very similar, except in 1999, to those of the species richness (Figure 2), *i.e.*, a quick increase two years after the clear-cut and a slower decrease after five years. The first year after clearing, species diversity continued to decrease in the clear-cut area even if the diversity in 1999 was not statistically different from 1998 (Tables 1 and 2 ; Figures 1 and 2). Evenness (Table 1) also decreased significantly ($p < 0.01$) from 1994, showing the increasing dominance of the chestnut.

Species richness and LAI

The data shown in Figure 3 suggests that species richness was related to LAI. Nevertheless the Spearman rank correlation coefficient did not allow to reject the null hypothesis, *i.e.*, the absence of any relationship between LAI and plant species richness. Using the species richness recorded in the complete plots gave similar results.

	1992		1994	1995	1996	1997	1998	1999
Species richness	4.70 ± 0.61	clear-cut	29.40 ± 5.40	28.93 ± 3.49	24.60 ± 2.69	14.00 ± 2.15	13.60 ± 1.85	17.20 ± 2.52
		uncut	4.20 ± 0.96	4.40 ± 1.71	5.20 ± 2.35	4.60 ± 1.18	3.80 ± 0.73	6.00 ± 1.39
Species diversity	0.32 ± 0.10	clear-cut	2.01 ± 0.31	1.55 ± 0.26	1.49 ± 0.16	1.30 ± 0.25	1.28 ± 0.30	0.87 ± 0.26
		uncut	0.36 ± 0.35	0.32 ± 0.21	0.34 ± 0.27	0.30 ± 0.29	0.32 ± 0.32	0.28 ± 0.23
Evenness	0.27 ± 0.09	clear-cut	0.65 ± 0.05	0.58 ± 0.06	0.56 ± 0.05	0.57 ± 0.07	0.55 ± 0.09	0.42 ± 0.09
		uncut	0.32 ± 0.27	0.32 ± 0.21	0.29 ± 0.23	0.26 ± 0.25	0.25 ± 0.22	0.16 ± 0.14

Table 1. Main data of plant species richness, diversity and evenness of a chestnut coppice stand («clear-cut»= clear-cut in 1994 + partial clearing in 1999) at Le Vernet (Cévennes, southern France). The initial values are estimated in 1992 from the data gathered in the uncut plot (1994-1999); Confidence intervals p = 0.05

		Cut						**Uncut**					
		↓ 1994	1995	1996	1997	1998 ⇓	1999	1994	1995	1996	1997	1998	1999
				SPECIES			RICHNESS						
	Clear-cut →												
	1994	-											
	1995	ns	-										
Cut	1996	ns	ns	-									
	1997	***	***	***	-								
	1998	***	***	***	ns	-							
	Clearing ⇒												
	1999	***	***	**	ns	*	-						
	1994	***	***	***	***	***	***	-					
	1995	***	***	***	***	***	***	ns	-				
Uncut	1996	***	***	***	***	***	***	ns	ns	-			
	1997	***	***	***	***	***	***	ns	ns	ns	-		
	1998	***	***	***	***	***	***	ns	ns	ns	ns	-	
	1999	***	***	***	***	***	***	ns	ns	ns	ns	ns	-
				SPEC IES			DIVERSITY						
	Clear-cut →												
	1994	-											
	1995	*	-										
Cut	1996	*	ns	-									
	1997	**	ns	ns	-								
	1998	**	ns	ns	ns	-							
	Clearing ⇒												
	1999	***	**	***	*	ns	-						
	1994	***	***	***	**	**	*	-					
	1995	***	***	***	***	**	*	ns	-				
Uncut	1996	***	***	***	***	**	*	ns	ns	-			
	1997	***	***	***	***	**	*	ns	ns	ns	-		
	1998	***	***	***	***	**	*	ns	ns	ns	ns	-	
	1999	***	***	***	***	**	*	ns	ns	ns	ns	ns	-

Table 2. Comparison of species richness and plant species diversity among years and between cut and uncut areas of a chestnut coppice stand at Le Vernet (Cévennes, southern France). ns = no difference; * = p < 0.05; ** = p < 0.01; *** = p < 0.001

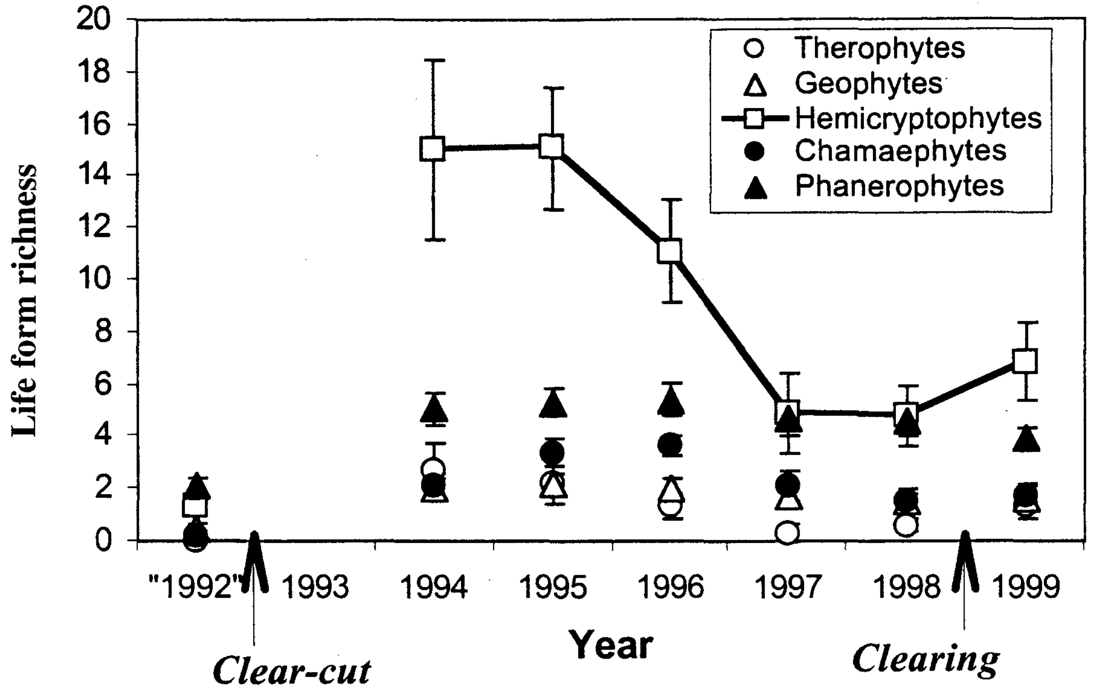

Figure 1. The plant species richness changes in the understorey of a clear-cut (winter of 1992-1993) and uncut (22 years old) chestnut (*Castanea sativa*) coppice stands at Le Vernet; The initial richness is estimated in 1992 from the uncut original coppice stand. Error bars at ± 95% confidence limits.

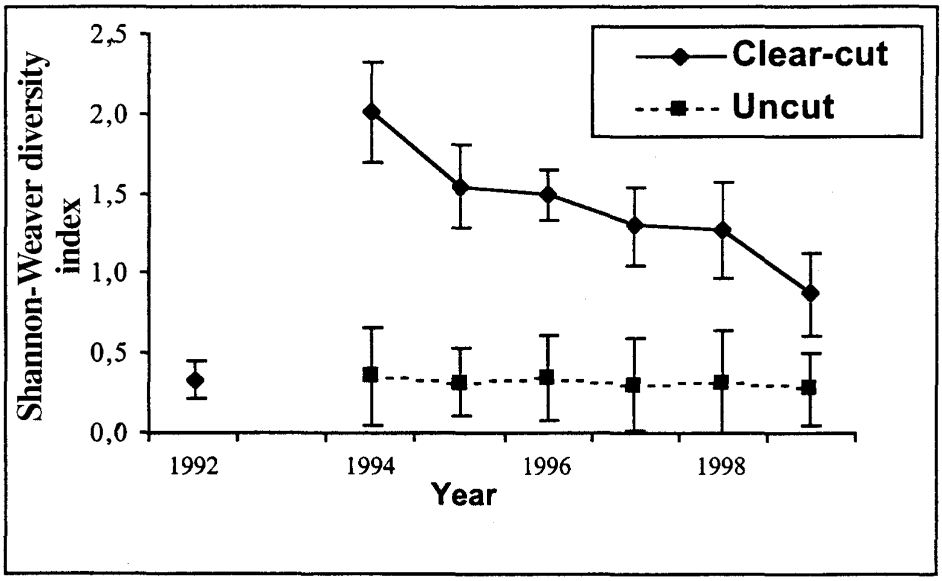

Figure 2. The plant species diversity changes (Shannon-Weaver's biodiversity index) in the understorey of a clear-cut (winter of 1992-1993) and uncut (22 years old) chestnut (*Castanea sativa*) coppice stand at Le Vernet. The initial diversity (1992) is estimated from the uncut original coppice stand (22 years old). Error bars at ± 95% confidence limits

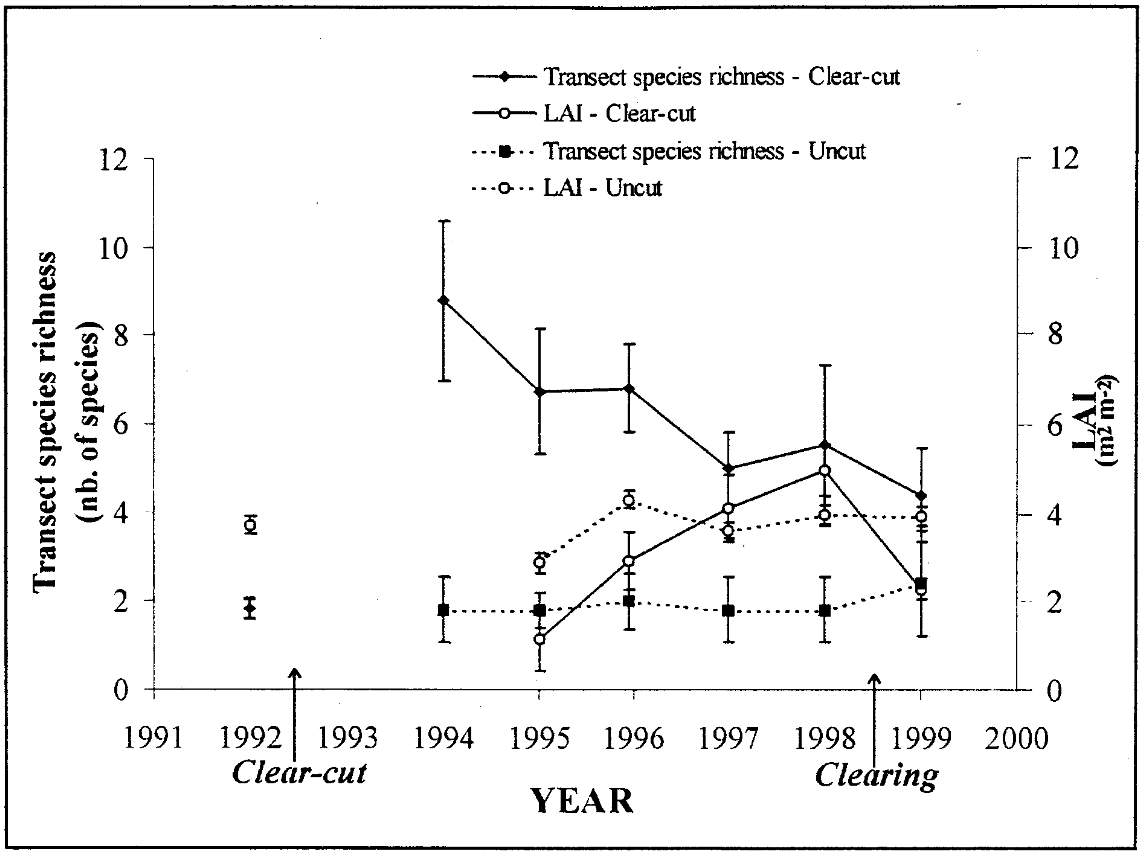

Figure 3. Plant species richness along the transect and Leaf Area Index (LAI) after the clear-cut (in the winter of 1992-1993) of a chestnut (*Castanea sativa*) coppice stand at Le Vernet. The 1992 values are estimated from the data gathered in the 22 years old uncut plot (1994-1999). Error bars represent ±95% confidence limits

This overall result was probably induced by the high variability of LAI values, but suggested the possible impact of the clear-cut on other ecosystem processes such as water cycle, nutrient fluxes, *etc.*

Species richness and life form spectra

Species richness of each life form was very low, particularly in the uncut area. Consequently, the data did not allow statistical comparisons between the clear-cut and uncut plots.

Considering only the clear-cut area, comparisons among years showed that a peak of hemicryptophyte species richness occurred in the first or, more often, the second year after the clear-cut. For this life form, loss of species also occurred very quickly and was statistically different from year to year until 1999 (Figure 4; Tables 1 and 3). Thus, species richness declined from 1996 to 1999.

For the other life forms, a small increase occurred after the clear-cut (Figure 4); after that, the decrease was statistically different among years, except for the geophytes which were very stable in species numbers (Table 3).

Thus, these results suggested the following trends (Figure 4):

- A quick but small species richness increase of most life forms after the clear-cut.
- A very large increase of the hemicryptophytes after the clear-cut.
- A decrease of species richness for all life forms in the five years following the clear-cut.
- A large decrease of the hemicryptophytes starting the third year after the clear-cut.

DISCUSSION AND CONCLUDING REMARKS

The main result of this study was the temporary large increase of plant species richness observed after clear-cutting. This result itself was not surprising and

	THEROPHYTES						GEOPHYTES						HEMICRYPTOPHYTES					
	1994	1995	1996	1997	1998	⇓ 1999	1994	1995	1996	1997	1998	⇓ 1999	1994	1995	1996	1997	1998	⇓ 1999
Clear-cut→																		
1994	-						-						-					
1995	NS	-					NS	-					NS	-				
1996	*	NS	-				NS	NS	-				NS	*	-			
1997	***	***	**	-			NS	NS	NS	-			***	***	***	-		
1998	**	**	*	NS	-		NS	NS	NS	NS	-		***	***	***	NS	-	
Clearing ⇒																		
1999	*	NS	NS	**	*	-	NS	NS	NS	NS	NS	-	***	***	**	*	*	-

	CHAMAEPHYTES						PHANEROPHYTES					
	1994	1995	1996	1997	1998	⇓ 1999	1994	1995	1996	1997	1998	⇓ 1999
Clear-cut→												
1994	-						-					
1995	**	-					NS	-				
1996	***	NS	-				NS	NS	-			
1997	NS	**	***	-			NS	NS	NS	-		
1998	NS	**	***	NS	-		NS	*	*	NS	-	
Clearing⇒												
1999	NS	***	***	NS	NS	-	*	**	**	NS	NS	-

Table 3. Comparison for each life form of the species richness among years in the clear-cut area of a chestnut coppice stand at the Le Vernet . ns = no difference; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

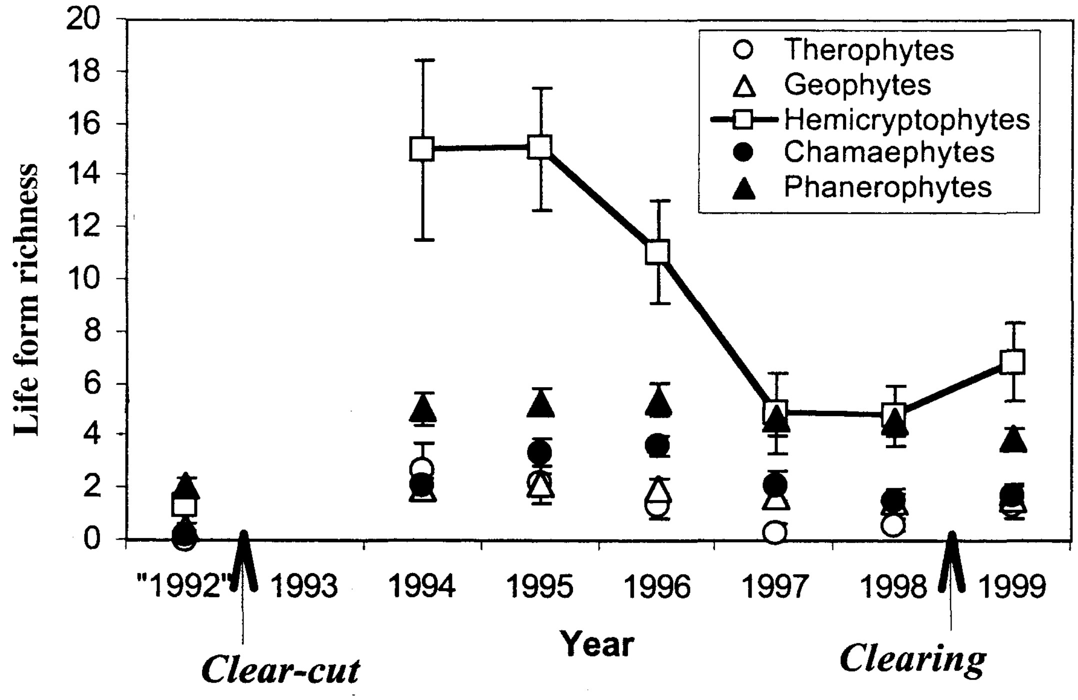

Figure 4. Life form spectrum changes after clear-cutting (winter of 1993-1993) of a chestnut (*Castanea sativa*) coppice stand at Le Vernet. The values of 1992 are estimated from the data gathered in the 22 years old uncut plot (1994-1999). Error bars are placed at ± 95% confidence limits (they are drawn only for hemicryptophytes and phanerophytes)

has been observed after forest clear-cutting or thinning (Bartolome *et al.*, 1994; Elliott & Swank, 1994; Tatoni & Roche, 1994), as well as after similar processes like fire, old field, *etc.* (Trabaud & Lepart, 1980; Escarré *et al.*, 1983; Tatoni & Roche, 1994; Prach *et al.*, 1997; Prieur-Richard, 2000). It has also often been observed in studies concerning gap and patch dynamics in forest ecosystems in temperate as well as Mediterranean regions (see, *e.g.*, van der Maarel, 1996 for a survey).

Nevertheless, the intensity of this process in the present study was remarkably high, since the initial plant species richness was only about 5 species per 100 m^2 plot in the original old coppice stand and it reached about 30 species per plot two years after the clear-cut.

This very high rate could perhaps be related to very high LAI in the old coppice stand. Given that climatic constraints are minimal in our study area, on the border of the Mediterranean climate region, we conclude that limited light resource is probably one of the main limiting factors to the maintenance of high understorey diversity, even if the relationship between LAI and species richness was not statistically significant. Nevertheless, studying other factors (rainfall pattern in the understorey, chemical soil properties, *etc.* could probably improve our results. The fact that these coppice stands are presently in a mosaic of various landscape units (crop, coppice stands, abandoned grassland, cultivated chestnut groves, *etc.*), which allows a seed rain of many species and, presumably, the constitution of a large, soil-borne seed bank, could also explain these results.

The other main result, *i.e.*, the high percentage of hemicryptophytes participating in the species richness increase after the clear-cut was more surprising (Rodríguez Tohà, 1999) since therophytes (*i.e.*, annuals) are generally the main life form appearing in the early stages of a succession (Escarré *et al.*, 1983; Prieur-Richard, 2000; Lavorel *et al.*, 1999). We did not find any processes that could explain this difference. Similar to the hemicryptophytes in the uncut area (*Festuca rubra*, *Hieracium murorum*, *etc.*), the hemicryptophytes appearing after the clear-cut were also generally very common species (*Poa nemoralis*, *Luzula campestris*, *Anthoxanthum odoratum*, *etc.*). Thus, in the present study, the increase of species richness exclusively concerns common widespread plant species (Appendix). However, at the higher spatial scale of the region there is a possible influence on biodiversity resulting from appropriate management of individual coppices.

What about the consequences of these results on the sustainability of these chestnut ecosystems? First of all, since we did not study the social and/or economical processes of the management of these chestnut ecosystems, we prefer to speak about the sustainability of the ecosystems and not of their sustainable development (Shearman, 1990; di Castri, 1998).

If species richness and plant diversity are sought to be kept and favored by a given management practice, the results presented here clearly indicate that a landscape mainly consisting of chestnut coppice stands would be a very poor one. The rare sites where diversity could be higher, *i.e.*, the recently clear-cut areas would become progressively more impoverished under such a regime, since they would no longer be «fed» by seeds or propagules of nearby «source» ecosystems like agricultural fields, well managed chestnut groves, *etc.* (Romane & Valérino, 1997; Etienne *et al.*, 1998).

Some field observations also suggest that a policy of reafforestation with exotic species (*Pseudotsuga menziesii*, *Pinus nigra*, *Picea abies*, *etc.*) would aggravate the loss of regional biodiversity. A landscape exclusively stemming from a mosaic of introduced tree species could not maintain a high plant species diversity (*cf.*, Vallauri *et al.*, in press).

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REFERENCES

Allison G.W., 1999. The implications of experimental design for biodiversity manipulations. *Amer. Natur.*, 153 : 26-45.

Bartolome J.W., Allen-Diaz B.H. & Tietje W.D., 1994. The effect of *Quercus douglasii* removal on understorey yield and composition. *J. Range Manage.*, 47 : 151-154.

Blondel J. & Aronson J., 1995. Biodiversity and ecosystem function in the Mediterranean Basin. Non-human and human determinants. *In* : G. Davis. & D.M. Richardson (eds.) *Biodiversity and ecosystem function in Mediterranean-type ecosystems.* Springer Verlag, Berlin: 43-119.

Blondel J. & Aronson J., 1999. *Biology and Wildlife of the Mediterranean region*. Oxford University Press, Oxford. 329 p.

Chen J., Franklin J.F. & Spies T.A., 1993. Contrasting microclimates among clearcut edge, and interior of old-growth Douglas-fir forests. *Agriculture Forest Meteor.*, 63 : 219-237.

Collins B. & Pickett S.T.A., 1987. Influence of canopy opening on the environment and herb layer in a northern hardwoods forest. *Vegetatio*, 70 : 3-10.

Daget J., 1976. *Modèles mathématiques en écologie*. Masson, Paris: 172 p.

Daget P., 1977. Le bioclimat méditerranéen : caractères généraux, modes de caractérisation. *Vegetatio*, 34 : 1-20.

Darwin C., 1859. *On the origin of species by means of natural selection or the preservation of favoured races in the struggle for life* [reprinted 1964]. Harvard University (USA) Cambridge (MA): 513 p.

Davis G.W. & Richardson D.M. (eds.) 1995. *Mediterranean-type ecosystems, the function of biodiversity*. Ecological Studies Series 109. Springer Verlag, Berlin. 366 p.

de Bolòs O., Vigo J., Masalles R.M. & Ninot J.M., 1990. *Flora manual del països catalans*. Editorial Pòrtic, Barcelona: 1 248 p.

Dell B., Hopkins A.J.M. & Lamont B.B. (eds.), 1986. *Resilience in Mediterranean-type Ecosystems*. Junk Publishers, Dordrecht. 168 p.

di Castri F., 1996. *La biodiversité*. Rapport mondial sur la science. Unesco (Ed.), Paris: 253-263.

di Castri F., 1998. The ecosystem in a scientific, economic and social context. Is sustainability possible? *In* S. Leonardi (ed.) *Sustainability of chestnut forest ecosystems*. Abstract proceedings of an International Symposium, Catania (Italy) University (18-23 September 1998): 22-24.

di Castri F. & Younès T., 1990. Fonction de la diversité biologique au sein de l'écosystème. *Acta Oecologica*, 11 : 429-444.

di Castri F. & Younès T., 1996. Introduction: biodiversity, the emergence of a new scientific field, its perspectives and constraints. *In* : F. di Castri & Younès T. (eds.) *Biodiversity, Science and Development*. CAB International, Paris: 1-11.

Elliot K.J. & Swank W., 1994. Changes in tree species diversity after successive clearcuts in the Southern Appalachians. *Vegetatio*, 115 : 11-18.

Escarré J., Houssard C., Debussche M. & Lepart J., 1983. Evolution de la végétation et du sol après abandon cultural en région méditerranéenne : étude de succession dans les garrigues du Montpelliérais (France). *Acta Œcologica, Œcologia Plantarum*, 4 : 221-239.

Etienne M., Aronson J. & Le Floc'h E., 1998. Abandoned lands and land use conflicts in southern France. Piloting ecosystem trajectories and redesigning outmoded landscapes in the 21st century. *In* : P.W. Rundel, G. Montenegro & F. Jaksic (eds.) *Landscape degradation and biodiversity in mediterranean-type ecosystems*. Ecological Studies Series 136. Springer Verlag, Berlin: 127-140.

Falissard B., 1996. *Comprendre et utiliser les statistiques dans les sciences de la vie*. Editions Masson, Paris: 332 p.

Federer C.A & Tanner C.B., 1966. Spectral distribution of light in the forest. *Ecology*, 47(4) : 555-560.

Forman R.T.T. & Godron M., 1986. *Landscape ecology*. Wiley, New-York: 619 p.

Fox B.J. & Fox M.D., 1986. Resilience of animal and plant communities to human disturbance. *In* : B. Dell, A.J.M. Hopkins & B.B. Lamont (eds.) *Resilience in Mediterranean-type Ecosystems*. W. Junk, Dordrecht: 39-64.

Gilliam F.S., Turrill N.L. & Bethadams M., 1995. Herbaceous-layer and overstory species in clear-cut and mature central Appalachian hardwood forests. *Ecol. Appl.*, 5 : 947-955.

Gomez Campo C. (ed.), 1985. *Plant conservation in the Mediterranean area*. W. Junk Publishers, Dordrecht: 269 p.

Gondard H., Romane F., Grandjanny M., Li Junqing & Aronson J.A., (accepted). Plant species diversity changes in abandoned chestnut (*Castanea sativa*) groves in southern France. *Biodiversity and Conservation*.

Goodall D.W., 1953. Point quadrat methods for the analysis of vegetation. The treatment of data for tussock grasses. *Aust. J. Bot.*, 1 : 457-461.

Hobbs R.J., Richardson D.M. & Davis G.W., 1995. Mediterranean-type ecosystems: opportunities and constraints for studying the function of biodiversity. *In* G.W Davis & D.M. Richardson (eds.) *Mediterranean-type ecosystems, the function of biodiversity*. Ecological Studies Series 109. Springer Verlag, Berlin: 1-42.

Huston M.A., 1997. Hidden treatments in ecological experiments: re-evaluating the ecosystem function of biodiversity. *Oecologia*, 110 : 449-460.

Kangas J. & Kuusipalo J., 1993. Integrating biodiversity into forest management planning and decision-making. *Forest Ecol. Manag.*, 61 : 1-15.

Kropp B.R. & Albee S., 1996. The effects of silvicultural treatments on occurrence of mycorrhizal sporocarps in a *Pinus contorta* forest: a preliminary study. *Biological Conservation*, 78 : 313-318.

Kuusipalo J. & Kangas J., 1994. Managing biodiversity in a forestry environment. *Conservation Biology*, 8 : 450-

Lavorel S., Lepart J., Debussche M., Lebreton J.-D. & Beffy J.-L., 1994. Small scale disturbances and the maintenance of species diversity in Mediterranean old fields. *Oikos*, 70 : 455-473.

Lavorel S., Rochette C. & Lebreton J.-D., 1999. Functional groups for response to disturbance in Mediterranean old fields. *Oikos*, 84 : 480-498.

Lepart J., 1997. De la diversité spécifique à la biodiversité, les raisons d'un succès. *Forêt Méditerranéenne*, 18 : 4-10.

LI-COR, 1992. *LAI-2000® Plant canopy analyser. Instrument Manual*. LI-COR, Box 4 425/4 421, Superior St., Lincoln, Nebraska, U.S.A.: 189 p.

Likens G.E., Bormann F.H., Pierce R.S. & Reiners W.A., 1978. Recovery of deforested ecosystem. Replacing the biomass nutrients lost in harvesting northern hardwood may take 60 to 80 years. *Science*, 199 : 492-496.

Magurran A.E., 1988. *Ecological diversity and its measurements.* Croom Helm, London: 179 p.

Mc Arthur R.H., 1955. Fluctuations of animal populations and a measure of community stability. *Ecology*, 36 : 533-536.

Peterson G., Allen C.R. & Holling C.S., 1998. Ecological resilience, biodiversity, and scale. *Ecosystems*, 1 : 6-18.

Pielou R.H., 1975. *Ecological diversity.* Wiley Intersciences: 165 p.

Prach K., Pysek P. & Smilauter P., 1997. Changes in species traits during succession: a search for pattern. *Oikos*, 79 : 201-205.

Prieur-Richard A.H., 2000. *Les communautés végétales plus diverses sont-elles plus résistantes aux invasions ? Une approche expérimentale dans les friches méditerranéennes.* Ph. D Thesis, Montpellier II University (France): 70 p.

Raunkiaer C., 1934. *The life forms of plants and statistical plant geography.* Oxford University Press: 632 p.

Rodriguez Tohà S., 1999. *Changement après coupe de la richesse spécifique et de la diversité biologique dans le sous-bois d'un taillis de châtaignier (*Castanea sativa *Miller) des Cévennes.* Mémoire de maîtrise de Biologie des populations et des écosystèmes, Montpellier II University: 25 p.

Romane F., Trabaud L. & Valérino L., 1994. Are human impacts decreasing the biodiversity in Mediterranean Basin ecosystems? *Noticerio de Biologia (Soc. Biol. Chile)*, 2 : 49.

Romane F. & Valérino L., 1997. Changements du paysage et biodiversité dans les châtaigneraies cévenoles. *Ecologia Mediterranea*, 23 : 121-129.

Schulze E.-D. & H.A. Mooney, (eds)., 1993. *Biodiversity and ecosystem function.* Ecological Studies Series 99. Springer Verlag, Berlin: 525 p.

Shearman R., 1990. The meaning and ethics of sustainability. *Environmental Management*, 14 : 1-8.

Tatoni T. & Roche P., 1994. Comparison of old-field and forest revegetation dynamics in Provence. *Journal of Vegetation Science*, 5 : 295-302.

Trabaud L. & Lepart J., 1980. Diversity and stability in *garrigues* ecosystems after fire. *Vegetatio*, 43 : 49-57.

Tutin T.G., Heywood V.H., Burges N.A., Valentine D.H., Walters S.M., & Webb D.A., 1964-1980. *Flora Europaea.* Cambridge University Press, Cambridge: 5 vols. - 1, *Lycopodiaceae* to *Plantanaceae*, xxxi, 464 p., v folded maps h.-t., 1964; 2, *Rosaceae* to *Umbelliferae*, xxviii, 455 p., v f. maps h.-t, 1968; 3, *Diapensiaceae* to *Myroporaceae*, xxx, 370 p., v f. maps h.-t., 1972; 4, *Plantaginaceae* to *Compositae* (and *Rubiaceae*), xxx, v f. maps h.-t., 1976; 5, *Alismataceae* to *Orchidaceae* (*Monocotyledones*), xxxvi, 452 p., v f. maps h.-t, 1980.

Vallauri D., Aronson J. & Barbero M. (in press). Forest restoration on badlands in the south-western Alps: ecological analysis and reappraisal. *Restoration Ecology.*

van der Maarel E., 1996. Vegetation dynamics and dynamic vegetation science. *Acta Bot. Neerl.*, 45 : 421-442.

Wikstrom P., 1999. Solving the stand management problem under biodiversity-related considerations. *Forest Ecology and Management,* 126 : 361-376.

APPENDIX : List of the *taxa* (identification at the specific level) observed at least one time, whatever the year, in the 20 plots from 1994 to 1999 (life forms mainly from de Bolòs *et al.*, 1990 and data base of the Institut Méditerranéen d'Ecologie et de PaléoEcologie in Marseille).

THEROPHYTES	
Anagallis	*arvensis*
Cardamine	*hirsuta*
Cerastium	*glomeratum*
Conyza	*bonariensis*
Galeopsis	*ladanum*
Galium	*parisiense*
Geranium	*lucidum*
Geranium	*robertianum*
Jasione	*montana*
Lactuca	*serriola*
Moehringia	*trinervia*
Polygonum	*aviculare*
Polygonum	*persicaria*
Sonchus	*asper*
Vicia	*sativa*
GEOPHYTES	
Cephalanthera	*rubra*
Cirsium	*arvense*
Epipactis	*helleborine*
Monotropa	*hypopitys*
Polypodium	*vulgare*
Pteridium	*aquilinum*
Tussilago	*farfara*
HEMICRYPTOPHYTES	
Acinos	*nepeta*
Anarrhinum	*bellidifolium*
Anthoxanthum	*odoratum*
Arctium	*lappa*
Asplenium	*obovatum*
Asplenium	*trichomanes*
Cirsium	*acaule*
Clinopodium	*vulgare*
Crepis	*albida*
Crepis	*capillaris*
Crepis	*vesicaria*
Daucus	*carota*
Deschampsia	*flexuosa*
Digitalis	*purpurea*
Dryopteris	*filix-mas*
Epilobium	*angustifolium*
Epilobium	*lanceolatum*
Epilobium	*montanum*
Eupatorium	*cannabinum*
Festuca	*ovina*
Fragaria	*vesca*
Galium	*mollugo*
Hieracium	*maculatum*
Hieracium	*murorum*
Hieracium	*umbellatum*
Holcus	*mollis*
Hypericum	*humifusum*
Hypericum	*perforatum*
Hypochoeris	*radicata*
Juncus	*effusus*
Lactuca	*virosa*
Linaria	*repens*
HEMICRYPTOPHYTES	(CONT.)
Lotus	*corniculatus*
Luzula	*campestris*
Luzula	*multiflora*
Medicago	*lupulina*
Melilotus	*albus*
Mycelis	*muralis*
Picris	*hieracioides*
Plantago	*lanceolata*
Plantago	*major*
Poa	*trivialis*
Poa	*nemoralis*
Potentilla	*erecta*
Potentilla	*recta*
Prunella	*vulgaris*
Ranunculus	*acris*
Ranunculus	*bulbosus*
Ranunculus	*repens*
Rumex	*acetosella*
Rumex	*obtusifolius*
Sanguisorba	*minor*
Saponaria	*officinalis*
Senecio	*jacobaea*
Silene	*vulgaris*
Solidago	*virgaurea*
Taraxacum	*officinale*
Teucrium	*scorodonia*
Trifolium	*pratense*
Trifolium	*repens*
Trisetum	*flavescens*
Urtica	*dioica*
Verbascum	*pulverulentum*
Viola	*odorata*
CHAMAEPHYTES	
Arenaria	*montana*
Calluna	*vulgaris*
Cerastium	*fontanum*
Erica	*cinerea*
Rubus	*ulmifolius*
Veronica	*officinalis*
PHANEROPHYTES	
Betula	*pendula*
Castanea	*sativa*
Cedrus	*atlantica*
Clematis	*vitalba*
Cytisus	*scoparius*
Erica	*scoparia*
Hedera	*helix*
Juniperus	*communis*
Pinus	*pinaster*
Pinus	*sylvestris*
Prunus	*avium*
Quercus	*ilex*
Rubus	*ulmifolius*
Salix	*caprea*
Sorbus	*aria*

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Alternative silvicultural systems in chestnut (*Castanea sativa* Mill.) coppice: effects of silvicultural practices on stand structure and tree growth*

Gestion sylviculturale alternative dans les taillis de châtaigner (*Castanea sativa* Mill.): effets du traitement sur la structure et la croissance du peuplement

Emilio AMORINI**, Silvia BRUSCHINI & Maria Chiara MANETTI

* The work has been carried out in equal part by the authors

** Corresponding author - Istituto Sperimentale per la Selvicoltura - Viale S. Margherita, 80, I - 52100 Arezzo, Italia
Tel: +39 0575 353021 Fax: +39 0575 353490 E-mail: issar@ats.it

ABSTRACT

The results of experimental investigations carried out by the Istituto Sperimentale per la Selvicoltura of Arezzo in the framework of national and european projects in order to define a sustainable silvicultural treatment for chestnut (*Castanea sativa* Mill.) coppice able to improve timber production, are reported. Silvicultural models alternative to short rotation coppice have been defined on the basis of early, frequent and of moderate-heavy intensity thinnings in order to: i) differentiate the traditional management under coppice system, ii) to increase the production of quality assortments, iii) to establish more functional and valuable stands from an ecological and environmental point of view. The aim of this study is to test the formulated silvicultural models throughout the evaluation of growth rhythm and of structural rearrangement by means of silvicultural treatments carried out with different intensities in coppices of different age. The experimental surveys have been carried out in young (15 years) and aged (38-42 years) coppice stands, located on Monte Amiata (Central Italy) at elevation between 800 and 1200 m a.s.l., on rich soils from volcanic substratum. The results confirm the high dynamism of coppices even at the older ages, the high sensitivity of the species to thinnings and the fast rearrangement of social ratios which determines the re-establishment of one-storeyed stands in a short time. In young coppices thinning practices (moderate-high intensity low thinnings) determine the fast re-establishment of a numerically conspicuous dominated layer only four years after the operation. In old coppices, low thinnings of moderate intensity stimulate the reactivity of dominant trees which support the sustained growth as a function of the gradual re-establishment of the canopy cover.

Key-words: chestnut, coppice, thinning, growth rhythm, stand structure

RESUME

Ce travail synthétise les résultats d'une série d'études réalisées par l'Istituto Sperimentale per la Selvicoltura d'Arezzo, ayant pour but la définition d'un traitement sylvicole applicable au taillis de châtaigner pour mettre en valeur la production en bois dans le cadre d'une gestion soutenable. On a défini des modèles de sylviculture alternatifs au taillis à courte rotation, sur la base d'éclaircies précoces, fréquentes et d'intensité modérée à forte. Le but est de diversifier une gestion devenue trop homogène, suite au régime de taillis, d'augmenter la production de bois de qualité et de créer des peuplements plus fonctionnels et à plus haute valeur écologique. L'objectif de l'étude est de valider les modèles, après le contrôle de l'accroissement et de la réorganisation structurale des peuplements suite à des éclaircies d'intensité différente sur taillis jeunes (15 ans) et plus âgés (38-42 ans) ; ces taillis sont situés sur le Monte Amiata (Italie centrale), entre 800 et 1200 mètres d'altitude, sur des sols d'origine volcanique de bonne fertilité. Les résultats confirment le dynamisme des taillis âgés, la bonne réactivité de l'espèce à l'éclaircie et la prompte réorganisation des peuplements qui reconstituent rapidement des structures monoplanes. Dans les jeunes taillis, l'éclaircie (par le bas et de moyenne-forte intensité) détermine la rapide reconstitution d'un étage dominé, seulement quatre ans après l'intervention. Même dans les taillis âgés, des éclaircies par le bas et de moyenne intensité stimulent la réactivité des individus dominants qui maintiennent des rythmes de croissance soutenus en fonction de la reconstitution graduelle du couvert.

Mots-clés : châtaigner, taillis, éclaircie, croissance, structure

RIASSUNTO

Gestione selvicolturale alternativa nei cedui di castagno (*Castanea sativa* Mill.) : effetti del trattamento sulla struttura e l'accrescimento del soprassuolo. Si riferiscono i risultati di una serie di indagini realizzate dall'ISS di Arezzo nel quadro di progetti di ricerca nazionali e finanziati dalla UE, finalizzati alla definizione di un trattamento selvicolturale applicabile ai cedui di castagno per valorizzarne la produzione legnosa nell'ambito di una gestione sostenibile. Sono stati definiti modelli selvicolturali alternativi al ceduo a turno breve sulla base di diradamenti precoci, frequenti e di discreta intensità con lo scopo di diversificare una gestione eccessivamente omogeneizzata dal governo a ceduo, di aumentare la produzione di assortimenti legnosi di qualità e di alto valore economico e di costituire soprassuoli più funzionali ed a maggiore valenza ecologica ed ambientale. L'obiettivo di questo studio è validare i modelli formulati attraverso la valutazione delle risposte incrementali e della riorganizzazione strutturale dei soprassuoli dopo interventi selvicolturali realizzati con differente intensità in cedui di età diversa. Le indagini sperimentali sono state condotte in popolamenti cedui giovani (15 anni) e adulti (38-42 anni), localizzati sul Monte Amiata (Italia centrale) a quote comprese tra 800 e 1200 m s.l.m., su suoli di buona o ottima fertilità, derivati da substrati vulcanici. I risultati confermano la notevole dinamicità dei cedui anche ad età avanzate, la forte reattività della specie al diradamento e la rapida riorganizzazione del soprassuolo che tende a ricostituire in tempi brevi strutture monoplane. Nei cedui giovani il diradamento (dal basso e di intensità medio-forte) determina la rapida ricostituzione di un piano dominato numericamente consistente, dopo soli quattro anni dall'intervento. Anche nei cedui adulti, diradamenti dal basso e di media intensità stimolano la reattività degli individui dominanti che mantengono ritmi di accrescimento sostenuti in funzione della ricostituzione graduale della copertura.

Parole chiave: castagno, ceduo, diradamento, accrescimento, struttura

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INTRODUCTION

The importance of chestnut tree from the economical, ecological and environmental point of view has been recognised for a long time by various authors either in national and european field (Bourgeois, 1992; Conedera & Giudici, 1994; Romane & Houssard, 1995; Becchi, 1996; Leonardi *et al.*, 1996; Avolio *et al.*, 1997; Bounous *et al.*, 1997; Minotta & Bassi, 1997; Berrocal *et al.*, 1998). Many research projects concern the study of a sustainable management for quality timber production from stands under coppice system; these projects examined the questions linked to silvicultural treatment, wood technology, ring shake, stands ecology, phytopathological status, genetic variability.

In Italy, the silvicultural history of chestnut woods is strictly related to social and economical organisation of extensive hilly and mountainous areas. Until '50 the orchards for fruit production were predominant; later due to the occurrence of social changes and the appearance of phytopathologies, they were abandoned and gradually converted into coppice system (Morandini, 1959; Palenzona *et al.*, 1987; Avolio, 1987). The traditional silvicultural treatment applied to these stands is planned on short rotations in order to produce small and medium poles for agricultural and structural use. Recently, a general market crisis has determined the prolongation of the rotations; therefore large areas with aged coppice stands are available to produce good quality timber by means of a silvicultural treatment more suited to the new requirements of sustainability.

From a technical point of view, the silvicultural method has been characterised and defined in the different phases (Amorini *et al.*, 1997a). The proposed cultivation models originated from the need to differentiate the management options, to improve the quality of timber production and to establish more functional stands. In this context the "Istituto Sperimentale per la Selvicoltura", in the framework of the national and european research projects (FOREST and ENVIRONMENT), has set up, since 1990, a series of experimental trials to define a sustainable silvicultural treatment able to improve also the quality of timber production (Amorini *et al.*, 1996a; Amorini *et al.*, 1996b; Amorini & Manetti, 1997; Cutini & Fabbio, 1997). The definition of cultivation models originated from a series of experimental trials on coppice stands of different age and under different silvicultural treatment. For their formulation the main biological characteristics of the species (sustained growth, tendency to originate one-storeyed stands and rapid regression of social rank) have been taken into account.

The aim of this study is to test the proposed models by means of the evaluation of growth rhythm and structural rearrangement after thinnings carried out with different intensity in coppices of different age.

MATERIALS AND METHODS

The alternative silvicultural models

The proposed alternative silvicultural models (Tables 1 and 2) differ mainly for the intensity of management and for the quality of assortments at the end of rotation and during the thinning cycle. The age of first thinning (10 or 15), the length of rotation (30 or 50 years), the frequency and the intensity of thinning are the distinctive characteristics of the two models. In both models the base principles are: i) the application of a low or intermediate thinning in accordance with the dynamics expressed by the chestnut stand under natural evolution, ii) a thinning grade able to preserve a balanced dominant storey over time. The medium rotation model is characterised by few thinning of heavy intensity (1/3 of basal area removal), while in the long rotation model the biomass removed decreases to 20-25%.

		Before thinning			**Removed**		**After thinning**		
Age years	Dominant height m	shoots number n ha^{-1}	basal area m^2 ha^{-1}	average dbh cm	shoots number %	basal area %	shoots number n ha^{-1}	basal area m^2 ha^{-1}	average dbh cm
10	> 10	5500	26.9	7.9	**50**	**35**	2750	17.5	9.0
mortality = *4 %*		*current increment of basal area* = *1.9* m^2 $ha^{-1}an^{-1}$							
15	13.5 - 15.5	2640	27.0	11.4	**50**	**30**	1320	18.9	13.5
mortality = *2 %*		*current increment of basal area* = *1,6* m^2 $ha^{-1}an^{-1}$							
22	16.5 - 18.0	1294	30.1	17.2	**40**	**30**	776	21.1	18.6
mortality = *1 %*		*current increment of basal area* = *1.4* m^2 ha^{-1} an^{-1}							
30	19.0 - 20.0	768	32.3	23.1					

Table 1. Silvicultural treatment alternative to short rotation coppice defined as "Medium Rotation Model". The length of rotation, the frequency and the intensity of thinnings and the main dendrometrical characteristics of the stand before and after thinning are reported

		Before thinning			**Removed**		**After thinning**		
Age years	dominant height m	shoots number n ha^{-1}	basal area m^2 ha^{-1}	average dbh cm	shoots number %	basal area %	shoots number n ha^{-1}	basal area m^2 ha^{-1}	average dbh cm
15	> 13	3900	31.5	10.1	**50**	**35**	1950	20.5	11.6
mortality = *3 %*		*current increment of basal area* = *1.6* m^2 $ha^{-1}an^{-1}$							
22	16.5 - 18.0	1892	31.7	14.6	**40**	**27**	1135	23.1	16.1
mortality = *2 %*		*current increment of basal area* = *1.4* m^2 $ha^{-1}an^{-1}$							
30	19.0 - 20.0	1112	34.3	19.8	**30**	**22**	779	26.8	20.9
mortality = *1.5 %*		*current increment of basal area* = *1.4* m^2 ha^{-1} an^{-1}							
37	21.0 - 22.0	767	35.2	24.2	**30**	**22**	537	27.4	25.5
mortality = *1 %*		*current increment of basal area* = *1.2* m^2 ha^{-1} an^{-1}							
44	22.5 - 23.0	531	35.8	29.3	**30**	**25**	372	26.9	30.3
mortality = *0 %*		*current increment of basal area* = *1.0* m^2 ha^{-1} an^{-1}							
50	23.5 - 24.0	370	32.9	33.6					

Table 2. Silvicultural treatment alternative to short rotation coppice defined as "Long Rotation Model". The length of rotation, the frequency and the intensity of thinnings and the main dendrometrical characteristics of the stand before and after thinning are reported

These proposals allow to get the extension of the positive growth phase over time, the balanced development of crown and stem and the diversification of stand structures at landscape level in the cultivation area. Because of the high degree of cultivation, they can be applied only in good site conditions and in the respect of some basic requirements as the threshold of dominant height and the recovery of basal area removed by thinning.

Important characters of these two models are the suitability to the different ownerships (public or private) and the flexibility of the system because it is possible to pass from a model to another depending on the management needs, as well as to restore the coppice system both in the subsequent stages of the cultivation regime than at the end of rotation because of the high resprouting capacity of chestnut stools (Bernetti, 1987).

The study area and experimental design

The researches were carried out in young (15 years) and aged (38-42 years) coppice stands located on Monte Amiata (Central Italy) between 800 and 1 200 m a.s.l., on rich soils from volcanic substratum and in good site conditions. The climate is mountain-mediterranean (annual rainfall = 1 547 mm; annual average temperature = 10°C) and is marked by summer drought and rainfall concentrated in autumn and winter. The stands, generally pure and of anthropic origin, are in the Quercus-Tilia-Acer vegetation belt. The main site characteristics and dendrometrical parameters of the plots under examination are reported (Table 3).

The two aged stand structures differ for their origin and for the silvicultural treatment applied. The current structure of HF (high forest) type can be defined as high forest because of the regular spatial distribution of stems and the presence of one shoot only per stool. This structure originates from two subsequent thinnings carried out at age 12 and 29 in a stand managed as coppice for poles production. On the contrary in the TC (thinned coppice) type the recent conversion from orchard for fruit production to coppice system is underlined by a low number of stools, still carrying 2-3 shoots; in this stand one thinning only was carried out at age 15.

The choice of the thinning regime to be tested followed the cultural indications of the proposed treatment models adjusting them to the actual conditions of the examined stands. In the young coppice, the good site index allowed to carry out a low and heavy thinning according to the indications forecast by the medium rotation model (first thinning at the age of 10). In the aged coppice, the indications from the long rotation model were used; the thinnings, tested at the age of in both experimental plots, differ for the intensity of basal area removed, more or less heavy as a function of the past silvicultural history of the stand.

The stands were characterised before the thinning by means of permanent plots and structural transects in which the dendrometrical (number of stools and shoots, dbh, height,) and structural (social rank, crown area, crown length, spatial distribution) parameters were surveyed (Amorini *et al.*, 1996). The surveys were also repeated in January 1998 in order to evaluate the effects of silvicultural treatments, 4 (YC), 3 (TC) and 6 (CC) years later.

RESULTS

Young coppice (YC)

Before thinning, the dendrometrical characters, basic to the application of the cultivation model as dominant height, number of shoots and basal area (Figure 1) were similar to those foreseen in the medium rotation model. The good site index - a dominant height of 13.8 m at 11 years - allowed to carry out a thinning with a slightly heavier intensity. The percentage of shoots number and basal area removed were 59 and 39% respectively, instead of 50 and 35%.

After four vegetative seasons, at age 15, the dendrometrical parameters, support for the alternative management, show higher values than those foreseen by the model. The dominant height reaches 16.0 m and the total biomass has already recovered the value expressed before thinning.

Besides, the current basal area increment (2.3 and 1.9 m^2 ha^{-1} yr^{-1} respectively in the plot and in the model) and the mortality rate (2.5 against 4.0%) as well as the fast rearrangement of social layers (the percentage of basal area in dominant and codominant layers decreases from 94% immediately after thinning to 75% four years later) underlined the opportunity to carry out the second thinning after short time.

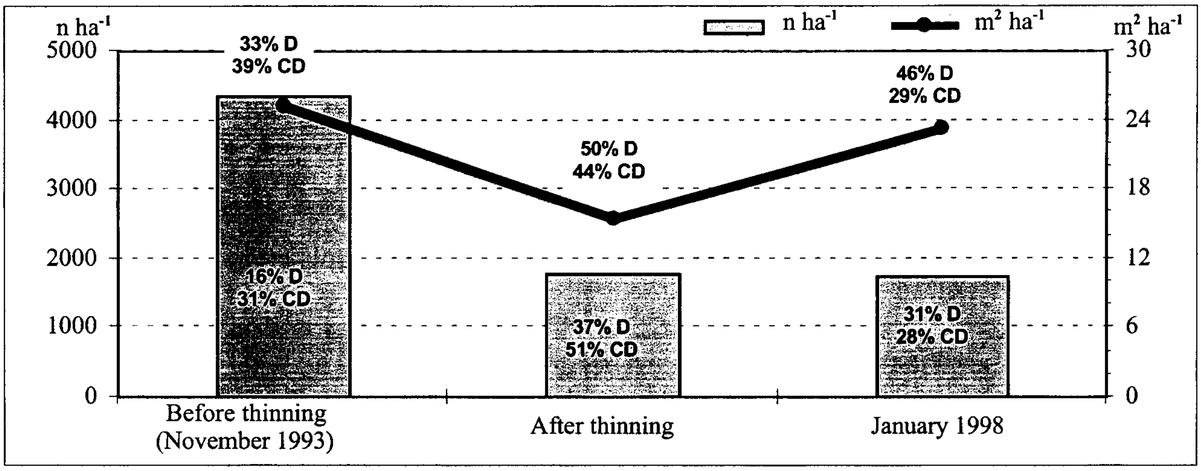

Figure 1. Young coppice (YC). Shoots number and basal area before and after thinning (at age 11) and 4 years later (January 1998). The percentage of the dominant (D) and codominant (CD) classes are also shown

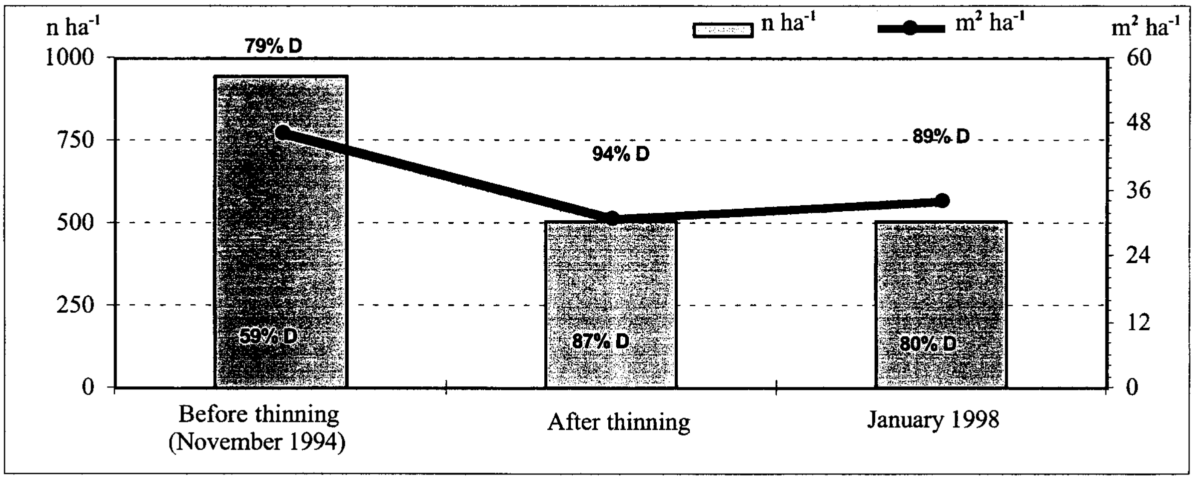

Figure 2. Thinned coppice (TC). Shoots number and basal area before and after thinning (at age 35) and 3 years later (January 1998). The percentage of the dominant class (D) is also shown

	Thinned coppice at age 11 (November 1993) 1st thinning (YC)	Thinned coppice at age 35 (November 1994) 2nd thinning (TC)	Thinned coppice at age 35 (November 1991) 3rd thinning (HF)
Elevation a.s.l. (m)	870	850	1090
Aspect	south-west	south	north-west
Slope (°)	8	6	10
Dominant height (m)	14.0	21.0	21.2
Number of stools (n ha-^{1})	697	414	720
Number of shoots (n ha-^{1})	4393	948	720
Basal area (m^2 ha-^{1})	31.14	46.48	34.28
% of removed basal area	32	34	14

Table 3. Main site characteristics and dendrometrical parameters of the examined stands before thinning and percentage of basal area removed by thinning. YC: young coppice; TC: thinned coppice; HF: high forest

Thinned coppice (TC)

In this structural type the silvicultural treatment applied at the age of 35, subsequent to only one thinning carried out at 15 years, followed the indications of the long rotation model (Figure 2). The aim was to constitute a dominant layer made up by well-balanced trees able to express a sustained and regular growth rhythm over time. The comparison of the dendrometrical parameters expressed by the plots and the model underlined the absence of an active silvicultural treatment; either the shoots number and the basal area showed values much higher in the study area. So in order to re-establish values of dendrometrical parameters close to those foreseen by the model at the same age, the intensity of thinning was heavier (46% and 34% respectively of shoots number and basal area).

The positive effect of thinning on stand structure and productivity is evident in the current increment of basal area (1.08 m^2 ha-^{1} yr-^{1}) expressed by the stand three years after thinning as well as in the analysis of the main descriptive parameters of the crowns (Table 4). The difference between the crown overlapping and canopy cover values explains the stand structural complexity. The thinning had considerably simplified the structure (difference from 51 to 18%) but it caused a positive and dynamic evolution of stand (difference = 23%), also underlined by the clear increase of the medium crown area (1.4 m^2 yr-^{1}). The rapid recovery of canopy cover is in fact another important character mainly when the goal "production" is linked to a multifunctional management of these stands.

Thinned coppice (HF)

The rules from the long rotation model were applied at the age of 35 years in a stand having the suited characters to undergo the thinning (Figure 3). The homogeneity of this silvicultural type is due to the structural shaping determined by the previous thinnings that progressively removed the regressive share of population and allowed a more harmonic development of the released trees.

The thinning removed a biomass rate lower (14%) than that foreseen by the model (22%) because of the high number of standards (72 ha-^{1}), still present at this age with a high basal area (33% of total basal area) and released because well integrated in the shoots population.

After six vegetative seasons, the stand has completely recovered the biomass removed; the basal area current increment is 1.3 m^2 ha-^{1} yr-^{1} (0.2 m^2 ha-^{1} yr-^{1} from standards), value higher than that indicated by the model. Also the analysis of the descriptive canopy parameters underlines the priority role of the silvicultural treatment and the noteworthy dynamics of these structures (Table 5). The smallest values of crown area recorded in this area in comparison with the TC plot are derived by a higher number of stools in the initial status and by the past silvicultural system that allowed a more regular spatial distribution of shoots, limiting the overlapping but maintaining the same canopy cover.

The limited differences between canopy cover and overlapping values indicate a marked structural simplification of this stand, determined by the previous thinnings and further enhanced by the last experimental one. The decrease of interindividual competition and structural complexity represents a means to obtain more equilibrated crowns and stems characterised by a regular growth rhythm, important assumptions to produce timber of a good quality (Macchioni & Pividori, 1996; Amorini *et al.*, 1997b; Fonti *et al.*, 1997).

The good site index, the recovery of biomass and canopy cover values and the re-establishment of social ratios allow to plan the next thinning at the age of 42 - 43 years when the trees released for the final harvesting will be selected.

DISCUSSION

The experimental trials carried out allow to assert that the two tested models are suitable to the real case-studies and sustainable from a productive and functional point of view. An important assumption for the application of the model is the evaluation of the site index of the stands because only coppices with a high fertility can react to heavy thinnings and maintain a high productivity level. Frequent thinnings are justified by the remarkable dynamics of these stands that show, just a few years after thinning, the fast rearrangement of social roles and the recovery of crown and growth parameters. The applied thinning, from low and of medium-heavy intensity, determine a simplification of the structure but concentrate the yielding capacity of the site on the selected individuals and contribute to the improvement of their morphological and physiological.

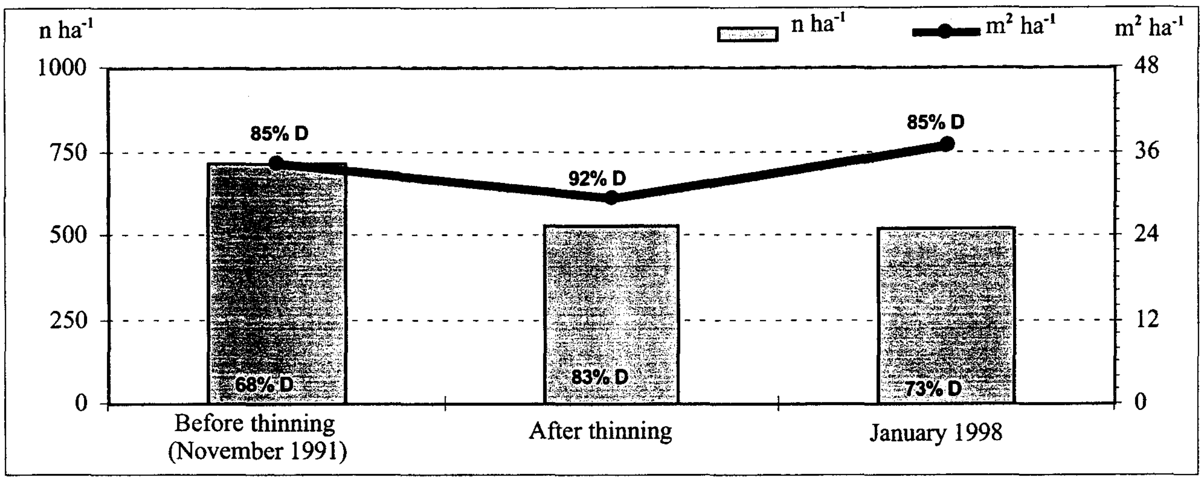

Figure 3. Thinned coppice (HF). Shoots number and basal area before and after thinning (at age 35) and 6 years later (January 1998). The percentage of the dominant class (D) is also shown

		Before thinning	After thinning	3 years later
Canopy cover	%	85	68	76
Overlapping	%	136	86	99
Crown area	m^2	17.0	20.7	25.0

Table 4. Thinned coppice (TC). Main descriptive canopy parameters and crown characteristics

		Before thinning	After thinning	6 years later
Canopy cover	%	84	73	85
Overlapping	%	106	87	104
Crown area	m^2	12.1	15.5	17.4

Table 5. Thinned coppice (HF). Main descriptive canopy parameters and crown characteristics

characteristics. Besides, the structural simplification, necessary when the main goal of cultivation is timber production, corresponds to the biological characteristics of the species that naturally aims to generate one storeyed stands.

The presence of coppices on large areas linked to a simplified management - short rotations and clearcuting - originated a homogeneous landscape in the cultivation area; the possibility to apply different management options represents therefore an important tool to increase the diversification of stand structures at landscape level.

Moreover, specific surveys about the influence of silvicultural treatment on stand ecology, genetic variability and canker evolution contributed to positively evaluate such models also from an ecological point of view. The onset of ring shake is on the contrary an aspect only partially investigated which needs to be further and extensively studied because its presence in chestnut timber can compromise the efforts of management.

REFERENCES

Amorini E., Bruschini S.& Manetti M.C., 1996a. I cedui di castagno del Monte Amiata: II analisi dendrometrica e strutturale di alcuni popolamenti sottoposti a diverso trattamento selvicolturale. *Ann. Acc. It. Sci. For.*, 45 : 213-234.

Amorini E., Bruschini S. & Manetti M.C., 1996b. I cedui di castagno del Monte Amiata: II analisi auxometrica ed osservazioni sulla cipollatura di alcuni popolamenti sottoposti a diverso trattamento selvicolturale. *Ann. Acc. It. Sci. For.*, 45 : 235-248.

Amorini E., Bruschini S. & Manetti M.C., 1997a. La sostenibilità della produzione legnosa di qualità dal ceduo di castagno: modello di trattamento alternativo al ceduo a turno breve. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno na-*

zionale sul castagno, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 217-231.

Amorini E., Bruschini S., Fioravanti M., Macchioni N., Manetti M.C., Thibaut B. & Uzielli L., 1997b. Studi sulle cause di insorgenza della cipollatura nel legno di castagno (*Castanea sativa* Mill.). *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 269-292.

Amorini E. & Manetti M.C., 1997. Le fustaie da legno di castagno del Monte Amiata. *Ann. Ist. Sper. Selv.*, Arezzo, 28: 53-61.

Avolio S., 1987. Il castagno nell'Italia meridionale (I parte). *Cellulosa e Carta*, 3: 12-23.

Avolio S., Dettori S. & Grassi G., 1997. Stato attuale della castanicoltura nelle regioni dell'Italia meridionale. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 68-82.

Becchi M., 1996. *Discorso sul castagno*. Consorzio Legnolegno scrl, Reggio Emilia : 209 p.

Bernetti G., 1987. *I boschi della Toscana*. Giunta Regionale Toscana, Edagricole., Bologna : 177 p.

Berrocal Del Brio M., Gallardo Lancho J.F. & Cardenoso Herrero J.M., 1998. *El Castano.* Mundi-Prensa, Madrid: 288 p.

Bounous G., Barrel A. & Pividori M., 1997. Stato attuale della castanicoltura nelle regioni dell'arco alpino e in Liguria. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 41-56.

Bourgeois C., 1992. *Le Châtaigner. Un arbre, un bois.* Institut pour le Developpement Forestier, Paris: 367 p.

Conedera M. & Giudici F., 1994. Problemi della fascia castanile al Sud delle Alpi della Svizzera: analisi della situazione e promovimento della ricerca. *Arbeitsberichte der Professur Forstpolitik und Forstokonomie, ETH*, Zurich: 35 p.

Cutini A. & Fabbio G., 1997. Impatto della gestione selvicolturale sulla funzionalità dei cedui di castagno. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno Nazionale sul Castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 245-257.

Fonti P., Giudici F., Kucera L., Ott E. & Pohler E., 1997. Studio sulla cipollatura in un ceduo castanile. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 293-302.

Leonardi S., Santa Regina I., Rapp M., Gallego H.A. & Rico M., 1996. Biomass, litterfall and nutrient content in *Castanea sativa* coppice stands of southern Europe. *Ann. Sci. For.*, 53: 1071-1081.

Macchioni N. & Pividori M., 1996. Ring shake and structural characteristics of a chestnut (*Castanea sativa* Mill.) coppice stand in northern Piedmont (northwest Italy). *Ann. Sci For.*, 53: 31-50.

Minotta G. & Bassi D., 1997. Stato attuale della castanicoltura nelle regioni dell'Italia centrale. *In:* Comunità Montana delle Prealpi Trevigiane (ed.), *Atti del Convegno nazionale sul castagno*, Cison di Valmarino (Treviso), 23-25 ottobre 1997: 57-67.

Morandini R., 1959. I problemi del castagno in Europa. *Monti e Boschi*, 1: 30-38.

Palenzona M., Ferrara A.M. & Prevosto M., 1987. L'economia del castagno nell'Italia settentrionale. *Cellulosa e Carta*, 3: 4-11.

Romane F. & Houssard C., 1995. The sustainability of chestnut ecosystem. *In*: Romane F. (ed.), *Sustainability of Mediterranean Ecosystems.* Ecosystem research report, n. 19, European Commission, Brussels.

ecologia mediterranea 26 (1-2), 163-167 (2000)

Edaphic characterization of chestnut tree orchards in Monterrei (Southeast Galicia, Spain)

Caractérisation des sols des châtaigneraies de Monterrei (Galice sud-est, Espagne)

J.M. QUEIJEIRO [1], M. DIAZ-RAVIÑA.[1,2] & J. de la MONTAÑA [1]

[1]Plant Biology and Soil Sciences Department, Vigo University, Edificio Politécnico, 32004 Orense, Spain. Tel: 07 34 988 387058 Fax : 07 34 988 387001 E-mail: jgarcia@uvigo.es
[2]Bioquímica del Suelo, Instituto de Investigaciones Agrobiológicas de Galicia (C.S.I.C.), Avda de Vigo s/n, Apartado 122, 15870 Santiago de Compostela, Spain.

ABSTRACT

Chestnut tree cultivation (*Castanea sativa* Mill.) has a long tradition in Galicia (Northwest of Spain), although in recent times its presence appears to be restricted to the far eastern and mid hill land sectors e.g. Monterrei area. The present study was conducted to characterize, from the physical-chemical view point, the soils under chestnut trees in the Monterrei region and evaluate their suitability for this culture. The results showed that most soils were Humic Cambisols developed over metamorphic rocks (phillite, micaschist, schist and slates) although crystalline materials (moscovite granites and two mica granites) could also be found. Soil texture ranged from sandy loam to silt loam and, in general, the soils were acid, with relatively high organic matter content in surface horizons and very low cation exchange capacity, with Al as dominant cation. The data also indicated that the organic matter content could result excessive and that extremely low pH or low Mg availability could induce moderate or strong limitations for chestnut cultivation.

Key-words : *Castanea sativa* Mill., soil fertility, limitations

RESUME

Le châtaignier (*Castanea sativa* Mill.) est utilisé en Galice (nord-ouest de l'Espagne) depuis très longtemps, mais actuellement sa présence reste limitée aux secteurs montagneux du sud-est (secteur de Monterrei). L'objectif de cette étude est de caractériser, au point du vue physico-chimique, les sols les plus répandus dans les vergers de châtaignier de Monterrei et de comparer ces résultats avec les exigences de cette espèce, afin de préciser la qualité des sols de Monterrei pour la culture du châtaignier.

Les résultats montrent que la plupart des sols sont des cambisols humiques développés sur des roches-mères métamorphiques (phyllites, micaschistes, schistes et ardoises), bien que l'espèce puisse être aussi présente sur des sols développés sur roches cristallines (muscovite et micas granites). La granulométrie des sols varie du sablo-limoneux à l'argilo-limoneux. Généralement, les sols sont acides, avec des teneurs élevées en matière organique dans les horizons superficiels. Leur capacité d'échange est faible et l'aluminium constitue toujours le cation dominant dans le complexe absorbant. Le niveau de matière organique peut s'avérer excessif et la forte acidité combinée à une faible teneur en magnésium, peuvent induire des contraintes modérées ou fortes pour la culture du châtaignier.

Mots-clés: *Castanea sativa* Mill., fertilité des sols, aptitude des sols

INTRODUCTION

Chestnut trees (*Castanea sativa* Mill.) are interesting species in maintaining agrosystem sustainability due to their high frugality as well as their efficiency in nutrients recycling under low nutrient availability conditions (Mahendrappa *et al.*, 1986; Ranger *et al.*, 1990). In addition, the chestnut tree is tolerant to acidic soil conditions. This high adaptability of chestnut trees to acidic and low nutrient environments has been shown for centuries. It has been also reported that the optimum tree growth is reached when organic matter content ranges between 2 and 3% (Breich, 1995) and that growth is limited in agrosystems with drainage problems in the subsoil. Numerous studies have showed that for centuries more than 150 varieties of chestnut trees have been cultivated without fertilizer input in Galicia (Northwest of Spain) where the representative soil characteristics are low pH, relatively high organic matter content and low nutrient status (Gonzalez-Prieto *et al.*, 1992; Fernández and Pereira, 1993). In principle, the regional characteristics seem to be quite adequate for chestnut growth, however information concerning the existence of climatic and edaphic limitations as well as the land suitability for this culture on different areas of this region is scarce. During the last years the chestnut tree cultivation has decreased considerably in Galicia, actually its presence seems to be confined to the agroforestry systems located in the far eastern mountain and mid hill land sectors e.g. Monterrei area in which chestnut trees are grown in association with herbaceous plants. The aim of this work is to characterize, from the physical-chemical view point, the soil component of these agrosystems. Furthermore, in order to evaluate the soils suitability for chestnut cultivation the results obtained were discussed in relation to the plant growth demands.

MATERIALS AND METHODS

Fourteen representative chestnut tree orchards located in the Monterrei area (altitude 400-1 263 m) were selected for this study. Trees are grown in association with agricultural crops (cereals), pastures or livestock. The mean annual rainfall and annual temperature varied from 900 to 1 500 mm and from 8.3° to 12.9 °C, respectively. The soils were classificated as Humic Cambisols (FAO-Unesco, 1990) and the dominant soil parent materials were metamorphic rocks (phillite, micaschist, schist and slates) although crystalline materials (moscovite granites and two mica granites) could also be found. Since soils were ploughed samples were only taken from the surface (0-30 cm) and deep layer (50-80 cm) of the soil profiles. All samples were air-dried after sampling, ground, sieved (2 mm) and stored at room temperature until used. The methods described by Guitián Ojea and Carballas (1976) were used to determine soil variables, including organic matter content (o.m., wet oxidation method), total nitrogen (N, Kjeldahl digestion), pH (H_2O, KCl and NaF), texture (international mechanical analysis method) and exchangeable ions (Ca, Mg, Na and K were extracted with 1*N* NH_4Cl and Al with 1*N* KCl; Al was measured by potentiometric titration, Ca and Mg by atomic absorption spectrophotometric analysis, and Na and K by flame photometric analysis. The effective cation exchange capacity (ECEC) was calculated from the sum of exchangeable cations (Meiwes *et al.*, 1986). All measurements were made in triplicate and results were expressed on an oven-dry matter basis. For each cation the percentage of saturation was calculated (StAl, StK, StCa, StMg).

RESULTS

As it was expected, the main characteristics of the soils under chestnuts trees were quite similar due to the fact that they were located in the same area. To facilitate comparison of data the average values were calculated using all soil samples (n = 14). The overall mean values and standard deviation (mean ± SD) as well as the range (minimum and maximum values) of each analysed variable in both surface and deep layers are summarized in Table 1. The values obtained lay within the range reported by Gonzalez-Prieto *et al.* (1996) in several soil ecosystems from the same region. The comparison of data obtained for the different soils showed that some differences could be detected in both physical (texture) and chemical characteristics (organic matter content, total N, exchangeable cations), whereas slight differences among soil samples as regard soil pH were observed. Soil texture, ranging from sandy loam to silt loam, was found to be strongly related to parent material

	Units	Soil depth (0-30 cm)			Soil depth (50-80 cm)		
		Mean ± SD	Min.	Max.	Mean ± SD	Min.	Max.
Gravels (G)	%	30.2	9.2	42.1	40.7	7.6	70.8
Coarse sand (CS)	%	24.9	10.2	55.1	25	6.9	49.1
Fine sand (FS)	%	26.8	14	45.1	27.3	7.3	40.3
Coarse silt (CS)	%	8.2	1.5	28.6	7.5	2.3	17.2
Fine silt (FS)	%	24.3	7.9	41.7	24.3	10.3	50.1
Clay (C)	%	15.3	7.0	23.0	16	10.5	25.5
pH H_20		4.5	4.1	5.0	4.6	4.1	5.1
pH KCl		3.9	3.4	4.3	4.0	3.2	4.8
pH NaF		9.0	7.8	10.6	9.3	8.1	10.2
O.M.	%	5.4	2.5	9.0	2.4	0.4	6.4
N	%	0.21	0.06	0.31	0.15	0.04	0.32
Ratio C/N		15.6	10.3	26.0	11.8	1.1	24.5
Ca	Cmol (+) kg^{-1}	0.53	0.23	1.20	0.21	0.03	0.65
K	Cmol (+) kg^{-1}	0.14	0.06	0.28	0.10	0.03	0.20
Mg	Cmol (+) kg^{-1}	0.19	0.06	0.4	0.15	0.02	0.55
Al	Cmol (+) kg^{-1}	3.59	1.85	6.03	3.58	1.50	9.08
ECEC	Cmol (+) kg^{-1}	4.56	2.27	6.61	4.12	1.99	10.01
StCa	%	12.2	4.1	32.1	5.6	0.7	13.9
StK	%	3.2	1.1	5.9	2.8	0.8	5.6
StMg	%	4.5	0.9	11.5	4.3	0.4	12.6
StAl	%	77.7	54.5	91.2	85.4	70.9	94.9

Table 1. Physical and chemical characteristics of soils under chestnut trees in Monterrei area (mean ± SD, n= 14). For symbols see material and methods section

Soil n°	**Texture**	**pH**	**O.M.**	**K**	**Mg**	**ECEC**
1		m		m	S	m
2		m				m
3		m	m			m
4		S				m
5		S		m	S	
6			m			
7		m	m			
8	m	S	S	m	S	
9	m	m	m	m		
10		S	m	m	S	
11		S	m	m	S	
12	m	S	m		m	
13	m			m	S	
14	S	m			m	

Table 2. Intensity of soil limitations for chestnut tree growth in Monterrei area (S: strong limitations; m: moderate limitations). Moderate limitations: texture, CSa 6 -14%, FSa 6 -14%, CSi 23 - 30%, FSi 26 - 40%, C 16 - 23%; pH 4.5 – 5 or 6 – 6.5; OM 5 - 8%; K 0.05 - 0.15 Cmol (+) kg^{-1}; Mg 0.15 - 0.24 cmol (+) kg^{-1}; ECEC <4 cmol (+) kg^{-1}

Strong limitations: texture, CSa < 6%, FSa < 6%, CSi > 30%, FSi > 40%, C > 23%; 4.5 < pH > 6.5; OM > 8%; K < 0.05 cmol (+) kg^{-1}; Mg < 0.15 cmol (+) kg^{-1}

being coarser in soils developed over granite rocks and finer in those over slates. The organic matter content as well as the C:N ratio values were relatively high, in contrast the soil pH and the effective cation exchange capacity values were quite low. Al was the dominant cation followed, with very low values, by Ca, Mg and K, respectively.

For each soil profile, the comparison of data obtained in the different horizons indicated that, as it was expected, the depth exerted an pronounced influence on main soil characteristics, particularly in the case of some chemical properties such as organic matter content, C/N ratio or exchangeable cations (Table 1). Surface layers presented higher values and showed lower coefficient variation than those in deep layers.

DISCUSSION

The data obtained in the physical-chemical characterization were compared with the reported threshold levels for different soil properties which may be required for growth of chestnut trees utilized for fruit production and located in Spain, France and Portugal (Buol *et al.*, 1975; Bará, 1986; Bourgeois, 1992; Calvo *et al.*, 1992; Breich, 1995; Ende and Evers, 1997; Portela *et al.*, 1999). The results obtained are showed in Table 2, that summarizes the intensity (moderate, strong) of edaphic limitations for chestnut tree growth in the Monterrei area.

It is recognized that the texture of the deep layer -between 50 and 80 cm- greatly affects the soil aptitude for chestnut tree cultivation. Since the tree does not grow in soils showing drainage problems, loam rather than fine textured subsoils are preferred. Likewise, coarse textured subsoils are not suitable for this cultivation due to the low water availability, however this seems to be not relevant for the selected soils. In five cases fine textures might represent moderate or strong limitations (clayey or silty) for the growth of chestnut trees (Table 2).

According to Breich (1995) between 2 and 3% of organic matter content is required for optimum chestnut tree growth. These values are lower than those commonly found in soils located in Galicia. Taking into account this criteria, most of the studied soils showed an excess of organic matter (Table 2). However, in these acid soils showing low nutrient availability, high Al content and sandy textures, a higher organic matter content (3-5%) may be adequate since field observations showed that both the tree growth and fruit production do not seem to be limited.

It is well known that chestnut tree is an acidophilic plant showing the highest crop production in soils with pH values of 5 to 6, although no important limitations occur in the pH range of 4.5 to 6.5. For the soils studied moderate or strong limitations can be expected due to the extremely low pH values observed for most surface samples (Table 2). Moreover, this is accompanied by a high exchangeable Al content that, in most cases, accounts for more than 80% of cation exchange capacity. It may be pointed out that in these soils, liming could be a suitable management practice to improve chestnut tree productivity because of its effects on both soil acidity and excess of organic matter.

Despite chestnut tree is a calcifuge plant, it requires Ca for growing, hence extremely low Ca contents and/or a high Al/Ca ratio can result in a detrimental effect on soil productivity. In principle, the soils selected do not seem to show Ca limitations as compared with the reported values (Breich, 1995; Calvo *et al.*, 1992). In the other hand, these trees are very exigent as regards K supply. In general, the highly unsaturated soils of the Monterrei area showed frequent strong limitations related to low Mg content, and moderate limitations for K content. Low Mg availability, which induced chlorosis, was also reported by other authors in Portuguese soils under chestnut trees (Portela *et al.*, 1999). Moderate limitations for ECEC were also observed in four of the studied soils (Table 2). Likewise moderate or strong limitations for available P content were also found for most soils (data not showed).

According the seeming edaphic limitations for chestnut tree cultivation the soils studied could be divided into three groups: i) four sites showing strong limitations in several soil properties (extremely low pH, low exchangeable Mg content), low K exchangeable and excess of Al in the exchange complex, they can be considered with low aptitude for chestnut growth ii) five sites that simultaneously presented several moderate limitations and this was occasionally accompanied by one important limitation (e.g. low pH, low Mg exchangeable or fine texture), they were soils with medium aptitude for chestnut growth, iii) five sites that can be considered with high aptitude, with only some moderate limitation.

The presented results show that the soils used for cultivation of chestnut tree in the Monterrei area are acid with high organic matter content in surface horizons and very low cation exchange capacity, with Al as dominant cation. Despite the existence of apparent edaphic limitations such as an excess of organic matter, extremely low pH or low Mg and K content the chestnut tree orchards have produced considerable and continuous yields over centuries. This seems to suggest that traditional varieties of chestnut trees are well adapted to these acidic soils without loss of productivity. A tentative explanation for this could be that proper water regimen supplied for low nutrient status. Further studies should be conducted in order to evaluate the agrosystems sustainability and determine if soil quality and/or production of chestnut trees can be improved by the modification of soil properties which seemingly could be a limitation for plant growth.

REFERENCES

Bará S., 1986. *Fertilización forestal.* Xunta de Galicia, Santiago de Compostela: 143 p.

Bourgeois C., 1992. *Le chataignier. Un arbre, un bois.* IDF. Paris: 367 p.

Breich H., 1995. *Le verger de châtaignier. Mise en place et entretien.* CTIFL. Centre de Laxande : 62 p.

Buol S. W., Sánchez P.A., Cate R. B. JR. & Granger M. A., 1975. Soil fertility capability classification. *In:* Bornemisza E. & Alvarado A. (eds.), *Soil Management in Tropical America.* North Car. St. Univ., Raleigh : 126-145.

Calvo R., Macías F. & Riveiro A., 1992. Aptitud agronómica de los suelos de la provincia de La Coruña (Cultivos, Pinos, Robles, Eucaliptos y Castaños). Diputación de La Coruña, La Coruña: 88 p.

Ende H.P. & Evers F.H., 1997. Visual magnesium deficiency symptoms (coniferous, deciduous trees) and threshold values (foliar, soil). *In*: Hüttl R.F. & Schaaf W. (eds.), *Magnesium Deficiency in Forest Ecosystems.* Kluvers Ecademic Public., London: 3-22.

FAO-Unesco, 1990. *Mapa Mundial de Suelos. Leyenda Revisada.* Roma : 142 p.

Fernández J. & Pereira S., 1993. *Inventario y Distribución de los Cultivares Tradicionales de Castaño (Castanea sativa Mill.) en Galicia.* Mon. INIA, 87. MAPA. Madrid : 271 p.

Gonzalez-Prieto S.J., Cabaneiro A., Villar M.C., Carballas M. & Carballas T., 1996. Effect of soil characteristics on N mineralization capacity in 112 native and agriculture soils from the norwest of Spain. *Biol. Fertil. Soils*, 22 : 252-260.

Gonzalez-Prieto S.J., Villar M.C., Carballas M. & Carballas T., 1992. Nitrogen mineralization and its controling factors in various kinds of temperature humid-zone soils. *Plant and Soil*, 144 : 31-44.

Gutián-Ojea F. & Carballas T., 1976. *Técnicas de análisis de suelos, 2ºnd ed.* Pico Sacro, Santiago de Compostela : 289 p.

Mahendrappa M.K., Foster N.W., Weetman G.F. & Krause H.H., 1986. Nutrient cycling and availability in forest soils. *Can. J. Soil Sci.*, 66 : 547-572.

Meiwes K.J., Khanna P.K. & Ulrich B., 1986. Parameters for describing soil acidification and their relevance to the stability of forest ecosystems. *Forest Ecol. Manage*, 15 :161-179.

Portela E., Ferreira-Cardoso J., Roboredo M., & Pimentel-Pereira M., 1999. Influence of magnesium deficiency on chestnut (*Castanea sativa* Mill.) yield and nut quality. *In*: Anaç D. & Martin-Prevel P. (eds.), *Improved Crop Quality by Nutrient Management.* Kluwer Academic Public., Dordrecht: 153-157.

Ranger J., Felix C., Bouchon J., Nys C. & Ravart M., 1990. Dynamique d'incorporation du carbone et des éléments nutritifs dans un taillis simple de châtaignier (*Castanea sativa* Mill.) *Ann. Sci. For.*, 47 : 413-433.

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Importance of *Castanea sativa* Mill. in honeys of central and north-eastern Sicily on the basis of the pollen grain analysis

Importance de *Castanea sativa* Mill. pour les miels de la Sicile centrale et nord-orientale, sur la base de l'analyse pollinique

W. DE LEONARDIS, C. DE SANTÌS, G. FICHERA. P.M.R. FIUMARA, N. LONGHITANO & A. ZIZZA

Department of Botany. University of Catania, Via A. Longo 19, 95125 Catania (Italy); e-mail: deleonardis@mbox.dipbot.unict.it

ABSTRACT

The microscopic analysis of pollen grains present in 28 honey samples collected in different locations of central and north-eastern Sicily showed the frequent presence of *Castanea sativa* Mill. pollen grains. Limited to the microscope analysis 11 samples were unifloral chestnut honeys and 16 multifloral honeys in which chestnut pollens predominated (>50%). The floristic aspects relative to the examined zones were also studied. These data, which have shown the apiarian importance of chestnut trees and their inherent economic significance, have also given another biological criterion in favor of chestnut ecosystem sustainability.

Key words: palynological analysis, *Castanea sativa*, chestnut sustainability

RESUME

L'analyse pollinique faite sur 28 échantillons de miel originaires de la Sicile centrale et nord-orientale a permis de mettre en évidence la présence fréquente de grains de *Castanea sativa* Mill. L'étude microscopique des miels a montré qu'il existe 11 miels monoflores de châtaignier et de 16 miels hétéroflores dans lesquels le pollen de châtaignier domine (>50%). Ont été aussi mis en évidence les aspects floristiques des territoires examinés. Ces données montrent l'importance apicole du châtaignier et son intérêt économique certain. Ces résultats justifient de prendre en compte les châtaigneraies dans une optique de développement durable.

Mots-clés : analyse pollinique, *Castanea sativa*, développement durable des châtaigneraies

INTRODUCTION

Vegetation in the submountain and hilly areas of Sicily consists of oaks, chestnuts and scrub composed of various flora interspersed with tracts of bush and pasture-land. Anthropic influence is evidenced by the presence of cultivated species (fruit orchards, vineyards, vegetables) and of introduced species such as *Eucalyptus camaldulensis*, *Robinia pseudacacia*, *Ailanthus altissima*, etc., which tend to replace the autochthonous taxa. Vegetation in the lower geographical zones is frequently typical of ruderal areas, of crops in the presence of weeds and uncultivated species (Giacomini, 1960, 1966; Hofmann, 1960; Furnari, 1965; Gramuglio, 1968; Maugeri, 1972, 1978; Poli *et al.*, 1972, 1978; Poli & Maugeri, 1974; Ronsisvalle & Signorello, 1979; Ferro *et al.*, 1980; etc.).

The chestnut, an entity with entomogamous pollination and very abundant pollen production, is frequently visited by pollinators for both its nectar and pollen (Maurizio & Graft, 1969; Cirnu, 1972). In contrast, other non-nectariferous *Fagaceae* (*Quercus* spp.) with anemogamous pollination are of lesser apiarian importance since only the pollens are collected.

As part of an extensive project for the melissopalynological analysis of Sicilian honeys (De Leonardis *et al.*, 1982a, 1982b, 1984a, 1984b, 1986a, 1986b, 1988, 1989a, 1989b, 1992, 1996, 1998; De Leonardis & Zizza, 1994; Zizza *et al.*, 1985a, 1985b), the present study, limited to the microscopic analysis of pollen grains present in honeys, aimed to establish the apiarian importance of the chestnut in Sicily in order to provide a further biological criterion in favour of the chestnut ecosystem sustainability.

MATERIALS AND METHODS

Morphobiometric analysis of pollen was carried out on specimens acetolysed according to Erdtman (1960) prior to observation with a Zeiss Axiolab microscope with 100x objective in oil immersion.

Palynological analyses were carried out according to the standards established by the International Commission of Agricultural Botany of the U.I.S.B (Louveaux *et al.*, 1978). The 28 honey samples examined, obtained by centrifugation, came from areas on Etna, the Nebrodi, the Peloritani and the Erei mountains (Table 1).

Nomenclature and systematic placement follow the works of Pignatti (1982) while identification of pollen grains is based on Ricciardelli D'Albore & Persano Oddo (1978) and Ricciardelli D'Albore (1997, 1998).

RESULTS AND DISCUSSION

Floristic aspects

In the zone were the apiaries are found (ca. 700-900 m a.s.l.) chestnut stands are generally made up of mixed woods with a prevalence of *Castanea sativa* and other arboreal types and shrubs. From the phytosociological point of view there are species characterized by *Querco-Fagetea* with *Rubus ulmifolius*, *Brachypodium sylvaticum*, *Hedera helix*, *Clinopodium vulgare*, *Quercus virgiliana*, *Lamium flexuosum*, *Tamus communis*, etc. and species characterized by *Quercetea ilicis* with *Cytisus villosus*, *Quercus ilex*, *Rubia peregrina*, *Calicotome infesta*, *Cyclamen repandum*, *Teucrium siculum*, *Asparagus acutifolius*, *Ruscus aculeatus*, etc. Other species present are: *Daucus carota*, *Trifolium pratense*, *T. stellatum*, *T. campestre*, *Vicia villosa* ssp. *varia*, *Lathyrus latifolius*, *Leopoldia comosa*, *Silene sicula*, *Linaria purpurea*, *Micromeria graeca*, *Achillea ligustica*, *Bellis perennis*, etc.

In the more impervious areas where there are accumulations of masses and debris there is a shrub vegetation characterized by groups of *Calicotome infesta* and *Cytisus villosus* with species characterized by *Quercetea ilicis* with *Teucrium siculum*, *Rubia peregrina*, *Quercus ilex*, *Cyclamen repandum*, *Smilax aspera*, *Silene sicula*, *Tolpis virgata*, *Rosa canina*, *Sanguisorba minor*, etc. In particular, Etna is characterized by shrub groups such as *Genista aetnensis* and *Spartium junceum* (Poli *et al.*, 1978b) associated with *Fraxinus ornus*, *Arabis turrita*, *Brachypodium sylvaticum*, *Rubus ulmifolius*, *Cytisus villosus*, *Teucrium siculum*, *Bromus sterilis*, *Centranthus ruber*, *Achillea ligustica*, *Tanacetum siculum*, *Daucus carota*, *Linaria purpurea*, *Trifolium arvense*, etc..

Sample	Origin	Honey
n.1	Erei	Multifloral
n.2	Etna	Multifloral
n.3	Etna	Unifloral
n.4	Etna	Unifloral
n.5	Etna	Multifloral
n.6	Etna	Unifloral
n.7	Etna	Unifloral
n.8	Etna	Unifloral
n.9	Etna	Unifloral
n.10	Etna	Multifloral
n.11	Etna	Multifloral
n.12	Etna	Unifloral
n.13	Etna	Unifloral
n.14	Etna	Multifloral
n.15	Nebrodi	Multifloral
n.16	Nebrodi	Unifloral
n.17	Nebrodi	Multifloral
n.18	Nebrodi	Multifloral
n.19	Nebrodi	Multifloral
n.20	Nebrodi	Multifloral
n.21	Nebrodi	Unifloral
n.22	Nebrodi	Multifloral
n.23	Nebrodi	Multifloral
n.24	Nebrodi	Multifloral
n.25	Nebrodi	Multifloral
n.26	Nebrodi	Multifloral
n.27	Nebrodi	Unifloral
n.28	Peloritani	Multifloral

Table 1. Origin and characterization of the honey samples

On the Nebrodi there are diffuse formations of shrubs that develop in the degraded areas of frequent fires and excessive pasturing. These are characterized by spiny and liane plants of *Crataego-Prunetea* such as *Calicotome infesta*, *Crataego monogyna*, *C. laciniata*, *Prunus spinosa*, *Rosa canina*, *Pyrus amygdaliformis*, *Smilax aspera*, etc. These species are often associated with *Cistus incanus* and *C. salvifolius*.

Along the edges of roads and paths, in sunlit areas, there is a vegetation than can be ascribed to the association of *Pteridio-Tanacetetum siculi* (Brullo & Marcenò, 1985) with *Tanacetum siculum*, *Pteridium aquilinum*, *Notobasis syriaca*, *Onopordon illyricum*, *Eryngium campestre*, *Cichorium intybus*, *Bromus sterilis*, *Origanum vulgare*, *Carduus pycnocephalus*, *Vicia villosa* ssp. *varia*, *Daucus carota*, etc.

In the more open parts, there are pastures with a prevalence of *Dactylis hispanica* and *Lolium perenne* often associated with *Plantago lanceolata*, *Trifolium repens*, *Ranunculus bulbosus*, *Avena sterilis*, *Melilotus sulcata*. At lower levels there are, near the apiaries, small areas of pastures prevalently of *Hedysarum coronarium*.

The infestive vegetation is various with different cultures present near the areas of apiaries. In the *Citrus* orchards the infestive vegetation in the winter-spring period (during which the chestnut flowers) is characterized by the association of *Fumario-Stellarietum neglectae* (Maugeri, 1972, 1978) belonging to the alliance *Fumario-Euphorbion* (*Polygono-Chenopodietalia*). Species characteristic of this association are *Stellaria neglecta* and *Fumaria capreolata* often associated with *Oxalis pes-caprae*, *Ranunculus muricatus* and *Scrophularia peregrina*.

Other species that are present with interest for apiculture are *Lamium amplexicaule*, *Chrysanthemum segetum*, *Calendula arvensis*, *Veronica persica*, *Capsella rubella*, *Medicago hispida*, *Geranium rotundifolium*, *Sisymbrium officinale*, *Brassica fruticulosa*, *Vicia villosa* ssp. *varia*, *Hedera helix*, *Vicia sativa*, *Anthemis praecox*, *Borago officinalis*, *Lathyrus clymenum*, *Hedysarum coronarium*, etc. Infestive vegetation of arboreal cultivation such as *Malus domestica*, *Pyrus communis* and others is characterized by groups of *Trifolium nigrescens* and *Galactites tomentosa* (Poli & Maugeri, 1974) referable to *Echio-Galactition*, to which the following are associated *Bromus hordeaceus*, *Bellardia trixago*, *Geranium rotundifolium*, *Brassica fruticulosa*, *Rumex pulcher*, *Avena barbata*, *Senecio vulgaris*, *Echium vulgare*, *Trifolium stellatum*, *Hypochoeris radicata*, *Vicia villosa* ssp. *varia*, *Trifolium campestre*, *Daucus carota*, *Clinopodium vulgare*, *Lotus ornithopodioides*, *Origanum vulgare*, *Calendula arvensis*, etc.

The floristic investigation could thus represent a new approach to evaluate the apiarian potential of chestnut stands and give the necessary encouragement for apiculture activities in these areas for the production of honeys of botanical origin and geographically controlled.

Palynological analysis

Limited to the microscope analysis of honeys examined, Table 1 clearly shows, other than the origin of the samples, that 11 of the 28 honey samples are unifloral chestnut honeys, 8 of which originated in the Etna area and 3 in the Nebrodi. The remaining 16 samples are multifloral honeys with a predominant presence - over 50% - of chestnut pollens. The Table 2 evidences the list of all taxa observed in honey samples.

Figure 1 shows the constant presence of pollen grains of *C. sativa* in all the samples with values not less than 50%. The most represented taxa are *Hedysarum coronarium* followed by *Brassica* type, *Eucalyptus* spp., *Rosaceae, Quercus* spp., *Trifolium* gr. *repens*, *Genisteae*, *Trifolium* gr. *pratense* and *Lobularia* type. The term “other pollens” indicates all the taxa with a frequency of <= 3% such as *Lotus* spp., *Vicia* spp., *Medicago* spp., *Robinia pseudacacia*, *Phaseolus/Vigna*, *Rubus* spp., *Prunus* spp., *Pyrus* spp., *Potentilla* spp., *Sanguisorba minor*, *Matthiola* spp., *Daucus* spp., *Cichorium* type, *Carduus* type, etc.

These results confirm for Sicily what is already known for other areas (Maurizio & Louveaux, 1965; Ferrazzi, 1977, 1982a, 1990; Ferrazzi & Patetta, 1980; Ricciardelli D'Albore & Piastrelli, 1977; Sánchez Cunqueiro & Sáenz Laín, 1982; Simonetti & Barbattini, 1986; Ferrazzi & Botasso, 1989; Ferrazzi *et al.*, 1990; Priore & Ferrazzi, 1991): the importance of *C. sativa* in apiarian terms is such as to rate this species as fundamental for honey production.

CONCLUSION

The chestnut produces considerable amounts of nectar and, given the size of chestnut woods, it thus enables bees to produce abundant quantities of unifloral honey. It is common not only in northern Italy where it constitutes one of the most important essential oils in apiculture (Ricciardelli D'Albore & Persano Oddo, 1978; Pérez de Zabalza Madoz & Gómez Ferreras, 1988; Ferrazzi, 1982b; Simonetti *et al.*, 1989; Persano Oddo *et al.*, 1995, 2000), but also in Switzerland, Germany, France, Spain, Hungary and Yugoslavia (Maurizio & Louveaux, 1965; Louveaux *et al.*, 1978).

Over the years the mountainous areas of Sicily have gradually been abandoned, with consequent environmental degradation. Developing apicultures in the presence of the chestnut as the primary essence in mountain zones – taking advantage of low pollution levels and a zero-cost resource like flowering – could be a source of income for the local populations whose main activity is pasturage allowing, therefore, a social economic development.

Families	**Taxa**
Pinaceae	*Pinus* spp.
Cupressaceae/	
Taxaceae	
Juglandaceae	*Juglans regia*
Betulaceae/	
Corylaceae	
Fagaceae	*Castanea sativa*
Fagaceae	*Quercus* spp.
Ulmaceae	*Celtis* spp.
Urticaceae	*Urtica/Parietaria*
Polygonaceae	*Rumex* spp.
Portulacaceae	*Portulaca oleracea*
Caryophyllaceae	
Caryophyllaceae	*Silene* spp.
Caryophyllaceae	*Spergularia* spp.
Chenopodiaceae/	
Amaranthaceae	
Cactaceae	*Opuntia* spp.
Ranunculaceae	
Brassicaceae	*Brassica* type
Brassicaceae	*Lobularia* type
Brassicaceae	*Matthiola* spp.
Resedaceae	*Reseda* spp.
Rosaceae	
Rosaceae	*Potentilla* spp.
Rosaceae	*Prunus* spp.
Rosaceae	*Pyrus* spp.
Rosaceae	*Rubus* spp.
Rosaceae	*Sanguisorba minor*
Fabaceae	*Coronilla* spp.
Fabaceae	*Dorycnium* spp.
Fabaceae	Genisteae
Fabaceae	*Hedysarum coronarium*
Fabaceae	*Lotus* spp.
Fabaceae	*Medicago* spp.
Fabaceae	*Melilotus* spp.
Fabaceae	*Phaseolus/Vigna*
Fabaceae	*Robinia pseudacacia*
Fabaceae	*Trifolium* gr. *pratense*
Fabaceae	*Trifolium* gr. *repens*
Fabaceae	*Vicia* spp.
Fabaceae	*Vicia faba/Pisum*
Oxalidaceae	*Oxalis* spp.
Euphorbiaceae	*Euphorbia* spp.
Euphorbiaceae	*Mercurialis* spp.
Rutaceae	*Citrus* spp.
Anacardiaceae	*Pistacia* spp.
Anacardiaceae	*Rhus coriaria*
Rhamnaceae	*Rhamnus* spp.
Vitaceae	*Parthenocissus* spp.
Vitaceae	*Vitis vinifera*
Cistaceae	*Cistus* spp.
Lythraceae	*Lythrum* spp.
Myrtaceae	*Eucalyptus* spp.
Araliaceae	*Hedera helix*
Apiaceae	
Apiaceae	*Ammoides pusilla*
Apiaceae	*Daucus* spp.
Apiaceae	*Eryngium* spp.
Apiaceae	*Smyrnium* spp.
Ericaceae	*Erica/Arbutus*
Oleaceae	
Rubiaceae	*Galium* spp.
Convolvulaceae	
Convolvulaceae	*Calystegia* spp.
Convolvulaceae	*Convolvulus* spp.
Boraginaceae	*Anchusa* spp.
Boraginaceae	*Borago officinalis*
Boraginaceae	*Cerinthe major*
Boraginaceae	*Cynoglossum* spp.
Boraginaceae	*Echium* spp.
Lamiaceae	*Salvia* spp.
Lamiaceae	*Sideritis romana*
Lamiaceae	*Teucrium* spp.
Lamiaceae	*Thymus* spp.
Scrophulariaceae	
Scrophulariaceae	*Antirrhinum* spp.
Scrophulariaceae	*Linaria* spp.
Scrophulariaceae	*Verbascum* spp.
Scrophulariaceae	*Veronica* spp.
Plantaginaceae	*Plantago lanceolata*
Valerianaceae	*Centranthus ruber*
Dipsacaceae	*Scabiosa* spp.
Campanulaceae	
Campanulaceae	*Campanula* type
Asteraceae	*Anthemis* type
Asteraceae	*Calendula* spp.
Asteraceae	*Carduus* type
Asteraceae	*Carlina/Atractylis*
Asteraceae	*Carthamus* type
Asteraceae	*Centaurea jacea* gr.
Asteraceae	*Cichorium* type
Asteraceae	*Galactites tomentosa*
Asteraceae	*Senecio* spp.
Liliaceae	*Allium* spp.
Liliaceae	*Asphodelus microcarpus*
Poaceae	
Araceae	

Table 2. List of taxa present in honey samples

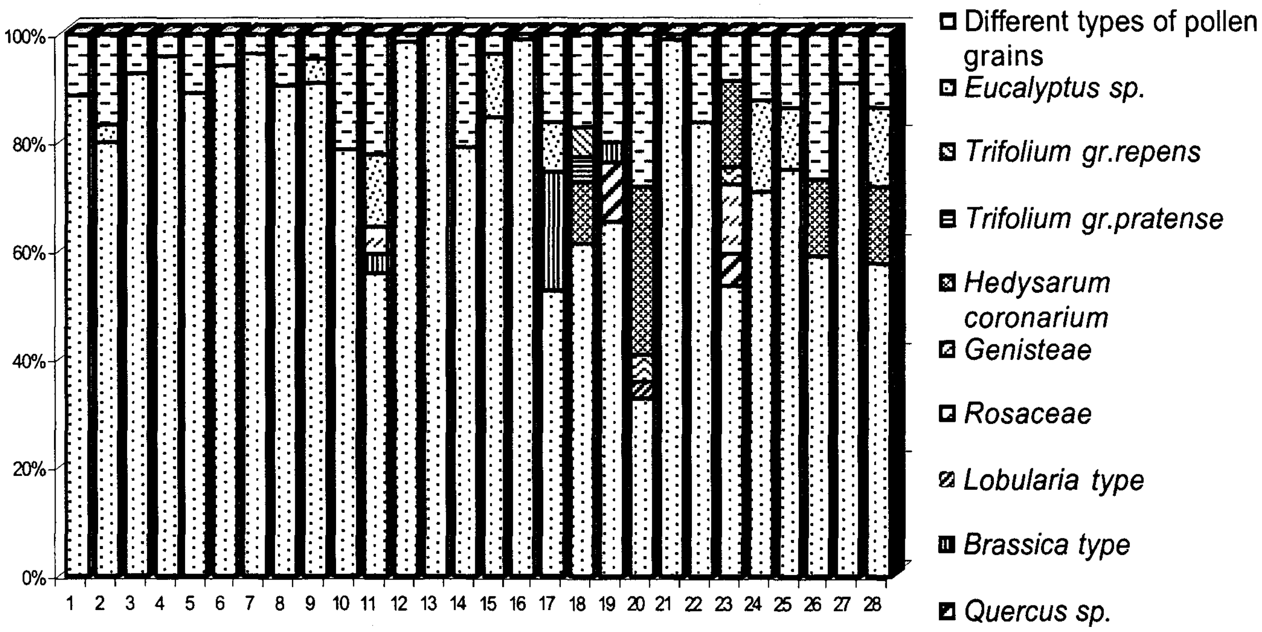

Figure 1. Percentage of pollen grains in honey samples

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REFERENCES

Brullo S. & Marcenò C., 1985. Contributo alla conoscenza della vegetazione nitrofila della Sicilia. *Colloques phytosoc.*, 12 : 23-148.

Cirnu I.V., 1972. *Plantes mellifères*. Ceres, Bucarest.

De Leonardis W., Duro A., Longhitano N., Piccione V., Scalia C. & Zizza A., 1984a. Schede melissopalinologiche della Flora Apistica Siciliana. II°. *Boll. Acc. Gioenia Sci. Nat. Catania,* 17 (324): 291-375.

De Leonardis W., Duro A., Longhitano N., Piccione V., Scalia C. & Zizza, A., 1984b. Schede melissopalinologiche della Flora Apistica Siciliana. III°. *Boll. Acc. Gioenia Sci. Nat. Catania,* 17 (324): 377-467.

De Leonardis W., Duro A., Longhitano N., Piccione V., Scalia C. & Zizza A., 1986a. Schede melissopalinologiche della Flora Apistica Siciliana. IV°. *Boll. Acc. Gioenia Sci. Nat. Catania,* 19 (327): 299-390.

De Leonardis W., Duro A., Longhitano N., Piccione V., Scalia C. & Zizza A., 1988. Schede melissopalinologiche della Flora Apistica Siciliana. V°. *Boll. Acc. Gioenia Sci. Nat. Catania,* 21 (333): 75-167.

De Leonardis W., Duro A., Longhitano N., Piccione V., Scalia C. & Zizza A., 1992. Schede melissopalinologiche della Flora Apistica Siciliana. VI°e VII°. *Boll. Acc. Gioenia Sci. Nat. Catania,* 25 (340): 279-395.

De Leonardis W., Ferrauto G., Fichera G., Longhitano N. & Zizza A., 1998. Contributo alla conoscenza dei mieli siciliani. Monti Peloritani (ME). In: Bertuzzi G. (ed.) *Giornata di Studi in Ricordo di Daria Bertolani Marchetti.* Aedes Muratoriana. Modena: 307-318..

De Leonardis W., Longhitano N., Meli R., Piccione V. & Zizza A., 1982a. Schede melissopalinologiche della Flora Apistica Siciliana. I°. *Inform. Bot. Ital.*, 14 (1): 27-93.

De Leonardis W., Longhitano N. & Piccione V., 1982b. Schede melissopalinologiche della Flora Apistica Siciliana. Introduzione. *Nat. Sicil.* 4-6 (3-4): 99-110.

De Leonardis W., Longhitano N. & Zizza A., 1989a. Relazione tra ambiente floristico e origine botanica dei mieli iblei (Sicilia sud-orientale). *Apicoltura,* 5: 73-118.

De Leonardis W., Longhitano N. & Zizza A., 1989b. Relazione tra ambiente floristico e analisi pollinica dei mieli iblei (Sicilia sud-orientale). *Inform. Bot. Ital.*, 21 (1/3): 308-319.

De Leonardis W., Piccione V. & Zizza A., 1986b. Flora Melissopalinologica Italiana. Chiavi d'identificazione. *Boll. Acc. Gioenia Sci. Nat. Catania,* 19 (329): 309-474.

De Leonardis W. & Zizza A., 1994. Flora di interesse apistico dell'isola di Salina (Arcipelago Eoliano). Prospettive e Potenzialità. *Apicoltura,* 9: 73-101.

Erdtman G., 1960. The acetolysis method. *Svensk. Bot. Tidskr.*, 54: 561-564.

Ferrazzi P., 1977. Analisi melissopalinologica di mieli della Liguria occidentale. *Apicolt. mod.*, 68: 74-79.

Ferrazzi P ., 1982a. Flora d'interesse apicolo della Val Sangone. *Apicolt. mod.*, 73: 89-99.

Ferrazzi P ., 1982b. Castagno. *Apicolt. mod.*, 73: 57-59.

Ferrazzi P., 1990. Attività bottinatrice di *Apis mellifera* L. in Valle Bormida. *Apicolt. mod.*, 81: 61-69.

Ferrazzi P. & Botasso, B., 1989. Indagini sull'attività di raccolta di Apis mellifera L. in Valle Maira. *Apicolt. mod.*, 80: 69-81.

Ferrazzi P. & Patetta A., 1980. Flora d'interesse apicolo della Liguria. *Apicolt. mod.*, 71: 51-59.

Ferrazzi P., Patetta A. & Manino A., 1990. Caratterizzazione dei mieli della Valle Maira. *Apicolt. mod.*, 81: 13-26.

Ferro G., Coniglione P., Oliveri S., Scuderi M. & Grasso S., 1980. Osservazioni fitosociologiche sugli aggruppamenti di Sicilia. *Atti Accad. Gioenia Sci. Nat. Catania*, s.7, 12: 39-66.

Furnari F., 1965. Boschi di *Quercus suber* L. e di *Quercus ilex* L. e garighe del *Rosmarino-Ericion* in territorio di Santo Pietro. (Sicilia meridionale). *Boll. Ist. Bot. Univ. Catania*, s.3, 5: 1-3.

Giacomini V., 1960. La flora dell'Etna. *Vie d'Italia, T.C.S.*, Milano, 66 (4): 947-506.

Giacomini V., 1966. L'Etna Parco Nazionale. Un paesaggio incomparabile da salvare e valorizzare. *Italia Forest. Montana* Firenze, 21 (3): 109-116.

Gramuglio G., 1968. Rinvenimento del faggio sui Monti Peloritani. *Giorn. Bot. Ital.*, 102 (3): 229-230.

Hofmann A., 1960. Il faggio in Sicilia. *Flora et Vegetatio Italica,* Sondrio, mem. 2, 235 p.

Louveaux J., Maurizio A. & Vorwohl G., 1978. Methods of melissopalynology. *Bee World*, 59: 139-157.

Maugeri G., 1972. Flora infestante gli agrumeti dell'Etna. *Boll. Accad. Gioenia Sci. Nat. Catania*, s. 4, 11: 186-213.

Maugeri G., 1978. La vegetazione infestante gli agrumeti dell'Etna. *Not. Fitosoc. Bologna*, 15: 45-55.

Maurizio A. & Grafl I., 1969. *Das Trachtpflanzenbuch*. Ehrenwirth Verlag, Munchen.

Maurizio A. & Louveaux J., 1965 *Pollens des plantes mellifères d'Europe*. Union des Groupements apicoles français, Paris: 148 p.

Pérez de Zabalza Madoz A.I. & Gomez Ferreras C., 1988. Análisis polínico de las mieles de la Navarra húmeda del Noroeste. In: Civis Llovera J., Valle Hernández M.F. (eds.), *Actas VI Simp. Palinol.* Salamanca: 239-245.

Persano Oddo L., Piazza M.G., Sabatini A.G. & Accorti M., 1995. Characterization of unifloral honeys. *Apidologie*, 26 (6): 453-465.

Persano Oddo L., Sabatini A.A., Accorti M., Marcazzan G.L., Piana M.L., Piazza M.G. & Pulcini P., 2000. *I mieli uniflorali italiani. Nuove schede di caratterizzazione*. Ministero delle Politiche Agricole e Forestali, Roma: 108 p.

Pignatti S., 1982. *Flora d'Italia*. Edagricole, Bologna.

Poli E., Di Benedetto L., Ferlito N. & Lo Giudice R., 1978a. Stazioni Etnee di Faggio a bassa quota. *Atti Accad. Gioenia Sci. Nat. Catania*, s. 7, 10: 135-148.

Poli E., Lo Giudice R. & Ferlito N., 1978b. La vegetazione della valle S. Giacomo (Etna). *Atti Acc. Gioenia Catania*, s-7, 10: 253-319.

Poli E. & Maugeri G., 1974. I boschi di Leccio del versante Nord-occidentale dell'Etna. *Boll. Accad. Gioenia Sci. Nat. Catania*, s. 4, 12 (5-6): 741-759.

Poli E., Signorello P. & Maugeri G., 1972. Contributo alla conoscenza della vegetazione dei Nebrodi. *Giorn. Bot. Ital.*, 106: 297-298.

Priore R. & Ferrazzi P., 1991. Relazioni tra *Apis mellifera* L. e flora in Campania. In: *Atti Convegno MURST 40% "Stato attuale e sviluppo della ricerca in apicoltura"*. Ist. Entom. Agr. Univ. Sassari: 139-143.

Ricciardelli D'Albore G., 1997. *Textbook of melissopalynology*. Apimondia Publishing House, Bucarest: 308 p.

Ricciardelli D'Albore G., 1998. *Mediterranean melissopalynology*. Ist. Entom. Agr. Perugia: 466 p.

Ricciardelli D'Albore G. & Persano Oddo L., 1978. *Flora apistica italiana*. Ist. Sper. Zool. Agr. Firenze: 278 p.

Ricciardelli D'Albore G. & Piastrelli G., 1977. Origine botanica dei mieli delle Marche. *Apicolt. mod.*, 68: 138-143.

Ronsisvalle G.A. & Signorello P., 1979. Contributo allo studio fitosociologico dei castagneti dell'Etna. *Boll. Acc. Gioenia Sci. Nat. Catania*, s. 4, 13 (9): 9-41.

Sánchez Cunqueiro C. & Sáenz Laín C., 1982. Análisis polínico de mieles de Pontevedra (Espãna). *Lazaroa,* 4: 253-268.

Simonetti G. & Barbattini R., 1986. Incidenza e relazioni tra flora apistica e gruppi corologici nel Friuli-Venezia Giulia. *Apicoltura,* 2: 77-93.

Simonetti G., Frilli F., Barbattini R. & Iob M., 1989. Flora di interesse apistico. *Apicoltura*, 5: 7-377.

Zizza A., De Leonardis W., Longhitano N. & Piccione V., 1985a. Schede melissopalinologiche della Flora Apistica Siciliana. Specie coltivate (1^a parte). *Boll. Acc. Gioenia Sci. Nat. Catania*, 18 (325): 103-214.

Zizza A., De Leonardis W., Longhitano N. & Piccione V., 1985b. Schede melissopalinologiche della Flora Apistica Siciliana. Specie coltivate (2^a parte). *Boll. Acc. Gioenia Sci. Nat. Catania*, 19 (327).

Symposium Participants List

ADUA Mario
Istituto Nazionale di Statistica
Via Cesare Baldo,16
I-00184 ROMA
Phone: +39 0646735112

BORGES Olga
Direcção Regional de Agricultura de Trás-os-Montes
Quinta do Valongo
P-5340 MIRANDELA
Phone: +351 278260900
Fax: +351 51278260954
e-mail: olgaborges@dratm.min-agricultura.pt

CARVALHO Jose Luis
Direcção Regional de Agricultura de Trás-os-Montes
Zona Agrária de Lamego, Calçada da Guerra
P-5100 LAMEGO
Phone: +351 254612660
Fax: +351 254615292

CHATZIPHILIPPIDIS Gregor
Forest Research Institute
GR-VASSILIKA
Phone: +30 31461171
Fax: +30 31461341
e-mail:gregor@fri.gr

CIANCIO Orazio
Istituto Assestamento e Tecnologia Forestale
Università di Firenze
via San Bonaventura, 13
I-50144 FIRENZE
Phone: +39 0553023140
Fax: +39 055319179
e-mail: accadfor@tin.it

CONEDERA Marco
Swiss Federal Institute of Forest, Snow and Landscape
WSL Sottostazione Sud delle Alpi
Via Belsoggiorno 22; cp 57
CH-6504 BELLINZONA
Phone: +41 918215231
Fax: +41 918215239
e-mail: marco.conedera@wsl.ch

CUTINI Andrea
Istituto Sperimentale per la Selvicoltura
Viale S. Margherita 80
I-52100 AREZZO
Phone: +39 0575353021
Fax: +39 0575353490
e-mail: issar@ats.it

DE SANTIS Carmelinda
Dipartimento di Botanica
Università degli Studi di Catania
Via A. Longo, 19
I-95125 CATANIA
Phone: +39095430901
Fax: +39095441209

DI CASTRI Francesco
CNRS-CEFE
1919, route de Mende
F-34293 MONTPELLIER CEDEX 5
Phone: +33 467613201
Fax: +33 467412138
e-mail: dicastri@cefe.cnrs-mop.fr

DI MARTINO Andrea
Dip. di Scienze Botaniche dell'Università di Palermo
Via Archirafi, 38
I-90123 PALERMO
Phone: +39 091616193
Fax: +39 0916176089

FAILLA Maria
Dipartimento di Metodologie Fisiche e Chemiche per l'Ingegneria
Università degli Studi di Catania
Città universitaria (edificio 10); Viale Andrea Doria 6
I-95125 CATANIA
Phone: +39 0957382757
Fax: +39 0957382798
e-mail: leonardi@dmfci.ing.unict.it

FERREIRA CARDOSO Jorge
SEBA - Universidade de Trás-os-Montes e Alto Douro, Apartado 202
P-5001-911 VILA REAL
Phone: +351 259320330
Fax: +351 259320480

FINESCHI Silvia
Istituto per l'Agroselvicoltura - CNR
Viale Marconi, 2
I-05010 PORANO (TR)
Phone: +39 0763374674
Fax: +39 0763374330
e-mail: S.Fineschi@ias.tr.cnr.it

FONTI Patrick
Swiss Federal Institute of Forest, Snow and Landscape
WSL Sottostazione Sud delle Alpi
Via Belsoggiorno 22; cp 57
CH-6504 BELLINZONA
Fax: +41 918215239
e-mail: patrick.fonti@wsl.ch

GALLARDO LANCHO Juan
CSIC-IRNA
Apartado 257
E-37071 SALAMANCA
Phone: +34 923219606
Fax: +34 923219609
e-mail: jgallard@gugu.usal.es

GARCIA QUEIJEIRO Jose Manuel
Facultad de Ciencias de Orense. Edificio Politécnico
Universidade de Vigo. As Lagoas
E-32004 ORENSE
Phone: +34 988387058
Fax: +34 988387001
e-mail: jgarcia@uvigo.es

GIUDICI Fulvio
Swiss Federal Institute of Forest, Snow and Landscape
WSL Sottostazione Sud delle Alpi
Via Belsoggiorno 22, cp 57
CH-6504 BELLINZONA
Phone: +41 918215232
Fax: +41 918215239
e-mail: fulvio.giudici@wsl.ch

KLUMP Raphael Thomas
Dipl. Forstwirt., Assessor D. F.
Insitut für Waldbau Austria
Peter-Jordan-Str., 70
A-1190 WIEN

LAUTERI Marco
Istituto per l'Agroselvicoltura - CNR
Viale Marconi, 2
I-05010 PORANO (TR)
Phone: +39 0763374674
Fax: +39 0763374330
e-mail: M.Lauteri@ias.tr.cnr.it

LEONARDI Salvatore
Dipartimento di Metodologie Fisiche e Chemiche per l'Ingegneria
Università degli Studi di Catania
Città universitaria (edificio 10); Viale Andrea Doria, 6
I-95125 CATANIA
Phone: +39 0957382754
Fax: +39 095333231
e-mail: leonardi@dmfci.ing.unict.it

LICK Heinz
Amt der steiermärkischen Landesregierung. Fachabteilung für das Forstwesen
Brückenkopfgasse, 6
A-8020 GRAZ
Phone: +43 3168774534
Fax: +43 3168774520
e-mail: heinz.lick@stmk.gv.at

LISCHER Christian
Botanisches Institut der Universität Basel
Schönbeinstraße, 6
CH-4056 BASEL

LONGHITANO Nunzio
Dipartimento di Botanica
Università degli Studi di Catania
Via A. Longo, 19
I-95125 CATANIA
Phone: +39 095430901
Fax: +39 095441209

MANETTI Maria Chiara
Istituto Sperimentale per la Selvicoltura
Viale S. Margherita 80
I-52100 AREZZO
Phone: +39 0575353021
Fax: +39 0575353490
e-mail: issar@ats.it

MARCELINO Vera
Laboratorium voor Mineralogie, Petrologie en Micropedologie
Geologisch Instituut; Krijgslaan 281/S8
B-9000 GENT
Phone: +32 92644561
Fax: +32 92644984

MARESI Giorgio
CNR Istituto per la Patologia degli Alberi Forestali
P.ale delle Cascine, 22
I-50144 FIRENZE
Phone: +39 0553288342
Fax: +39 055354786

MARTINS Afonso
Departamento de Edafologia
Universidade de Trás-os-Montes e Alto Douro
Apartado 202
P-5001-911 VILA REAL
Phone: +351 259350209
Fax: +351 259320480
e-mail: amartins@utad.pt

MONTEIRO Manuel António
Direcção Regional de Agricultura de Trás-os-Montes
Quinta do Valongo
P-5370 MIRANDELA
Phone: +351 278260900
Fax: +351 278260954
e-mail: dratm.dsag.dpa@telepac.pt

NOCENTINI Susanna
Istituto Assestamento e Tecnologia Forestale
Università di Firenze
via San Bonaventura, 13
I-50144 FIRENZE
Phone: +39 0553023140
Fax: +39 055319179

PIRES Ana Luisa
Departamento de Edafologia
Universidade de Trás-os-Montes e Alto Douro
Apartado 202
P-5001-911 VILA REAL
Phone: +351 259350211
Fax: +351 259320480
e-mail: alpires@utad.pt

PIVIDORI Mario
Dip. di Agronomia, Selvicultura e Gestione del Territorio
Università di Torino
Via L. da Vinci, 44
I-10095 GRUGLIASCO (To)
Phone: +390 114115270
Fax: +390 114113487
e-mail: mpividori@iol.it

PORTELA Ester
Departamento de Edafologia
Universidade de Trás-os-Montes e Alto Douro
Apartado 202
P-5001-911 VILA REAL
Phone: +351 259350208
Fax: +351 259320480
e-mail: eportela@utad.pt

PRIVITERA Maria
Dipartimento di Botanica
Università degli Studi di Catania
Via A. Longo, 19
I-95125 CATANIA
Phone: +39 095430901
Fax: +39 095441209
e-mail: privitera@mbox.dipbot.unict.it

ROMANE François
CEFE-CNRS
1919, route de Mende
F-34293 MONTPELLIER CEDEX 5
Phone: +33 467613277
Fax: +33 67412138
e-mail: romane@cefe.cnrs-mop.fr

RONSISVALLE Giuseppe
Dipartimento di Botanica
Università degli Studi di Catania
Via A. Longo, 19
I-95125 CATANIA
Phone: +39095430901
Fax: +39095441209
e-mail: ronsi@mbox.dipbot.unict.it

ROTS Jan
IBN - DLO
P.O. Box 23
NL-6700 AA WAGENINGEN
Phone: +31 317477700
Fax: +31 317424988
e-mail: A.J.G.Rots@ibn.dlo.nl

SEVRIN Eric
Institut pour le Développement Forestier
13, avenue des Droits de l'Homme
F-45921 ORLEANS CEDEX 9
Phone: +33 238719062
Fax: +33 238719063
e-mail: esevrin@association-idf.com

SIGNORELLO Giovani
DISEAF
Università degli Studi di Catania
Via Valdisavoia, 5
I-95123 CATANIA

SIRACUSA Giuseppe
Dipartimento di Metodologie Fisiche e Chemiche per l'Ingegneria
Università degli Studi di Catania
Città universitaria (edificio 10)
Viale Andrea Doria, 6
I-95125 CATANIA
Phone: +39 0957382757
Fax: +39 0957382798
e-mail: segretaria@dmfci.ing.unict.it

TURCHETTI Tullio
CNR - IPAF
Piazzale delle Cascine, 28
I-50144 FIRENZE
Phone: +39 055368918
Fax: +39 055358746
e-mail: Turchetti@csplm.fi.cnr.it

VILLANI Fiorella
CNR - Istituto per l'Agroselvicoltura
Viale Marconi, 2
I-05010 PORANO (TR)
Phone: +39 0763374674
Fax: +39 0763374330
e-mail: F.Villani@ias.tr.cnr.it

LOUIS - JEAN
avenue d'Embrun, 05003 GAP cedex
Tél. : 04.92.53.17.00
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Préparation du manuscrit

Les articles (dactylographiés en double interligne, en format A4) doivent être rédigés de préférence en français ou en anglais, mais les travaux en espagnol ou en italien sont aussi acceptés. Si l'article soumis n'est pas rédigé en anglais, il est demandé (en plus des résumés) une version anglaise abrégée ainsi qu'une traduction en anglais des titres des figures et tableaux.
L'article doit être complet : titres français et anglais, auteur(s) et adresse(s), résumés en français et anglais (au minimum), version anglaise abrégée (si le texte n'est pas en anglais), mots-clés, texte, puis remerciements, bibliographie, figures et tableaux. Le texte des articles originaux de recherche devrait normalement comporter quatre parties : introduction, méthodes, résultats, discussion.
En ce qui concerne la saisie du texte, il est simplement demandé aux auteurs de distinguer clairement les titres des différents paragraphes. Les titres ne seront pas numérotés. Pour numéroter les sous-titres, éviter les lettres. Attention, l'emploi de mots « soulignés » est à proscrire. Les noms d'auteurs cités figureront en minuscules dans le texte comme dans la bibliographie. En français, n'utilisez les majuscules que pour les noms propres, sauf exception justifiée. Les ponctuations doubles (: ; ? !) sont précédées d'un espace, contrairement aux ponctuations simples (, .). En revanche, toutes les ponctuations sont suivies d'un espace. La mise en forme définitive du texte sera assurée par la revue. L'adresse de chaque auteur sera indiquée. Dans le cas où la publication serait le fait de plusieurs auteurs, il doit être précisé lors du premier envoi la personne à qui doit être retourné l'article après lecture.

Résumés, mots-clés et version abrégée

Les résumés doivent comporter 300 mots au maximum et la version anglaise abrégée 1000 mots (environ une page). Le nombre de mots-clés est limité à six, dans la langue des résumés ; ils ne doivent généralement pas figurer dans le titre.

Bibliographie

La bibliographie regroupera toutes les références citées et elles seules. Les références seront rangées dans l'ordre alphabétique des auteurs et de façon chronologique. Les abréviations internationales des titres des revues doivent être utilisées (sauf en cas de doute). Vérifier attentivement le manuscrit pour s'assurer que toutes les références citées dans le texte apparaissent bien en bibliographie et inversement. La mise en forme doit suivre les exemples suivants :

- article : Andow D.A., Karieva P., Levin S.A. & Okubo A., 1990. Spread of invading organisms. *J. Ecol.*, 4 : 177-188.
- ouvrage : Harper J.L., 1977. *Population biology of plants*. Academic Press, London. 300 p.
- article d'ouvrage : May R.M., 1989. Levels of organization in ecology. *In* : Cherret J.M. (ed.), *Ecological concepts*. Blackwell Scientific Public., Oxford : 339-363.
- actes d'un colloque : Grootaert P., 1984. Biodiversity in insects, speciation and behaviour in Diptera. *In* : Hoffmann M. & Van der Veken P. (eds), *Proceedings of the symposium on « Biodiversity : study, exploration, conservation »*, Ghent, 18 November 1992 : 121-141.

Citations et renvois appelés dans le texte

Les mots « figures » et « tableaux » annoncés dans le texte sont écrits en toutes lettres et en minuscules. Indiquer le nom d'auteur et l'année de publication (mais indiquer tous les auteurs dans la bibliographie). Exemples: « Since Dupont (1962) has shown that... », or « This is in agreement with previous results (Durand *et al.*, 1990 ; Dupond & Dupont, 1997) ... ». Le numéro de page de la citation n'est mentionné que dans le cas où elle est entre guillemets. Si la publication est écrite par plus de deux auteurs, le nom du premier doit être suivi par *et al.*

Abréviations, nomenclature et mots latins

L'usage d'une abréviation technique doit être précédé de sa signification lors de sa première apparition. Les codes de nomenclature doivent êtres respectés selon les conventions internationales. Les mots latins doivent être mis en italiques (*et al.*, *a priori*, *etc.*), et en particulier les noms de plantes ou d'animaux. Lors de la première apparition du nom d'une espèce, il est demandé d'y faire figurer le nom d'auteur (exemple : *Olea europaea* L.).

Figures et tableaux

Les figures et tableaux (précédés des légendes correspondantes sur une feuille séparée) doivent être remis séparément du texte, prêts à l'impression, sans nécessiter de réduction (donc au maximum : format 16 x 22 cm ou 8 x 22 cm). Tous les documents devant êtres insérés dans le texte doivent êtres annoncés, numérotés dans l'ordre croissant et légendés. Les tableaux informatisés ne doivent pas comporter de signes (: ou |) pour marquer les colonnes.

Tirés-à-part

Il est fourni 25 tirés-à-part par article, même lorsqu'il y a des auteurs multiples. Des tirés-à-part supplémentaires peuvent être obtenus à la demande : ils seront facturés.

Instructions to authors

Ecologia Mediterranea publishes original research report and reviews in the fields of fundamental and applied ecology of Mediterranean areas, except descriptive articles or articles about systematics. The editors of Ecologia Mediterranea invite original contributions in the fields of: bioclimatology, biogeography, conservation biology, population biology, genetic ecology, landscape ecology, microbial ecology, vegetal and animal ecology, ecophysiology, palaeoecology, palaeoclimatology, but not marine ecology. Symposium proceedings, review articles, methodological notes, book reviews and comments on recent papers in the journal are also published. Manuscripts are reviewed by appropriate referees, or by members of the Editorial Board, or by the Editors themselves. The final decision to accept or reject a manuscript is made by the Editors. Please send 3 copies of the manuscript to the editors. When an article is accepted, the authors should take the reviewers' comments into consideration. They must send back to the journal Editorial Office their corrected printed manuscript (one copy) and include the corresponding floppy disk (as far as possible: 3.5" PC, Word 7 or .RTF) within 3 months. The authors are asked to check the conformity between printed and computerised versions. Enclose the original illustrations. Corrected proofs must be returned to the journal Editorial Office without delay. Books and monographs to be reviewed must be submitted to the Editors.

Manuscript preparation

Manuscripts (typewritten with double spacing and A4 paper size) should preferably be written in French or English, but Spanish and Italian are accepted. If the language is not English, you should include an English short version and English titles for figures and tables.

The manuscript must be complete: French and English titles, author(s) and address(es), French and English abstracts (at least), an English short version (only if it is not the language used in the article), key-words, text, references, acknowledgements, figures and tables. For research papers, the text should normally consist of 4 sections: introduction, methods, results and discussion.

When typing the manuscript, please distinguish titles clearly from other paragraphs. Titles and subtitles should not be numbered. Avoid using letters to number subtitles. Use lower-case letters for names. Do not underline any words. In English, there is one space after punctuation, none before.

Copy editing of manuscripts is performed by the journal.

Each author's address should be specified. The first time, please state the complete address of the correspondent author to whom the proofs should be sent.

Abstract, key-words, abridged version

Abstracts should be no longer than 300 words. The English abridged version should not exceed one page (1000 words). Do not use more than six key-words (translated in the abstract's language). Key-words should not be present in the title.

References

All publications quoted in the text should be presented in a list of references following the text. The list of references should be arranged alphabetically by author and chronologically per author. You should abbreviate the titles of periodicals in the list of references (except if you are not sure of it). Make sure that all citations and references correspond. Use the following system for references:

- journal article:

Andow D.A., Karieva P., Levin S.A. & Okubo A., 1990. Spread of invading organisms. *J. Ecol.*, 4 : 177-188.

- book:

Harper J.L., 1977. *Population biology of plants.* Academic Press, London. 300 p.

- book section:

May R.M., 1989. Levels of organisation in ecology. *In* : Cherret J.M. (ed.), *Ecological concepts.* Blackwell Scientific Public., Oxford : 339-363.

- conference proceedings:

Grootaert P., 1984. Biodiversity in insects, speciation and behaviour in Diptera. *In* : Hoffmann M. & Van der Veken P. (eds.), *Proceedings of the symposium on « Biodiversity: study, exploration, conservation »*, Ghent, 18 November 1992 : 121-141.

Citations in-text

The words « figures » and « tables » announced in-text should be written *in extenso* and in lower-case letters. In the text, refer to the author's name and year of publication (followed by pages only if it is a quotation). If a publication is written by more than two authors, the name of the first author should be used followed by « *et al.* » (this indication, however, should never be used in the list of references : first author and co-authors should be mentioned). Examples: « Since Dupont (1962) has shown that... », or « This is in agreement with previous results (Durand *et al.*, 1990 ; Dupond & Dupont, 1997) ... ».

Abbreviation, Latin words

Explanation of a technical abbreviation is required when first used. International convention codes for nomenclature should be used. Latin words should be in italics (*et al., a priori, etc.*), particularly for taxonomic classifications (the first time, please state the author's name: for example, *Olea europaea* Linnée).

Figures and tables

All illustrations should be submitted separately and they should be preceded by the figure and table legends on a separate page. Figures and tables should be sent « ready to be printed », without need to be reduced (so their size should be 16 x 22 cm or 8 x 22 cm maximum). All the illustrations being in-text should be quoted, numbered in sequence and should have a legend. Computerised tables' columns should not be represented by signs (: or |).

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