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# Decomposers and the Fire Cycle in a Phryganic (East Mediterranean) Ecosystem

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**Abstract.** Dehydrogenase activity, cellulose decomposition, nitrification, and $CO_2$ release were measured for 2 years to estimate the effects of a wildfire over a phryganic ecosystem. In decomposers' subsystem we found that fire mainly affected the nitrification process during the whole period, and soil respiration for the second post-fire year, when compared with the control site. Our data suggest that after 3–4 months the activity of microbial decomposers is almost the same at the two sites, suggesting that fire is not a catastrophic event, but a simple perturbation common to Mediterranean-type ecosystems.

## Introduction

About 40% of the total surface of Greece is covered with Mediterranean-type ecosystems characterized climatically by mild, wet winters, and dry, hot summers. Two basic ecosystem types can be distinguished in these areas: *maquis*, which usually are found at the wet end of the precipitation gradient, and *phrygana*, at the dry end. When their major adaptation to overcome the summer drought is considered, maquis (synonyms: *choresh*—*Israel*, *monte bajo*—Spain, *chaparral*—USA, *fynbos*—S. Africa, *matorral*—Chile, *mallee*—Australia) are characterized by evergreen sclerophylly, whereas phrygana (synonyms: *batha*—Israel, *tomillares*—Spain, *coastal sage*—USA, *renosterbos*—S. Africa, *barocal*—Portugal, *gariga*—Italy) show a seasonal dimorphism by which they minimize their transpiring biomass during summer.

Today, at least for areas of the earth with a Mediterranean-type climate such as California, S. Africa, and Australia, fire is generally accepted as a natural and inevitable event incorporated in the information pool of these ecosystems. In producer's subsystem, after a fire all the dominant plants recover by resprouting, activation of seed germination, or both. In general, 5–10 years after a fire, a burned system is similar to unburned ones. Also, time delay for the fire due to anthropogenic actions usually results in degradation of the system as well as a decrease of species diversity.

Although abundant information is available concerning the recovery of producers, little information is available concerning decomposers. Consequently, we studied changes in soil microbial subsystem following fire. We are aware of the difficulties of investigating parameters representing soil microbial processes; therefore, we chose dehydrogenase activity, nitrification, cellulose decomposition, and $CO_2$ release from

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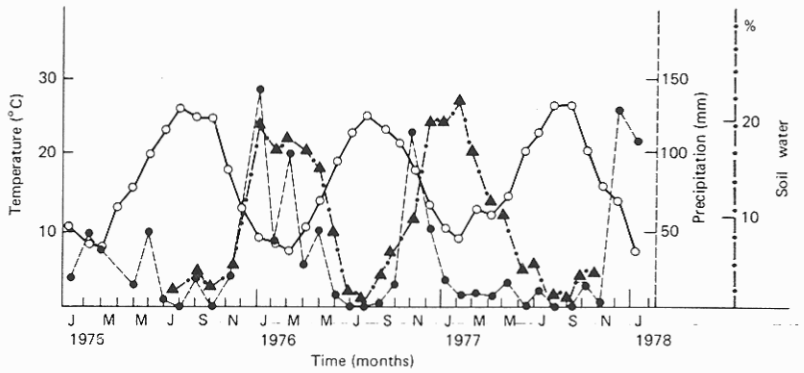


**Fig. 1.** A climatic diagram containing data for the study area during the experimental period

soil as our main focal points because they describe the system from a functional point of view.

## Materials and Methods

### *Study Site*

In late July 1976 about 200 ha of phrygana were burned accidentally on the Hymettus mountain close to the Athens University Campus. Since its pre-fire structure and function was described already by Margaris [14], the area was ideal because it was well known and because it was close to areas with unburned vegetation and soil type. The study area is about 400 m above sea level, and the terrain is moderately steep with slopes of 10–15°.

The dominant woody species were plants that occur typically in phryganic ecosystems, including *Phlomis fruticosa, Sarcopoterium spinosum,* and *Euphorbia acanthothamnos,* which accounted for 77% of the above ground biomass of the system (approximately 1000 gm $^{-2}$ before the fire). The remaining 33% consisted of subshrubs such as *Thymus capitatus, Cistus* spp, *Helianthemum numularum, Asparagus aphyllus, Teucrium polium,* as well as some annual and perennial herbaceous plants.

All shrubs were burned to the ground by the 1976 fire leaving only charred snags. Almost all the litter was also consumed, leaving the soil covered with ash up to 2 cm in depth. Climatic data for the study period are shown in Fig. 1.

### *Procedures*

*Estimation of Microbial Numbers.* Microbial populations of bacteria and fungi were estimated by dilution plate counts [15,16] in 5 soil samples collected 3 months after the fire from the upper 3 cm of the burned and the unburned sites' soil.

*Estimation of Microbial Biomass.* Three soil samples of 300 g each, collected from the upper 3 cm of soil from the burned and the unburned sites, were exposed to chloroform for sterilization. The samples then were inoculated and were incubated for 20 days according to the method of Jenkinson [11]. Microbial biomass was calculated from the difference of $CO_2$ released during incubation.

*Dehydrogenase Activity.* Each month 5 soil samples from the upper 3 cm at both sites were tested for dehydrogenase activity by the triphenyltetrazolium chloride (TTC) method [12].

*Cellulose Decomposition.* Cellulose decomposition was studied in the upper 10 cm of the burned and unburned

**Table 1.** Soil microbial populations measured in the upper 3 cm of the burned and unburned sites of the phryganic ecosystem.

| | No of Cells/g soil | |
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| | Burned | Unburned |
| Bacteria | | |
| Phrygana (Greece) | $68 \times 10^4$ | $28 \times 10^3$ |
| Chaparral (California) | $268 \times 10^5$ | $65 \times 10^5$ |
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| Chaparral (California) | $447 \times 10^4$ | $19 \times 10^4$ |

site using filter paper. The method is described elsewhere [5, 6]. For the computation of decomposition constants, a first-order decay reaction was assumed:

$$x_t = x_0 e^{-kt}$$

where:

$x_t$ = amount of material remaining after time t (days)

$x_o$ = amount of material at the beginning of the period

k = decay constant (decomposition rate per day)

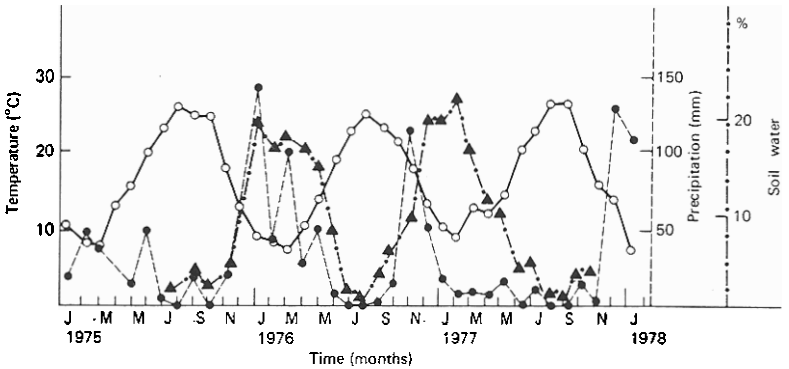
*Soil Nitrate Content and Nitrification.* Nitrate content of the soil was estimated monthly in samples collected from the upper 3 cm of both burned and unburned sites, using the phenoldisulfonic method [2]. For the determination of soil nitrifying capacity, every second month 3 air-dried soil samples (of the upper 3 cm) weighing 20 g each were placed in beakers, brought to 60% of field water capacity, and kept in the dark for 21 days at 25 ± 1°C. The nitrifying capacity was calculated from the difference in the nitrate content at the beginning and end of the 21-day period.

*Soil $CO_2$ Release.* Soil $CO_2$ release was measured by the inverted boxes technique [7,19]. Ten cylindrical aluminum cylinders (20 cm high and 10 cm in diameter) were inverted at each site covering a beaker containing 20 ml of 1N KOH. A 24 h equilibration period was allowed. Amounts of $CO_2$ evolved were estimated by titration using a N/10 HCl solution. The measurements were carried out every 15–20 days in the burned and unburned sites.

## Results and Discussion

Results concerning the numbers of bacteria and fungi of the Greek phryganic ecosystem are shown in Table 1. A slight decrease in fungal population was observed, while bacteria appeared to increase in number. In the method used for the fungal enumeration, spores were isolated in preference to fungal hyphae. The increase in the bacterial populations could be attributed to the high pH values (pH: 7.5–8.0) observed in the burned soil.

Using the sterilization-reinoculation technique, we found that the total microbial biomass in the upper 3 cm soil in the burned area was 0.5 g/100 g of soil 2 months after fire, 30% less than the microbial biomass in the unburned soil.

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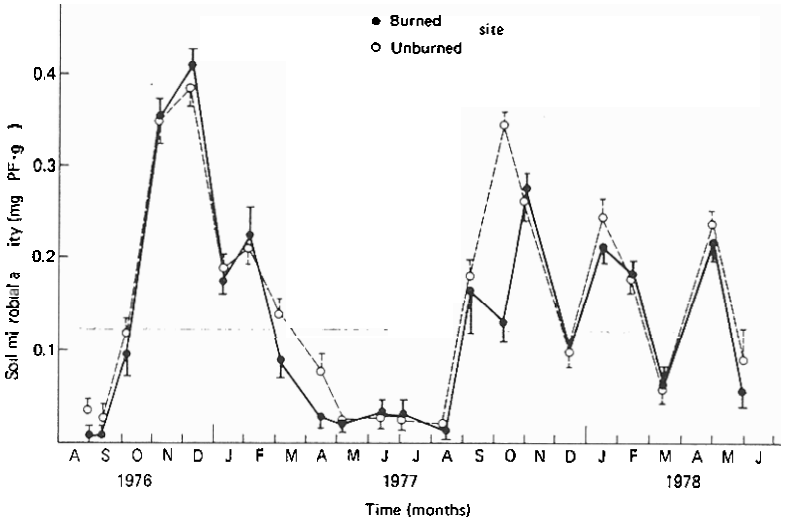


**Fig. 2.** Soil microbial activity in the burned and unburned phryganic ecosystem between August 1976 and June 1978.

*Dehydrogenase System Activity*

Using dehydrogenase activity it was found that the activity in the top 3 cm of soil appeared to be the same in the burned and unburned soils (Fig. 2). However, the disadvantages of this method must be considered since several biological parameters are involved, such as activity of free enzymes released by lysed microorganisms or plant roots, or enzymes excreted by integral microbial cells, meso- and micro-fauna [18].

*Cellulose Decomposition*

Figures 3A and 3B present data concerning cellulose decomposition with and without the addition of urea in both burned and unburned areas. Each value is the mean of 10 samples taken at each collection day, and the vertical bars represent the standard errors.

For the pure cellulose treatment (Fig. 3A) a lag phase of 32 days was observed in both sample areas in which the decay constants for burned and unburned soils were found to be $k_{0\text{-}32} = 0.7\%\ \text{day}^{-1}$, followed by high rate of decomposition with the decay constants increasing to $k_{32\text{-}180} = 1.5\%\ \text{day}^{-1}$ (burned) and $k_{32\text{-}180} = 1.1\%\ \text{day}^{-1}$ (unburned).

It is well known [10] that one of the factors which may be limiting in cellulose utilization is nitrogen concentrarion. We tested the effect of urea addition on cellulose decomposition rates. Results are plotted in Fig. 3B.

In the presence of added urea, a 32-day lag phase was observed during which the decay constants were $k_{0\text{-}32} = 0.6\%\ \text{day}^{-1}$ (burned) and $k_{0\text{-}32} = 0.9\%\ \text{day}^{-1}$ (unburned). Again, the lag phase was followed by a relatively high rate and decay

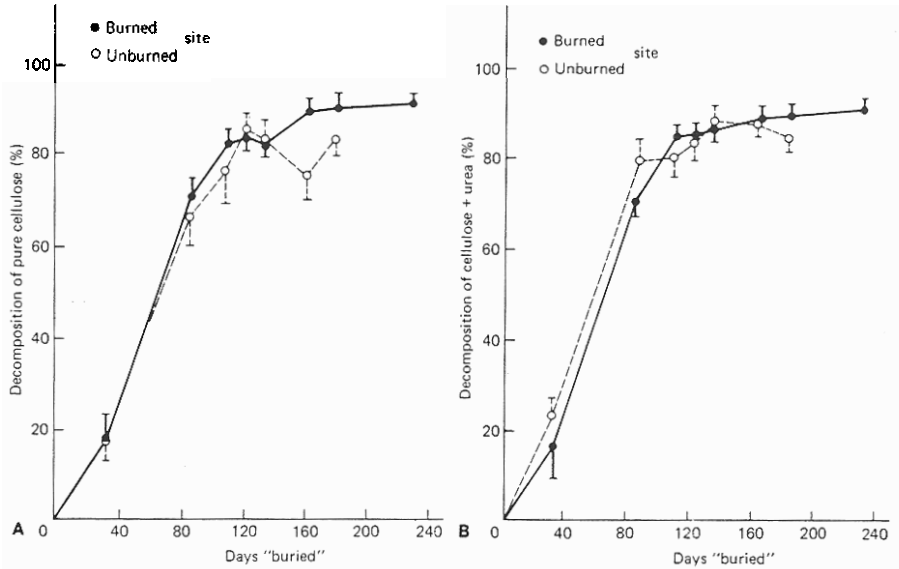


**Fig. 3.** Decomposition of cellulose filter papers, pure (A) or with the addition of urea solution (B), in the burned and the unburned sites of the phryganic ecosystem.

constant of $k_{32\text{-}180} = 1.1\%\ day^{-1}$ (unburned). There were no statistically significant differences (t-paired test) between burned and unburned sites of the ecosystem with and without added urea.

Results from a similar study [9] of a Missouri grassland showed that the decomposition rate was higher in the summer than in the winter and greater in areas where the surface biomass had been removed (burned or mowed site), probably as a result of higher temperatures in the bare soil, which may have induced higher microbial activity, a phenomenon that did not appear to occur in the phrygana community.

### *Soil Nitrate Content and Nitrification*

Since nitrogen is one of the limiting nutrients in Mediterranean-type ecosystems [17], and is easily lost through volatilization during fire [1], we studied the nitrate content of the burned and unburned soils.

Data on nitrate content in the upper 3 cm of both sites are shown in Fig. 4. In general, the burned soil contains more nitrates than the unburned soil during the whole period of our study. This difference could be interpreted in terms either of more intense nitrification in the burned site or of increased nitrate removal due to the higher plant biomass absorbing them in the unburned site. In order to test these two hypotheses, we estimated the soil nitrifying capacity in the laboratory. The results given in Fig. 5 show that immediately after the fire the nitrifying capacity was low; but it soon increased and remained higher in the burned site throughout the 2-year post-fire study period.

An increase in soil nitrates after fire has been reported by several investigators [3, 4,

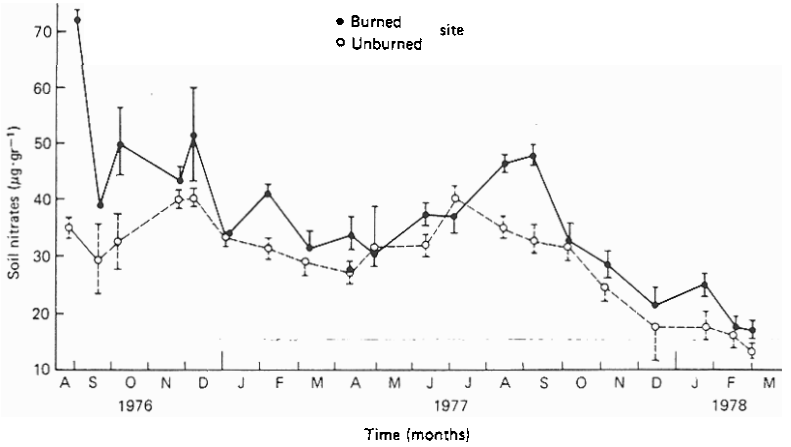


**Fig. 4.** Soil nitrate content in the upper 3 cm of the burned and unburned sites of the phryganic ecosystem.

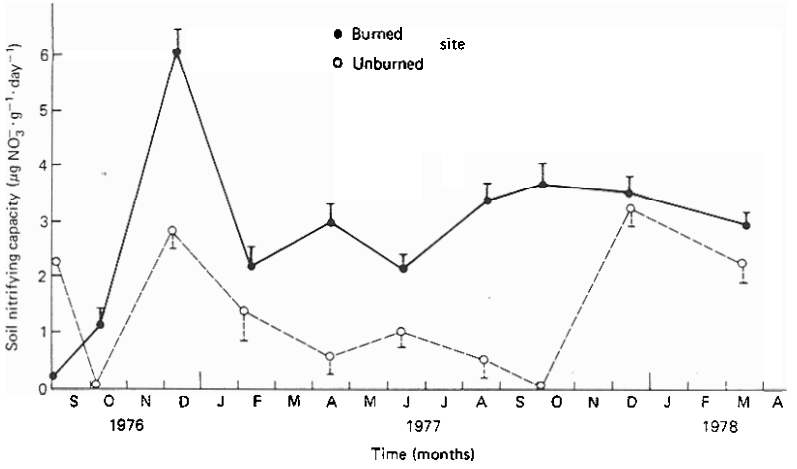


**Fig. 5.** Soil nitrifying capacity of the burned and unburned sites of the phryganic ecosystem.

8], especially for the California chaparral, and each report has attributed this increase to different causes: For instance, Christensen [3, 4] suggested that nitrification occurs in the burned area after inhibitors have been inactivated, whereas DeBano and Dunn [8] reported some heterotrophic origin of nitrification. At any rate, it is clear that nitrification is active and is intensified after fire, due to autotrophic or heterotrophic activity resulting in plant recovery.

Since phryganic ecosystems are often subjected to recurring fires, they appear to have developed adaptive strategies by which nitrogen is quickly replenished to maintain their stability. Interestingly, just after the first rains following the fire, the burned site was

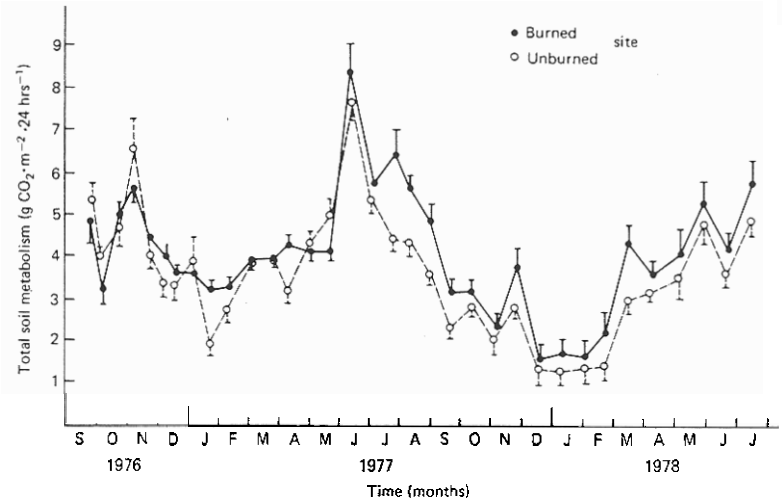


**Fig. 6.** Total soil metabolism estimated as $CO_2$ released from the burned and the unburned sites of the phryganic ecosystem.

covered by leguminous species germinated from undestroyed seeds. Apart of this direct replenishment, nitrogen cycling in the soil, is quite important, since plant recovery after fire depends greatly on it. Although some plant species utilize soil $NH_4^+$ for their growth and maintenance needs, traditionally it is believed that $NO_3^-$ is the form most easily taken up by plants, and $NO_3^-$ production increases in burned areas.

### *Soil $CO_2$ Release*

Results dealing with soil respiration measured as $CO_2$ released from the soil are presented in Fig. 6. A strong seasonality in $CO_2$ release was observed, characterized by high levels both at the end of spring, when temperature ceases to be a controlling factor, and during autumn, when drought is no longer restrictive.

Statistical tests show that soil respiration in the first post-fire year does not differ in the burned and unburned sites. Herman and Kucera [9] came to the same conclusion for Missouri grasslands.

During the second post-fire year total soil metabolism was greater at the burned site. The growth of herbaceous plants during the first post-fire year and the subsequent production of more easily decomposed litter (herbaceous plants) available to the decomposers' subsystem could explain to some degree the above mentioned increase in soil respiration.

A calculation of the total amount of $CO_2$ produced between September 1976 and June 1977 showed that 2528 g/m$^2$ was produced in the burned site, while 2483 g/m$^2$ was produced at the unburned site. In the second period (July 1977–June 1978) the corresponding values were 2719 g/m$^2$ and 2134 g/m$^2$. If the $CO_2$ release values are

transformed to energy equivalents using MacFadyen's conversion factors[1] [13], an energy amount of 6826 kcal/m$^2$ was used in the burned site between September 1976 and June 1977, which is slightly more than that used in the unburned soil (6704 kcal/m$^2$). Between July 1977 and June 1978, the energy values, 7342 kcal/m$^2$ (burned) and 5761 kcal/m$^2$ (unburned), differ significantly.

Our data suggest that within approximately 4 months after fire in a phryganic system, the activity of microbial decomposers is almost the same at otherwise similar burned and unburned sites. It appears that fire is not a catastrophic event in Mediterranean-type ecosystems.

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[1] kg dry matter = 4,800 kcal = 907 lt $CO_2$ 1 lt $CO_2$ = 5.3 kcal = 1.106 g dry matter