

3.1. Reconstruction of the vegetation from palynological analysis

Jiménez-Moreno, G.
University of Granada

Abstract

The study of the sedimentary pollen record for the last 11,500 years from lakes and bogs of Sierra Nevada indicate maximum temperatures and moisture between 10,500 and 7,000 years ago. This is deduced from the abundance of tree species (especially *Pinus* and *Quercus* and in lesser proportions *Betula*) in Sierra Nevada and the abundance of algae (*Pediastrum*, *Botryococcus*) in the alpine wetlands. Some 7,000 years ago, progressive aridification began, diminishing tree species and increasing xerophilous herbs (e.g. *Artemisia*, *Amaranthaceae*). This aridification process was interrupted by climatic oscillations, including several periods of severe droughts (e.g. the Medieval period) alternating with wet periods (e.g. the Roman period). Severe human impact became evident in Sierra Nevada some 3,000 years ago through pasturing and eutrophication of certain wetlands as well as the recent massive cultivation of olive (since 1900 A.D.) at the lowest elevations and pine reforestation elsewhere (since the 1950s).

> Aims and Methodology

The pollen grains of the sedimentary record for the last 11,500 years have been studied in different lakes and bogs of Sierra Nevada. In each sediment sample, pollen grains were identified with the use of a light microscope (400x) to the level of family or genus. The grains were classified by comparisons with a current pollen collection and different atlases. The abundance values of the different species were transformed to percentages with respect to the total (without including aquatic species; e.g. Cyperaceae). The pollen diagrams were zoned from a cluster analysis using the software CONISS. The percentage of algae was calculated with respect to the total sum of pollen grains.

> Results

Holocene general trends.

11,500 – 10,500 years. The pollen spectra of Laguna de Río Seco are characterized by the abundance of *Artemisia*, *Ephedra*, and *Amaranthaceae*, and in lesser proportions *Poaceae*, *Juniperus*, *Salix*, *Herniaria*, and *Silene* types (Figure 1). *Botryococcus* reached the highest percentages of the entire record.

10,500 – 7,000 years. Both in the lake Laguna de Río Seco as well as in the bogs Borreguiles de la Virgen (Figures 1 and 2), maximum percentages were reached by tree species, particularly *Pinus* and *Quercus* (deciduous), but also by *Betula*, *Alnus*, and *Salix* [1,2]. On the other hand, *Artemisia*, *Juniperus*, and *Amaranthaceae* registered the lowest percentages. The aquatic species, such as *Botryococcus*, *Pediastrum*, and *Cyperaceae* peaked during this period.

7,000 – 5,000 years. *Pinus* remained abundant, but other forest species such as deciduous *Quercus* and *Betula* decreased. The aquatic species also diminished considerably.

5,000 – 3,000 years. *Pinus* progressively declined (Figure 3) whereas *Artemisia* and *Amaranthaceae* increased.

3,000 – present. *Pinus* continued to diminish until c. 1950, when both Laguna de Río Seco and the Borreguiles de la Virgen registered considerable increases. *Artemisia* and *Amaranthaceae* also continued to prosper. *Sporormiella*, a fungus associated with herbivore faeces, augmented measurably both in the record of Río Seco (last 3,000 years) as well as in the Borreguiles de la Virgen (last 200 years). The abundance of tecomaeas (Protozoa, Rhizopoda) in Borreguiles de la Virgen in the last 200 years signifies eutrophication [2].

Changes in the vegetation at the millennium scale.

Apart from the general trend towards the decline in tree species in the last 7,000 years, sharp cyclic variations have appeared in pollen abundance, especially in *Pinus* and *Quercus*. In the sequences of Río Seco and Borreguiles de la Virgen, minimum values were found for oaks (both deciduous and evergreen) between 3800-3100 and 1800-600 BP (Figure 4).

➤ Discussion and conclusions

Deglaciation in Sierra Nevada (11,500 – 10,500 years ago)

The oldest sedimentary record for Laguna de Río Seco indicates a steppe-type vegetation (*Artemisia*, *Amaranthaceae*, *Ephedra*), this being associated with colder and more arid conditions. Similar data for pollen have been recorded in the peat bog of Padul [4], in the cave of Carihuella [5], and in the Alborán Sea.

Early warm and wet Holocene (10,500 – 7,000 years ago)

The abundance of forest species (*Pinus*, *Quercus*, *Betula*) and aquatic taxa (*Botryococcus*, *Pediastrum*) during the early Holocene in Sierra Nevada indicates warmer and moister conditions than registered during the last 12,000 years. A very warm early Holocene

could be explained by the maximum in summer insolation that was reached at this time and that caused a climatic warming. The maximum in moisture could be explained by greater contrast in temperatures between the land and the sea in the Mediterranean region during autumn, prompting heavier precipitation during autumn and winter.

The cooling and aridification during the middle and late Holocene (7,000 ago– present)

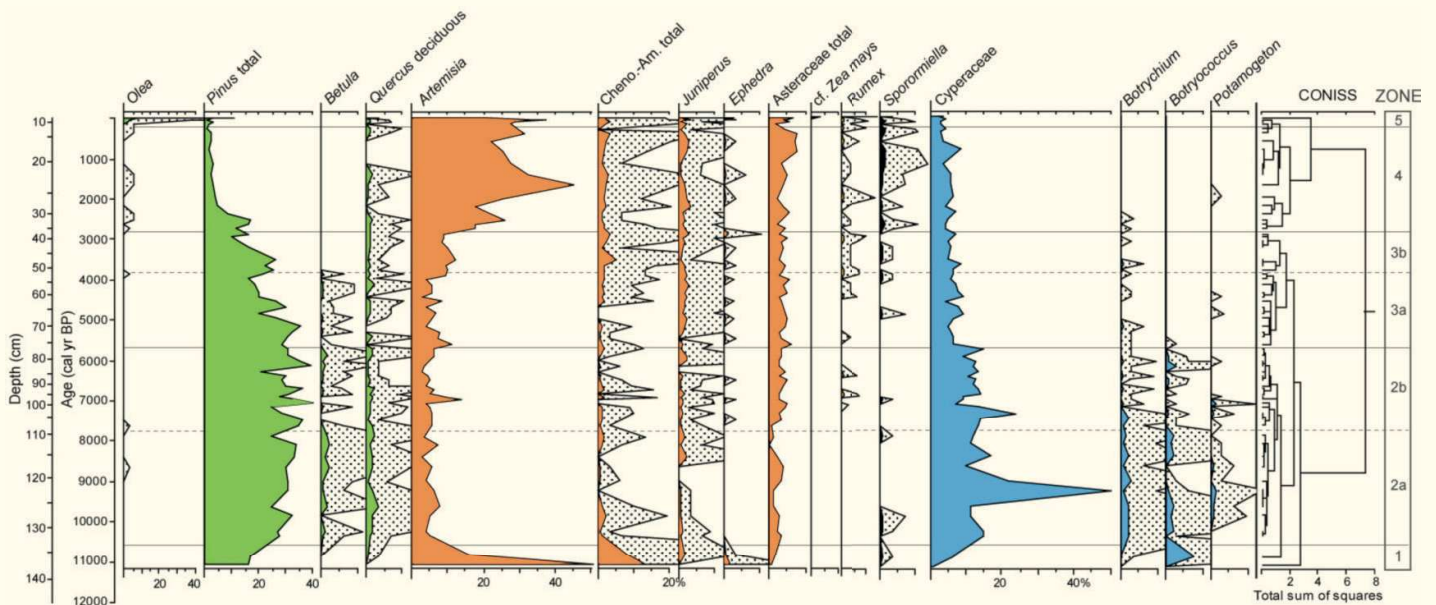
The pollen record of Sierra Nevada shows a progressive process of deforestation and decline in aquatic species in the sedimentary record of the wetlands. This trend, which began about 7,000 years ago and intensified from 5,000 years ago onwards, could be accounted for by a progressive cooling of the climate and, above all, the growing aridity. This aridification has been

deduced from other pollen records of the region (e.g. Sierra de Cazorla, Alborán Sea) and from many other palaeoclimatic indicators throughout the Mediterranean region (speleothems, lake levels, fluvial and wind input). This climatic change, falling temperatures, and advancing aridity, can be explained by the less intense summer insolation.

Climatic variations on the millennium scale

The trend towards aridity is characterized in the pollen record of Sierra Nevada by cyclic changes at a lower time scale. More severe droughts can be recognized around 6,500, 5,200, 4,000–3,500, and 1,500 years ago. Some of these droughts are regionally and globally recognized (see abstract in [1]). One well-documented example is the drought that characterized the Medieval period, which was very clear in the pollen record

Figure 1



Synthetic diagram of pollen from Laguna de Río Seco. In green the tree species, red the grass species, blue the aquatic species. The right zones identified through time are indicated on the right side. Modified from [1].

of Laguna de la Mula [3]. There were relatively moist periods between arid ones, as noted in Laguna de la Mula, coinciding with the moisture maximum of the Roman period [4].

These climatic variations are probably related to cyclic changes in the frequency of the North Atlantic Oscillation (NAO). Arid periods would be due to longer NAO + phases while wetter

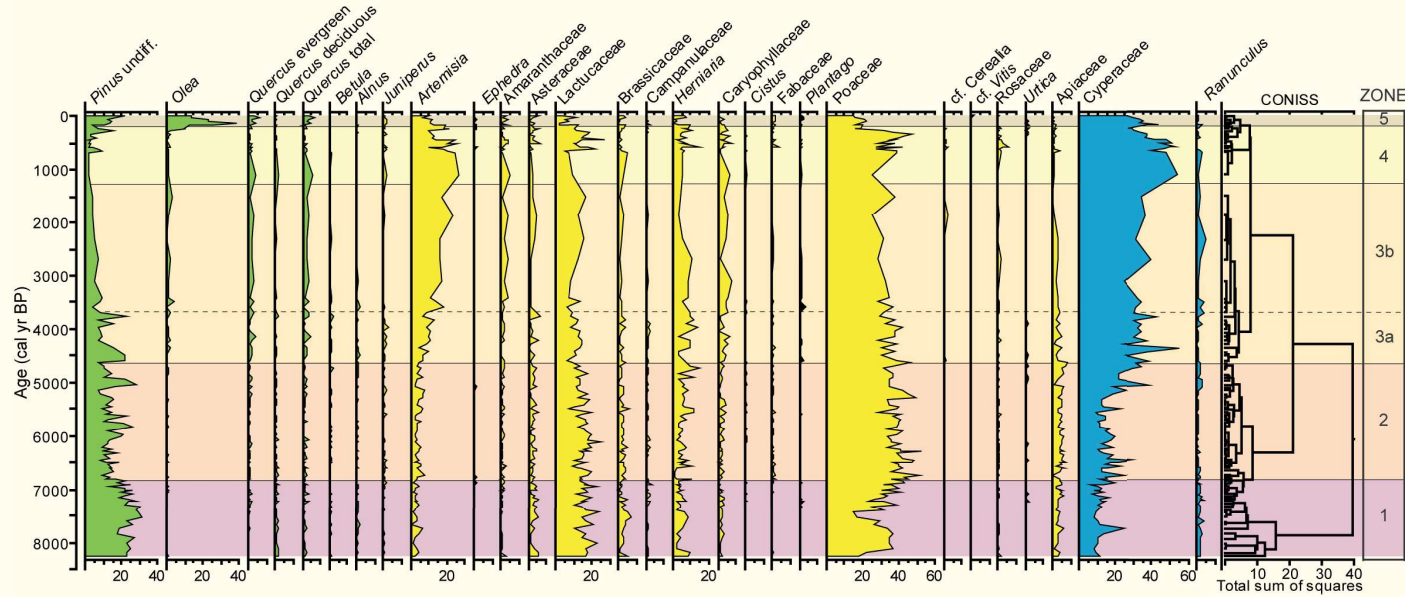
periods would be due to longer NAO - phases. These latter ones would give rise to heavier precipitation throughout the Mediterranean region.

**Human impact on the vegetation:
grazing and cultivation**

Multiple evidence indicate that from about 3,000 years ago to the present, human activity

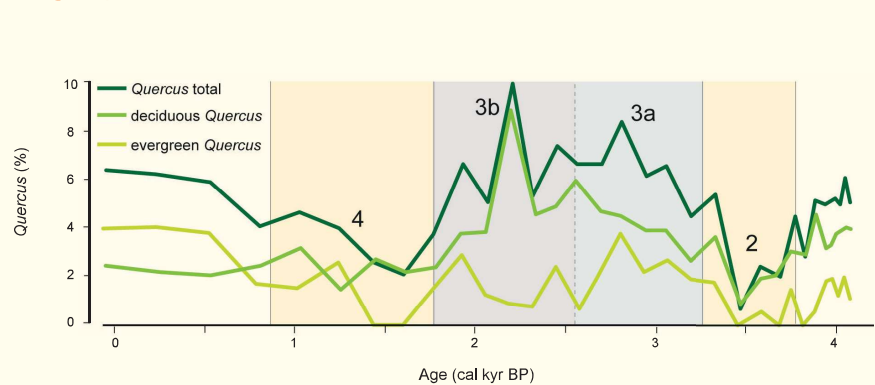
intensified in Sierra Nevada. From that moment onwards, fires frequency increased in this regions [3], together with grazing and mining activities. More recently, olive cultivation at large scale at the lowest elevations and reforestation activities have taken place.

Figure 2



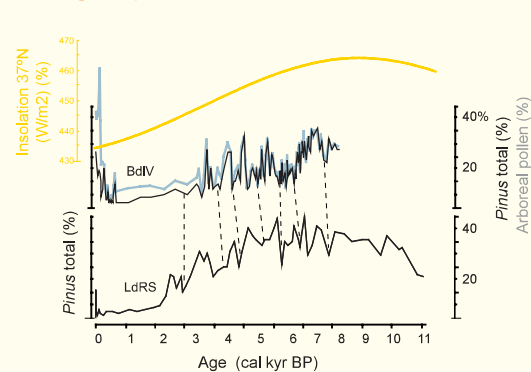
Synthetic diagram of pollen from Borreguiles de la Virgen. In green the forest species, yellow the grass species, and blue the aquatic species. Pollen areas identified over time are indicated on the right. Modified from [2].

Figure 3



Temporal evolution of the oak percentages (deciduous and evergreen) in the last 4,000 years recorded in Laguna de la Mula [3]. The maximum percentages of deciduous oaks were recorded during the wet Roman period (in blue). Two relatively arid periods are shown in yellow.

Figure 4



Comparison between the percentage of pines from Laguna de Río Seco and from Borreguiles de la Virgen [1-2], with the summer insolation curve at 37°N. The trend corresponds to a deforestation (aridification) from 7,000 years ago onwards.