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# CLIMATE VARIABILITY AND LAND-USE CHANGES SINCE MEDIEVAL TIMES INFERRED FROM THE LAGUNA ZOÑAR SEDIMENTARY RECORD (ANDALUCIA, SPAIN).

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Laguna Zoñar is the deepest (up to 15 m) and largest (37 ha, surface area) of the 10 lakes that belong to the Natural Park of Southern Córboba (Andalucía, Spain). The climate is sub-humid Mediterranean, with an average annual rainfall of about 540 mm and with an annual evapo-transpiration estimated over 1500 mm. The lake is monomictic; waters are saline (2.4 $gL^{-1}$), alkaline and of ($Cl^{-}$)-($SO_4^{2-}$)-($Na^{+}$) type. The lake is mainly fed by springs located in the S and E margins. The watershed has been intensively farmed during centuries, and the only surface outlet to the Cabras River was deepened to drain the surrounding areas and also partially the Zoñar Lake. In the 1960s, springs were diverted for human use, and lake level dropped. Since the area was protected in the early 1980s, lake level recovered and large littoral areas were submerged. The surface outlet was flooded but it was not-reopen, so, today, the lake has not surface outlet.

Two sediment cores 1.72 m, and 1.17 m long were retrieved in the deepest basin of Laguna Zoñar (14.5 m water depth). The 1.17 cm long core was sub-sampled in the field at 0.5 and 1 cm intervals for $^{210}$Pb and $^{137}$Cs dating. Magnetic susceptibility was measured every 2 cm. Sedimentary facies were defined by macroscopic visual description including color, grain-size, sedimentary structures, fossil content, and by microscopic smear slide observations. The core was sampled for organic matter, grain size, mineralogy, trace-element geochemistry, pollen, diatoms, and ostracodes. The chronology is constrained by two AMS $^{14}$C dates from the longer core ($593 \pm 38$ $^{14}$C yr B.P. at 124-126 cm depth, and $1771 \pm 38$ $^{14}$C yr B.P. at 166 cm ) and by $^{210}$Pb and $^{137}$Cs dating in the parallel short core. Both cores were correlated using sedimentary facies, grain size, and organic matter profiles.

Detailed sedimentary facies analyses performed in a 170 cm-long core from the deepest part of the Zoñar Lake reveal the complex lake response to climate, human impact and environmental change since medieval times. Eight sedimentary facies have been identified Facies 1 to 5 are massive to faintly laminated carbonate muds with variable composition and bedding. Facies 6 to 8 are organic-rich and finely laminated facies. The eight facies group in two facies associations. Facies Association A integrates cm- to dm- bedded, massive to slightly laminated calcite muds (F. 1, 2, 3 and 4) and represent deposition in the open lacustrine realm of a freshwater-brackish lake with variable, but significant, detrital input and facies Association B that integrates finely laminated (F. 7 and 8), organic-rich (F. 6) and massive calcitic mud (F. 5) facies. Four main units have been identified in the core: Unit 4 (140-170 cm) represents a clastic-dominated lacustrine environment. Unit 3 (59 – 140 cm) is composed of two sequences showing the gradual transition from a clastic-dominated to a mixed clastic-authigenic lake. Unit 2 represents the period with the lowest lake level and the highest chemical and isotopic concentrations. Unit 1 (0-24 cm) is interpreted as deposition after lake levels recovered and water concentration decreased. The chemical composition profiles show more constant values in the lower units 4 and 3 and higher variability in the upper units 2 and 1. The results are coherent with increasing erosion in the Zoñar watershed during deposition of Unit 2 and 1, and a small recovery in the last years. The ostracode assemblage from Zoñar is characterized by individuals of Ilyocypris sp., a few Candona sp. and Potamocypris sp. and suggests an environment with shallow and flowing water likely affected by stream input. Diatom assemblages are dominated by the tychoplanktonic *Fragilaria brevistriata*, and the periphytic *Cocconeis neothumensis* throughout most of the core. Pollen assemblages in samples from both cores are typical of Mediterranean landscapes dominated by *Olea*, evergreen *Quercus* and Cupressaceae. *Olea* percentages are the highest at the top samples (up to 80 %) reflecting the large increase in olive tree cultivation since the late $19^{th}$ century.

The study of cores from Laguna Zoñar provides a detailed record of environmental, climatic and anthropogenic changes in a Mediterranean watershed since Medieval times. The direct relationship between rainfall and lake level observed during the last decades suggests that climate variability is a main controller of lake level in the past. Sedimentological and biological proxies indicate that higher lake levels dominated prior to the $13^{th}$ century. The most significant limnological change started in the late $18^{th}$ century when more finely laminated facies deposited and it corresponds to a period of dominant wet anomalies. A dry period at the end of the $19^{th}$ century corresponds to the onset of deposition of finely laminated, organic – rich facies during a low lake level stage. The end of deposition of laminated facies started at about 1960s and does not correlate with a significant change in rainfall. Increased farming activity may have played a major role in this limnological change in the lake. Once the lake was declared a protected area in the early 1980s, the average lake levels increased. Pollen indicators also reflect this limnological change during the last few decades. Geochemical indicators show a relative decrease in soil erosion during the last decades, but not change in the amount of fertilizer that reach the lake. Our study also provides an opportunity to evaluate the relative significance of human versus climatic factors in lake hydrology and watershed changes during historical times. These paleolimnological reconstructions can be used by natural resources agencies to better define the lake management policies and to assess the results of the restoration efforts started two decades ago.