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Centennial-scale vegetation and climate changes in the Middle Atlas, Morocco: new insights from multi-proxy investigations at Lake Sidi Ali

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The karstic lakes of the Middle Atlas, Morocco, represent a valuable archive of environmental and climatic change for Northwest Africa. Here we present the results of centennial-scale palynological and charcoal analyses as part of a multiproxy palaeolimnological study of sediment cores from Lake Sidi Ali in the Middle Atlas, Morocco (33° 03 N, 05° 00 W; 2,080 m a.s.l.). Supported by absolute dating including 23 more than twenty AMS 14C dates on pollen concentrates, the record covers the entire Holocene and offers insights into vegetation and climate change at a regionally unprecedented centennial-scale. Pollen assemblages are dominated by steppic herbs, evergreen oaks (Quercus), junipers (Cupressaceae) and Atlantic cedar (Cedrus atlantica). A long-term evolution of the montane vegetation is recorded, reflecting progressive changes in the dominant arboreal taxa and leading to the full establishment of the emblematic cedar forests of the area during the mid-Holocene by 6000 cal BP. Orbital-scale changes in seasonality and growing season moisture availability linked to declining summer insolation are implicated, with a transition from (a) warm, dry summers associated with summer drought tolerant taxa especially evergreen Quercus, high algal productivity in the lake, and high background levels of microcharcoal reflecting distant fire activity during the early Holocene, to (b) cool, relatively humid summers with dominance of montane conifers, declining algal productivity in the lake, and episodic local fire activity during the mid- to late Holocene. Superimposed on the long-term environmental changes are recurrent centennial-scale fluctuations in vegetation composition, reflecting competitive dynamics between the major taxa, initially between steppic and arboreal elements, and later between the major tree taxa. Parallels with hydrological proxies including stable O and C isotopes suggest common responses to climatic drivers (fluctuations in moisture sources and abundance) on centennial timescales, with links to North Atlantic climate instabilities. For example, the local establishment of Cedrus is marked by abrupt setbacks during the early Holocene at ca. 10.3 ka and 8.4 ka. These early failures of Cedrus colonisation occur alongside increases in evergreen Quercus and steppic taxa. Background regional fire regime is furthermore enhanced following these events. Impacts of centennial-scale variability are evident throughout the Holocene, until at least until the last 2000 years, when anthropogenic disturbance becomes a dominant driver of environmental change in the lake catchment.