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# Postfire regeneration of a thermomediterranean shrubland area in south-eastern Spain

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## Abstract

Postfire regeneration of thermomediterranean shrublands burnt in 1998 was studied in the Province of Murcia (SE Spain). The vegetation structure of sites with different exposures was compared with that of adjacent unburnt areas. Three years after the fire, the mean vegetation cover of the burnt sites was still significantly lower than that of the non-burnt areas. However, the results of a Detrended Correspondence Analysis indicate that fires induce only minor changes in the species composition and the vegetation structure. Fire seems to be a common phenomenon, and the dominant species are characterized by pre-adaptations to withstand fires. The most frequent pre-adaptation is the ability to resprout rapidly from subterranean parts, whereas the regeneration from seeds is clearly less important in the most dominant species.

**Key words**: Fire, Resprouter, Seeder, South-eastern Spain, Thermomediterranean climate.

## Resumen

*Regeneración postincendio de un matorral termomediterráneo en el sureste de España.*

Se estudia la regeneración postincendio de un matorral termomediterráneo, incendiado en 1998, en la provincia de Murcia (SE de España). Se compara la estructura de la vegetación de lugares con diferentes exposiciones frente a la de áreas próximas no quemadas. Tres años después del fuego, la cobertura de la vegetación en los lugares incendiados era significativamente más baja que la de áreas no quemadas. Los resultados de un DCA indican que los fuegos sólo inducen pequeños cambios en la composición de especies y en la estructura de la vegetación. Los fuegos espontáneos son un fenómeno común y por ello las especies dominantes se caracterizan por una serie de preadaptaciones a los mismos. La más frecuente es la posibilidad de rebrote rápido a partir de partes subterráneas, en tanto que la regeneración a partir de semillas es claramente menos importante en las especies dominantes.

**Palabras clave**: Fuego, Rebrotes, Regeneración por semillas, Sureste de España, Termomediterráneo.

## Introduction

The major ecological forces controlling Mediterranean vegetation are climatic stress, lack of nutrients and fire. During summer drought, fires are particularly common in the Mediterranean winter rain regions, when the water content of living and accumulated dead biomass decreases dramatically. Burning facilitates rapid mineralization of organic material and thus partly replaces the otherwise rather ineffective biological decomposition (Bond & van Wilgen 1996).

Not surprisingly, many species show traits, which enable them to survive fires. Many woody plants recover rapidly by resprouting from subterranean organs such as rhizomes, burls or lignotubers (see James 1984 for a review). Other species are able to regenerate from a soil-stored or aerial seed bank (Fenner 1985, Pierce & Cowling 1991, Ferrandis et al. 1999). In addition, the open post-fire environment provides space and new safe sites for the germination and establishment of long-range dispersers or weak competitors which might increase floristic diversity (Trabaud & Lepart 1980).

Vegetation successions after fire have been intensively studied in the Mediterranean region (e.g. Trabaud & Lepart 1980, Casal et al. 1990, Mazzoleni & Pizzolongo 1990, Moravec 1990, Tárrega & Luis-Calabuig 1990, Tárrega et al. 1995, Tárrega et al. 1997; Pérez & Moreno 1998). Several studies demonstrate a rapid recovery of vegetation to the pre-fire conditions. This may be due to the fact that the vegetation has been influenced by fire for a long time (Trabaud & Lepart 1980, Naveh 1990), and communities sensitive to fire were replaced long ago. Hanes (1971) used the term «autosuccession» for this form of vegetation dynamics, which is restricted to alterations in coverage of certain species, while species composition remains essentially unchanged. This process is clearly distinct from the typical succession leading to a true climax community.

However, most of these studies deal with the impact of fire on forest communities, while little is known about the response of shrubland communities on drier sites. The thermomediterranean coastal area of the Province Murcia is characterized by an endemic shrubland community, dominated by *Periploca angustifolia* and *Maytenus senegalensis* (Mayteno-Periplocetum angustifoliae). This community is restricted to a narrow area on the coast between Calblanque (Murcia) and Cabo de Gata (Almería; Freitag 1971) and shows many floristic and ecological similarities to the vegetation of arid Northern Africa. At present, these communities are highly fragmented due to the increasing land use, mainly for tourism, and many sites have been strongly degraded. As the vegetation cover is sparse due to the aridity, fires are a common phenomenon but they do not occur as frequently as in zones further north of the country with higher precipitation and, thus, greater fuel-loads. There are no studies on regeneration after fire for this endemic and highly endangered plant community. In the present paper, we compare the vegetation composition among study sites of different exposures, which were burnt in 1998, with that of unaffected adjacent areas in order to get an idea about the impact of fire on plant diversity, early successional sequences and principal changes in structure.

## Materials and Methods

### Study sites

The study area is located in the coastal region of Murcia in the south-eastern part of the Iberian Peninsula. Data was collected at Cabezo de la Galera, a hilly shrubland area near Portman that burnt in June 1998, affecting an area of 22 ha. The climate in the region is semi-arid, with a mean annual temperature of 18°C, minimal temperatures above 0°C, and a mean annual rainfall of about 300 mm (González 1999). The annual precipitation regime is bimodal, with the highest precipitation between autumn and spring and a very dry and warm summer period. Geologically, the study site is part of the «Nevado-Filabride» complex of the Betical Zone (Sánchez Gómez et al. 1998). Sedimentary rocks with hardly any topsoil and low carbonate contents prevail.

### Sampling and data analysis

In the burnt area, several releves were sampled at different exposures in April and May 2001 according to the Braun-Blanquet method (Braun-Blanquet 1964). The sample included burnt sites and adjacent areas, which had not been affected by fire recently. The latter served as control plots. Selection criteria for the control plots were comparable conditions with regard to exposure, inclination, and soil characteristics. The cover was estimated using the Londo-Scale (Londo 1976). Mosses and lichens were ignored. Nomenclature of species refers to Tutin et al. (1964-1980), syntaxonomic classification of the species follows Peinado et al. (1992). The unburnt sites were compared with the burnt sites in order to analyse changes of vegetation composition caused by fire. Differences in the percentage cover of the most frequent plant species were tested using the nonparametric Mann-Whitney-U-Test ((*) = $p < 0.1$, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$; two-tailed).

Mixed soil samples were analysed for pH(KCl), carbonate (Scheibler-apparatus) and plant-available content of monovalent ($K^+$, $Na^+$) and bivalent ($Ca^{2+}$, $Mg^{2+}$) cations ($NH_4Cl$-extraction followed by atomic absorption spectrometry) for each exposure and treatment (burnt/unburnt). The set of environmental parameters was thus limited, so we refrained from using constrained multivariate analyses, which would have let to a poor representation of the underlying floristic variability (McCune 1997). Instead, we used non-canonical Detrended Correspondence Analysis (DCA) on the main phytosociological table. All species data was log-transformed prior to analysis (y= log [x+1]). Initial inspection of the data designated two samples as outliers (mean distance based on the Bray-Curtis/ Steinhaus index >2 s.d. from sample mean). They were excluded from the DCA. Detrending was done by segments. In this way distances in the ordination plot approximate ecological distances in terms of species turnovers, which is a desirable property in studies on vegetation succession. One species turnover is equivalent to 4 multivariate standard deviations or 400 units along the ordination axes (Jongman et al. 1995). This is not the case with linear methods (e.g. PCA), which were accordingly not used in the analysis, although the relatively short gradient (<2.5 s.d.) would suggest a test with PCA.

In a second step, ordination axes were interpreted by after-the-fact correlations with environmental data (fire, inclination, carbonate, pH-value, content of $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$). Aspect was transformed by calculating the cosinus and the sinus of the exposure degrees, thus yielding a variable for «northernness» and «easternness». Multivariate analyses were carried out with the PC-ORD package (McCune & Mefford 1995).

## Results

The vegetation at Cabezo de la Galera is characterized by the presence of several character species of the Lapiedro-Stipetum tenacissimae and Mayteno-Periplocetum angustifoliae (Table 1). *Distichoselinum tenuifolium, Stipa tenacissima, Gladiolus illyricus, Periploca angustifolia* and *Fumana laevipes* are highly constant on all study sites. Hemicryptophytes are the dominant growth form as a result of the high cover values of *Stipa tenacissima* and *Brachypodium retusum.* On sites facing westwards and southwards, the percentage of hemicryptophytes is dramatically reduced after fire, which corresponds to the lower coverage of *Stipa tenacissima* three years after the fire (Fig. 1). The percentage of chamaephytes, geophytes and nano-phanerophytes remain stable before and after the fire on south- and west-facing slopes. In contrast, chamaephytes and nano-phanerophytes are reduced after fire on north-facing sites, while the hemicryptophytes showed similar cover values in burnt and unburnt plots. Therophytes were abundant on north-facing slopes without major differences between control plots and burnt sites. Their number on south and west-exposed slopes is very low, but rises slightly after fire (Fig. 1).

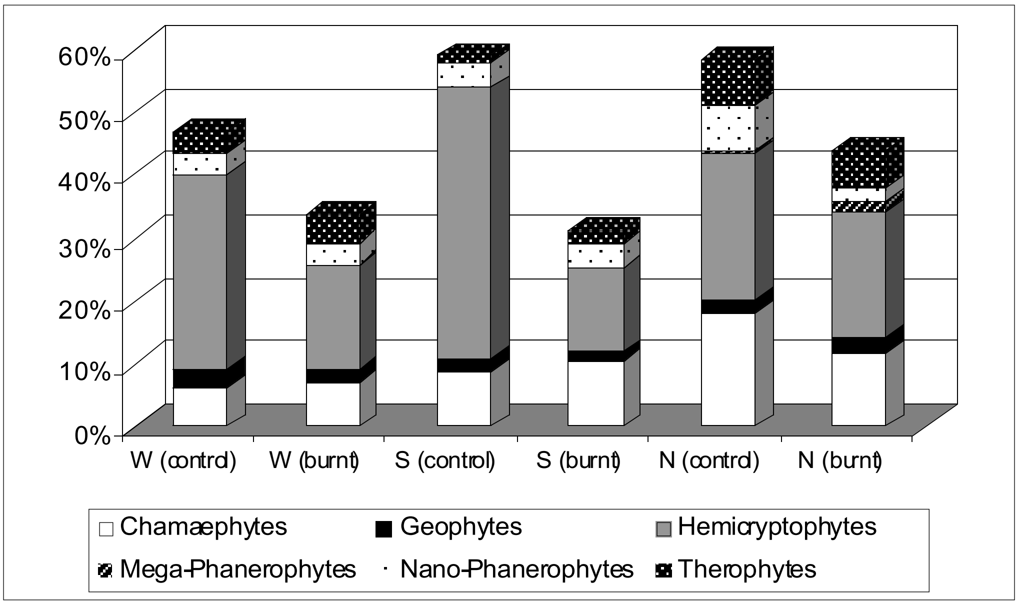


Figure 1. Spectra of life forms on the study sites (values are sums of cover percentages).
W, S, N = west-facing, south-facing, north-facing slopes.
Figura 1. Formas de vida en los lugares estudiados.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Number of releves | 6 | 4 | 5 | 7 | 5 | 5 |
| | Exposition (degrees) | W(29) | W(295) | S(230) | S(173) | N(340) | N(340) |
| | Fire impact | none | 1998 | none | 1998 | none | 1998 |
| | Altitude above sea level | 84 | 102 | 100 | 110 | 95 | 110 |
| | Inclination | 12 | 13 | 20 | 15 | 17 | 10 |
| | pH (KCl) | 7.1 | 7.2 | 7.3 | 7.2 | 7.1 | 7.1 |
| | Carbonate content (%) | 12.9 | 8.8 | 13.2 | 13.3 | 8.8 | 6.6 |
| | Na+ (mg/kg) | 7.7 | 12.1 | 13.5 | 12.1 | 7.0 | 7.3 |
| | K+ (mg/kg) | 11.0 | 12.3 | 9.7 | 10.4 | 8.2 | 8.6 |
| | Ca2+ (mg/kg) | 10.3 | 5.8 | 8.9 | 10.0 | 9.6 | 9.3 |
| | Mg2+ (mg/kg) | 13.7 | 12.5 | 13.8 | 16.0 | 14.0 | 13.2 |
| | Vegetation cover (%) ***C | 49 | 32(*) | 59 | 31* | 54 | 42* |
| | Total species number | 39 | 31 | 29 | 42 | 51 | 44 |
| | Species number per releve | 17 | 19 | 16 | 18 | 30 | 24 |
| Life formn | Character species of Lapiedra martinezi-Stipetum tenacissimae Rivas-Martínez & Alcaraz 1984 and higher syntaxa | | | | | | |
| H | *Distichoselinum tenuifolium* | V(3) | V(4) | V(2) | V(1) | V(2) | V(4) |
| H | *Stipa tenacissima* *C | V(30) | V(10) | V(30) | V(10) | V(2) | V(10) |
| G | *Gladiolus illyricus* *B | V(1) | V(1) | II(1) | V(1) | V(1) | V(1) |
| H | *Brachypodium retusum* | V(1) | V(1) | | II(1) | V(1) | V(2) |
| H | *Avenula bromoides* | I(2) | II(1) | | I(1) | III(1) | II(1) |
| | *Helictotrichon filifolium* | | | | | | I(4) |
| | *Lapiedra martinezii* | | | | | I(1) | |
| | Character species of Mayteno europaei-Periplocetum angustifoliae Rivas-Martínez 1975 and higher syntaxa | | | | | | |
| NP | *Periploca angustifolia* | V(4) | V(3) | V(2) | V(2) | VIII(1) | II(2) |
| | *Calicotome intermedia* | III(2) | III(1) | II(25) | II(15) | V(4) | V(2) |
| | *Arisarum simorrhinum* | III(2) | IV(1) | I(1) | | III(1) | II(1) |
| Ch | *Asparragus horridus* | | | V(1) | IV(1) | I(1) | III(1) |
| MP | *Chamaerops humilis* | I(1) | II(1) | | | I(2) | II(4) |
| | *Osyris quatripartita* | | | I(1) | II(15) | I(1) | |
| | Companions with a constancy > 25% | | | | | | |
| | *Fumana laevipes* | V(1) | V(1) | V(1) | V(15) | V(1) | V(1) |
| Th | *Anagallis arvensis* | V(1) | IV(1) | I(1) | I(1) | V(1) | V(1) |
| | *Reichardia tingitana* | IV(1) | V(1) | I(1) | IV(1) | IV(1) | II(1) |
| | *Convolvulus lanuginosus* **B | I(2) | V(1) | | V(1) | IV(1) | II(2) |
| | *Leontodon hispidus* (*)B | II(1) | V(1) | | III(1) | V(1) | V(1) |
| | *Thymus zygis* *C | III(1) | II(1) | IV(1) | III(1) | V(2) | II(1) |
| | Genista umbellata | III(1) | III(1) | IV(2) | III(1) | III(1) | II(1) |
| | *Satureja obovata* subsp *canescens* | I(1) | | III(2) | V(1) | V(1) | II(15) |
| | *Teucrium carthaginense* | IV(1) | V(1) | I(1) | | IV(1) | IV(1) |
| | *Euphorbia exigua* | III(1) | III(1) | I(1) | I(1) | IV(1) | V(1) |
| | *Lavandula dentata* | IV(1) | III(1) | | IV(1) | II(1) | III(1) |
| | *Teucrium pseudochamaepitys* (*)B | III(1) | V(1) | | I(2) | IV(1) | V(1) |
| | *Brassica tournefortii* | II(1) | III(1) | I(1) | I(1) | IV(1) | V(1) |
| | *Ruta angustifolia* *B | II(1) | IV(1) | | V(1) | II(1) | I(1) |
| | *Polygala rupestris* | I(1) | III(1) | | III(1) | IV(1) | II(1) |
| | *Convolvulus althaeoides* | I(1) | II(1) | II(1) | III(1) | I(1) | I(1) |
| | *Eryngium campestre* | IV(1) | | II(1) | II(1) | I(1) | I(1) |
| | *Lithodora fruticosa* | I(1) | | | | V(4) | IV(2) |
| | *Sedum sediforme* *C | III(1) | | III(1) | I(1) | II(1) | I(1) |
| | *Cuscuta epithymum* | | II(1) | I(1) | | IV(1) | III(1) |
| | *Linum strictum* | | II(1) | | | III(1) | IV(1) |
| | *Urginea maritima* | II(15) | | III(1) | | I(1) | II(15) |

Table 1. Summary of the vegetation survey at Portman, Province of Murcia. The values for environmental parameters are medians. Species' abundance data is shown as constancy classes, indicating the relative frequency in the data set (I = occurring in 1-20% of all relevés, II = 21-40% etc). Numbers in brackets refer to the median of coverage in %. Significant differences between cover in burnt and unburnt samples are indicated with asterisks followed by a letter ((*) = p < 0.1, * = p < 0.05, ** = p < 0.01, *** = p < 0.001; two-tailed; C for higher values in control, B for higher values on burnt sites). The legend explaining the life forms is found in Fig. 1.
Tabla 1. Resumen de los datos de vegetación en Portman, Provincia de Murcia.

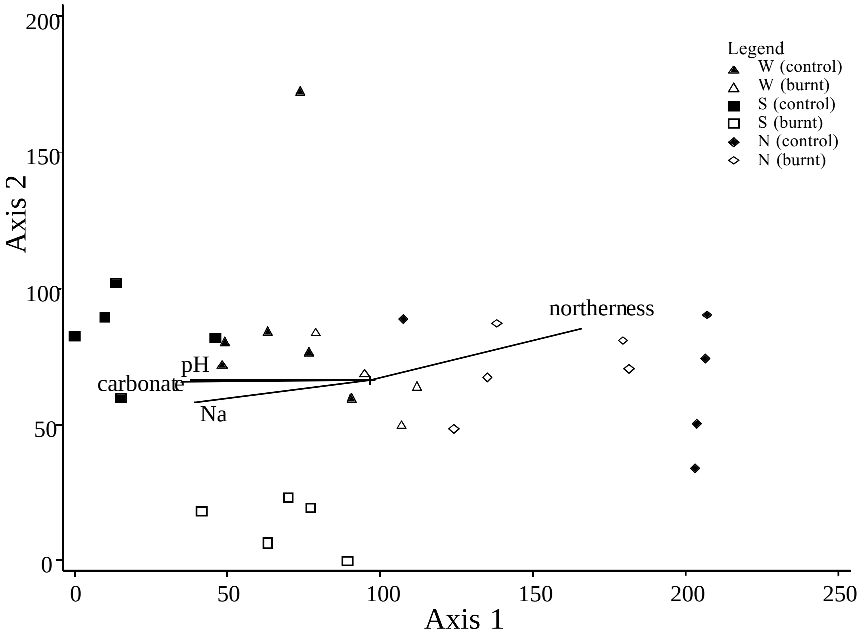


Figure 2. DCA with log transformed data. Only vectors of environmental parameters with r2 > 0.4 are included.
Figura 2. DCA con datos log transformados.

Three years after fire, the mean vegetation cover on the burnt study sites was still significantly lower than in the non-burnt areas (Table 1, $p < 0.001$). Cover values of *Stipa tenacissima, Sedum sediforme* and *Thymus zygis* were significantly higher on unburnt sites, while *Convolvulus lanuginosus, Gladiolus illyricus, Ruta angustifolia, Leontodon hispidus* and *Teucrium pseudochamaepitys* show higher coverage on the burnt sites. However, there are neither significant differences in species diversity of burnt or unburnt sites, nor were any species exclusively restricted to either burnt or unburnt sites. As shown by Table 1, species numbers are generally higher on north-facing slopes, and total species numbers are lower three years after the fire impact on north and west-facing slopes. In contrast, south-facing control plots showed increased species richness after fire. However, differences are rather small for southern and western slopes, so the only significant effect was reduced species richness on northern exposures.

The pH(KCl)-values of the different study sites range between 7.1 and 7.3 (Table 1). Values were slightly higher on south-facing slopes, probably as a consequence of higher evaporation and thus accumulation of cations in the topsoil. The overall content of monovalent cations is slightly higher on the burnt than on the unburnt sites. For the bivalent cations $Ca^{2+}$ and $Mg^{2+}$, this effect was only observed on sites facing southwards.

In the DCA (Fig. 2), releves are clearly differentiated along axis 1 ($r2 = 0.549$) but scattered over a wide area along the second axis which explains low variance ($r2 < 0.01$). Sample plots with southern exposure are grouped on the left part of the first axis, those exposed to the north on the right, those exposed to the west lie between the former two. This gradient is confirmed by a high correlation of «northernness» with the first axis ($r2 > 0.4$). The contents of $Na^+$ and carbonate as well as the pH-value are further environmental parameters correlating negatively with the first axis. The centroid for the fire impact lay close to the centre of the diagram, suggesting that fires have little impact on the vegetation composition. This is supported by the general shortness of the floristic gradient in the DCA. It extends over less than 2 multivariate standard deviations (equalling 200 units), which corresponds roughly to a species turnover of 50% between the most dissimilar samples. However, fires tend to make sites floristically more similar, although the impact is small, since the burnt sites are largely clustered in the centre of the diagram, while the unburnt control plots are grouped at the outer margins of the ordination. This seems reasonable with respect to the average distance of the control plots with the fire-prone plots. While control plots show an average distance of 0.40 (based on the Steinhaus/Bray-Curtis index), fire sites are somewhat less dissimilar at an average distance of 0.28.

## Discussion

Within three years after the fire, regeneration of the vegetation in the thermomediterranean shrubland area of Cabezo de la Galera had not been complete, and overall cover of burnt sites was still lower than on the control plots. This was largely a consequence of the dominant *Stipa tenacissima* because its large tussocks had not yet reached the pre-fire extent. The generally low, albeit significantly higher cover of *Convolvulus lanuginosus, Gladiolus illyricus, Ruta angustifolia, Leontodon hispidus* and *Teucrium pseudochamaepitys* on the burnt study sites can be explained by the increased availability of open spaces and/ or higher resource availability due to the decreasing coverage of the dominant hemicryptophytes. The clear exposure gradient in the DCA is easily explained by the different water availability that results in a higher presence of Mayteno-Periplocetum species (*Calicotome intermedia* and *Chamaerops humilis*) on study sites facing northwards. South-facing sites are drier, have sparse vegetation coverage, and species of the Lapiedro-Stipetum tenacissimae (mainly *Stipa tenacissima*) are present with higher coverage values. The pH-value differences are caused by the higher concentration of carbonate and $Na^+$ on these sites. Such increased values of pH after fire as well as of monovalent cations were frequently observed by several authors (e.g. St. John & Rundel 1976), but are usually only of short duration, as examplified by Herranz et al. (1991).

Notably, the resprouting hemicryptophytes *Brachypodium retusum, Distichoselinum tenuifolium*, the nano-phanerophytes *Periploca angustifolia, Chamaerops humilis* and *Genista umbellata,* as well as the geophytes *Gladiolus illyricus* and *Arisarum simorrhinum* had recovered well three years after the fire. Species which regenerate mainly or exclusively by seeds, such as *Convolvulus lanuginosus, Fumana laevipes* and annuals (such as *Anagallis arvensis, Reichardia tingitana* or *Leontodon hispidus*) re-establish well after fire but regenerate slowly with respect to their abundance and coverage. The extreme harshness of this dry environment and the lack of deep topsoil might be the main reasons for the low production of biomass above the ground. The therophytic life-form was also found rarely during postfire regeneration of *Quercus coccifera* shrublands (Trabaud 1987), though seeders are abundant in postfire environments of woodlands (Westman 1988) and heathlands (Ojeda et al. 1996) in the moister areas of the eastern Mediterranean.

The observed differences of vegetation and species coverage after fires are in line with previous studies. Calvo et al. (2002) studied the recovery time of several shrub species after fire and found out that most species reached their original cover value after 4 years, though single species needed about 12 years to recover completely. In our study area, cover on north-facing slopes has already almost completely recovered after three years. This is a consequence of more favourable growth conditions on the shady slopes. A similar phenomenon has been described by Guo (2001) from Californian chaparral. North-facing slopes exhibited higher species richness and faster vegetation recovery in terms of biomass accumulation and return to pre-fire species composition than south-facing slopes. Therefore, we suspect, that even in Cabezo de la Galera cover values will adjust within a few more years.

The absence of a correlation of the factor fire with one of the ordination axes indicates a high adaptation level of the vegetation to this disturbance. None of the species recorded on the study sites is restricted to burnt or unburnt sites, and thus none appears to be a true pyrophyte, as they are found in the Californian chaparral (Keeley 1986, Keeley 1994) or in the south-african fynbos (Cowling 1992, van Wilgen et al. 1992), where many annual species are restricted to early post-fire successional stages. Moreover, there is no true succession in the sense of a substitution of a community by another one. There are only minor differences in the species composition of control plots and burnt sites, although fire leads to somewhat higher similarity of the vegetation on the different slopes (Figures 1, 2).

Thus, fire has certainly been a selective force in the evolution of the present vegetation (Naveh 1975) and this thermomediterranean shrubland community has to be considered as being strongly resilient to fires. The vegetation rapidly returns to its pre-fire state in terms of species composition, as already described for other regions by Keeley (1986), Trabaud (1987) or Herranz et al. (1991). According to this, the term «autosuccession» as used by Hanes (1971), seems well suited for the regenerative processes in this thermomediterranean scrubland.

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