Bull. Environ. Contam. Toxicol. (1985) 34:280–284

Bulletin of Environmental Contamination and Toxicology

Air Pollution Effects on Attica's Natural Ecosystems

N. S. Margaris, M. Arianoutsou, S. Tselas, and L. Loukas

Division of Ecology, Department of Biology, School of Sciences, University of Thessaloniki, 54006 Thessaloniki, Greece

During the last decade Athens, the capital of Greece has experienced the results of tremendous and uncontrolled growth. Almost 4 million people, 40% of the total population of the country live in Athens. Traffic jams are very common, while the quality of air has been getting worse year after year. The problems compeled immediate action as the first signs of danger to public health became apparent. Political crises are emerging frequently nowadays and the opposition blames the government for the holding situation.

Step by step the people's growing environmental awareness has forced the decision-makers to put into action an ambitious program of monitoring air quality, not only as regards the direct effects of air pollution on the inhabitants well being, but also taking into account the impact on the area's natural ecosystems. Considering that the city is lacking green sites, increased public interest is directed towards a full understanding of the present situation and the possibility of preventing degradation of these few green spots as well.

The natural ecosystems of the Athens metropolitan area are mostly phryganic ecosystems, characterized by warm, dry summers (Margaris 1976). Similar ecosystems, like the coastal sage of California, are known to have suffered from air pollution, especially the productivity level, which decreases as pollution becomes greater (Winner et al. 1978; Kozlowski 1980; Westman and Preston 1980).

This paper presents data on productivity and diversity of six sites in the Athens metropolitan area, selected according to their pollution load.

MATERIALS AND METHODS

The six sites selected for experimentation are shown in Figure 1. Since quantitative data on air pollutant distribution in the Athens metropolitan area are almost non-existent, we made this selection on the basis of unpublished information provided by the Ministry of the Environment and from our empirical preliminary data. Accordingly, the sites ranging from the least to the most problematic ones are as follows: Skaramagas - Korydalos - Petroupolis - Tourkovounia - Hymettus - Penteli.

Figure 1. Map of Athens metropolitan area showing the selected sampling sites. 1: Skaramagas, 2: Korydalos, 3: Petroupolis, 4: Tourkovounia, 5: Hymettus, 6: Penteli.

The vegetation naturally occuring in all the sites belongs to phryganic formation, in which the dominant woody plants (Table 1) are seasonal dimorphics (Margaris 1981).

Numbers of plant woody species were measured in 10 quadrats of 100 m^2 area in order to have data comparable with existing information from Greece (Diamantopoulos 1983) and from other mediterranean countries (Parsons and Moldenke 1975; Parsons 1976). The cover was estimated by counting the canopy in 25 sampling plots 4 m^2 each.

Aboveground phytomass was measured after harvesting the standing crop of the plants in 10 quadrats 1 m^2 each, at 4 seasons yearly.

Table 1. Dominant woody plants of the six experimental sites of the Athens metropolitan area.

Skaramagas	Korydalos	Petroupolis
Phlomis fruticosa	*Phlomis fruticosa*	*Thymus capitatus*
Euphorbia acanthothamnos	*Thymus capitatus*	*Phlomis fruticosa*
Phagnalon graecum	*E. acanthothamnos*	*Phagnalon graecum*
Thymus capitatus	*Ballota acetabulosa*	*E. acanthothamnos*
Pyrus amygdaliformis	*Phagnalon graecum*	*Olea europea*
Tourkovounia	Hymettus	Penteli
Sarcopoterium spinosum	*Thymus capitatus*	*Cistus creticus*
Thymus capitatus	*Quercus coccifera*	*Sarcopoterium spinosum*
Ballota acetabulosa	*Cistus creticus*	*Quercus coccifera*
Phlomis fruticosa	*Satureja thymbra*	*Pistacia lentiscus*
Asparagus aphyllous	*E. acanthothamnos*	*Genista acanthoclada*

This number of sampling plots has been proved to be statistically valid (Margaris 1976). The harvested material was transported to the laboratory, where the green parts were separated from the non-green and dried in an oven at 60°C to constant weight. Results are expressed in dry weight per square meter.

RESULTS AND DISCUSSION

The numbers of woody plants are very much restricted in two of the six sites studied (Table 2). In Skaramagas and Korydalos 50% and 30%, respectively, of the normally expected plant species (~20, Diamantopoulos 1983) are not found. This is strong evidence of environmental degradation.

Table 2. Number of woody species (10 quadrats, 10X10 m) in the six experimental sites.

Sites	Families	Genera	Species
Skaramagas	8	9	9
Korydalos	10	14	14
Petroupolis	11	18	19
Tourkovounia	10	17	18
Hymettus	12	17	18
Penteli	12	20	21

Data concerning the aboveground biomass follow a gradient from the least to the most polluted sites (Table 3). It seems that Penteli and Hymettus are in a good condition, since the biomass yield is almost the same as in other non-polluted phryganic ecosystems (Margaris 1976). To the contrary, among the other sites, Skaramagas yielding only 90 $g.m^{-2}$ is already a desert. Data on plant cover and leaf area indices (Table 3) strongly support the above.

Table 3. Productive characteristic of the ecosystems in the six experimental sites of the Athens metropolitan area.

Sites	Biomass ($g.m^{-2}$)	% Green	% Plant Cover	Leaf Area Index
Skaramagas	89	13	28	0.12
Korydalos	314	27	51	0.80
Petroupolis	345	18	49	0.28
Tourkovounia	396	17	54	0.50
Hymettus	680	22	81	0.83
Penteli	697	30	72	1.20

It is clear that the energy entering the phryganic ecosystems of Athens metropolitan area is not adequately captured. An indication of this fact, which results in the ecosystem vigour or rigidity, is offered by the ratio of aboveground biomass to cover. If some plants, while having the same cover, yield different amounts of biomass, something must be going wrong. The above ratio for *Thymus capitatus* varies from 30 in Penteli site to 6.5 and 4.1 in Tourkovounia and Korydalos respectively. In the case of *Phlomis fruticosa* (Figure 2) this ratio is 15 in Hymettus site, while it is only 2.7 in Skaramagas. The same situation is also true for *Euphorbia acanthothamnos*, where this ratio varies from 7.2 in Hymettus to just 0.45 in Skaramagas.

Reviewing these preliminary data we can say that air pollution drastically affects the famous Attican landscape, by transforming it into a desert.

Figure 2. *Phlomis fruticosa* individuals from sites with high pollution load (left part of the figure) and no pollution (right part) evidently different in their morphology.

REFERENCES

Diamantopoulos J (1983) Structure and distribution of Greek phryganic ecosystems. Ph.d. Thesis, University of Thessaloniki.

Kozlowski TT (1980) Impacts of air pollution on forest ecosystem. Biosience 30:88-93.

Margaris NS (1976) Structure and dynamics in a phryganic (East Mediterranean) ecosystem. J Biogeogr 3:249-259.

Margaris NS (1981) Adaptive strategies in plants dominating Mediterranean-type ecosystems. In: Di Castri F, Goodall DW and Specht RL (eds) Ecosystems of the World. Vol. 11. Mediterranean-type shrublands. Amsterdam-Oxford-New York, Elsevier Scientific Co. p 643.

Parsons DJ (1976)Vegetation structure in the mediterranean scrub communities of California and Chile. J Ecol 64:435-447.

Parsons DJ, Moldenke AR (1975) Convergence in vegetation structure along analogous climatic gradients in California and Chile. Ecology 56(4):950-957.

Westman WE, Preston KP (1980) Sulfur dioxide and oxidant effects on Californian coastal sage scrub. In: Proceedings of the 1980 Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems. Pasific Southwest Forest and Range Experiment Station. Berkeley, California.

Winner WE, Bewley JD, Krouse HR, Brown HM (1978) Stable sulfur isotope analysis of CO_2 pollution impact on vegetation. Oecologia 36: 350-361.

Received March 2,1984; accepted April 20,1984