TYPE Editorial
PUBLISHED 04 August 2025
DOI 10.3389/fearc.2025.1653001

OPEN ACCESS

EDITED AND REVIEWED BY
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RECEIVED 24 June 2025
ACCEPTED 10 July 2025
PUBLISHED 04 August 2025

CITATION
Styring A, Bishop RR, Gröcke DR and Szpak P (2025) Editorial: Stable isotope analysis of archaeobotanical remains.
Front. Environ. Archaeol. 4:1653001.
doi: 10.3389/fearc.2025.1653001

Editorial: Stable isotope analysis of archaeobotanical remains

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KEYWORDS

plants, agriculture, archaeology, carbon isotopes, nitrogen isotopes, crops and agricultural practices, cereals

Editorial on the Research Topic
Stable isotope analysis of archaeobotanical remains

The stable isotope investigation of modern plants has been undertaken for over 60 years, and it is well-known that these isotopic values provide valuable insights into plant growing conditions, including the climatic, environmental and soil conditions in which they grow. Plant stable isotopes can also be used to reconstruct past environmental conditions and geological records (see: Diefendorf et al., 2010; Gröcke, 1998, 2002; Heaton, 1999; Kohn, 2010; Nordt et al., 2017; Tieszen, 1991).

In archaeology, stable isotope analysis of plant remains has been used to provide important information about past environments, specifically elucidating ancient agricultural practices (e.g., Araus et al., 2014; Bishop et al., 2022; Bogaard et al., 2013) and contextualizing ecological and social interactions between flora and fauna (e.g., Isaakidou et al., 2022). They also provide an isotopic reference point for the reconstruction of human and animal diets (e.g., Knipper et al., 2017; Tao et al., 2022). Specifically, nitrogen isotope values of cereal grains and pulse seeds are affected by soil amendment strategies—such as manuring and bio-fertilization (e.g., Blanz et al., 2019; Fraser et al., 2011; Gröcke et al., 2021)—whose identification has informed wider insights into the associated labor inputs and social organization of farming (e.g., Bogaard et al., 2013). Carbon isotope values of cereals primarily relate to water use efficiency and can therefore provide more specific information on water management practices, such as irrigation (Wallace et al., 2013). Carbon isotopes may also provide information about microenvironment variation between different cultivation plots (e.g., variation in soil type and moisture retention/drainage) (Bishop et al., 2022).

While stable isotope analysis of plant remains preserved on archaeological sites is becoming more common in the scientific literature, there remain many unknowns that limit our ability to fully understand and reconstruct the environmental, ecological and social interactions between flora and fauna in the past. The primary aim of this Research Topic is to highlight the potential of plant stable isotope analysis to elucidate past growing conditions and constrain and understand ecological baselines for palaeodietary reconstruction. We hope that this Research Topic of nine papers presents a field that is expanding year-on-year and that it will attract more researchers to continue exploring the wonderful realm of stable isotopes in plants—both in the present through the study of living plants, and in the past through the study of archaeobotanical remains.

Four papers in this Research Topic use data from modern plants to expand on our understanding of how stable isotopes of different plant taxa are affected by their growing conditions.

Styring et al. investigated the relationship between canopy density and carbon isotope values of hazelnut shells as a method to reconstruct woodland openness in the past. Applying this method to archaeological nutshells, they found that nuts from Mesolithic through to Iron Age sites were harvested from progressively more open environments, mirroring pollen records that indicate a significant reduction in forest cover between these periods. Their study demonstrates how isotopic analysis of wild plants can improve our understanding of the types of micro-habitats in which people foraged thousands of years ago and how humans might have impacted these over time.

Varalli et al. and Wu et al. specifically investigated plant stable isotopes across a broader geographical range and a wider range of crop taxa than the large-seeded C_3 crops (wheats, barley and pulse seeds) from the Fertile Crescent that have been the primary focus of previous studies. Varalli et al. explored how carbon and nitrogen isotope values of C_4 sorghum and finger millet varied among ten growing locations in Ethiopia. They reported that carbon isotope values of sorghum increased with altitude, apparently driven by corresponding increases in relative humidity and water availability that have been observed to increase the carbon isotope values of C_4 crops in other studies (Lightfoot et al., 2020; Reid et al., 2018; Sanborn et al., 2021). However, in contrast to many other studies of other C_3 and C_4 plant taxa, they found no relationship between precipitation, relative humidity or temperature in millet and sorghum nitrogen isotope values; highlighting the importance of species- and site-specific studies that are tailored to the environmental conditions that could be expected in the past. Wu et al. demonstrated that carbon and nitrogen isotope values can be used to differentiate between rice growing in waterlogged paddy conditions and rice growing in dry fields. Unlike Varalli et al. and Wu et al. found that the relationship between environmental conditions and plant isotope values is not always straightforward, however, with different rice varieties showing different relationships between growing conditions and their stable isotope values.

Blanz et al. studied the effect of soil amendment strategies on cereal sulfur isotope values, finding that the addition of seaweed to cultivation plots shifts the sulfur isotopes toward marine signatures. The results of this study have implications for the reconstruction of past diets, since the consumption of crops fertilized with seaweed would impact the isotope values used from bone collagen to reconstruct ancient dietary sources (i.e., marine vs. terrestrial).

The impact of preservation conditions is also assessed in this Research Topic by Teira-Brión et al., who determined the effect of charring on the isotopic values of common and foxtail millet grains. This adds to the growing corpus of studies that have determined the average isotopic offset associated with heating cereal grains (barley, oat, pearl millet, rye, sorghum, wheats) (Nitsch et al., 2015; Stroud et al., 2023; Styring et al., 2019; Varalli et al., 2023), both helping to define the likely heating conditions under which archaeologically preserved crop remains were charred, and allowing a correction to account for this charring.

Two papers in this Research Topic addressed *how* to plan and conduct isotopic studies of archaeobotanical remains, highlighting the best practices in plant stable isotope research. Styring et al. call for a consistent and transparent approach, outlining a number of issues that can influence the interpretation of plant isotope values, as well as setting out some recommendations to consider in future studies. James et al. provide a case in point, demonstrating that the isotope values of single individual grains are significantly more variable than those of aggregate "bulk" samples of multiple grains from the same archaeological context. They show that sample selection can be a key influence on our interpretation of crop isotope values in terms of the variability of agricultural practices.

Finally, two papers use stable isotope analysis of archaeobotanical remains to provide important new insights into agricultural practices in the past, building on the temporal and geographical range, and methodological approach, of previous studies. Ritchey et al. have provided the first isotopic report into how barley was grown 4000 meters above sea level by agropastoralists on the Tibetan plateau and Ben Makhad et al. used a novel statistical approach to infer how intensively cereals were fertilized during the Gallic and Roman periods in northern France.

In summary, the papers in this Research Topic have provided just a taste of the application and scope of modern and archaeobotanical isotopic studies, but there remains a considerable amount for us to explore and understand. Future research will no doubt improve on our ability to reconstruct past environments, agricultural practices, and dietary preferences, expanding the isotopic systems that are studied, addressing outstanding concerns about contamination and diagenesis, and paving the way for archaeological research to be more inclusive in the analysis of all components in the food web ecosystem (e.g., plants, animals, humans).

Author contributions

AS: Writing – review & editing, Writing – original draft. RB: Writing – original draft, Writing – review & editing. DG: Writing – original draft, Writing – review & editing. PS: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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