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TRENDS IN POST-FIRE BIOMASS RECOVERY IN AN *ERICA AUSTRALIS* HEATHLAND

ISABEL FERNÁNDEZ-ABASCAL, REYES TÁRREGA, ESTANISLAO LUIS-CALABUIG AND ELENA MARCOS

Area de Ecología, Fac. Ciencias Biológicas y Ambientales, Univ. León, 24071 León, Spain.
E-mail: deglcg@unileon.es

Abstract

The aboveground biomass in plots of a heathland dominated by *Erica australis*, burned on different dates, is compared. The rapid recovery by vegetative resprout of *Erica australis*, which is the dominant woody species from the first year and has practically stabilised its biomass after 5 years, was observed. However, the total biomass continued to increase with higher values in the control plot because *Calluna vulgaris*, whose recovery is slower as it regenerated from seed, is also important. Herbs were the dominant biotype one year after the fire, with statistically significant differences in comparison with the rest. The temporal recovery dynamics of the community presents a logarithmic adjustment due to the increase in non-photosynthetic biomass, as the photosynthetic biomass tended to remain stable. When the percentages of both fractions are considered, a highly significant (99%) logarithmic adjustment is observed, both for the community as a whole and for the most frequently occurring woody species.

Introduction

Fire has been considered a key factor in maintaining the structure and functioning of the Mediterranean ecosystems (Naveh 1975) and has been used as a traditional management tool by farmers and shepherds (Luis *et al.* 2000). However, the socio-economic changes of the last few decades have brought an enormous spread in heathland communities as a result of pasture and crops being abandoned. This is related to an increase in the burned surface and the incidence of large fires (Moreno *et al.* 1998). In this respect the quantity and characteristics of plant fuel are important in determining the behaviour of fire (Rego *et al.* 1994, Gill & Moore 1998) and, in turn, depend on the time passed since the last fire and on the recovery dynamics of each community. Better knowledge of this dynamics is therefore required for good management, as, although there are numerous studies analysing the post-fire recovery of plant cover (for example, most of those included in Trabaud 1998), there are less studying the changes in the biomass from the ecological viewpoint (Casal *et al.* 1984, Fernandez-Santos & Gómez-Gutierrez 1994, Fernandes *et al.* 1998).

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The aim of the present paper is to determine the recovery dynamics of the above ground biomass after a fire in a heathland community, in which plots burned in two different years and unburned ones were very close. We intended to determine the changes in the plant community as a whole as well as in each of the main woody species, comparing the changes in the photosynthetic and non-photosynthetic fractions in terms of time passed since the fire.

Materials and methods

A large heathland area dominated by *Erica australis*, located in the province of León (Spain), close to Corcos village, (UTM co-ordinates 30TUN284277) was selected for the study. The climate is subhumid Mediterranean with a mean annual temperature of 10.9°C and annual precipitation of 926 mm; the dry period occurs in July (mean rain fall 24 mm) and August (mean rain fall 26 mm) (Ministerio de Agricultura 1980). The soil is a Cambisol Dístrico (Forteza 1987) formed on tertiary materials of the upper Miocene, siliceous conglomerates and grades (Ministerio de Industria y Energía 1982). The area is on a gentle slope (10-15%) and the altitude is 1000-1100 m over sea level. The mature stage in this area corresponds to a *Quercus pyrenaica* forest, but most of the area is heathland, as a result of grazing being deserted in the sixties with the mass exodus from rural areas to cities. Fire is a normal management tool in these areas, and, although the livestock load is practically nil at present and this practice is forbidden by the authorities, some old shepherds continue to burn more or less periodically. The aboveground biomass is normally completely destroyed in these fires, but not the subterranean parts (Luis *et al.* 2000).

Two plots were submitted to prescribed burning in the summers of 1991 (Plot B-91) and 1993 (Plot B-93), respectively, and no fires have been recorded in the third one for at least 25 years, this was used as an unburned control area (Plot UB). Samplings were carried out in September 1994 and October 1998, so data 1, 5 (B-93 plot), and 3, 7 (B-91 plot) years post-fire are available. There are also two samplings of the control area, which are considered as 25 and 29 years post-fire and whose data were considered separately to determine whether there is any variability. To determine the above ground biomass 3 quadrats measuring 1 m^2 were sampled in each plot and study year. They were randomly chosen and the existing vegetation was cut down to ground level, separating each woody species and considering herbaceous ones as a whole. The samples were brought to the laboratory and the photosynthetic and non-photosynthetic fractions of the woody species were separated. The samples were then dried at 100°C for 12 hours, in order to estimate their biomass as dry weight.

The data on total biomass as well as on those of herbaceous species and dominant woody ones were compared by analysis of variance to determine whether there were differences in terms of post-fire recovery time. The absolute values (expressed in g/m^2) were considered first and then the percentages in terms of total biomass were compared, to determine whether there were changes in the proportions of the different species. When the value of p in the analysis of variance was < 0.05 the differences were considered to be statistically significant and the Tukey test (Tukey 1949) was used for the comparisons between pairs.

A global comparison was also made by similarity analysis, using the Euclidean distance, and the results were grouped using the U.P.G.M.A. method (Sneath & Sokal 1973).

The mean data of the 3 quadrats were used in this analysis, expressing the values as a percentage of the total biomass.

The analysis of variance was also used to determine whether there were significant differences in the temporal dynamics in the percentages of the photosynthetic and non-photosynthetic fractions, for each woody species and for the total biomass. In the cases in which a temporal tendency was observed, the statistical quality of the adjustment to the more usual growth curves was estimated.

Results

Recovery of the biomass after fire is relatively fast. One year after the fire it did not attain 100 g/m^2, but in the plot burned 3 years before the mean exceeded 700 g/m^2 (Fig. 1). The tendency to increase continued, since the biomass in the unburned plot (about 1800 g/m^2 after 25 and 29 years) was greater than in the others, but the differences are only significant in comparison with the 1 and 3 year plots. Most of this biomass corresponds to *Erica australis*, a species which recolonizes rapidly because of its capacity to resprout actively after a fire. In the fifth year its biomass was similar to that of the control plot. The other species have much less biomass, even though they were very constant in the area, like *Arctostaphylos uva-ursi* and *Halimium alyssoides. Calluna vulgaris* was of certain quantitative importance only in the unburned plot. It is not possible to detect statistically significant differences in the biomass of woody species between the different plots.

The biomass of herbaceous species was significantly greater in the 5-year plot (Fig. 1), but no tendency in terms of time since the fire was observed and it seems to be more associated with the characteristics of each plot, or the weather of each concrete year. Thus, the herbaceous species were more abundant in plot B-93 (in the first year and 5 years post-fire). In addition, an increase in herbaceous species seems appreciable in the sampling carried out in 1998 in comparison with that of 1994, when each plot is compared to itself (5 vs 1 years, 7 vs 3 years and 29 vs 25 years).

If the biomass values are expressed as a percentage of the total biomass in each plot and sampling period and the rank-abundance graphs are represented (Fig. 2), it can be observed that one year after the fire the herbaceous species were the dominant biotype in B-93 with more than 65% of the total biomass. In this plot the herbaceous species were only 7% of the total after 5 years, although their biomass in absolute value increased; in the other plots they did not usually reach 1%. On comparing the percentages of the herbaceous species by analysis of variance, statistically significant differences are found between the value after one year and all the others. However, no significant changes are observed in the proportions of the different woody species in terms of time. *Erica australis* was the most abundant woody species from the first year, although it only represented 18% of the total biomass. The clearest dominance effect was recorded between 3 and 7 years. In the unburned plot, the *Erica australis* biomass was 50% of the total, but other species, amongst which *Calluna vulgaris* stands out, were also abundant. A tendency was observed for the richness of woody species to increase over time together with a decrease in the dominance effect (Fig. 2), which results in greater diversity.

These results are confirmed by the dendrogram obtained in the global comparison from the values expressed as percentages of the total biomass (Fig. 3). The recently burned plot

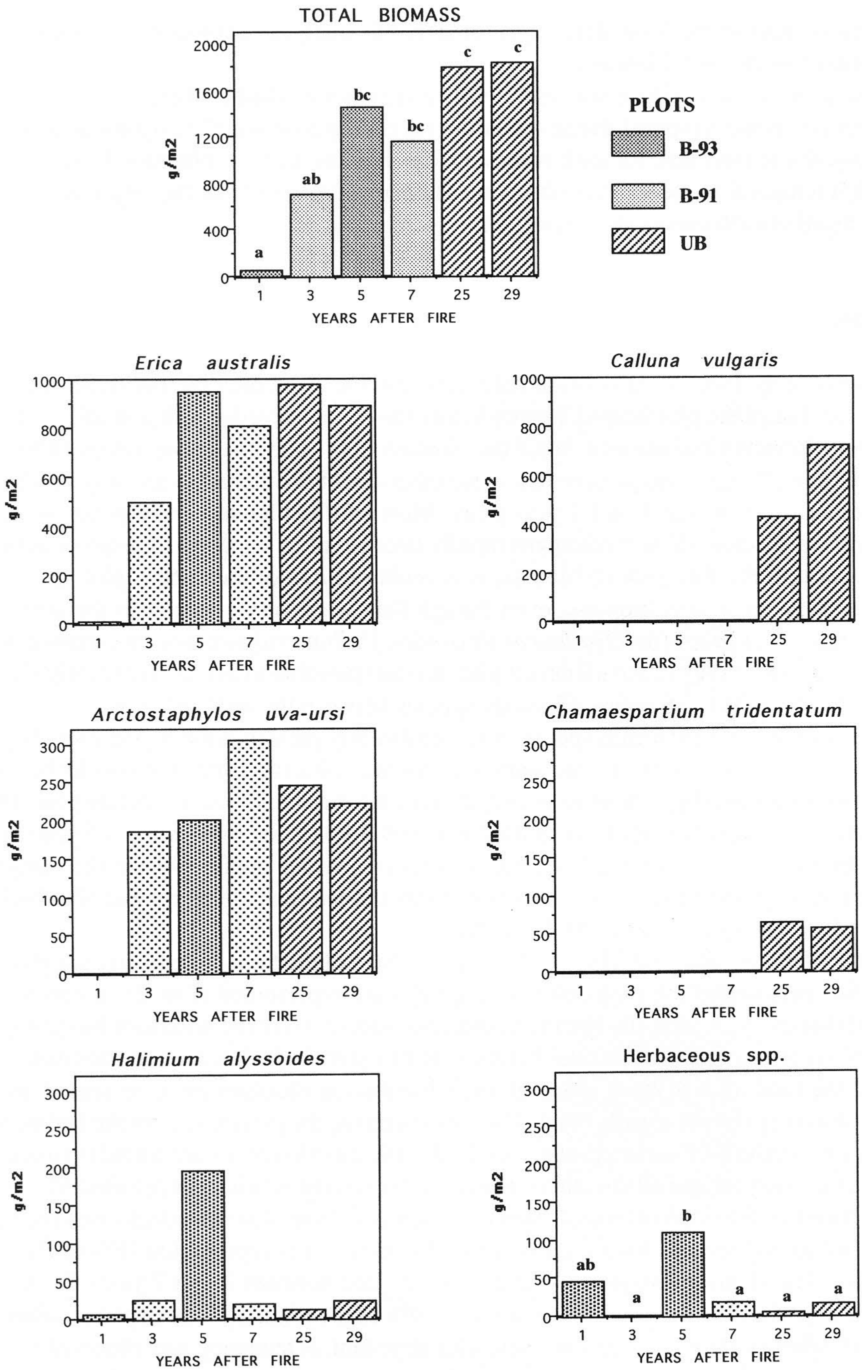

Fig. 1. Mean values of total biomass, each dominant shrub species and herbaceous species biomass in the different plots during the study period. The analysis of variance detected significant differences only among total biomass and herbaceous biomass values; in these graphs, different letters indicate significant differences by Tukey test ($p < 0.05$).

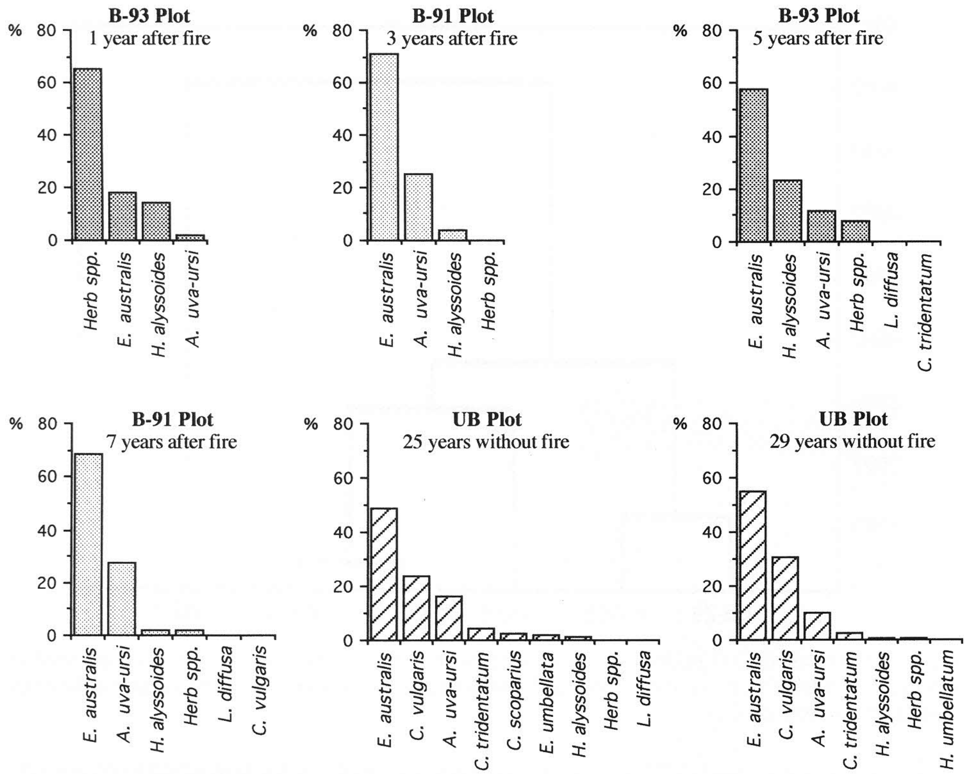

Fig. 2. Percentages of biomass values (rank-abundance graphs) for each woody species and all herbaceous species in each plot and sampling period.

seems to be the most different, due to its enormous proportion of herbaceous species. In addition two groups can be distinguished, one formed by the two samplings in the unburned plot with a greater richness of woody species (Fig. 2), and the other formed by the intermediate recovery times characterised by the highest proportion of *Erica australis*. Therefore, although it was not possible to detect statistically significant differences in the proportions of woody species over time, when the mean values in each plot were analysed by an analysis of similarity a certain temporal tendency is observed.

When changes in the photosynthetic and non-photosynthetic fractions are compared, the non-photosynthetic biomass tends to increase over time, as a result of the increase of the woody parts, with a significant adjustment to a logarithmic curve (Fig. 4). However, the photosynthetic biomass tends to remain relatively stable. Analysing each woody species separately, the adjustment is not statistically significant for either of the two fractions in absolute values (g/m^2). Nevertheless, if the values are expressed as a percentage, in all the species, which appear from the beginning and are maintained in the plots burned on different dates, there is a tendency for the non-photosynthetic fraction to increase at the expense of the photosynthetic one. The adjustment to a logarithmic curve is highly significant (>99%); in some cases the adjustment to a sigmoid curve is also significant, but the quality of the adjustment is lower. In the dominant species, *Erica australis*, the non-photo-

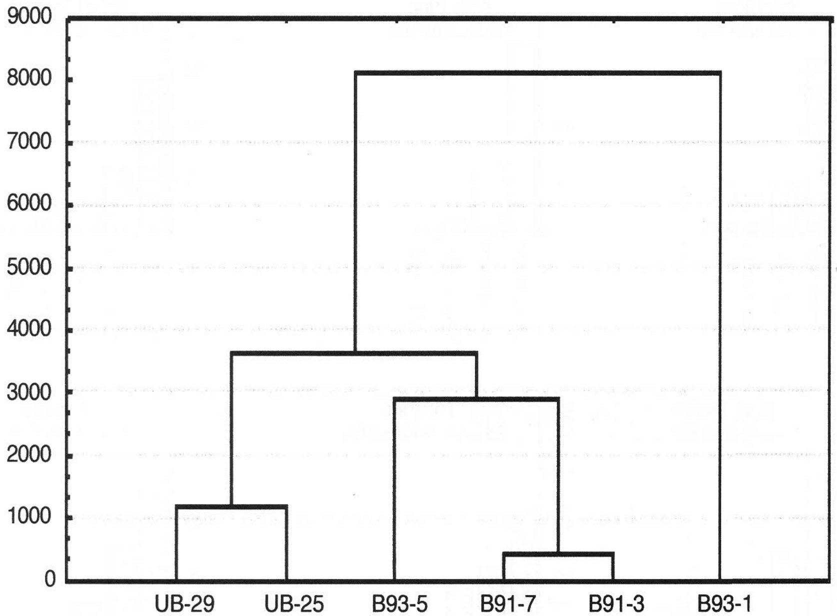

Fig. 3. Affinity analysis (Euclidean distances) between the plots. (Biomass values are expressed as percentages of total biomass in each plot and sampling period. Numbers after the names of the plots indicate years after fire).

synthetic fraction exceeded 50% from the second year and the same happened to *Halimium alyssoides*. However, only in the unburned plots there was a dominance of the non-photosynthetic parts over the green ones in *Arctostaphylos uva-ursi*.

This result is confirmed when the values are compared by analysis of variance. In the case of the total biomass and that of *Erica australis* the differences are statistically significant between the values one year after the fire and all the others, whilst three years after fire differences are only detected in comparison with the unburned plots (Table 1). In contrast, no significant differences were observed in *Arctostaphylos uva-ursi* between 1 and 3 years after fire plots, though they were between them and the control plots (25 and 29 years). Significant differences were only detected for *Halimium alyssoides* between 1 year plot and the oldest plots (7 years after the fire and the unburned plot). No significant differences were detected for *Calluna vulgaris*, which only appeared with some importance in the unburned plot.

Discussion

In other studies carried out on this type of communities, the plant cover recovery is very fast. The dominant species, *Erica australis*, is capable of actively resprouting after a fire and other disturbances and attains cover values similar to the one existing before the fire after 4 years (Calvo *et al.* 1998). The present study confirms that this quick recovery also occurs for the biomass, with values similar to those of the control plot from the fifth year. The plant composition of the community (Fig. 2) does not show any important changes

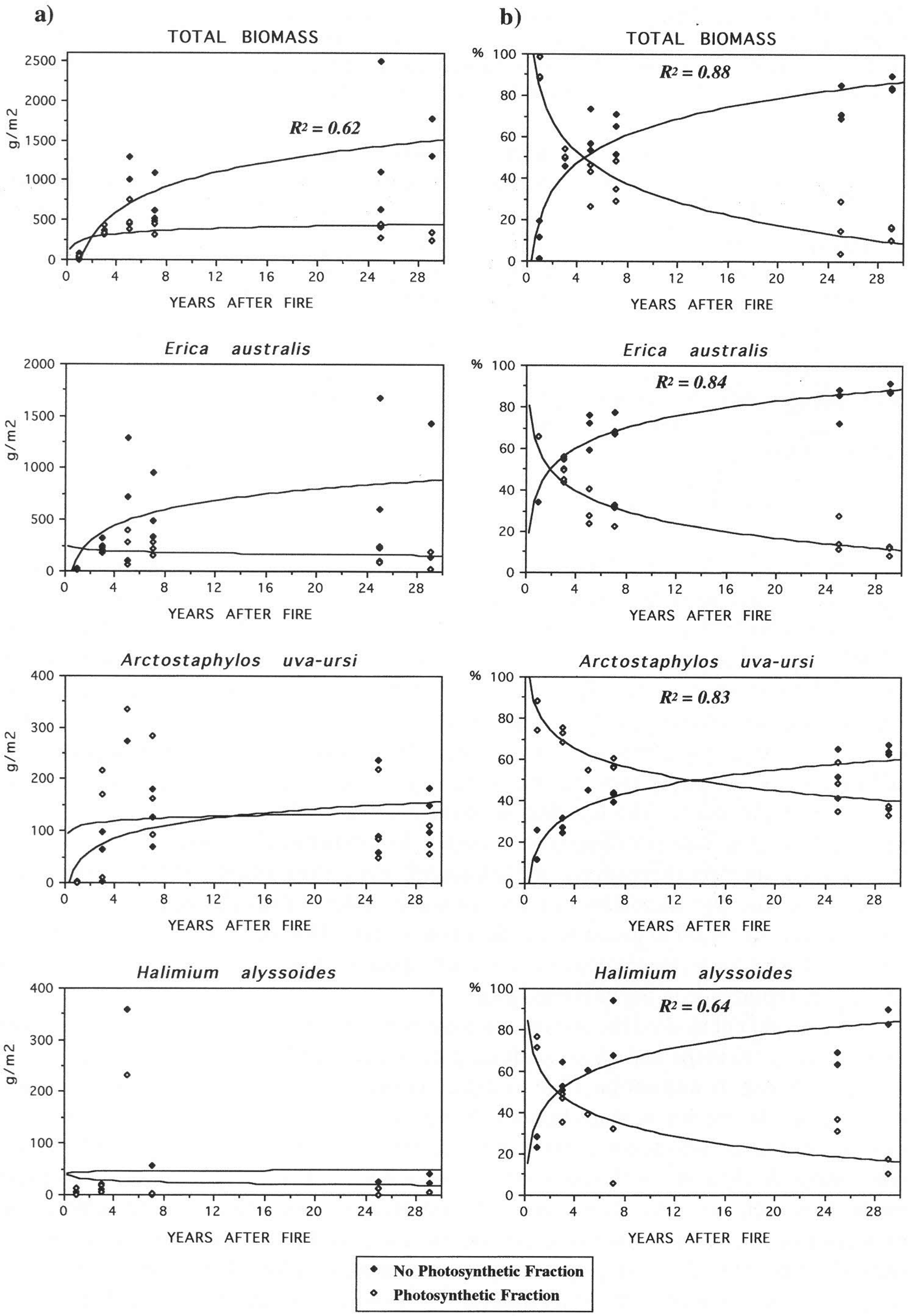

Fig. 4a. Logarithmic curve fitting for photosynthetic and non-photosynthetic biomass values (g/m^2). The fit is only significant (99%) for non-photosysthetic total biomass.

Fig. 4b. Logarithmic curve fitting for percentages of photosynthetic and non-photosynthetic fractions (%). The fit is significant (99%) in all cases.

Table 1. Mean values of the percentages of the non-photosynthetic fraction for the total biomass and for the most frequently occurring woody species in the three plots in both of the study years. Different letters indicate statistically significant differences between the different post-fire recovery years by Tukey-test ($p < 0.05$). (The photosynthetic fraction percentage is reciprocal).

	B-93 1 year	B-91 3 years	B-93 5 years	B-91 7 years	UB 25 years	UB 29 years
Total Biomass	11%	47%	61%	63%	75%	86%
	a	b	bc	bc	c	c
Erica australis	34%	54%	69%	71%	82%	88%
	a	b	bc	bc	c	c
Arctostaphylos uva-ursi	19%	28%	45%	42%	53%	64%
	a	a	ab	ab	b	b
Halimium alyssoides	26%	56%	61%	81%	66%	86%
	a	ab	ab	b	b	b
Calluna vulgaris					79%	74%
					a	a

from the third year after the fire, which coincides with results observed by various authors who recorded recovery by autosuccession in Mediterranean shrub communities (Hanes 1971, Naveh 1975, Keeley 1986, Trabaud 1987, Mazzoleni & Esposito 1993, Reyes *et al.* 2000). Only one year after the fire a clear dominance of herbaceous species biomass was observed. These species are soon displaced when the shrubs recover. The main difference between the unburned plot and the others is the larger biomass of *Calluna vulgaris*. This species behaves as a seeder in these areas (Ojeda 2001), only recovering from seeds and, in addition, does not usually appear in the first two years after fire (Calvo *et al.* 1992, Vera & Obeso 1995), in spite of the fact that in studies on the seed bank it was found that heat favoured its germination (Valbuena *et al.* 2000). To regenerate the aboveground as well as the subterranean parts, the recovery of *Calluna vulgaris* is slower than that of the resprouters (*Erica australis, Arctostaphylos uva-ursi*) or some seeders of smaller size, like *Halimium alyssoides*, which need to invest less in their root system. However, when enough time has passed, *Calluna vulgaris* exceeds these woody species of smaller size and is the second species in importance in the unburned plot.

In the heathland studied the increase in total biomass shows a logarithmic type growth due to the growth in the non-photosynthetic parts, since the photosynthetic biomass hardly varies over time. It was not possible to detect a temporal tendency in the biomass of the different woody species, perhaps because the age of the individual specimens of each species was not taken into account, but rather the time since the fire in the plot where they were found; in addition, the biomass is not expressed per individual specimen but by square meter. However, very clear tendencies were observed on considering the percentages of both photosynthetic and non-photosynthetic fractions for the total biomass in each plot as well as for the most frequently appearing species in all the plots. This coincides with the results obtained by other authors on different shrub species (Ojea *et al.* 1988, Fernandez-Santos & Gómez Gutierrez 1994, Fernandez-Santos *et al.* 1999), although the growth recorded when biomass is related to the age of individuals is of the sigmoid type.

The increase in non-photosynthetic biomass at the expense of the photosynthetic one corresponds to one of the most general tendencies in succession, the decrease in the net production/biomass ratio (Odum 1971). On the other hand the increase in the proportion of woody parts, in general with a lower water content than the green parts, together with the net increase in the total biomass over time, can be related to a greater risk of fires. Most authors state that in addition to the total load, the characteristics of plant fuel are fundamental when determining their flammability and combustibility (Rego *et al.* 1994, Bond & Van Wilgen 1996, Gill & Moore 1998). Amongst them the seasonal dynamics of water content stands out. Although in general the green parts usually lose water more quickly than the woody parts in summer (Santalla 2001), in other studies carried out on the same area a higher water content appeared in the species of the more recently burned plots in comparison with the unburned ones (Villalón *et al.* 2001).

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