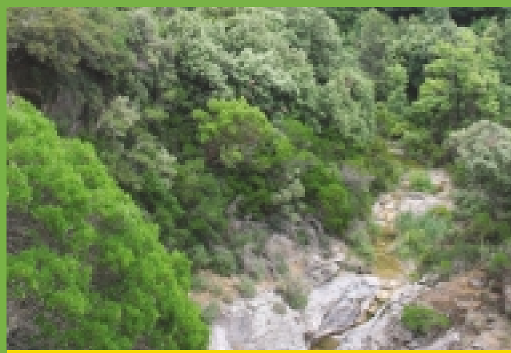
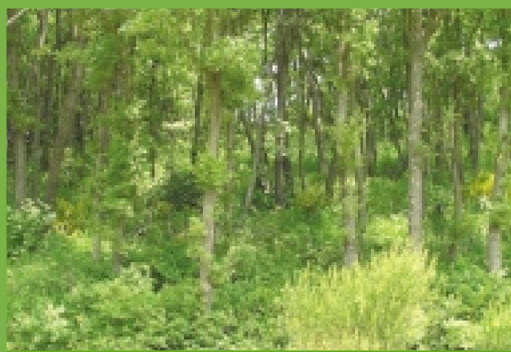
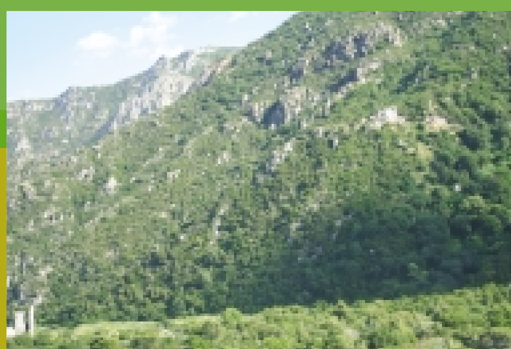
Guidelines for the rehabilitation of degraded oak forests

Sp. Dafis, P. Kakouros







THE GOULANDRIS NATURAL HISTORY MUSEUM
GREEK BIOTOPE/WETLAND CENTRE

LIFE03 NAT/GR/000093
Rehabilitation of coppice *Quercus frainetto* woods (9280) and *Quercus ilex* woods (9340) to high forest

BENEFICIARY:
HOLY COMMUNITY OF MOUNT ATHOS

Authors

Professor Spyros Dafis
Greek Biotope/Wetland Centre, 14th km Thessalonikis-Mihanionas, PO Box 60394, 57001 Thermi, Greece, ntafis@ekby.gr

Petros Kakouros
Greek Biotope/Wetland Centre, 14th km Thessalonikis-Mihanionas, PO Box 60394, 57001 Thermi, Greece, petros@ekby.gr

Associate professor Theocharis Zagas
Aristotle University of Thessaloniki (AUTh), School of Forestry and Natural Environment, 54124 Thessaloniki, Greece, zagas@for.auth.gr

Assistant professor Petros Gkanatsas
Aristotle University of Thessaloniki (AUTh), School of Forestry and Natural Environment, 54124 Thessaloniki, Greece, pgana@for.auth.gr

Assistant professor Thekla Tsitsoni
Aristotle University of Thessaloniki (AUTh), School of Forestry and Natural Environment, 54124 Thessaloniki, Greece, tsitsoni@for.auth.gr

Professor O. la Marca
DISTAF, Università di Firenze, Via S. Bonaventura, 50100 Firenze, Italy, orazio.lamarca@unifi.it

Laura M.R. Rinaldi
IVALSA, CNR, Via Madonna del Piano, 50019 Sesto fiorentino (Fi), Italy, rinaldi@ivalsa.cnr.it

I. Cañellas
CIFOR-INIA, Cª de la Coruña km 7.5, 28040 Madrid, Spain, canellas@inia.es

Milen. Del Rio
CIFOR-INIA, Cª de la Coruña km 7.5, 280 40 Madrid, Spain.

S. Roig
CIFOR-INIA, Cª de la Coruña km 7.5, 280 40 Madrid, Spain.

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Contents

1. Introduction

In the Mediterranean, the oak forests along with other types of forests, grasslands or fields, constitute a mosaic of landscapes, which reflects the interaction of the Mediterranean climate with the long lasting presence of man for many centuries. These forests were affected by an early human intervention, which reduced their area, disrupted their continuity, modified their structure as well as the structure of the species of different plants and animals that inhabit there and led to soil degradation almost everywhere.

Leaving aside the total destruction of the forest, the most important change that man provoked is the alteration of the forests from those that used to regenerate from the seed of the trees to those that now regenerate from the offshoots of the remaining stock and root system after the woodcutting of the trees (coppice). This change is almost always combined with the intensive exploitation of the productive ability of the forest ecosystem through the clear cuttings. In the long run, this intensive exploitation modifies species composition since plant and animal species that require mature forests of great height and open under storey are lost. That is due to the fact that these forests gradually turn into mosaics of age-mate uniform stands in terms of structure and lack of variety of habitats. At the same time, the cutting of small sized and rich in nutrients wood at small intervals and the frequent exposure of the soil to rain combined with the great needs of the regenerating (developing) trees for nutrients, lead to the exhaustion and the erosion of the soil, in a degree that differs depending on the geology, the local climate and the topography.

The problems that are related with the coppice oak forests have already been detected since the begining of 20th century and several efforts have been exerted for their inversion to high forests, wherever this is possible. Until today, those efforts were focusing on deciduous oak forests (*Quercus frainetto, Q. pubescens* etc.) either through inversion to high forests through selective inversion thinning or introduction of conifers so as to accelerate the restoration to high forest.

The goals of those efforts were protective (protection of the soil from erosion-protection against flood) as well as financial because, in many cases, introduction of conifers were preferred with the ulterior purpose of wood production after a few years. Rehabilitation of evergreen oak forests where evergreen oak species (kermes oak and holm oak) prevail had very low priority, since their annual wood production is of low value and is used only as fire-wood. However, this consideration overlooks the value of these forests as an element of the Mediterranean landscapes as well as their role in the conservation of the biodiversity and other landscape functions that are related to the culture and economy, especially of the countryside.

Therefore, the rehabilitation of the coppice oak forests must not be narrowly viewed from the forest management perspective but in the context of the restoration of the structure and functions of a landscape as well as preserving the biodiversity.

Provided all of the above are true in general, then, in the sites of the NATURA 2000 Network, the management of the forests must additionally keep up with the original goals of the network and follow these rules:

- Utilization of silvicultural measures that contribute to the conservation of the species diversity.
- Restoration and rehabilitation of the degraded forests.
- Conservation of traditional management practices when they are positively connected with the conservation of the biodiversity.
- Amelioration of the harvesting methods in order to minimize both the effects on nature and burdening on the personnel.

Bearing those rules in mind, the present edition focuses on the rehabilitation of the coppice oak forests through selective inversion thinnings that have already been applied with positive results on both the biodiversity and the productivity of the forests.

Chapter 2 opens with a brief description of the oak forests followed by the main causes and features of their degradation and closes with the aims of their rehabilitation.

Chapter 3 analytically describes the restoration and rehabilitation methods used in the coppice forests while emphasizing on the natural methods.

Since not only scientists in Greece, but in the whole Mediterranean too deal with the issue of the inversion of the oak forests, the results of such experiments in Greece, Italy and Spain are presented in Chapter 4. In what concerns Greece, there is a presentation of the implementation of selective inversion thinnings in the holm oak and hungarian oak forests of Mount Athos by Prof. Dafis and Mr. Kakouros, while following, Zagas et al. bring forward the results of an experiment regarding various degrees of selective inversion thinnings in holm oak stands in Chalkidiki. From Italy, la Marca and Rinaldi also present the results of a comparative experiment in a holm oak forest between a classic coppice management, an inversion through a predetermined percentage of thinning and a non-treatment, whereas in Spain, Cañellas et al. present the results of different degrees of thinnings in *Q. pyrenaica* and *Q. faginea* forests. An interesting element of the latter contribution is that a negative selection was applied, while the implementation of selective inversion thinnings is based on the positive selection.

Afterwards, in Chapter 5, a monitoring method for the results of the inversion treatments is proposed in order to be able to examine the level of achieving its goals and to restore any possible defects.

2. The oak forests in Greece

Greece is pre-eminently a country of oak forests, something that is valid for all European Mediterranean countries. The deciduous oak forests occupy an area of nearly 1.500.000 ha, which corresponds to the 44% of the total forestland of our country or alternatively to the 76% of the deciduous sclerophyllous forests (Tsaprounis 1992). Evergreen oak forests and mainly bushes, where kermes oak (*Quercus coccifera*) and holm oak (*Quercus ilex*) prevail, occupy a significant part of the land extending to an area of nearly 470.000 ha.

Image 1. Aged coppice holm oak forest.

2.1. Degradation of the holm oak and deciduous oak forests

2.1.1. Degraded holm oak forests

The greatest part of the once dense holm oak forests was either reclaimed for the acquisition of agricultural land, building of villages and creation of infrastructures or degraded and transformed to coppice forests (Images 1 & 2), whose management and exploitation were easier to handle due to their small size trunks (Image 3). They were mainly utilized for the production of firewood and charcoal due to their excellent quality. In many of these forests, the degradation led to their transformation either to closed shvoblands (Image 4), or to thin bushes, or to garrique or even to phrygana, which is one of the last degradation stages of the Mediterranean forests. Moreover, frequently repeated fires and overgrazing of livestock supported their further degradation.

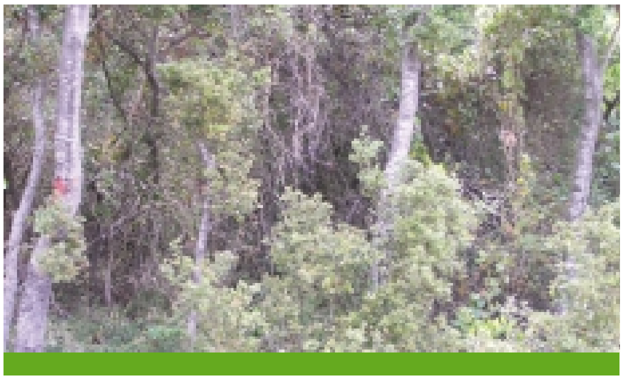


Image 2. Young holm oak forest.

The structure and the floristic composition of the coppice holm oak forests and of the closed or thin bushes depends on the intensity of the disturbance, the quality of the landscape, the type of rock and the local climate.

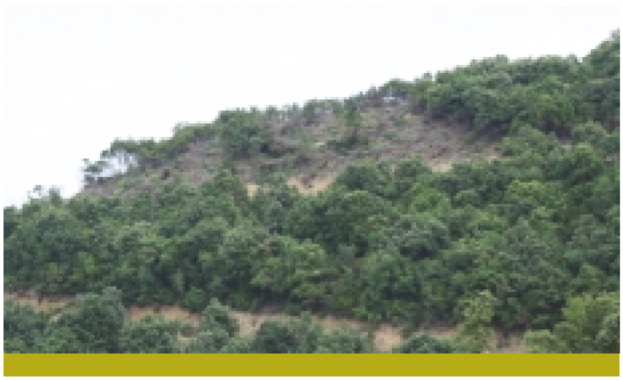


Image 3. Clear cuts.

Image 4. Closed broadleaved evergreen shrub lands.

2.1.2. Degraded deciduous oak forests

In the past, the intensive exploitation of the deciduous oak ecosystems through predatory woodcuttings, pollarding and overgrazing, resulted in many of them becoming degraded and in some to have adopted a bushy form (Image 5).

However, the majority of these ecosystems are found in the stage of natural rehabilitation thanks mainly to the reduction of grazing, particularly of the goats and also to the organizing of the woodcutting and the stopping of pollarding. The result today is the emergence of admirable ecosystems with oak in the upper floor, in Hornbeam the middle floor and Hornbeam and other shadow tolerant species in the under floor, in the place of bush-like formations that existed there 30-40 years ago. Nevertheless and with only a few exceptions, the oak forests preserve their coppice management form producing principally firewood. At the same time, the oak –with the exception of the Pubescent oak– has the ability to produce precious wood, which is much more valuable than firewood, especially in places with a good landscape quality and a proper structure of stands.

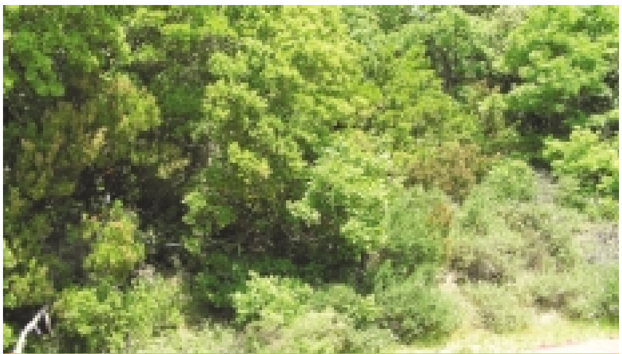


Image 5. Degraded hungarian oak forest in bush form mixed with broadleaved evergreen species.

In the locations where these degraded ecosystems overlap with black pine forests (*Pinus nigra* subsp. *pallasiana*) or fir forests (*Abies cephalonica, Abies borisii regis and Abies pseydocilicica Mattfeld.*) and especially in the ecotone, a gradual invasion of the latter species is observed, that tend to either replace the oak or create mixed stands of oak and pine or oak and fir in various ratios and mixing forms. Furthermore, in the locations where the oak ecosystems overlap with those of the beech, something that is usual in Northern Greece, a particular habitat of beech and oak (especially the sessil and the hungarian oak) formations is created in the ecotone, where the competitive ability of the beech is relatively reduced. This habitat is identified as a habitat type of Community Importance according to the Directive 92/43/EEC and it is recorded with the code 9280.

Today, the stands of deciduous oaks we find are the following:

- Coppice age-mate stands or with reserved trees or clumps of trees.
- Midle foreit stands having sclerophyllous oak in the upper floor and oak with or without other species in the under floor and middle floor. This form is relatively rare and comes from successive reservation.
- High forest stands, which are very rare and occupy a small area.
- Pruned coppice stands, which have a special structure and are used for pollarding. This form is mainly found at the Koupatsohoria in Grevena (Koupatsarides) and in Pomakohoria in Thrace.

2.2. Rehabilitation objectives of the coppice oak forests

Both the holm oak and the deciduous oak forests with a coppice management form are defined by their age-mate and uniform structure, the frequent disturbance of the soil and forest ecosystem during their harvesting, the production of wood appropriate only for firewood, the low standing woodstock and the increased risk of spreading fire. Additionally, they are impenetrable almost until they are cut which creates an inhospitable landscape for travelers and visitors and obstructs the forest personnel from walking through (for example, during the putting out of fires). At this point, it must be clarified that the drawbacks of the coppice management form do not also regard the coppice regeneration technique, which, in some cases, can be used to bring about ecological and financial benefits.

Rehabilitation is a process that emphasizes the reparation of ecosystem processes, productivity and services for the improvement of the structure and the functions of a specific, degraded ecosystem (SER 2002). The objectives concerning the rehabilitation of a forest or a stand with a coppice management form can be the following:

- The restoration of the structural diversity of the forest, which may be also adjusted to the production of large size wood provided that the forestry is compatible with the conservation of the species and the habitat types of the forest. However and in any case, the necessity of protecting the species and the habitat types should always be a priority.
- The restoration of the natural vegetation diversity on the upper floor of the forest or the stand, which usually provokes the gradual restoration of the middle floor and under floor.
- The protection of the soil from erosion and degradation of its productive ability.

3. Rehabilitation methods of holm oak and sclerophyllous oak coppice forests

The rehabilitation method that will be implemented depends on the forest's state, the degree of degradation and the objective of the rehabilitation. There are two categories of methods:

a. The natural rehabilitation methods based on cultivating treatments, like the inversion using cultivating woodcuttings through positive selection, and
b. The artificial rehabilitation based on the modification of species and the introduction of fast-growing conifer species (introduction of conifers) or sclerophyllous species.

3.1. Natural rehabilitation using cultivating treatments through positive selection

The natural rehabilitation that uses cultivating treatments is based on the cultivating selective inversion thinnings that do not differ in the way they are implemented or in their philosophy from the selective thinnings, i.e. the thinnings that take place during the cultivation of a high forest.

Inversion is a term used to characterize those thinnings that, along with the quality improvement of the standing woodstock of the stands, and thus the quality of the products, aim to change the management form of a stand into another (Dafis 1990).

In the case of the oak forests, like the holm oak and hungarian oak forests, the thinnings aim to change the management form from coppice to high forest. After a few repetitions of the inversion thinnings the stands, despite their coppice origin, tend to take the form of a high forest. The French name for this kind of form is Futaîe sur souche (high forest over coppice).

Implementation prerequisites and guidelines

Coppice stands under inversion must be handled as if they were high forest stands and are subject to all the silvicultural treatments that are implemented in high forests. The basic rule of the inversion thinnings is the selection and favouring of the best individuals (positive selection). Moreover, if there are high quality saplings, they are obviously preferred, while, in the case of the coppice trees, we select those, which, aside the good quality appearance of their trunk and canopy, seem to be also sufficiently individualised. Wherever there are nests of shoots, they are gradually thinned for the facilitation of the woodcutting labours as well as for the production of greater-size wood.

The questions that rise during the implementation of this method are:

- Which are the appropriate stands for the implementation of this method?
- Which is the right age to start the implementation of the method?
- How should the first inversion thinnings be performed?
- When should the inversion thinnings be repeated?
- How intensive should the inversion thinnings be?

A. Holm oak forests

Appropriate stands for the implementation of the method

It is intended that this method be implemented primarily on good quality stands where holm oak prevails (percentage coverage > 50%) or where holm oak and laurel (Laurus nobilis) dominate together in a percentage of more than 50%. Such cases are:

- Forests or shrubs of holm oak, kermes oak, jasmine box (*Phillyrea latifolia*), strawberry tree, wild strawberry tree (*Arbutus andrachne*) and heath (*Erica arborea*).
- Forests or shrubs where holm oak is dominant and occasionally there is laurel, manna ash (*Fraxinus ornus*), judas tree (*Cercis siliquastrum*) and strawberry tree as well as abundance of climbing plants such as the pricly ivy (*Smilax aspera*), the black bryon (*Tamus communis*), the ivy (*Hedera helix*).

- Forests or bushes where holm oak and Laurel dominate together and there is an occasional appearance of manna ash, judas tree, jasmine box and strawberry tree with a simultaneous abundant presence of climbing species, as with the latter type.

However, if there are enough finances we can also extend to stands with a smaller holm oak ratio.

Age to start the method

The appropriate time for the first inversion treatment must be determined through accurate observations and depends on the structure of the stand and the landscape quality. It is never too early to make an inversion when the treatments are gentle, careful and cautious. On the contrary, inversion thinnings that begin late are always a drawback because individualisation of shoots is delayed, trunk density is high and as a result the regeneration with seeds is very difficult. Therefore, the younger they are the better to start the inversion. In general, in the case of holm oak the inversion thinnings should start at the age of 20-30 years depending on the structure and the landscape quality. At those ages, it is easier to distinguish the best individuals.

How to perform the first inversion thinnings

The inversion method that has prevailed to be implemented by many foresters during the inversion thinnings, aims to the removal of those trees that harm the crown of one or more individuals that have a better trunk shape. This means that the person who marks, first goes to the individual of the stand that, in comparison to its 'neighbor' or 'neighbors', is of lower qualitative value and it is the one that harms them. It is then marked for removal. Thus, this marking is seemingly moving towards the apparently given natural direction i.e.towards those individuals that the one who makes the marking believes that they have to be removed because they are of lower qualitative value and harm other, better individuals. But does this woodcutting favor the really better or only the relatively better individuals of the stand? The answer is that this selection favours the relatively better individuals, because during this method, the selection of the best is always done in comparison with the worse and not the better trees of the stand. If these are compared with the better individuals then it is possible to view them as lower quality individuals. This way of selection is characterized as **negative selection** (Dafis 1990).

On the contrary, during inversion thinnings the best of the best trees are located and are characterised as **desirable individuals E** (Figure 1) and these are the trees that are favored through the removal of their strongest competitor, regardless of the quality of its trunk or its growth rate. This method of selection is characterised as **positive selection.**
In the **first thinning (A1)**, the focus lies on selecting the desirable individuals of this stage. Of these, as many evenly in space distributed desirable individuals are selected as possible in order to benefit each one without strongly reducing the canopy density of the upper floor. This is realised by cutting the strongest competitor every time and only rarely and exceptionally cutting the second strongest competitor. The **selected individuals** are selected from among the desirable ones and are called **E1** in the first thinning stage (Figure 1).

An E1 tree will always belong to a small group of desirable individuals (E), which are easily distinguished from the other ones with respect to their trunk quality, the shape of their crown and their growth capacity (vigour). This group stands out from the neighbouring ones by the fact that its individuals are directly or indirectly adjacent to and socially associated with the selected individual E1. In other words, they resemble a cell, whose nucleus is E1. Anything not related to E1 or that belongs to another group, differs with respect to quality or comprises an indifferent complementary part of the stand.

Even well-cultivated stands of thin trunks may include sites (groups) without selected individuals. In other words, they are cells without a nucleus. Such sites are occupied by qualitatively indifferent

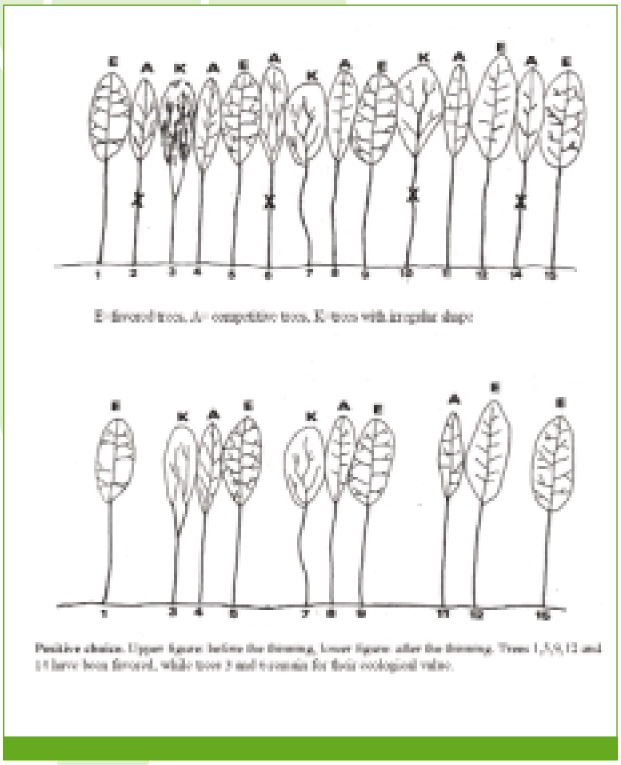


Figure 1. Schematic presentation of the positive selection procedure as applied to stands of broadleaf species. (adapted from Dafis 1990).

complementary trees. But even in these sites, the relatively better individual is selected and assisted by cutting its strongest competitor, because in addition to quality improvements, we are also interested in strengthening the stand. These trees comprise surrogate desirable individuals.

In the course of time, these selected individuals grow and become stronger and create a resistant frame against storms and snow, which covers the entire stand surface, including future individuals that definitely remain in the stand in order to acquire protective independence. Every time we have to search each small group for the selected individual E1 at the time. Once this is identified, it is easy to identify its strongest competitor. It is not rare for the competitor to also be a desirable individual. This should not, however, prevent us from removing it. Stands that have been cultivated correctly and according to schedule have such a wealth of prime material to choose from that we should not regret sacrificing such a good individual in order to assist its superior.

It should be noted that during the positive selection procedure, comparison of the quality of individuals is comparative and not absolute and that the qualitative structure of the stand is given.

The effects of thinning are quickly noticeable, possibly from the first spring after thinning, depending on soil and climate conditions. The selected individual and the tree that incidentally benefited from the removal of the selected individual's strongest competitor, which were suppressed, are freed and begin to spread their branches into the vacant space that has been created, thereby expanding their crown in this direction. The effects of thinning are not only noticeable among individuals of the dominant crown class, but also among the intermediate stand, though individuals of the suppressed class often die when they are suddenly exposed to direct sunlight.

In order to ensure the success of inversion thinning, markings should be applied by experienced personnel who know the area well and have an overall understanding of the ecological and technical factors that should be taken into account.

An additional advantage of positive selection in comparison to negative selection is that it does not encourage the removal of individuals with morphological defects (infested or dead sections, hollows, etc.) or superannuated trees, which are valuable for preserving biodiversity.

Repeat time of selective inversion thinning

If the stand is abandoned until the last effect of thinning disappears, then our new intervention will be carried out too late. Hence, the question regarding an appropriate repeat time arises.

A lot has been said and written on this issue, but it seems that it still has not been fully answered. Formulating a rule here would not be appropriate because the structure of each forest is so diverse that it eludes formulas. It should also be understood that thinning is not repeated, but there is a 1st, 2nd, 3rd intervention until the nth time, which are carried out in accordance with certain principles. In this way none corresponds exactly to another intervention because every intervention is performed once and because the stand is altered by the previous thinning intervention and the intervening growth and also because the forester who performed the first thinning intervention and wishes to mark the second one is usually not the same person.

Consequently, the time for the **second thinning stage (A2)** comes about when the effect of the first thinning stage (A1) on the best stand individuals or on the greatest section of the stand surface stops. There is also a practical rule that is applied to Danish thinning. According to this rule, we return to same stand at intervals of years that correspond to the decades of the stand's age. In practice, we return every 4-5 years up to the age of thin trunks and then at every rotation age (7-10 years).

Positive selection is repeated in the second thinning stage, as in the first one. As a rule, E1 trees and the best individuals from the second selection may be selected as E2 individuals and benefit again from the removal of their strongest competitor.

During the period that intervened between the first and the second thinning, certain selected individuals from the first thinning state (E1) may have been damaged in some way, grown more slowly or demonstrated unwanted deficiencies that are only at this point discernible. In this case, and provided that the production of industrial timber is one of the objects of inversion thinning, it is evident that they cannot be selected as E2 trees and will be replaced by other, better, neighbouring individuals, which at the first thinning stage were desirable but had not been selected. The formerly selected E1 trees are at best classed as unsuitable or indifferent.

This indicates that selections are not always successful, a fact attributed to variations in the growth of forest trees, which are not identified during marking, and assessment variations by the persons responsible for marking, which are more strongly evident in the externalisation of actions, such as for instance the method of marking.

The same method as with A2 is applied in the **next thinning stage (A3)**. Namely, we search for the best individuals, which are selected as **E3** and benefit from the removal of their strongest competitor. Hence, improvement thinning is repeated by always following the same fundamental principles. The same is also repeated for thinning stages A4, A5,etc. Since we can never be certain of the correctness of our choices, the selected individuals should not be marked in a manner that lasts until the next thinning stage. Each selection during subsequent thinning stages should be carried out from the beginning, and it should not be influenced by the previous ones.

Also, in the course of time certain stand individuals will be rendered non desirable in forestry terms on account of diseases or other disturbances, and removed, provided that they may be felled without affecting the soil and stand and the preservation of animal and plant species. On the same grounds, degraded individuals of a mature age may also be felled during thinning, though this should be carried out as a supplementary action and not as part of thinning, since the trees for the latter are and should continue to be positively selected. This necessitates the participation of fauna experts or the training of persons responsible for marking.

So far, no mention has been made of the distance between selected individuals and their link structure. A practical rule stipulates that the distance between selected individuals should be 15-20 times their diameter at chest height, and many recommend triangular linking, which enables the selection of more individuals. In practice, however, it is not possible to work by following fixed rules. Distance and distribution both depend on the natural distribution of the selected individuals in the area.

It is, however, advisable that distribution should be as uniform as possible and that the distance between selected trees not exceeds 15-20 times their diameter at chest height, though this does not mean that where necessary the distance cannot be exceeded or reduced. It is important to make the right choice of selected individuals and to assist them correctly by creating a suitable vegetation zone. This brings us to the fifth issue.

Intensity of selective inversion thinning interventions

During the first stage, the competitors that are cut (removed) have a small crown, and therefore our interventions are of a low intensity. In the course of time the crowns of selected and other stand individuals grow, and therefore thinning interventions become more rigorous. Moreover, the selected individuals become stronger after each thinning intervention and are established as pillars of the entire stand against damage from snow and storms. Through these individuals, which are uniformly distributed in the entire area and whom the thinning interventions have turned into vigorous trees from an early stage, the forest is equipped with a network of resilient elements that, in their capacity as a frame, protect it from external influences. Therefore, in a correctly thinned stand there is no fear of the canopy roof becoming fragmented with every new intervention.

The issue regarding the desirable degree of thinning cannot be separated from the appropriate time for repeat thinning. The fundamental rule is that only the amount of timber that is necessary should be removed each time.

No specific degree of thinning applies to selective inversion thinning, which is defined as crown thinning because it only applies to the dominant crown class. The frequency and extent of interventions are adjusted each time in accordance with the rehabilitation objective, the level and structure of the stand and the species. Correct selective inversion thinning does not rely on specifications or mathematical formulas and rules, but requires well-educated foresters with knowledge and experience of the forest and trees.

Only by correctly appraising each individual case is it possible to arrive at a correct decision. The size of the crown, trunk slenderness (litheness), width of the tree's annual rings and, in particular, comparisons and experience enable the correct 'thinning degree', which can be substantiated as advisable, to be chosen. Different opinions only arise if agreement has not been reached on the objective and the method. A crucial point is the correct choice of selected individuals and their support through the removal of their strongest competitor with the aim of creating a suitable vegetation zone. It should also be noted that, as a percentage of wood reserves, and depending on stand structure and density, rigorous thinning may be considered weak in its effect at reducing stand density, while low intensity thinning may be rigorous because it significantly reduces the density of an already low stand density. Interesting facts on the effect of different degrees of thinning are presented in Chapter 4.

It should, however, be noted that in certain holm oak stands of the forest of the Holy Monastery of Xenofontos (Holy Mountain, Greece) that underwent relatively intense thinning interventions, relatively extensive incidents of fallen and ruptured trees due to snow were recorded because the trees had not become strong enough to withstand severe snowfall. Fallen trees due to snow and wind in holm oak foreststs are also reported in Italy, so it seems that thinning interventions are accompanied by an increase in such risks, which should be taken into account when planning interventions, which in turn should be adapted to local conditions.

Another question that often arises concerns the thinning of stands that have so far remained uncultivated and specifically whether it is possible to apply the negative selection method ex post facto. The answer is NO! It is not possible to make up for stands that were not included in the cultivation earlier at a later stage. It is of greater importance and urgency to assist the few selected stand individuals.

At this point it should be noted that the method's success also depends on the correct felling method and the management of logging residue. As noted by Dafis (1990), cutting coppice shoots should be done in a way that does not facilitate stump rot and infestation in the remaining standing coppice shoots and precipitates their individualisation. Correct and incorrect cutting methods are illustrated in Figure 2. With respect to the management of logging residue, it is advisable to place this parallel to the contour lines in order to contribute to the prevention of erosion. infestations, while they are also dangerous to forest workers (adapted from Dafis, 1990).

B. Hungarian oak forests

The principles for rehabilitating coppice stands of hungarian oak are the same as those described for coppice holm oak forests. The only essential difference with respect to the selective inversion thinning of holm oak is that in addition to the trees' vigour, greater attention is given to the quality of the trunk and crown of selected trees, since in the case of hungarian oak forests the productive capacity of stands may be exploited for the production of valuable timber for construction and furniture.

Stands that are suitable for application of the method
Usually there is a double objective to rehabilitation by means of selective inversion thinning interventions

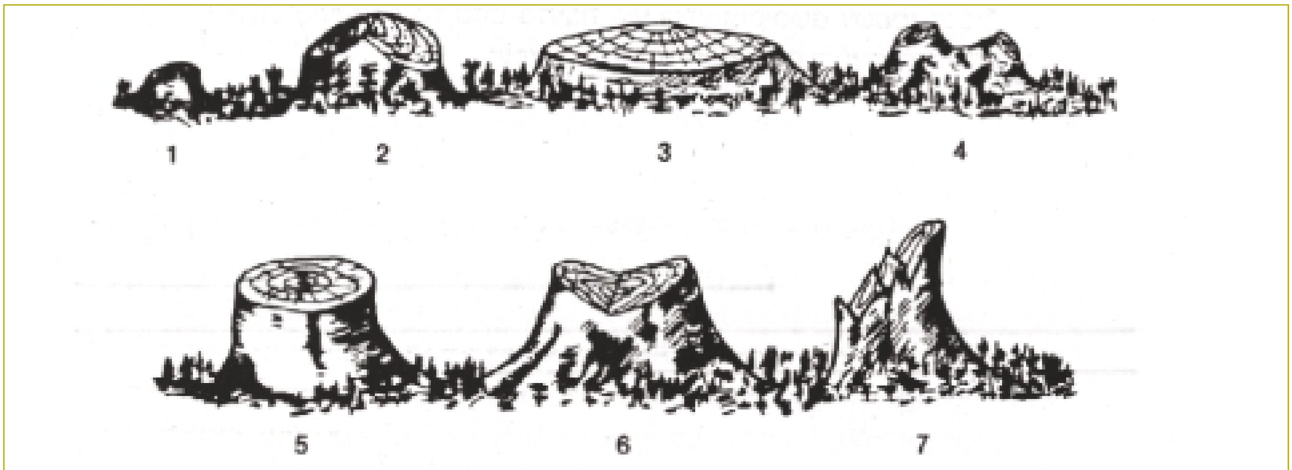


Figure 2. Different cutting methods. Recommended incisions 1, 2, 3, 4. Unacceptable incisions 5, 6, 7. No. 5 is too high, does not allow individualisation and prevents wood movement, Nos. 6 and 7 are grooved or rugged and create the conditions for fungus .

in oak forests, which aims at the conversion of coppice stands to high forests and the exploitation of the stand's productive capacity for the production of valuable wood; stands situated on good quality sites with a satisfactory structure are suitable for application of this method. According to the classification of site quality into six categories (Dafis, 1966), this method may be applied to site qualities I, II and III and possibly IV, on condition that at least 150 individuals with well-formed trunks and crowns grow per hectare. Where conservation of biodiversity is a priority, cultivation interventions may also be applied to stands situated on lower quality sites in order to accelerate their conversion to high forests.

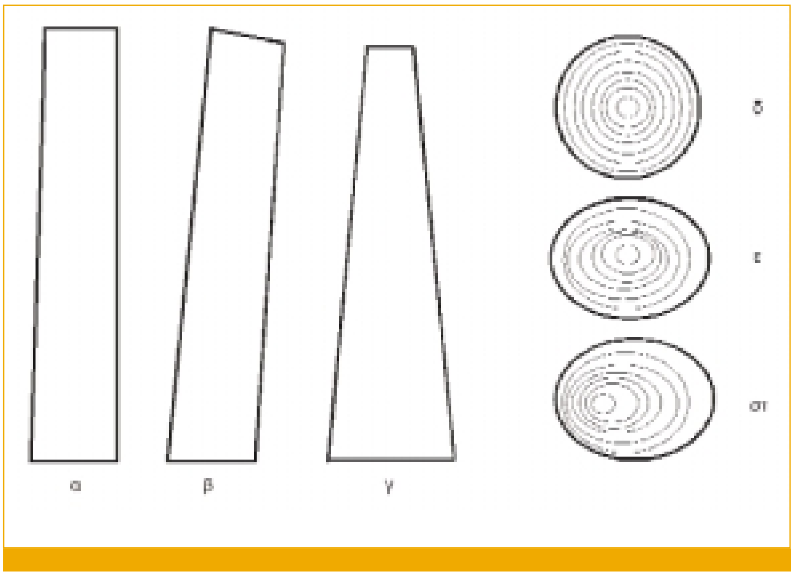


Figure 3. Qualitative trunk characteristics: a) upright trunk, b) trunk with many gradients and an eccentric cross-section, c) trunk with a marked reduction in its diameter in proportion to its height, d) ideal cross-section, e) elliptic cross-section and f) eccentric cross-section.

Application age

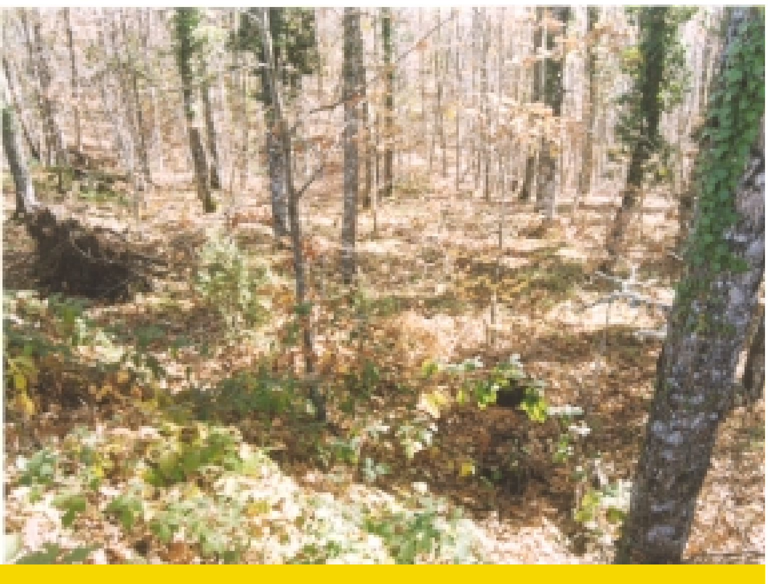
The earlier this method is applied, the better. Practically, it may be applied after the 20th year, when the potential for selection will be greater, although Chatziphilippidis and Spyroglou (1998) and Smyris et al. (1999) recommend that it be initiated from ten years or earlier. The latter support its earliest possible application aimed at the faster individualisation of shoots, because they noticed that cutting one individual from the same coppice group also benefits the remaining individuals. After the 40th year the potential for selection and the effect of selective inversion thinning are greatly reduced.

Initial selective inversion thinning intervention

The same method is applied as in the case of Quercus ilex forests, with the inclusion of criteria on trunk quality and crown vigour. According to Dafis (1990), a trunk may be expected to produce high quality timber if it is upright, has a circular cross-section and its diameter only decreases slightly with height; low quality characteristics are warped and forked trunks with an elliptic or eccentric cross-section (Figure 3).

Repeat time of selective inversion thinning

In general, the same applies as with thinning interventions in holm oak forests. If, however, the production of valuable timber is one of the objectives of inversion thinning and in the period between the first and second thinning stage certain individuals selected during the first thinning state (E1) have been damaged in any way whatsoever, grown more slowly or demonstrated unwanted deficiencies, then their reselection as E2 should be assessed. If they are not selected, they will be replaced by other, better neighbouring individuals, which at the first thinning had been found desirable but were not selected. The formerly selected E1 trees are at best classed as unsuitable or indifferent. This indicates that selections are not always successful, a fact attributed to variations in the growth of forest trees, which are not identified during marking, and assessment variations by the persons responsible for marking, which are more strongly evident in the externalisation of actions, such as for instance the method of marking.



Images 1 and 2. Hungarian oak stands at Stratoniko, Chalkidiki, which have undergone inversion thinning since the beginning of the 1980s.

Intensity of selective inversion thinning interventions
With respect to the intensity and repeat of thinning interventions, everything that has been said about the natural rehabilitation of holm oak foreststs also applies. Images 1 and 2 illustrate examples of stands that have undergone inversion thinning in the area of Chalkidiki.

3.2. Other natural rehabilitation methods

Other methods of natural rehabilitation are also applied in the Mediterranean, as will be illustrated in greater detail in Chapter 4. In particular, inversion thinning through felling interventions has been applied in Spain on the basis of negative selection and a predetermined thinning percentage with respect to the canopy or the basal area. In Italy, thinning interventions are applied by predetermining the number of individuals and the basal area to be removed.

Both methods had a positive effect on the growth of preserved trees, while in the case of Italy, positive effects on biodiversity, landscape aesthetics and forest use by visitors have also been affirmed. It should be noted that neither of the two methods is concerned with improving the quality of remaining trees.

3.3. Artificial rehabilitation by changing the species

A. Holm oak forests

Artificial rehabilitation by changing the species
The method of rehabilitating degraded broadleaf evergreen scrub and holm oak forests by artificially introducing quick growing conifer and broadleaf species, such as various eucalyptus species, has been applied throughout the Mediterranean and particularly the Western Mediterranean, though also in Greece.

In Portugal various species of fast growing eucalyptus were used, primarily *Eucalyptus globulus*, secondarily *Eucalyptus camaldulensis* and occasionally *Eucalyptus maidenii*. Eucalyptus trees were mainly used in NW Portugal where rainfall reaches or even exceeds 2000 mm and the climate is purely Atlantic, in order to artificially rehabilitate scrubs of *Quercus ilex* subsp. *rotundifolia* and to reforest fields. Eucalyptus plantations in Portugal cover an area of 700,000 ha or 21% of total forested areas. The main conifer species to be used were the European coastal pine (*Pinus maritima*), the Stone pine (*Pinus pinea*) and the Aleppo pine (*Pinus halepensis*).

The wood that eucalyptus plantations produced supplied pulp and paper mills and also flooring factories, particularly the species *E. globolus*. In the course of time, the results of these plantations, which at first were spectacular, began to cause scepticism.

Spain also applied the same rehabilitation policy for degraded scrub. Forests and forested areas (matorral) in Spain amount to 27,000,000 ha or 53% of its total area. Of these, 2% belong to the public, 30% to local authorities, 65% to private individuals and 3% to cooperatives or wood processing industries (Forstliche Fakultät der Universität Göttingen 1980). Reforestation was carried out on terraces that were created by heavy machinery, such as earth moving machinery, which also removed the scrub. Various different eucalyptus species were used and the plantations are being managed as coppices with a rotation age of 15 years for the production of fibreboard. After three rotations, the overmature coppices are renewed through replanting. Up to 50% of the cost of reforestation was subsidised by the public. *P. plantations* were also created, mainly of *P. maritima* (*P. pinaster* subsp. *maritima*) and Stone pine, with a rotation age of 25 years for the production of paper-pulp. Stone pine plantations were also used for the production of nuts. In addition to the said species, other conifers that were also used included the Aleppo pine (*P. halepensis*) and, particularly on the western and southern coastal areas, the species *Cedrus atlantica*, *Chamoecyparis lawsoniana* and *Libocedrus docurrens*. The leaves from the first pruning of eucalyptus plantations were used for the extraction of eucalyptus oil, an activity that has been abandoned because it is not economically worthwhile.

In Spain as long as in Portugal, a reduction in the productive capacity of plantations has been noted, while reforestations with conifers have been blamed for degrading the landscape, which becomes monotonous, reducing biodiversity and increasing flammability.

Given of these severe ecological problems LPN (Liga para a Protecçáo da Natureza 1992) presented the following conclusions, which may also be used as criteria for selecting the method:

1. Reforestations are not automatically beneficial to the environment; the used species and techniques should be suited to the particular site.
2. Fast-growing species pose serious threats to the environment, which are caused by the properties of species and applied forestry practices. Reforestation with such species, particularly eucalyptus, should not be subsidised.
3. Provisions for contributing to management expenses encourage reforestation activities, but the use of inappropriate management techniques (use of pesticides, insecticides, fungicides) may be damaging to the environment.

On these grounds, rehabilitation or regeneration by changing the species is only acceptable where the soil has been degraded to such an extent that it does not respond to the biological needs of existing species and where the qualitative structure of stands is such that it does not allow the application of the rehabilitation method of thinning interventions.

In these cases, too, however, particular attention should also be given to the appropriate selection of species in order to ensure that they are fully adapted to the area's ecological conditions and do not degrade the landscape, and to the appropriate selection of reforestation methods, which should be environmentally friendly.

Artificial regeneration

Artificial regeneration, by seeding or planting holm oak saplings in areas where holm oak forests or scrub once existed but which were cleared and given over to agriculture, which has also been abandoned, has only been applied for research and not on a wide scale in any Mediterranean country. Such an experimental trial was carried out in 1993 in Toledo in Central Spain at an altitude of 450 m. Average annual rainfall amounts to 403,1 ±81 mm and average temperature is 14,9±1,1 °C (Rey Benayasa and Camacho-Cruz 2004). One-year old seedlings were used. The area used by the experiment was an abandoned field that had been used in the past for grain.

The seedlings were planted in squares of 10x10 m, with 50 seedlings to each square, in holes 40 cm deep and 20 cm in diameter. Four types of treatment plots were included in the experiment: a reference plot, a plot that was irrigated during the dry period of July-August, a plot that was shaded and a plot that combined irrigation and shade. Irrigation was carried out through two artificial rains, one in July and one in August, with an amount equivalent to 60 mm of rain each time and 120 mm for the entire year. Artificial shading was accomplished by placing black polyethylene at a height of 2 m above ground surface, which reduced sun radiation by 68%. Each treatment was repeated 4 times and a total of 16 rectangular plots were used. The experiment was set up in 1993 and treatments were repeated for three years. In 1996 treatments were stopped and the first results were evaluated. The measurements were repeated in 2002. Seedling mortality, diameter at the trunk base, crown height and appearance were assessed. Differences between the reference plot and the other treatment plots were significant with respect to all said parameters, while differences between treatment plots were insignificant. The authors reject the combination of shading and irrigation due to the great cost and recommend a three-year irrigation or shading period, depending on the estimated cost. The average height of seedlings at the age of nine years was $\simeq$1.0 m for the reference plot, 1.3 m for the irrigated plot, 1.2 m for the shaded plot and 1.0 m for the combined irrigation-shading plot. This height is very low and may possibly be explained by the limited productive capacity of the used soil.

This method is quite expensive for application by private individuals aiming to exploit it economically. It could only used for aesthetic purposes and in order to restore the landscape.

B. Hungarian oak forests

Artificial rehabilitation by changing the species (introduction of conifer species)

This method is primarily applied in cases where the soil has been degraded to such an extent that it can no longer support existing species. In such cases, we alter the species through the introduction of mainly frugal conifers, such as black pine, something that occurs naturally where oak ecosystems come into contact with corresponding black pine or fir ecosystems.

This method, is applied to relatively small areas, which are the size of a group, copse or small stand, situated on the poorest quality sites (V, VI), namely on south-facing ridges and slopes. Under no circumstances should the species be replaced on a wide scale because, in addition to degrading the landscape, the introduction of conifers will also bring about a change to ecological niches with unpredictable consequences for the soil and biodiversity.

The method is applied as follows: when a coppice stand reaches maturity, namely its rotation age, it is cleared, and after the felled timber has been removed, two-year old black pine saplings are planted in autumn in a link structure of 1.5x1.5 m at the sites specified for the introduction of conifers. Planting is done in holes without prior treatment of the soil. If the stand is being naturally converted through thinning interventions, then only the sections intended for the introduction of conifers should be cleared. Hence, mixed oak and black pine stands are created at a ratio of 0.6-0.8 oak and 0.4-0.2 black pine (*Pinus nigra*).

Introduction of black pine has been applied to the area of Cholomondas in Chalkidiki and according to Smyris and Ganatsas (1995) it is successful.

Artificial regeneration

In Greece there are only a few examples of an experimental nature regarding the regeneration of oak stands, which as reported by Ganatsas et al. (2003) are situated in the areas of Seich Sou in Thessaloniki (*Q. pubescens* and *Q. ilex*), Kassandra in Chalkidiki (*Q. ilex* and *Q. coccifera*) and Mytilini on Lesvos island (*Q. ithaburensis* sub. *macrolepis, Q. ilex* and *Q. coccifera*). From these, it appears that the establishment of oak species is quite difficult and more research is required on improving the effectiveness of planting.

According to Ganatsas et al. (2003), the use of oak saplings in reforestation faces a number of difficulties, which are mainly due to the oak's ecological physiology and the manner in which the root system of young trees develops. They recommend, however, the continuation of efforts on the following conditions:

1. Correct choice of species.
2. Ensuring the high quality of planting material, which should be appropriately prepared for arid conditions.
3. Tending the saplings after planting.
4. Use of seeding on condition that seeds are protected from animals and birds that eat them.

By contrast, there are a number of examples regarding wide-scale projects aimed at the total substitution of oak trees with conifers, by inter-coppicing oak forests in Nigrita, Grevena and Agrinio, and even including the use of foreign species such as *P. maritime*, with negative economic and ecological results (Tsitsoni 2003).

4. Rehabilitation and regeneration of coppice oak forests with the use of natural methods in the Mediterranean

4.1. Rehabilitation of coppice holm oak and hungarian oak forests through selective inversion thinning at Mount Athos

Spyros Dafis and Petros Kakouros
Greek Biotope/Wetland Centre, 14th km Thessaloniki-Mihaniona, 57001, Thermi, Greece

Introduction

Selective inversion thinning has been applied to a number of areas, mainly to deciduous oak forests of Northern Greece. According to Smyris and Ganatsas (1995) and Smyris et al. (1999), inversion thinning interventions that were initially applied in 1973 in the area of Taxiarchis with the use of the said method resulted in an increase in the volume of wood, indicating a more optimal utilisation of the soil's productive capacity, and the differentiation of the forest's structure (rigorous thinning led to a two-storey structure, while normal thinning led to a less differentiated structure). They also found that the different degrees of thinning do not affect vertical growth. Chatziphilippidis and Spyroglou (1998) arrived at similar conclusions and stressed the need to plan and apply the inversion thinning method carefully. The interventions at Kerdylia also had a positive effect on *Quercus frainetto* and *Q. petraea* subsp *medwediewii* forests (Tsitsoni 2003).

Overall, it may be concluded that the method is completely successful with respect to the objectives of forest ecosystem rehabilitation and compatible with biodiversity preservation. It should also be noted that there is sufficient scientific knowledge and stuff to support its application given the distribution of adequate number of experienced foresters and forestry personnel throughout Greece.

The method of rehabilitating degraded coppiced forests or closed scrub formations of *Quercus ilex* (holm oak) through selective inversion thinning was first applied in Greece by the AUTH Laboratory of Silviculture (Zagas et al. 2004), with results that satisfy the overall objectives of inversion thinning of holm oak and deciduous oak forests and the specific objectives of the areas belonging to the NATURA 2000 network.

The bibliography also mentions cases of selective inversion thinning of holm oak forests (e.g. Morocco), but it is not clear if the aim of these thinning interventions was to convert the coppices to high forests or to improve the scrub meadows that can be found there.

Outside Greece, the selective inversion thinning method is known, but it is not applied on a wide scale. In the last decade, however, trial applications of selective inversion thinning of oak forests without altering the species have been carried out in Italy[1] and Spain, which indicates a growing interest in the subject, since it is recognised that rehabilitation through thinning interventions contributes to increasing biodiversity, improves the quality of wood reserves and decreases the risk of fire (Velez 1990). Given the overall positive results from applying thinning interventions that aim at rehabilitating coppice oak forests and the growing interest in the state of holm oak forests around the Mediterranean, it was a real excellent opportunity that come true that in 2004 when the Holy Community of Mount Athos decided to support the rehabilitation of hungarian oak and holm oak forests through the project "Rehabilitation of coppice *Quercus frainetto* (9280) and *Quercus ilex* (9340) woods to high forests".

Investigation area and methods

The areas under investigation are the deciduous oak (*Q. frainetto)* and holm oak (*Q. ilex*) forests of Mount Athos. Up to the mid-19th century the entire Mount Athos peninsula was covered by high forests with a great variety and number of species. At that time, the forests of Mount Athos were particularly dense, and included a great variety of species. Almost a century later, the German plant community expert Rauh, who visited Mount Athos in the 1940s, reported that despite the conversion of many forests to coppices, the vegetation maintained its leafiness and density.

The forests of broadleaf evergreens that surrounded most Holy Monasteries were always used to meet the monks' fuel needs. This is the reason that most degraded forests (scrubs) of broadleaf evergreens are situated around or close to Holy Monasteries.

At around the end of the 19th century, and particularly after the October revolution of 1917 and the agricultural reforms of 1924, in combination with the loss of monastery dependencies to Russia and the Ukraine and the expropriation of agricultural land in Greece, many monasteries were forced to exploit their forests, mainly the chestnut and broadleaf evergreen forests, which were converted to coppices for the production of industrial timber and firewood respectively. The high quality firewood that was produced by broadleaf evergreens (holm oak, holly, strawberry tree, jasmine box, and laurel) was supplied at reasonable prices to, mainly, the market of Thessaloniki, and to other areas, to which it was transported by caique. As a result of this change in the management objective of broadleaf evergreen forests, almost the entire area was converted to low forests or high scrub (maquis). The oak forests of Mount Athos also suffered the same fate.

Today, great sections of the broadleaf evergreen and holm forests have been converted to scrub and low forest, and only certain remnants, such as the holm oak forest of Agia Anna, remind us of their past grandeur.

In Mount Athos since the 1990s there have also been isolated attempts at rehabilitating oak coppices through the selective inversion thinning, primarily, of oak forests and occasionally of holm oak forests. These attempts were carried out on the initiative of

1. E.g. LIFE Environment project SUMMACOP (www.regione.umbria.it/summacop), which aimed to test various approaches to managing coppice forests in order to achieve the forest's sustainable development and to meet the specific needs of the local population and the forest owners.

certain monks who were responsible for managing the forests and had empirical experience of the advantages of thinning such forests.

Through the said Life NATURE project, the attempt at rehabilitating coppice forests was systematised and extended to other vegetation types, such as mixed holm oak-kermes oak stands.

The method of selective inversion thinning was applied with the aim of rehabilitating the structure of the forests in order to promote biodiversity, reduce the risks of the rapid spreading of forest fires and to re-establish the landscape's primitive features. A total area of 500 ha, scattered across the entire Mount Athos area and containing different environments, was thinned. Holm oak dominate the selected stands on its own (percentage of cover density > 50%) or in combination with laurel, achieving a percentage of cover density in excess of 50%. It was also endeavoured to select stands that were older than 20 years and taller than 5 m. This height was necessary for the selection of the better shoots. Thinning interventions were carried out from April to October in the years 2005 and 2006.

The intensity of thinning was not fixed, on account of the great diversity in vegetation and stand structure. A criterion regarding thinning intensity was to prevent fragmentation of the canopy and to preserve a cohesive 'frame' of trunks for the gradual strengthening of the stand. In general, however, thinning interventions at holm oak forests were relatively rigorous (20-30% of the number of trees in the dominant crown class), while at broadleaf oak forests they were of a moderate intensity (15-20% of wood reserves). The interventions were carried out at sites with a limited to average gradient and differing exposure levels and geological beds. Site altitude ranged from sea level to 1000 m, with holm oak interventions taking place primarily at lower altitudes and hungarian oak at higher ones.

In order to evaluate the selective inversion thinning interventions, a network of plots was established for monitoring the evolution of the cultivated stands. The network consists of 45 plots, sized 600 m^2, which are divided into two equal sections, one of which has undergone inversion thinning and the other has been allowed to evolve naturally (reference plot). Basic forestry data was collected from each of these plots (tree height, canopy base height and chest-height diameter) along with vegetation relevees. This data will comprise the reference data for the future monitoring of the stands.

Results

Silvicultural data. The forestry data that were collected cannot be used for the immediate drawing of conclusions with respect to the effect of thinning interventions because of the limited amount of time that elapsed between the thinning interventions (in some cases only a few months), and hence a comparison between the plot sections that underwent thinning and the reference plots would not be meaningful.

In total, 2,870 trees were measured in the plots that were thinned and 670 trees in the reference plots. Table 1 provides a summary illustration of the average measurements according to species.

Vegetation data. From the relevees that have been taken by Tsiripidis and Fotiadis (2006) 152 taxa have been located. From those species 8 are included in national or international list of protected or endangered species.

In particular, *Ruscus aculeatus* is included in Annex V of Directive 92/43/EC (Habitats Directive) while *Fritillaria pontica* and *Muscari comosum* are protected by the Presentential Degree 67/1981. *Ruscus aculeatus* is also included in the Red Data Book as species with no information for Greece as long as on international level. *Rosa arvensis* is also included in IUCN Red Data Book as endangered on international level and as species with no information

Table 1. Summary data from measurements at the monitoring plots.

	Broadleaved oak forests	*Quercus ilex* forests
Average height at reference plots (m.) ± sd	6,052 ± 1.82	7,939 ± 2.06
Average height at thinned sections (m.) ± sd	7,314 ± 1.78	7,454 ± 2.13
Average diameter at reference plots (cm) ± sd	8,013 ± 4.36	10,835 ± 4.23
Average diameter at thinned sections (cm) ± sd	8,564 ± 3.31	9,224 ± 4.03

for Greece. *Cephalanthera longifolia, Epipactis microphylla, Limodorum abortivum* and *Platanthera chlorantha* are protected from the Convention for International Trade of Endangered Species (CITES).

With respect to differentiations in the vegetation between sections that were thinned and the reference plots, Tsiripidis and Fotiadis (2006) ascertained no changes to the plant communities of the plots that underwent selective inversion thinning, though a slight effect has already been noted with respect to the species' population.

Naturally, the most immediately perceptible difference concerns the great improvement in access to stands that were thinned, which were previously inaccessible (Images 1 and 2).

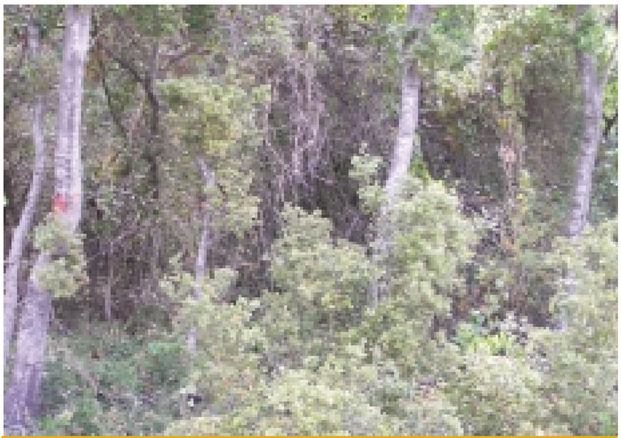


Image 1. No thinned stand.

Conclusions

Although it is very early to draw any conclusions regarding the success of the interventions, the initial indications are encouraging. With respect to plant diversity there seems to be an increase in the number of species belonging to the under story, while in certain cases the appearance in the under story of species that need more light was also noted. In general terms, the remaining trees seem to be occupying the space created by the felled trees, though certain problems with respect to ruptures due to snow were also noted in some holm oak stands, whose tall thin trunks did not have enough time to develop sufficient strength to withstand the pressure of snow. This problem, however, is limited. Another ecosystem function that seems to have improved is the decomposition of ground organic matter, which has

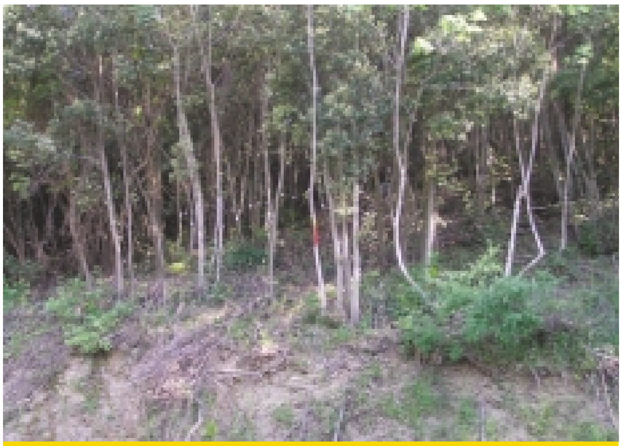


Image 2. Thinned stand.

probably been accelerated.
Overall, the application of selective inversion thinning at Mount Athos is a particularly important endeavour since:

- It is the first time that the method has been applied to such a large area of holm oak forests and their various structures.
- The method was applied to an area where the management of forests has many objectives (spiritual, preservation of nature, economic), so in the long term it will be possible to conduct more wide-ranging evaluations (economic, forest output, exploitation of materials etc.).
- Permanent plots for monitoring the results of the intervention have been installed.

Bibliography

Zagas, T. D., P.P. Ganatsas, Thekla Tsitsoni and Marianthi Tsakaldimi. 2004. Thinning effect on stand structure of holm oak stand in northern Greece. In: Arianoutsou, M. and V.P. Papanastasis (eds), Proceedings of the 10th MEDECOS Conference, April 25-May 1, 2004. Rhodes, Greece. Millpress, Rotterdam.

Smyris, P. and P. Ganatsas. 1995. Results of inversion thinning of oak forests at Cholomondas in Chalkidiki. In: Forestry Development, Ownership-Planning, Proceedings of the 6th Panhellenic Forest Science Conference, Chania, April 1994. Hellenic Forestry Society, pp 301-317 (in Greek).

Smyris, P., M. Aslanidou and I. Milios. 1999. Oak thinning (Quercus conferta Kit.). In: Contemporary silviculture problems. Proceedings of the 8th Panhellenic Forest Science Conference, Alexandroupolis, April 1998. Hellenic Forestry Society, pp 417-424 (in Greek).

Chatziphilippidis, G. and G. Spyroglou. 1998. Effect of logging on broadleaf oak forests (Quercus frainetto). In: Contemporary silviculture problems. Proceedings of 8th Panhellenic Forest Science Conference, Alexandroupolis, April 1998. Hellenic Forestry Society, pp 417-424 (in Greek).

Tsiripidis, I. and G. Fotiadis. 2006. Assessment of the effect of selective inversion thinning interventions on the flora of the Quercus ilex and oak forests of Mount Athos. Greek Biotope/Wetland Centre, 20 pp + annex (in Greek).

Tsitsoni, Thekla. 2003. Forestry study of oak forests in Greece. Proceedings of 11th Panhellenic Forest Science Conference, Ancient Olympia, October 2003. Hellenic Forestry Society, pp 116-125 (in Greek).

Vélez, R. 1990. Preventing forest fires through silviculture. Unasylva 162, 5 p.

4.2. Silvicultural treatments of holm oak coppice forests for their conversion to high forest

Theocharis D. Zagas,
Petros P. Gkanatsas,
Thekla K. Tsitsoni
Aristotle University of Thessaloniki (AUTh),
School of Forestry and Natural Environment,
54124 Thessaloniki, Greece

Introduction

One of the most significant ecological and forestry problems in our country concerns managing coppice forests, which have not been systematically studied, although they cover significant areas. In recent decades some studies have been undertaken on the conversion of oak forests (Dafis 1966, Zagas, et al. 1998, Thanasis and Zagas 2001, Zagas et al. 2003), but none has dealt with holm oak forests.

The first investigation of coppice forests started in 1996, undertaken by the members of the Forestry Laboratory at AUTh (Hatzistathis et al. 1996, Zagas et al. 1998). Holm oak forests spread at low altitudes and are usually found in regions near the sea. In recent years a group of scientists have recognised the special social benefit of such forests (aesthetic, protective, hydrological, ecological function) (Tsitsoni and Zagas 1992, Hatzistathis et al. 1996). This is why it is considered imperative that, at least where the location is of top quality, such coppice forests should be managed through suitable silvicultural care (Dafis 1966, 1990) so as to become high forests or a combination of the two types; this leads to the following advantages (Mattheus 1989, Zagas and Hatzistathis 1995, Thanasis and Zagas 2001):

- Increased biodiversity, ecological stability and long-term economic interest of such forests.
- Reduction of soil erosion and improvement of standards.
- Help in fighting the greenhouse effect
- Improvement of the quality of products in the future.
- Contribution towards the production of more and better water.
- Contribution towards the protection of valuable biotopes.
- Contribution towards improving landscape aesthetics.

The research was undertaken in the holm oak forests at Stavros, Thessaloniki, within the framework of the Environment European Programme (1994-1995). The aim of the study was to:

1) determine the condition of the stand from a silvicultural point of view;
2) assess the effect of various intensities of thinning: a) on the stand growth, b) the structure and qualitative composition of stands, c) the fire resistance of stands, since fires comprise an important hazard for the destruction of these forests, and
3) determine the intensity of thinning according to the special features of the stands.

Materials and methods

In the region of Stavros, Thessaloniki, three plots, as similar as possible in regard to their standards, were selected, each one covering 0.5 ha. On each plot, 4 blocks, 40 mx25 m, were created. Between the blocks, a non-intervention zone, at least 5 m wide, was left. Then, all trees with a diameter exceeding 4 cm were numbered and their diameter, height and foliage starting height were measured.
All trees were classified on the basis of the IUFRO silvicultural system (Dafis 1962, Quellet and Zarvonican 1988).

Table 1. Increase of stand basal area (G) with various manipulations seven years after the first thinning.

				7 years after thinning	
Treatment	G before thinning (m^2/ha)	G removed with timbering (m^2/ha)	G after thinning (m^2/ha)	G total (m^2/ha)	increase G (m^2/ha)
Control	7.23	0	7.23	9.50	2.27
Mild thinning	11.33	1.13	10.20	11.19	0.99
Medium thinning	19.75	3.27	16.48	22.43	5.95
Intensive thinning	25.58	7.52	18.06	22.59	4.53

After that, in each one of the four blocks high thinning was performed with a positive selection of different intensity, as follows:

- Mild thinning, removing 10% of stand basal area in the first block.
- Medium thinning, removing 20% of stand basal area in the second block.
- Intensive thinning, removing 30% of stand basal area in the third block.
- Control –no intervention– in the fourth block.

After seven years passed, the same measurements were performed once again to determine the effect of the thinning on the growth and characteristics of stands.

Results

The density of the stands before thinning was great and ranged from 3,010 to 5,300 individuals/hectare. As shown in Table 1, growth conditions improved after thinning on the plots of medium and intensive thinning. Total growth of stand basal area in the first case was 5.95 m^2/ha and in the second 4.53 m^2/ha. On the contrary, mild thinning did not contribute to stand growth. The greatest height growth was observed in the intensive thinning plot, while the best diameter growth was observed in the medium thinning plot.

Conclusions

Seven years after thinning was performed, the following conclusions were drawn. It should be noted that in order to draw fully documented results, much longer time periods are required and that is why this research project is still in progress.

1. The conditions of the stands were improved, from a silvicultural/biological point of view, as follows:
   - The best growth conditions were achieved with medium thinning.
   - The best vitality was observed on plots where medium thinning was performed.
   - The best stem quality was observed on plots where intensive thinning was performed.
   - All thinning, regardless of its intensity, improved stem quality.
2. The most suitable thinning for the improvement of stands fire-resistance was medium thinning (20%) (Zagas et al. 1998).
3. Medium and intensive thinning accelerated the differentiation of stands into upper and middle storeys, increasing their resilience against external factors. Furthermore, they contributed towards early fruit-bearing.
4. Medium and intensive thinning favoured elite individuals, which comprise the future of stands.
5. The conditions of stand growth differ within very small distances and that is why thinning should be

adapted to actual conditions. Intensive thinning should be performed in dense stands of good standards, whereas mild thinning could be the rule for all stands, since it offers most advantages.

Bibliography

Dafis, Sp., 1962. Struktur und Zuwachsanalysen von natuerlichen Foehrenwaeldrn. Bern. Verlag hans Hubert.

Dafis, Sp., 1966. Research into the standards and efficiency of oak coppice and chestnut forests of North-Eastern Halkidiki. Ph.D. Dissertation for the Forestry and Hydronomics Lab at Aristotle University of Thessaloniki. P. 120

Dafis, Sp., 1973. Classification of the vegetation of Greece. Aristotle University of Thessaloniki. Horticulture & Forestry School Annuals. Vol. 15: 75-86.

Dafis, Sp., 1990. Applied Silviculture. Yiachoudi-Yiapouli Publishing. Thessaloniki.

Hatzistathis A., Zagas T., Gkanatsas P. & Tsitsoni T., 1996. Thinning treatment effects on stand structure and quality of holm oak coppice. Proc. of second Balkan scientific conference on Study, Conservation and Utilisation of Forest Resources. Sofia 1996. Vol. 1: 11-16.

Matthews J., 1989. Silvicultural Systems. Oxford Science Publications. Oxford University Press. New York.

Ouellet D., & Zarnovican R., 1988. Cultural treatment of young yellow birch (Betula alleghanien-sis Britton) stands: tree classification and stand structure. Can. J. For. Res. 18: 1581-1586.

Thanassis, G. and Zagas, T., 2001. Contribution of coppice oak forest thinning on the eastern slopes of the Kerdyllia Range to the conservation of the natural environment of the broader region. Minutes of the 9th Hellenic Forestry Conference. Kozani, October 17-20, 2000: 609-619.

Tsitsoni, Th. and Zagas, T., 1994. The contribution of Ca sandra forests to the development of the region; silvicultural manipulation to improve their various functions. Minutes of the 6th Hellenic Forestry Conference. Chania, April 6-8, 1994: 162-167.

Zagas, T. and Chatzistathis, D., 1995. Ecological management of productive forest ecosystems. Minutes of Natura 2000 Conference (EU Directive 92/43) October 12, 1995: 109-117.

Zagas, T., Gkanatsas, P. Tsitsoni, T. & Hatzistathis. A. 1998. Influence of silvicultural treatment on ecology, quality and fire resistance in Quercus ilex coppice stands, in N. Greece. Proc. of VII International Congress of Ecology (INTECOL), Florence 19-25 July 1998: 473.

Zagas, T., Papapetrou, P. and Thanassis, G., 2003. Research into the growth conditions of oak coppice forest in Kastania, Northern Pieria; possibility of stand thinning. Minutes of the 11th Hellenic Forestry Conference. Ancient Olympia, September 30 October 2, 2003.

4.3. The conversion to high forest of holm oak coppice (*Quercus ilex L.*): preliminary results.

O. la Marca[1] L.M.R. Rinaldi[2]
[1]DISTAF, Università di Firenze,
Via S. Bonaventura, 501 00 Firenze, Italy
[2]IVALSA, CNR, Via Madonna del Piano,
500 19 Sesto fiorentino (Fi), Italy

Introduction

Holm oak (*Quercus ilex* L.) is considered to be a Steno Mediterranean species to be found along the Italian coasts independently from pedological substrate and can also be found in the Iberian peninsular.

In the case of the Promontory of Gargano in the south of Italy, the holm oak stands (Ostrya-Quercetum ilicis) besides colonizing areas at lower altitudes marginal for agriculture also grow to a height of 800 m above sea level in internal areas with a sunny exposure. Considering the evolution of these forests in the last 40-50 years, it seems that the area of holm oak woodland is in phase of expansion. In the area examined the holm oak coppices cover a large area both in the pure state and mixed with other species of the same vegetation level. On the slopes exposed to the south it is even possible to find holm oak sporadically or in small groups up to almost 1,000 m a.s.l. holm oak has been a component of the forests and landscapes of the Gargano since historical times. For the past 40-50 years the most usual form of holm oak silvicultural system was the coppice with a few standards per hectare according to short rotations (generally 15 years) both to satisfy the strong demand for fire wood in order to obtain a particular kind of coal known as cannello.

Previous research has shown the convenience of the extension of the rotations (Hermanin et al 1990). The decreasing human presence and the considerable regeneration capacity of this species have noticeably improved the general situation of holm oak coppices, the completing of canopy closure, accumulating growing stock and, in the best soil conditions, even increasing biodiversity.

Material and methods

This study examined 45 year old holm oak coppices situated at a level of 650 m a.s.l. on a slope of about 40% inclination and exposed to the south. Soils attributed to rendzina often showed the calcareous surfacing matrix. The climate is Mediterranean type with a rainfall around 650-700 mm per year, high atmospheric humidity and three months of aridity in summer (sensu Bagnouls-Gaussen). Holm oak dominates specific compositions in which flowering ash (*Fraxinus ornus*) and hornbeam (*Ostrya carpinifolia*) are also present sporadically. Density is full and the tree stamp number is high. From the phytosociological point of view ilex is attributed to the Ostryo-Quercetum ilicis. The brushwood is represented above all by *Asplenium onopteris, Asplenium trichomanes, Cyclamen neapolitanum, Ruscus aculeatus,* and all species of ilex grove.

The design for experiment was a randomised block with three replications, six areas each of 1600 m^2. The treatments compared (la Marca et al. 1995 and 1996) repeated three times are:
1. Conversion to high forest.
2. Natural evolution (control).

The conversion has been performed by the so called indirect method, a previous selection of around 2000 shoots per hectare with a mean diameter about 12 cm and a basal area about 22 m^2.

The following parameters were examined: aspects defining biodiversity (valued through the Shannon index), wood productivity, impact on landscape (resulting from the visual perception of the silvicultural treatments), wood stability against meteoric adversities (valued through the quantification of the damaged plants or death). The perspectives over a medium and long period have been affected on the base of the above mentioned evaluations, the author's experiences and literature data. The area where the experiment took place is presented in Image 1.

Image 1. Sample plots one year after silvicultural treatments.

Results and Discussion

The results of this work demonstrate that snow and wind represent a serious adversity for holm oak (*Quercus ilex* L.) stands (Table 1). The sample plots converted to high forest mostly resulted damaged while those destined to natural evolution (control) resulted more resilient from this point of view. It deals with a consistent damage considering that shoots selected to form high forest will stand for a very long period and considering that high forest is expected to produce well shaped trees having a well balanced canopy in order to produce seeds.

In all cases the compactness of the canopy and also the efficiency of the forest have not been compromised because the damaged shoots, considering regeneration capacity of holm oak in general, tend to reform their own crown.

As regards to the results of biodiversity, it was seen that in the areas converted to high forest, the floral richness is higher due to the 'entry' of herbaceous and shrubby plants, especially meadow and glade flowers inversely correlated to the stand canopy. It was seen that the areas poorer in flowers were those left to natural evolution (control). Also in the coppice, as time passes, the floral richness decreases, increasing the degree of canopy of the standing trees. Such floral diversity examined through the Shannon index (Shannon and Weaver 1949) varied from 1.75 to 2.46 respectively for the plots left to natural evolution (control) and those to high forest.

Table 1. Snow and wind damage.

	Number of shoots per hectare			Damages	
Treatments	**Before storm**	**Damaged**	**After storm**	**Shoots (% before the events)**	**Volume m^3/ha**
Control	6790	196	6,594	2.9	17
Conversion to high forest	2031	413	1,618	20.3	28

Image 2. Sample plots thirteen years after silvicultural treatments. No difference between control and conversion stands.

Table 2. Analysis of variance for the diameter of shoots.

	Sum Squared	df	Mean Squared	F	P value
Treatment	9.441329	1	9.441329	64.80705	0.001293
Error	0.582735	4	0.145684		

According to Margalef (1993) the maximum values of diversity are about 5 in natural ecosystems. After more than ten years from the beginning of the treatment the afore mention differences have decreased owing to the increase of the stands to high forest and for the enlargement of the crown of the stands. The areas destined to high forest have seen a reduction in density of about 50% of the basal area which has gone from 40-45 m^2/ha to about 20-22 m^2/ha, the collecting samples in terms of mass has been about 100 m^3. Further more as regards the productive aspect, the areas destined to high forest showed a mean diameter increase of about 27-28 mm as compared to 3-4 mm in the control area after 12 years from the beginning of the treatment. Data were highly significative (P=0.001) (Table 2).

The impact on the landscape, valued as above, both in plots converted to high forest and in the control ones resulted less perceptible or completely imperceptible. The study area, as is appeared 13 years after is presented in Image 2.

Conclusions

Above all this study has revealed the effects of the different forms of silvicultural system on holm oak coppice. The coppice problem in general can be faced through the adoption of different choices of silvicultural system: maintenance of the coppice system, conversion to high forest, natural evolution.

The present study, starting by these considerations, represents a first contribution regarding the conversion to high forest in comparison to natural evolution (control). The conversion to high forest in comparison to the plots left to natural evolution is certainly the silvicultural treatment that involves a greater floristic wealth, a good answer of growth, a modest impact on the landscape and so it is appreciated by the public. On the other hand the areas dedicated to high forest are more sensitive to damage from wind and snow. Other problems regard the good result of seed regeneration when the work of conversion is completed and the stand reaches maturity on rocky soil with little depth of soil. In general the opinion is that if there are not sufficient guarantees of the plants taking root or seed regeneration, the problem must be faced with great prudence, with perhaps deciding on the treatment to coppice and then later for conversion to high forest.

In conclusion, although some aspects remain to be clarified, the conversion to high forest appears to be the cultural treatment which could most profitably be applied to *Quercus ilex*.

Bibliography

Hermanin, L. e M. Pollini. 1990. Produzione legnosa e paesaggio.Considerazioni sul turno in cedui di leccio. Cellulosa e Carta 2, p.6-10.

La Marca, O., P.A. Marziliano, N. Moretti N. e G.Pignatti. 1995.Dinamica strutturale e flogistica in un ceduo di l eccio. Annali Accademia Italiana di Scienze Forestali, Vol. XXXIV.

La Marca, O., P.A. Marziliano, N. Moretti N. e A. Santoro.1996.Management in aging holm oak (Quercus ilex L.): experimental results after four growing season. Annali Istituto Sperimentale Selvicoltura 27, p. 161-165.

Margalef, R.1993. Teoría de los sistemas ecológicos 2nd. Ed. Universitad de Barcelona. 290 p.

Shannon, C.I. and W. Weaver W. 1949. The matematical theory of communication. Illinois Books. Urban.

4.4. Growth response to thinning in oak coppices stands in Span

Cañellas I., Del Rio M., Roig S.
CIFOR-INIA, Cª de la Coruña km 7.5, 280 40 Madrid, canellas@inia.es

Introduction

Due to rural development, spectacular changes in land uses have been affecting numerous regions of Europe in recent decades, particularly in mountain areas and in Mediterranean countries. Nowadays, management of the extensive areas of Quercus species coppices is one of the largest problems that forestry research is facing in Mediterranean countries. In the past, these stands were managed as coppice or coppice with standards by cutting trees every 20 years. They had a prominent place within the traditional economy of Mediterranean regions, as providers of firewood, charcoal, fuel for glass making, products such as tannin, and also by providing grazing areas for livestock, primarily sheep and cows. This treatment was progressively abandoned due to the decrease in use of firewood and charcoal as an energy source. As a result of the lack of management, these stands show now severe ecological, economic and social constraints such as high tree densities, almost no seed regeneration, stand decay, and loss of economic and social benefits, etc., this may endanger the existence of Quercus stands in the long run. At the driest and lowest quality sites, there is stagnation in growth, and one of the greatest risks for these coppices is their destruction by forest fires (Serrada et al., 1992).

The recognition of these problems in such wide areas, and the increasing interest in implementing direct and indirect production uses for these stands (silvopastoral uses, recreation, environmental preservation) justify the urgent need to study and manage them (San Miguel, 1983; San Miguel at al., 1995). Several studies throughout the Mediterranean area (Cañellas et al., 1994a, 1994b; Cutini et al., 1996; Ducrey, 1991; Guérad et al., 2001; Mayor and Roda, 1993) led to possible alternatives to the current coppice situation, from the abandonment of silvicultural practices to a more intense level of management: reforestation, agricultural uses, establishment of pastures, new coppice systems, conversion to open woodlands, transformation to high forest, etc. *Quercus pyrenaica* Wild., *Q. faginea* Lam. and *Q. ilex* L., main Mediterranean Quercus species in Spain, seem to be better to the two last alternatives in Spanish conditions (Cañellas et al., 1994b, 1996; Roda et al., 1999; Serrada et al.,1992).

The Centre for Forest Research (CIFOR-INIA) planned a set of thinning experiments to transform the structure of *Q. pyrenaica* and *Q. faginea* coppice, focusing on various aspects: stand structure and production, litter fall, shoot production, acorn production, herbaceous vegetation, etc. (Cañellas et al., 1994b; San Miguel, 1983; Zulueta, 1981; Zulueta and Montero, 1982). The main objective of this work was to analyse the effect of thinning on growth and development at individual level in a *Q. pyrenaica* and *Q. faginea* coppices.

Material and methods

A. Quercus faginea coppices

Data used in this study come from a *Q. faginea* coppice forest placed in Barriopedro, (Guadalajara province, Spain). Its aspect is north-west, altitude is 850 m a.s.l. and the mean slope is 20%. It is located at 2º 45′ 16″ W longitude and 40º 48′ 18″ N latitude. Annual rainfalls are 568 mm and mean temperature, 12º C. Soil type is a calcic cambisol.

In 1979 a thinning experience following an unbalanced randomized design, with 21 plots (20x40 m^2) and four treatments The tested treatments were the following: C-Control; T1-light thinning (1,780 stems/ha), T2-moderate thinning (1,025 stems/ha), T3-heavy thinning (758 stems/ha).

Due to the irregularity of the land, the experiment was carried out in blocks according to different slope gradient. Five inventories were carried, in 1980, 1984, 1992, 1997 and 2002. Within the thinning plots the spatial coordinates, diameter at breast height (dbh) of all trees and total height for a permanent sample of 40 trees covering the full dbh range were recorded in the five inventories.

B. Quercus pyrenaica coppice

The experimental trial was carried out on a 30 years old one-storied *Q. pyrenaica* stand in Rascafría (Central mountain range of Spain), on a 30% Southeast facing slope, at 1350 m a.s.l., (40° 54′ N latitude, 3° 51′ W longitude). Annual rainfall there is 1,037 mm and the soil type is a humic cambisol.

The thinning experiment was carried out during the winter of 1994. Four treatments were tested: A-Control; C-light thinning (25% of basal area removal); D-moderate thinning (35%) and E-heavy thinning (50%). The thinning type was from low, eliminating small trees, trees with badly shaped crowns, twisted stems, diseased trees, etc.

The experiment was implemented according to a completely random design with four treatments and two replications. The squared size treatment plot was 1600 m^2. At the beginning of the experiment, all the standing stems were included in the inventory and all stems were permanently numbered. In each plot, the following measurements were made: diameter at breast height (dbh, cm) for all living stems, and total height for a permanent sample of 40 trees covering the full dbh range. Measurement inventories were carried out every 4 years after the thinning (1994, 1998 and 2002).

In both experimental trials time-dependence of tree growth rates where tested by repeated measurement analysis of variance (Moser et al., 1990). To evaluate the effect of thinning treatments and blocks in growth, analysis of variance was carried out of the main crop after thinning for each inventory.

Results and discussion

Table 1 and 2 show the main crop variables per treatments after thinning by *Q. pyrenaica* and *Q. faginea* coppices.

Although Mediterranean coppice forests have usually a small growth rate, they show a positive growth response to thinning, as evidenced by enhanced growth rates of studied *Q. faginea* coppice 1.4, 1.9 and 2.3 mm/year and *Q. pyrenaica* coppice with 1.6, 2.2 and 2.6 mm/year of diameter increment with light, moderate and heavy thinning respectively. Similar results were found in other coppices forest of Mediterranean species. For holm oak Ducrey and Toth (1992) gave values of 1.5 mm/year of mean diameter increment for moderate thinning and Mayor and Rodà (1993) of 1.43 mm/year with the same intensity of thinning. This positive response in growth rate advises to apply thinning in Mediterranean coppices in spite of its low productivity.

Q. pyrenaica and *Q. faginea* responded to thinning differently according to tree size. In absolute terms, growth of large stems was stimulated by thinning more than that of smaller trees. Large trees probably have a greater capacity for resources acquisition, and are thus more able to take advantage of the

Table 1. Evolution of the main crop variables per treatments after thinning.

Treatment	Inventory	N/ha	G	D	H	Ho
Thinned T1	1980	1829	6.27	6.41	5.01	6.81
	1984	1829	7.84	7.19	5.12	6.99
	1992	1829	10.40	8.32	5.29	7.29
	1997	1812	11.62	8.78	5.42	7.42
	2002	1802	13.81	9.68	5.55	7.50
Thinned T2	1980	1035	4.41	7.13	5.41	6.94
	1984	1035	5.76	8.23	5.54	7.15
	1992	1035	7.99	9.72	5.73	7.43
	1997	1015	9.19	10.29	4.11	7.62
	2002	1012	11.03	11.53	6.04	7.73
Thinned T3	1980	758	2.89	6.79	5.25	6.63
	1984	758	4.53	8.02	5.38	6.81
	1992	758	6.38	10.13	5.70	7.20
	1997	758	7.47	10.96	5.88	7.39
	2002	758	8.83	12.10	6.03	7.51

G: Basal area (m^2 ha-1); D: Mean diameter (cm); H: mean height (m); Ho: top height (m). T1-light thinning; T2-moderate thinning; T3-heavy thinning.

Table 2. Main stand Quercus pyrenaica variables per plot at the beginning of the experiment (30 years old).

	Stand before thinning						Stand removed		
Treatment	N	Dg	Hg	G	Bm	BT	N/ha	G	BT
Unthinned	4506	10,1	7.6	36.4	31.8	143.4			
Unthinned	4144	10.6	7.8	36.8	36.4	150.8			
Thinned C	4869	9.4	8.7	33.5	26.0	126.5	2813	8.6	23.1
Thinned C	4506	9.5	8.8	32.2	27.6	124.2	2681	8.7	23.2
Thinned D	5325	8.5	8.3	30.0	20.1	107.2	3531	10.5	27.6
Thinned D	5300	9.1	8.6	34.5	23.9	126.5	3550	12.7	35.7
Thinned E	5394	9.0	8.8	34.3	23.0	124.3	4063	17.2	52.4
Thinned E	4913	9.4	8.9	33.9	26.3	129.2	3719	16.9	52.43

N: stem number per hectare; Dg: quadratic mean diameter (cm); Hg: mean height (m); G: basal area (m^2 ha-1); Bm: biomass of mean tree (kg tree-1); BT: total biomass (t ha-1).

increase of resources availability that takes place after thinning, and to eventually use these resources for growth. Similar results were obtained by Mayor and Roda (1993), Ducrey and Toth (1992) and Cartan-Son et al. 1992). In these cited studies the annual radial growth is positively correlated with diameter size and differences between diameter classes were statistically significant for the study period. More specifically, a higher capacity for canopy expansion, more vigorous branches, and higher uptake of water and nutrients from a larger root system are probably involved in this response.

Growth response to thinning was strong for each time intervals in both species and stem diameter increments were higher for thinned than for unthinned plots (Figures 1 and 2). *Q. pyrenaica* diameter increments were higher during the second period (1998-2002) than during the first one; these results do not agree with others like these obtained by Mayor and Rodà (1993) with *Quercus ilex*, which show an opposite trend probably due to climatic conditions during the experiment. In the same way, in *Q. faginea* stem diameter increments were different in every studied period probably due to climatic conditions during the take of data (Mayor and Roda, 1993). Between 1992 and 1997, when a smaller growth was observed, there was a dry period in this area, confirming the influence of the water resources in Mediterranean forest ecosystem on growth.

The maintenance of growth response to thinning during all the experience suggests a thinning rotation of 20 years for Quejigo oak coppice in this site. This thinning rotation agrees with the results for this species of Bravo et al. (2001), who found a higher growth until 17 years after a thinning. Some authors (Cutter et al., 1991; Mayor and Rodà, 1993; Bravo et al., 2001) found that other perennial and deciduous oaks showed growth responses to thinning rates until 10-12 years after thinning, with growth rates then falling to preliminary values. In *Quercus pyrenaica* coppice has not been observed stagnation in diameter increment eight years after the thinning. A long thinning rotation makes more favorable the practice of thinning in this kind of coppice, because its productivity is too low to justify a great inversion.

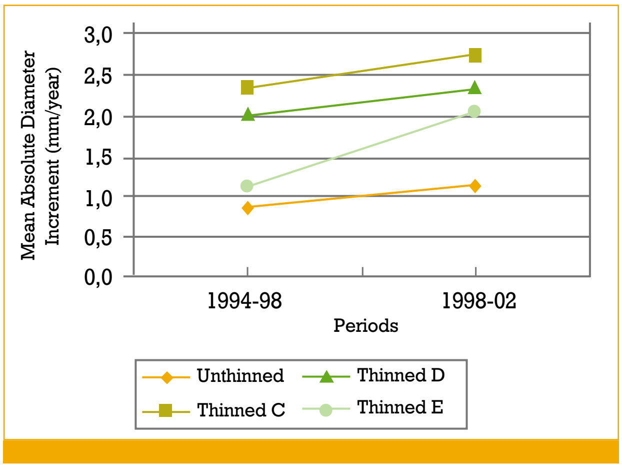


Figure 1. Mean diameter increment in Q. pyrenaica coppices for the three treatments and inventories. C: light thinning; D: moderate thinning; E: heavy thinning.

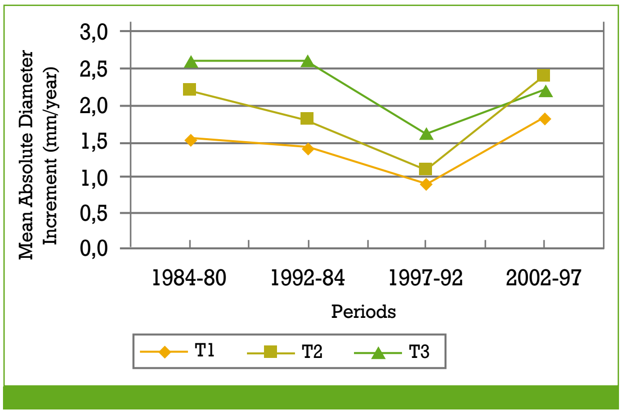


Figure 2. Mean diameter increment in Q. faginea for the three treatments and inventories. T1: light thinning; T2: moderate thinning; T3: heavy thinning.

In order to define silvicultural system based in well established ecological consideration for the management of *Q. pyrenaica* and *Q. faginea* stands, further investigations should consider the interactions between thinning intensities and site conditions (site quality), the duration and the consistence of changes induced by thinning and they should also assess the responses to thinning at the whole stand level (Cutini and Mascia, 1996; Ducrey and Boisserie, 1992; Ducrey and Turrel, 1992).

Bibliography

Bravo, A.; Sànchez, I.; Serrada, R. 2001. Determinación de rotaciones óptimas en la aplicación de resalveos de conversión a monte alto en tallares de encina y de quejigo en la zona central de la Península Ibérica. Proceedings of the III Spanish Forestry Congress. Granada, September 2001.

Cañellas I., Montero G., Ortega C., Torres E., Transformación del monte bajo de quejigo (Quercus faginea Lamk.) a monte adehesado por claras de diferente intensidad. Primeros resultados, in Pascoa et al. (Eds.), Los Recursos Forestales en Desarrollo Rural, vol I, 1994a, pp. 163-170.

Cañellas I., Montero G., San Miguel per la Selvicoltura, 27 (1996): 25-29.

Cartan–Son M., Floret C., Galan M.J., Grandjanny M., Le Floc'h E., Maistre M., Perret P., Romane F., Factors affecting radical of Quercus ilex L., in a coppice stand in A., Montoto J.L., Bachiller A., Transformation of rebollo oak coppice (Quercus pyrenaica Willd.) into open woodlands by thinning at different intensities. Preliminary results. Investigación Agraria. Sist. Rec. For. Fuera de serie (1994b) 71-78.

Cañellas I., Montero G., Jiménez M.D., Litter fall in rebollo oak (Quercus pyrenaica Willd.) coppice thinned with various intensities. Annalli Istituto Sperimentale southern France, Vegetatio 99-100 (1992) 61-68.

Cutini A., Mascia V., Silvicultural treatment of holm oak Quercus ilex L.) coppices in Southern Sardinia: effects of thinning on water potential, transpiration and stomatal conductance, Annali Istituto Sperimentale Selvicoltura 27 (1996) 65-70.

Cutter B.E., Lowell K.E., Dwyer J.P., Thinning effects on diameter growth in black and scarlet oak as shown by tree ring analyses, Forest Ecology and Management 43 (1991) 1-13.

Ducrey M., Quelle sylviculture et quel avenir pour les taillis de chêne vert (Quercus ilex L.) de la région méditerranéenne française, Revue Forestière Française XLIV, 1 (1992) 12-33.

Ducrey M., Boisserie M., Recru naturel dans des taillis de chêne vert (Quercus ilex L.) à la suite d'exploitations partielles, Ann. Sci For. 49 (1992) 91-109.

Ducrey, M., Toth, J. 1992. Effect of cleaning and thinning on height and girth increment in holm oak coppices (Quercus ilex) L. Vegetatio 99-100, 365-376.

Ducrey M., Turrel M., Influence of cutting methods and dates on stump sprouting in holm oak (Quercus ilex L.) coppice, Ann. Sci. For. 49 (1992) 449-464.

Guérad N., Barthélémy D., Cabanettes A., Courdier F., Trichet P., Willm J., Influence de la compétition herbacée sur la croissance et l'architecture de jeunes chênes rouges d'Amérique (Quercus rubra L.) en plantation, Ann. For. Sci. 58 (2001) 395-410.

Mayor X., Roda F., Growth response of holm oak (Quercus ilex L.) to commercial thinning in the Montseny mountains (NE Spain), Ann. Sci. For. 50 (1993) 247-256.

Moser E.B., Saxton A.M., Pezeshki S.R., Repeated measures analysis of variance: application to tree research, Can J. For. Res 20 (1990) 524-535.

Roda F., Retana J., Gracia C., Bellot J., Ecology of Mediterranean evergreen oak forests, Ecological Studies 137, Springer, 1999.

San Miguel A., Inventario de la vegetación herbàcea en montes de Quercus pyrenaica Willd. Diseño e intensidad de muestreo, An. INIA. Ser. Forestal 7 (1983) 55-66.

San Miguel A., Cañellas I., Montero G., Serrada R., Situación actual de la investigación forestal sobre las especies mediterràneas del género Quercus en España, IUFRO XX Congress, Tampere (Finland),1995.

Serrada R., Allué M., San Miguel A., The coppice system in Spain. Current situation, state of art and major areas to be investigated. Annali dell'Istituto Sperimentale per la Selvicoltura XXIII (1992) 266-275.

Zulueta De J., Recherches en vue de l'amélioration des pâturages dans les forêts de Q. pyrenaica et Q. faginea en Espagne, Forêt Méditerranéenne, 3 (1) (1981) 58-61.

Zulueta De J., Montero G., Posibilidades de mejora silvopascícola en montes bajos de quejigo (Quercus faginea Lamk). Efecto de los aclareos en la producción de bellota, An. INIA, Serie Forestal 6 (1982) 75-87.

5. Monitoring

Irrespective of the method used, the rehabilitation of forest ecosystems is a process that achieves its objects gradually and usually reaches its conclusion a few decades after its inception. It is therefore clear that in order to assess its success during the intermediate stages and at its conclusion, it is necessary to establish a system for monitoring the ecosystem's main characteristics with respect to tree growth, stand structure, biodiversity, soil, etc., right from the outset of interventions.

The principles of a monitoring system on the inversion of coppiced forests do not differ from any other system with respect to biodiversity monitoring (Anagnostopoulou, 1996), though the system does display certain particularities in relation to specific forest ecosystem conditions on the one hand and the management of coppices on the other.

Permanent monitoring plots are crucial to such a programme; they are established at the start of selective inversion thinning interventions and they supply structure and diversity information, regarding mainly flora but also other groups of species.

Other programme actions include the adoption of clear and simple guidelines regarding the collection of data, the assumption by the area's management organisation of the responsibility to collect data, systematic cooperation with expert scientists in assessing the results and the utilisation of these results in planning the management of these forests.

5.1. Establishment and maintenance of plots for coppice holm oak and hungarian oak forests

Each plot should cover an area of 600 m^2 and have the shape of a rectangle measuring 40x15 m (recommended) or 30x20 (if the other shape is not possible), and its longest side should run parallel to the contour lines (Figure 1). These plots should be divided into two equal sections; one section constitutes the reference plot where no interventions will take place, while the other section will undergo normal selective inversion thinning interventions. In other words, each sub plot covers an area of 20x15 m or 15x20 m.

Selection of plot location is very important. Specifically, the slope, exposure and geologic substrate of the plot should be as uniform as possible and the ground should display a relatively uniform configuration and rock cover. Frequently used footpaths should not cross the plot and the vegetation features should be uniform; in other words, the plot should not be located in an ecotone. A specialised forester and a plant expert should help in the selection of the plot location.

Figure 1. Establishment of monitoring plots.

Delimitation. This is a particularly important issue because the boundaries should remain unchanged for many years, and they should not be affected by the evolution of the forest or by accidental events (fire, falling trees due to snow, wind, etc.).

For this purpose it is recommended to delimit each

Image 1 Marking of plot with coloured and metal ring.

Image 2. Plot identity tag.

plot by appropriately marking the trees located at its peaks, thereby ensuring visibility from a distance, and using metal stakes that are driven into the ground. The trees located at the 'corners' of the plot should be marked with a coloured and a suitable metal ring (Image 1) at chest height. Division of the plot into two equal sections means that each plot should be marked at six points. In addition, a metal tag should be attached to the corner that is most visible from the plot's approach route (Image 2).

Mapping. Each plot should be recorded on a map of a scale of 1:20,000 depicting the geometric centre of each plot, along with its code, real shape and layout.

Plot maintenance is crucial to the operation of the programme. All markings indicating the plot's location, measurement indicators, etc., should be monitored frequently for damages and repaired or replaced. Particular attention should be given during interventions, in order to replace trees bearing plot markings that need to be felled with other trees or indicator posts.

5.2. Collection and management of data

Various types of information may be collected from such plots, depending on the specific objects of long-term research. For the purpose of monitoring the results of selective inversion thinning it is necessary to collect data from all the trees in the cultivated plot with a chest-height diameter (1.3 m) exceeding 4 cm and from a sample of 20-25% of trees in the reference plot. The trees to be monitored in the reference plot should constitute a proportional representation of the species in the cultivated plot and, where possible, all diameter categories as well.

The monitored trees should be marked permanently with small metal or plastic tags that are placed at the base of the trunk. The information that should, at the very least, be collected includes chest-height diameter, height and canopy base height.

With respect to vegetation data, it is recommended that plant samples be collected according to the Braun Blanqeut method. It would also be useful to collect soil samples, if feasible. Measurements regarding growth and vegetation data should be repeated every 5 years.

It is particularly important that data is collected under the guidance of expert scientists and that a person is assigned the responsibility of collecting and safeguarding the data. It is also advisable to store data in print and digital format.

6. Guide bibliography

Anagnostopoulou, Maria (editor). 1996. Monitoring guide for the NATURA 2000 network areas. Goulandris Natural History Museum–Greek Biotope/Wetland Centre. Thermi. 163 p. (in Greek).

Ganatsas, P., Marianthi Tsakaldimi and Thekla Tsitsoni. 2003. Using oak species in reforestation projects in Greece. Proceedings of 11th Panhellenic Forest Science Conference, Ancient Olympia, October 2003. Hellenic Forestry Society, pp. 126-132. (in Greek).

Forstlichen Fakultät de Universität Göttingen. 1980. Exkursionbericht von der studienreise der nach Andalusien vom 26.03-04.06.

Dafis, Sp. 1966. Site quality and forest productivity research in oak and chestnut forests in NE Chalkidiki. University Forest Administration and Management Fund. Thessaloniki. (in Greek).

Dafis, Sp. 1990. Applied silviculture. Giachoudis – Giapoulis. Thessaloniki. 258 p. (in Greek).

Liga para a Protecçao da Natureza. 1992. The Impact of structural funds upon the evolution of forests in Portugal. Past and Future. Lisboa. 14 p.

Rey Benayasa, J. M. and Angelica Camacho-Cruz. 2004. Performance of Quercus ilex saplings planted in abandoned Mediterranean cropland after long-term interruption of their management. Forest Ecology and Management 194, p. 223–233.

Society for Ecological Restoration Science & Policy Working Group. 2002. The SER Primer on Ecological Restoration. www.ser.org.

Smyris, P., M. Aslanidou and I. Milios. 1999. Oak thinning (Quercus conferta Kit.). In: Contemporary silviculture problems. Proceedings of 8th Panhellenic Forest Science Conference, Alexandroupoli, April 1998. Hellenic Forestry Society. pp. 417-424. (in Greek).

Tsaprounis, I. (editor). 1992. Results of the First Forest Inventory. Ministry of Agriculture, General Secretariat of Forests and Natural environment. Athens. 134 p.

Tsitsoni, Thekla. 2003. Forestry study of oak forests in Greece. Proceedings of 11th Panhellenic Forest Science Conference, Ancient Olympia, October 2003. Hellenic Forestry Society. Pp. 116-125. (in Greek).

Chatziphilipidis, G. and G. Spyroglou. 1998. Effect of logging on broadleaf oak forests (Quercus frainetto). In: Contemporary silviculture problems. Proceedings of 8th Panhellenic Forest Science Conference, Alexandroupoli, April 1998. Hellenic Forestry Society. pp. 417-424. (in Greek).

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