Ecology of Mediterranean woody plants in polluted environments: transfer of trace elements from soil to plants, nutritional status and seedling establishment

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Global change includes soil degradation and pollution. The biogeochemical cycles of natural elements, in particular of trace elements, have been much altered by activities such us mining, agriculture and industry. Despite the increasing importance of soil degradation in a global change context, the possible consequences of trace element pollution for Mediterranean terrestrial ecosystems have not been much studied.

We studied different ecological processes in the soil-plant subsystem in a polluted area in SW Spain. We analysed the transfer of trace elements from soil to the aboveground biomass, for a set of 11 native tree and shrub species. Thus, we could assess the possible risk of bioaccumulation in these species. We also studied the nutrient uptake and nutritional status of the main tree species in the area (*Olea europaea, Populus alba, Quercus ilex* subsp. *ballota*). Finally, we studied the survival, growth and establishment of holm oak (*Q. ilex*) seedlings. We combined field observations and experiments, with assays under controlled conditions to study plant responses to these changing environments.

The transfer of the trace elements from soils to the aboveground biomass depended on the element and the species. For eight studied trace elements, Cadmium, Zinc and Copper were the most mobile elements in the soil-plant system. Most of the species showed low trace element concentrations in their leaves [1]. The exception were *Populus alba* and *Salix atrocinerea*, which accumulated up to 1.7 and 7 mg kg^{-1} of Cadmiun and 400 and 800 mg kg^{-1} of Zinc, respectively. Greenhouse experiments confirmed that, for *Q. ilex*, Cadmiun is mostly retained in roots, with a maximum of 0.3 % of translocation from roots to leaves. We detected evidences of negative interactions between soil pollution and P uptake, especially for *O. europaea.* In this species pollution explained a 40% of the variability of leaf P concentrations, and was negatively correlated to the the N:Mg ratio and the leaf chlorophyll content, under field conditions. Under controlled conditions, high concentrations of some trace elements decreased leaf photosynthesis rates, reducing plant growth. However, under field conditions, the bioavailable concentrations were much lower than those concentrations causing deleterious effects under controlled conditions [2]. Thus, other factors rather than soil pollution, such us light and soil moisture, were more determinant for seedling establishment under field conditions.

[1] Domínguez MT, Marañón T, Murillo JM, Schulin R, Robinson BH. 2008.Trace element accumulation in woody plants of the Guadiamar valley, SW Spain: a large scale phytomanagement case study. Environmental Pollution 152:50-59.

[2] Domínguez MT, Madejón, P., Marañón T, Murillo JM. 2008. Afforestation of a trace-element polluted area in SW Spain: woody plant performance and trace element accumulation. European Journal of Forest Research. (in review).

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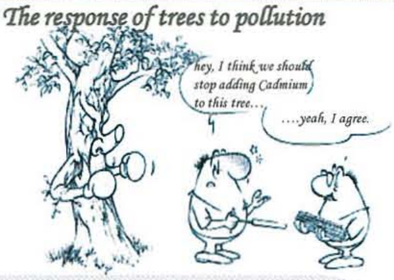

Global Change includes soil degradation and pollution. The possible consequences of some pollutants, such as **heavy metals,** for Mediterranean terrestrial ecosystems have not been much studied. **In a range of Mediterranean woody plants we studied:**

1. Risk of bioaccumulation of metals in aboveground biomass

1. Risk of bioaccumulation of metals in aboveground biomass: In polluted sites from **SW Spain**, the higher soil-plant transfer is showed by Cadmium and Zinc in Salicaceae species (Fig.1). In general, **the accumulation in leaves is low**; for *Quercus ilex*, the retention of metals in fine roots prevents the bioaccumulation in leaves (Fig. 2)

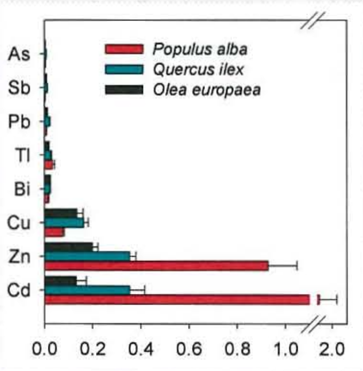

Fig. 1. Transfer of heavy metals from soils to trees (leaf : soil concentration ratios).

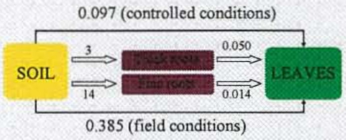

Fig. 2. Flux of Cadmium from soil to *Quercus ilex* aboveground biomass. Transfer coefficients are indicated.

*The leaves of white poplar (*Populus alba*) bioaccumulate Cadmium and Zinc*

2. Influence of pollution on nutritional status of trees

2. Influence of pollution on **nutritional status of trees**: under field conditions, the main effect is the **decrease in the P leaf** concentration and the alteration of **N:P ratio** in *Olea europaea* (Fig. 3)

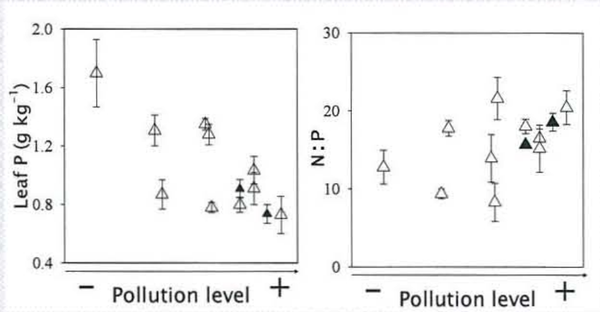

Fig. 3. Influence of heavy metal pollution on the P content of *Olea europaea* leaves, growing in polluted sites from SW Spain.

3. Ecophysiological responses of seedlings

3. Ecophysiological responses of seedlings to pollutants: under controlled conditions, **high concentrations** of Cadmium and Thallium **reduce photosynthesis and growth rates** in *Quercus ilex* and *Pistacia lentiscus* (Fig. 4). The mechanisms of interaction depends on the element. For example, Thallium produces a high chlorophyll degradation.

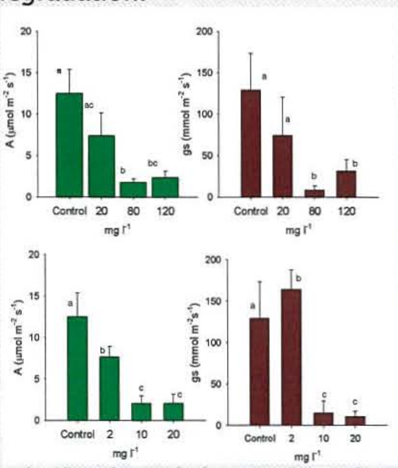

Fig. 4. Net photosynthesis rates (A) and stomatic conductance (gs) of *Quercus ilex* seedlings exposed to different concentration of Cadmiun (up) and Thallium (down).

Greenhouse experiments with Quercus ilex *seedlings exposed to heavy metals*

4. Seedling establishment in polluted sites

4. Seedling establishment in polluted sites: these sites are harsh environments for seedling establishment. Abiotic factors such us **high irradiance** and **summer drought** can be **more important** for seedling survival than soil pollution. **Facilitation by shrubs** plays an important role in the restoration of these degraded areas (Fig. 5)

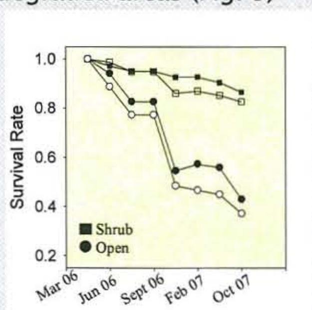

Fig. 5. Survival curves of *Quercus ilex* seedlings emerged in unpolluted (filled symbols) and polluted sites (open symbols), in different microhabitats (under shrubs or in open sites).

Summer stress can be higher than chemical stress in polluted sites for woody plant seedlings. Facilitation by shrubs increase seedling survival.

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