# Post-fire management in Mediterranean forest: researching to prevent global change

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### Abstract

Over the last few decades forest fire regimes have been changing, with fire recurrence and burned surfaces increasing: about 45000 forest fires occur in Europe each year and more than 4 million hectares were burned in the Mediterranean Basin, from 1995 to 2004. These processes could be influenced and are influencing global climate change. Forests are giving various improvements such as $CO_2$ fixation and absorption, water cycle contributions, erosion and desertification reduction, biodiversity protection (both species and habitats), etc. So landscape modifications and large-scale forest fires are contributing to global change.

Therefore, post-fire forest management and valuation of allometric relationships (to estimate forest stand variables) are very important and useful tools in adapting classic silvicultural treatments to new problems and obtaining a management regime that is able to mitigate global change and develop a sustainable use of resources.

In order to achieve those aims, post-fire management researches are been developed in SE Spain. *Quercus ilex* L. and *Pinus halepensis* Mill. stands were affected by large forest fires in 1993 and 1994. Natural regeneration occurred after fire and produced a very high density of Aleppo pine saplings and holm-oak resprouts in these places. Aleppo pine stands were designed with two factorial variables: silvicultural treatments and quality site. In coppice stands, silvicultural treatments (thinning) and recurrence of fire were the studied variables. Monitorized trees, in the sampling plots, were subjected to different measures to value growth, reproductive characteristics, biomass production, LAI and nutrient foliar content.

Results for coppice stands showed a lower primary production, growth and nutrient foliar content in recurrence fire regime(less than ten years) but they could be increased by moderated thinning(5000 trees/ha in final density). In Aleppo pine stands was proved that hard thinning (800 trees/ha final density) increased growth, biomass and leaf area index and nutrient foliar content. Also, it was promoting early flowering age and a larger canopy storage seed banks. These parameters were lower in the worst quality site. Also is concluded that, fire recurrence and silvicultural treatments are influencing mean annual productivity in coppice stands and LAI measurements could estimate forest stand variables. For Aleppo pine is concluded that higher quality site promotes higher values in the studied variables, silvicultural treatments also are influencing them and biodiversity values changes with fire regimes.

So is advised hard thinning in young Aleppo pine stands to achieve healthy pine trees and promote early cone-bearing and large canopy storage seed bank to insure natural post-fire regeneration(if weather conditions were optimal). Also advice to carry out thinning to coppice stands to recover productivity.

**Key words**: *Quercus ilex* L.; *Pinus halepensis* Mill.; resilience; thinning; resprout; canopy seed bank; $CO_2$ sink.

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## Introduction

A forest offers important and vital environmental services. Trees give us various improvements such as $CO_2$ fixation and absorption, water cycle contributions, erosion and desertification reduction, biodiversity protection (both species and habitats), etc. They depend on global changes which include anthropic impacts since human activity is negatively affecting natural ecosystems.

The principal components of global change are climate change (temperature is increasing significantly and rain patterns are changing (recurrent droughts)), atmospheric change: ($CO_2$ and other greenhouse gases are increasing), land use change and habitat fragmentation (land conversion and increase of surface use) and over-exploitation of resources (unsustainable use of agriculture, fishing, water resources, etc.). These threats could be reduced by forest activity as a carbon sink, minimizing carbon dioxide in the atmosphere (one of the greenhouse gases). Also, forests accumulate natural biodiversity and protect soil from erosion, so landscape modifications and large-scale forest fires are contributing to global change (climate change and disturbances are in continuously interaction). The projected changes (principally in temperature and precipitation) are going to increase fire severity, length of fire season and fire recurrence (Miranda and others 1994) which could promote to a permanent establishment of early succession forest stages (Terradas 1996).

Every year about 45,000 forest fires occur in Europe, destroying a huge area of forests and other rural lands. Between 1995 and 2004, more than 4 million hectares were burnt in the Mediterranean Region (larger than the Netherlands surface). Besides the social (loss of lives and houses) and environmental damages, forest fires also have considerable economic consequences, not only because of the destruction caused, but also because of the enormous quantities of resources spent in fire fighting, prevention, and mitigation measures. This is a problem already affecting Central and Northern Europe as well, most likely a consequence of climate change, and in order to prevent $CO_2$ increases and global warming, biomass production is improving a higher importance in the Mediterranean Basin (and all over the world). In addition, European forests have been proved to be significant in global carbon cycle. So new tools providing a better understanding of that role will improve forest management in order to increase or maintain the carbon sink (Nabuurs and others 1997).

Forests and fires have always been associated, namely in Mediterranean-type climates. Because of this close relationship, the natural vegetation of fire-prone regions has evolved strongly influenced by fire recurrence, making it the most important forest problem in several European countries, with an enormous environmental impact. Fire-fighting, fire control and fire-preventive tools are being developed. Post-fire situation is not so highly researched but is very important for forest persistence. Soil erosion, flooding or biodiversity impacts have to be controlled, in the sort-term, after a forest fire. In addition, some wildfires could open a window to influence secondary succession direction towards less prone forests (Moreira and others 2006). To achieve it, scientifically-based knowledge is important to support the different management solutions for burned areas. In other hand, a considerable effort has been put into forest fire research (fuel management and combustibility) in recent years, but results are difficult to apply due to asymmetries and heterogeneity in the characteristics of different fire-prone regions within Europe. In forestry tool development, it is important to be aware that methods for calculating biomass are based on commercial volumes, and could be rendered inaccurate when different silviculture treatments are applied because of the potential variability in allometric relationships depending on site, density or weather (Lopez-Serrano, 2005). For these reasons, studies regarding methodologies focused on biomass quantification (above and belowground) and coppice forest stands productivity, depending on sampling date and post-fire treatments are helping to develop relationships and new tools for easier and no destructive samplings to record measurements.

Thus, the main objectives of this study were: i) to contribute to the knowledge of the biometric function depending on date and post-fire treatments; ii) to check if the thinning treatments could improve growth, reproduction and productivity in young natural post-fire forest stands; iii) to assess stocks and productivity on dry biomass and fixed $CO_2$ and iv) to examine the fire effects on two tipycal Mediterranean ecosystems with different adaptative strategies to fire.

Forest fire sciences should be able to obtain and develop prevention and management tools to respond the permanent threat of fires, which are the main causes of $CO_2$ release, erosion and biodiversity loss. Therefore, post-fire forest management is a useful tool in adapting classic silvicultural treatments to new problems and obtaining a management regime that is able to mitigate global change and develop a sustainable use of resources.

# Material and methods

## *Study site*

In summer 1993 and 1994, larger forest fires occured in SE Spain. Three of them burnt about 500, 15,000 and 30,000 ha in Campillo de Altobuey, Cuenca (Cuenca), Yeste (Albacete) and Calasparra (Murcia) respectively. Site characteristics are shown in *table 1.*

***Table 1***— *Site characteristics. ALT: Campillo de Altobuey; YES: Yeste; CAL: Calasparra.. COORD: Coordinates are given on WGS 1984 UTM Zone 30N system; AR (Annual rainfall) and T(Temperature) were calculated with last thirty years data; ST: Soil texture is based on USDA triangle.*

| | | SITUATION | | CLIMATE | | SOIL | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SITE | ACRONYMUS | COORD | ALTITUDE (m) | AR (mm) | T (ºC) | ST | pH | N (pct) | P (ppm) | K (ppm ) |
| CAMPILLO DE ALTOBUEY | **ALT** | 1º 51´ W 39º 40´ N | 1020 | 517 | 12.67 | SANDY LOAM | 7.7 | 0.17 | 3.58 | 415.8 |
| YESTE | **YES** | 2º 20´ W 38º 22´ N | 1010 | 530 | 13.01 | | 8.6 | 0.45 | 3.60 | 200.1 |
| CALASPARRA | **CAL** | 1º 38´ W 38º 16´ N | 325 | 290 | 16.5 | | 8.7 | 0.19 | 3.43 | 215.2 |

Forest stands of Aleppo pine(*Pinus. halepensis* Mill.) was the natural vegetation in YES and CAL belong to some particular species, such as *Quercus coccifera, Rosmarinus officinalis., Juniperus oxycedrus L., Rhamnus lycioides L., Thymus sp. and Cistus s*p.(De las Heras and others 2004). In contrast, the natural vegetation in Campillo de Altobuey was very different. Copicce stands (*Quercus ilex*, below 2 m height) and other shrubs, such as *Junyperus comunis, Sidertis incana, Thymus vulgaris* and *Helianthemum cinereum,* were the principal species in this site (Lopez-Serrano and others 2006). Natural post-fire regeneration produced a very high density of *P.halepensis* saplings and *Quercus ilex* resprouts in these sites.The average tree density was 5116 ± 2134 trees/ha in YES, 46,000 ± 20,400 trees/ha in Calasparra (González-Ochoa and others 2004). In Campillo de Altobuey there were 14,761 ± 1,353 of resprouts /ha.

## *Experimental design*

A factorial design with one factor (thinning intensity level) was carried out for each dominant species. For Aleppo pine forest stands, two thinning intensity levels were managed: $T_t$(1600 trees/ha final density) and $T_c$ (control, i.e., without thinning). There were three replicates (rectangular plots, 150 $m^2$) for each treatment at each site (YES and CAL). For evergreen oak stand, four thinning intensities were done: $T_M$ (medium thinning: 5000 trees/ha), $T_D$ (drastic thinning: 1800 trees/ha), $T_F$ (total felling) and C (control, i.e., without treatment). Twelve rectangular plots (15 x 20 m) were fixed within an experimental block of 45 x 115 m.Thinning intensity levels were randomly assigned to plots. Trees and scrubs were felled with a clearing saw, 2 cm below ground. In order to avoid a border effect, a distance of about 6-m was kept between plots. Treatments were randomly assigned and carried out in plots in late summer 1999. Thus, to assess the initial heterogeneity per plot, initial density of the plots ($D_{initial}$, trees/ha), as an intraspecific competition index. Also, dominant height (Hd, cm) was considered as variable, it was considered as micro-quality site index.

A new forest fire occurred in ALT in summer 2001. Some of the studied plots were burnt again. They were called RF (recurrent fire plots) and were redesigned. Also four new plots burnt just in 2001 (NB) were designed. Resprouting and biomass was recorded in next autumm.

To obtain diameter and the height distribution, sampled trees were recorded. Total height (cm) and diameter (mm, taken 30 cm above the ground) before the treatments were imposed. Once thinning treatments had been carried out, sampling trees were marked with plastic tags. Height and diameter were measured again. These measurements were repeated later (in spring 2001 and 2004). In order to compare the treatments effects the starting conditions had to be considered in the statistical analysis.

## Nutrient analysis

The spatial variability for nutrient concentration in trees and the short number of subsamples needed for carrying out nutrient determinations could had produced inaccuracies within the mean nutrient concentration. Nutrient concentration in trees is phenotypically plastic with regard the microtopographic variability (Arthur and others, 1999), also spatial and seasonal variability is known which can induce to inaccuracies. Sample collection was carried out in autumn 2001. It was standardized to enable the valid comparison with other reported values. In this study nine seasonal samplings have been taken in different dates. Six to ten trees were randomly selected in each plot. For each tree, a sample (about 10 g in pine-trees and 5 g in oaks) was obtained from a shoot in the up-third of the live crown. Samples were leaves from the no light competition foliage area. Data recorded was averaged to obtain one sample by plot. Although composite analysis does not permit the assessment of within-plot nutrient variability (tree variability), it will provide reasonable estimation of mean foliar nutrient concentrations by plot. Leave preparation and operations to record concentration are larger explained in Lopez-Serrano and others 2006.

## Reproductive strategies

The studied species have two different adaptatives strategies to forest fire.

In *Pinus halepensis* stands, seed bank released was calculated to predict the post-fire forest resilience in a eleven age years old stand (in winter 2005). Several cones were collected from both localities and carried to laboratory. They were opened and seeds were extracted. Sample seeds were collected and sound and unsound seed percentage, viability and germination were calculated. Aerial seed bank density was also calculated. More details about methodology is shown in De las Heras and others, 2007. To characterize the reproduction phase (juvenile or reproductive), the percentage of reproductive population was estimated for each plot, considering reproductive tree when have one strobili or cone at least. $J_{50}$ value is defined as the age when 50 percent of the population is reproductive (Thanos and Daskalakou, 2000), when that value is reached is considered that populations promotes from juvenile to reproductive phase

In *Quercus ilex* stands, new resprouting was recorded in ALT next autumm post-fire. It was measured as in the old plots burned in 1993 as in four new burnt plots. In order to estimate the crown coverage of a systematic line sampling was carried out. Three parallel lineal transects ( 20 m length, spaced 5 m and separate 2.5 m of each side of the plot) was designed to measure the crown coverage.

## Net primary production and biomass

The general approach to estimate stocks and net primary production (NPP) was to obtain the current plant biomass (above and belowground) and the rate of increase in plant biomass. NPP is defined as difference between total energy fixed through photosynthesis (gross primary productivity) and energy lost through respiration and mortality, representing the net C uptake from the atmosphere into vegetation (Melillo and others 1993). So, it would be necessary add the net biomass fixed for others species in addition to *Q. ilex* but we have considered that those were not significant (<1 percent). To estimate above ground biomass and leaf area of young trees by plot, allometric relationships were applied to the set of individuals included in each plot (being the diameter at 30 cm above ground, the predictive variable for each young tree). To define allometric relationships, a destructive essay of young trees was carried out in Nov-1999 and Feb-2001. *Quercus ilex* is a typical resprouter and the pre-existing root system remains live (Kruger and Reich 1997). To estimate above and below ground biomass and leaf area of resprouts by plot, we carried out a double sampling with ratio estimator (De Vries, 1986). resprouts subsamples were selected in each plot. To estimate annual sink of $CO_{2,}$ in both young trees and resprouts, dry biomass was multiply by conversion factors. The content on C for the wood was 0.5 t per t of wood dry biomass (De Vries and others 2003).To calculate leaves sink we used a different conversion factor depending on the leaves procedence(from young trees or resprouts) and kind of stand (low or high fire recurrence). Finally to obtain total $CO_2$, carbon content was multiply by 3.67 (ratio of molecular weight of $CO_2$ to molecular weight of C). An extended version of this npp and biomass could be consulted in Lopez-Serrano and others, in press.

### Statistical Analysis

The effect of each factor on variables studied was tested using indicator variables (or dummy variables) in multiple regression analysis.

In order to test the effects of treatments on temporal values of foliar concentrations for each element, we used a multiple regression analysis approach with predictive variables a General Linear Model (GLM). All models were simplified using the forward stepwise regression method, based on the general linear test statistic. The best model was chosen by selecting the highest $R^2$, lowest SEE, lack of colineality of the predicting variables (low variance inflation factor), and based on residuals analysis. Multifactor ANOVA was used to compare means between groups. Tukey test at 95 percent interval confidence was used to check which means are significantly different from which others. Besides, Pearson's correlation method was applied in order to obtain correlation coefficients. All analyses were conducted at $p<0.05$.

## Results

*Table 2* summarizes the forest stand characteristics for each species, factor and site. Results were obtained separatly for each species.

For *Quercus ilex* stands (ALT), results relationed total height and diameter to thinning intensity.They showed highest height in lower thinning intensities. In contrast, higher diameter increments were obtained in lower thinning intensities, even highest diameter was recorded in C plots. Relative increments (in both, diameter and in height) also depend on initial magnitude of the variables before treatments, so medium intensity thinning (to 5000 trees/ha final density) was the best treatment that improved the growth in diameter. Other way, drastic thinning (to 1800 trees/ha, final density) was even worse than the control plots for height increment.

For *Pinus halepensis* stands, thinning treatment (to 1600 trees/ha, final density) improved significantly both, diameter and total height, although did exist a site and plot effect (González-Ochoa and others 2004). All trees in both sites increased in height and diameter, but increase was higher where thinning treatment was applied. Same results were obtained for both sites but different growth between sites was a consequence of a better site quality in YES.

***Table 2***— *Grotwh measurement. ALT: Campillo de Altobuey; YES: Yeste; CAL: Calasparra. C and $T_C$: control (no treatment); $T_M$: medium intensity thinning; $T_D$: drastic intensity thinning; $T_F$: total felling; $T_T$: thinning to 1600 trees $ha^{-1}$. $D_{FINAL}$: tree density (tree $ha^{-1}$) $\bar{d}$: averaged diameter (cm); $\bar{h}$ :averaged height( cm). Hd: Dominant height (cm). Mean values are presented for results obtained in 2001(*Q.ilex *stands) and 2005 (*P. halepensis *stands))*

| SITE | TREATMENT | $D_{FINAL}$ | $\bar{d}$ | $\bar{h}$ | Hd |
|---|---|---|---|---|---|
| **ALT** | C | 18789±3840 | 16,1±0,3 | 75,0±6,2 | 161±5 |
| | $T_M$ | 5000 | 15,9±0,3 | 96,3±7,0 | 183±1 |
| | $T_D$ | 1800 | 13,1±1,2 | 74,4±4,4 | 153±13 |
| | $T_F$ | 0 | 13,3±1,1 | 84,2±6,8 | - |
| **YES** | $T_C$ | 5189±1358 | 3,04±0,30 | 140,23±3,04 | 190,67±9,80 |
| | $T_T$ | 1600 | 4,22±0,11 | 156,95±4,22 | 216,17±8,61 |
| **CAL** | $T_C$ | 49994±12592 | 1,54±0,07 | 103,04±9,12 | 138,33±8,22 |
| | $T_T$ | 1600 | 2,26±,0,08 | 109,52±6,36 | 161,00±10,80 |

Comparing both species (*table 3*) each foliar nutrient concentration was higher for *Quercus* than for *Pinus halepensis*, some exceptions for the Mg values. Foliar concentration where no significant differences were found and mean concentration trend for both species was: Corg>N>Ca>K>Mg>P. This result coincides with the foliar nutrients concentration of *Larix decidua (*Myre and Camiré 1996).

For evergreen oak, no significant differences were found at the beginning and the end of the period of study for all nutrients (except for Corg that decreased). Only N, when drastic thinning was applied, increased significantly. In general, N, Ca and Mg increased their concentration, P does not change and K and Corg decreased. After a new fire in August 2001, all nutrients concentrations of the new resprouting were higher in post-fire regenerated trees, except for Corg that decreased and Ca that did not change.

For Aleppo pine, in YES site, no significant differences were found for foliar concentrations of N, P, Mg and Ca for both treatments (control and thinning). In contrast, K and Corg decreased significantly at the end of the period of study. In CAL, Mg and Ca final foliar concentrations were similar to the initials. K and Corg showed a significant decrease in the study period, in contrast to N and P concentrations, which increased significantly (Lopez-Serrano and others, 2006).

***Table 3—****Foliar nutrient concentrations (pct, mean±standard error) sampled in beginning auttum 2001.*
*† N: nitrogen, P: phosphorus, K: potassium, Mg: magnesium, Ca: calcium,* $C_{org}$*: organic carbon.*
C and $T_C$: control(no treatment); $T_M$: medium intensity thinning; $T_D$: drastic intensity thinning; $T_F$: total felling; NB: control plots burnt in 2001; $T_T$: thinning to 1600 pine trees ha$^{-1}$.

| SITE | Treatment | N | P | K | Ca | Mg | $C_{org}$ |
|---|---|---|---|---|---|---|---|
| **ALT** | C | 1,56±0,02 | 0,105±0,005 | 0,51±0,02 | 1,06±0,07 | 0,27±0,02 | 19±2,6 |
| | $T_M$ | 1,55±0,10 | 0,110±0,010 | 0,58±0,01 | 1,11±0,05 | 0,18±0,01 | 22±1,2 |
| | $T_D$ | 1,43±0,02 | 0,093±0,01 | 0,52±0,16 | 1,02±0,19 | 0,21±0,03 | 25±0,4 |
| | $T_F$ | 1,59±0,11 | 0,113±0,012 | 0,53±0,09 | 1,32±0,04 | 0,19±0,01 | 22±1,0 |
| | NB | 1,71±0,08 | 0,112±0,006 | 0,69±0,04 | 0,88±0,05 | 0,18±0,02 | 22±1,4 |
| **YES** | $T_C$ | 0.88±0.04 | 0.058±0.003 | 0.19±0.02 | 0.73±0.06 | 0.29±0.03 | 26.6±1.1 |
| | $T_T$ | 0.99±0.06 | 0.057±0.003 | 0.20±0.02 | 0.64±0.06 | 0.31±0.06 | 27.7±1.1 |
| **CAL** | $T_C$ | 1.23±0.10 | 0.080±0.010 | 0.37±0.05 | 0.54±0.09 | 0.19±0.01 | 28.4±0.7 |
| | $T_T$ | 1.31±0.05 | 0.070±0.006 | 0.37±0.06 | 0.72±0.08 | 0.18±0.01 | 26.3±1.8 |

Reproductive characteristics in Aleppo pine are showed in *table 4*. Maturity phase is represented as percentage of trees with cones. When this percentage achieves fifty percent is considered that this pine stand reach out the reproductive phase which ocurred in thinned plots in YES The averaged number of male cones showed significant differences among silvicultural treatments and site (highest values in YES for thinned plots). In the case of female cones, also the highest average number was found in treated plots in YES. Same results were obtained for total amount of cones which are containing the aerial storage seed bank.

***Table 4—****Reproductive characteristichs for Pinus halepensis for each treatment and quality site in 2005 (mean ± standard error). FC: total number of female cones; TC: total number of cones per hectarea. ASB: aerial seed bank (seed ha*$^{-1}$*); pctTWC: percentage of trees with cones. Small letters are meaning siginificant differences.*
$T_C$: control (no treatment); $T_T$: *thinning to 1600 tree ha*$^{-1}$.

| SITE | TREATMENT | FC | TC | ASB | pctTWC |
|---|---|---|---|---|---|
| **YES** | $T_C$ | 92,33±50,35 $^b$ | 1355±1210 $^b$ | 75738±22358 $^b$ | 38±26 $^b$ |
| | $T_T$ | 135,33±69,72 $^a$ | 3455±1783 $^a$ | 242755±64895 $^a$ | 52±14 $^a$ |
| **CAL** | $T_C$ | 11,83±4,79 $^d$ | 666±495 $^c$ | 99189±67524 $^b$ | 21±12 $^c$ |
| | $T_T$ | 39,50±26,79 $^c$ | 944±424 $^b$ | 19577±16522 $^c$ | 26±18 $^c$ |

*Figure 1* summarizes growth and productivity of both species based on biomass and total productivity and represented as equivalent fixed in $CO_2$. Represented in bars, dry biomass before treatments was higher in *Quercus ilex* stands than *Pinus halepensis* stands excluding control in YES. No significant differences were found between treatments in each species, although control plots had higher dry biomass. After treatments, total annual productivity (TAP, including both trees and resprouts growth for oaks) was obtained. Total annual productivity did not showed significant differences due to thinning treatments for evergreen oak(ranging between 7.59 to 8.76 t.ha$^{-1}$y$^{-1}$), although was higher for

thinned plots than for control plots (Lopez-Serrano and others, in press). For Aleppo pine, differences among localities were significant, YES had higher values than CAL. In both localities TAP was significantly improved by thinning. Figure 1 showed the important contribution of these coppice and pine stands to sink of one of the most important greenhouse gases, $CO_2$.

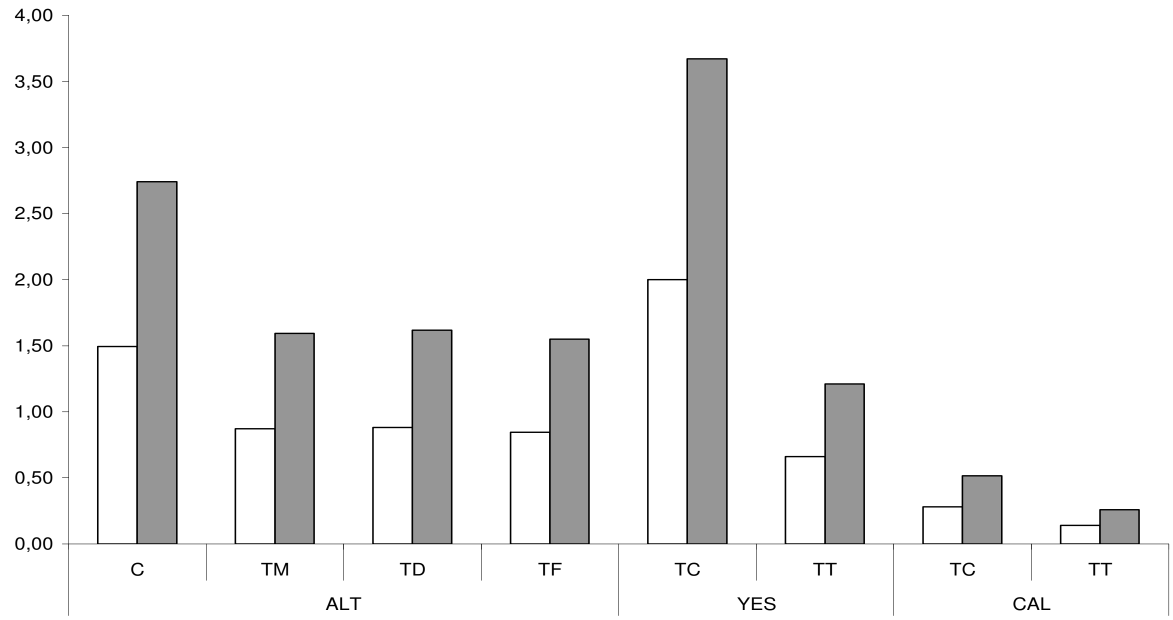


**Figure 1**—Mean annual productivity since 1993 to 1999 and Total annual productivity for 2001 (6 years old coppice stands). Both results are representing above and belowground biomass. Differences were no significant. White bars: dry biomass after treatments in equivalent fixed $CO_2$ (t $ha^{-1}$.$year^{-1}$); Grey bars: Total annual productivity in equivalent fixed $CO_2$ (t $ha^{-1}year^{-1}$).

*Figure 2* is showing total biomass productivity in evergreen oak stands before and after the new forest fire.. Thinning had no effect on this parameter. After the new fire, plots in recurrent fire stand (thinning no significant) had less total biomass productivity than new burnt stands. Moreover, if we compare the total productivity on resprouts (above and below ground) in the last 3 months after the new fire, 0.73 t/ha and 2.29 t/ha respectively, that fact is confirmed. SLA results were confirming that it is influenced by site and date. Also, it showed that leaf age is a significant parameter influencing it (Lopez-Serrano and others, in press).

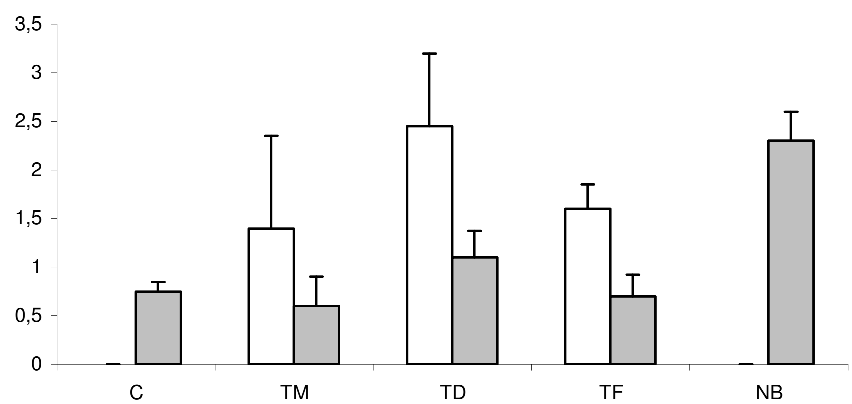


**Figure 2**—Total above and belowground biomass of resprouts (t/ha). White bars:data sampled in February-2001 (one year after thinning). Lined bars: data sampled in October-2001(3 months after new fire). C: control; $T_M$: medium intensity thinning; $T_D$: drastic intensity thinning; $T_F$: total felling; NB: control plots burnt in 2001.

## Discussion

Site quality is considered the main factor influencing variations in stand development variables. To manage natural non-economical productive forest is necessary to know particular weather conditions, but not only spatial conditions, even climatic changes in time. So characterization stands and regional climatic regime are necessaries to make better decisions (Peters, 1990).

To characterize forest also is important to take into account intra and inter-specific competition. Main factor influencing intraspecific competition is tree density. Both density and site quality, was significantly influencing growth as height as diameter (Lopez-Serrano and others 2006; Moya and others, in press). This is due to water and nutrients resources and availability. Post-fire conditions, climate change or selvicultural treatments influence availability and mobility of main macronutrients (Sabate and others 2002, Gonzalez-Ochoa and others 2004, Lopez-Serrano and others 2005). Our results, for *Quercus ilex,* are confirming that foliar nutrient concentration increase according to the recurrence of fire and thinning intensity. However, *Pinus halepensis* foliar nutrient concentration was increased by thinning but was decreasing in time. Results are according to the high capacity to accumulate nutrients for growth of these two Mediterranean species (Sardans and others 2006).

Reproductive strategy has an important effect on the stand growth: if we compared the total height averaged for *Quercus* and *Pinus*, although *Pinus* growth is faster than *Quercus*, they have a similar height average at 6 years old. An important consequence of thinning in *Quercus* was the spectacular resprouting one year later (February 2001). Drastic and full thinning produced very high resprouting coverage. In addition, a significantly relationship was found between the resprout coverage and thinning intensity. Resprouting coverage was lower in plots subjected to high recurrence fires. Results are influenced by initial tree density which was different in each site. Intraspecific germination variability in aleppo pine could be due to different canopy seed dispersion (Trabaud 1987), weather in that year (Daskalakou and Thanos 1996) and seed predation (Nathan and Ne'eman 2000).

Density and site quality are influencing also first reproduction year in *Pinus halepensis,* taking early flowering as fire adaptation (Tapias 2001). Results obtained are corroborating it, high quality site have higher cone production (both male and female). Also cone production was higher in thinned plots. Only thinned plots in YES (measured at twelve years) had reached $J_{50}$, i.e. age when 50 percent of the population is reproductive (Thanos 2000).

In early stages of forest stands growth for *Quercus ilex*, Mean and Total annual productivity were not influenced by thinning. Also is checked that recurrence of fires is decreasing biomass production which is no influenced by selvicultural treatments. $CO_2$ sink contribution was calculated, obtaining a high amount. They are significant $CO_2$ sinks and could be a useful tool to calculate forest fires emissions. SLA results confirm site and date influence (Lopez-Serrano and others 2000) and also that younger leafs are related to higher values, so SLA influent factors are site, date sampling and tree age.

Forest management practices may be implemented. The managed forest can deal with new disturbance regimes under climate change. Interactions between forest management and disturbance need to be improved in order to impede, mitigate or facilitate solutions (Dale and others 2000). To achieve this, products of the fire behaviour and fire ecology sciences have to be approached and included in a structures and consistent way. So scientific bases on post fire management have to be developed and it has to be transferred to users (as recommendations, legislation or technical guidelines). Finally we conclude that Mediterranean forests are influenced by climate change, increasing intensity and severity of fires. That situation is decreasing primary production and liberating $CO_2$ to the atmosphere. It can be re-focused using appropriated forest management and developing post-fire treatments. Thinning in young natural regenerated stands can be used to promote growth, net primary production and improve forest persistence and $CO_2$ sink, although its intensity could vary depending on species and quality site.

## Acknowledgments

The authors thank the Regional Forestry Services of Castilla-La Mancha for providing the research sites and field collaborators. This research was funded by the R+D+I Spanish National Programme (AGL2004-07506/FOR).

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