Afromontane forests and climate change

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Olea capensis macrocarpa. Credit: Abu Shawka

In the world of paleoecology, little has been known about the historical record of ecosystems in the West African highlands, especially with regard to glacial cycles amidst a shifting climate and their effects on species diversity. It has long been a subject of debate whether stability or instability of tropical forests is responsible for the high levels of species richness found there.

One theory holds that stable and species-rich "refugia," or enclaves, of tropical forest survived periods of climatic instability within larger areas of grassland-dominated landscape. Pollen data to support this theory are ambiguous however, as they come mainly from marine core samples that represent a large region of vegetation zones and do not resolve well to a local level. Continental records and genetic data are similarly inconclusive with regard to stability or instability of this ecosystem.

Equatorial mountains, on the other hand, are believed to have been stable moist habitat throughout many glacial episodes, acting as "glacial refugia" to support richly biodiverse montane forests up to the present day. An alternative theory holds that these forests only recently stabilized and became refugia during the Holocene epoch beginning around 20 ka (20,000 years ago).

To better understand the ecological history of Afromontane forests, an international team of researchers examined pollen data from two core samples recovered from Lake Bambili, a system of two high-altitude volcanic crater basins in Cameroon. Lake Bambili, at 2273 meters (~ 7500 feet) above sea level, lies within an Afromontane forest belt which is bounded at its upper limits by an Afro-alpine grassland, and at its lower limits by submontane forests and savannas, which in turn form the

transition to tropical rain forests.

The first core sample, B1, retrieved from the upper basin of Lake Bambili, provided a continuous pollen sequence dating back to the beginning of the Holocene. The second core, B2, which lacked tephra horizons—layers of volcanic ash—to more accurately confirm its radiocarbon chronology, was correlated with adjacent marine records recovered offshore from Cameroon. This core sequence provided a continuous pollen record dating back 88.9 ka to the Last Interglacial period, and in particular provided a picture of three distinct forest phases separated by phases where grasslands predominated during glacial periods.

The researchers characterize the contraction and expansion of Afromontane forests amidst the temperature backgrounds of Marine Isotope Stages (MIS). Each of the three forest phases was quite distinct in terms of biome composition. The first phase, during MIS 5—from 82.6 ka to 72 ka ago—is characterized by lower-level montane forest and upper-level Afromontane forest. The second forest development phase, a more moderate phase during MIS 3, from 53 to 38 ka, also included lower-level montane forest and upper-level Afromontane forest, but with lower proportions of woody taxa and a more narrow altitudinal range. The third phase, occurring from 10 to 3.3 ka ago, contained lower-level montane forest as well as tropical seasonal forest.

Regarding the glacial intervals, the researchers note that Afro-alpine grasslands dominated for a short period at MIS 5 (~82 ka ago), and for a long period between MIS 4 to MIS 2 from 72 to 15.5 ka ago. They found lowland steppes and desert biomes predominating during the glacial maxima, with a pronounced effect at MIS 2 with "the near-absence of forest elements." The data at MIS 2 represented the driest episode within the 90 ka core record.

Unlike the case in East Africa, there is no record indicating the presence of actual glacier formations in the equatorial West African highlands. In East Africa, glaciers pushed the upper treeline lower. Pollen data do suggest that Afromontane trees in the highlands were in fact more widely distributed at lower altitudes than they are today. As an example of this, they cite the Afromontane tree *Olea capensis*, which has been able to successfully migrate to lower altitudes during the last glacial maximum only to return to higher altitudes during warmer periods. The record of one species cannot be considered exemplary of the Afromontane biome as a whole, however.

In order to understand the dynamics of the Afromontane forest with regard to expansion/contraction and migration over time, the researchers sought to define its upper and lower limits. The upper limit is hence defined as the proportion of Afro-alpine grasslands in relation to Afromontane forests, whereas the lower limit is defined as the ratio of lower-level montane forest to tropical seasonal forest.

Interestingly, the supposedly stable Afromontane forests proved to be anything but. As Anne-Marie Lezine and her fellow researchers state "The most remarkable result of our study is the ecological instability of the Afromontane forest belts compared with the relative stability of lowland tropical seasonal forest over the past 90 ka." The Afromontane forest at its upper limit proved to be most vulnerable to a changing climate, whereas its lower limit was defined by relatively stable equatorial forests. These findings cast doubt on the widely held view that such tropical lowland forests were indeed unstable and in flux, and only survived amidst pockets of refugia.

Unlike the case of Afromontane forests in East Africa, where long term ecological stability over the past 40 ka is thought to have contributed to its currently high level of biodiversity, vegetation diversity levels in the highlands of Cameroon have proven to be highly variable over time, an

observation in line with the instability of Afromontane forests shown here. While minimum levels of diversity tracked the lowest position of the upper Afromontane treeline between 35 and 26 ka, higher than present levels of pollen richness occurred during forest expansion phases.

"The increase in diversity estimates started well before the LGM [Last Glacial Maximum] and accelerated from 20 ka ago onward. The highest diversity was then reached during the Younger Dryas dry event (~12.9 to 11.7 ka ago) (25), during a phase of major ecological disturbance and not during the following early Holocene phase of forest stability at 10 to 9 ka ago."

All of this has led the study authors to conclude "that Afromontane forests of Cameroon are neither 'glacial' nor 'contemporary' refugia. Glacial climates did not lead to forest disappearance but had a major impact on the upper treeline, which shifted dramatically, revealing the sensitivity of the upper montane biomes to climate change."

More information: Anne-Marie Lézine et al. A 90,000-year record of Afromontane forest responses to climate change. *Science*. 11 Jan 2019: Vol. 363, Issue 6423, pp. 177-181. DOI: 10.1126/science.aav6821