

A new plant carbon isotopic framework for identifying forest and grassland transitions over the last 30 million years

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As vegetation responds to climate change at rates and magnitudes not observed in millions of years, it becomes increasingly necessary to use the paleorecord to better understand how vegetation has adapted to past warm periods. In the absence of plant fossils, preserved plant-derived organic matter and specific compounds (e.g., leaf waxes) can be used to reconstruct paleovegetation. Terrestrial plants almost exclusively synthesize carbon using the C₃ or C₄ photosynthetic pathways, which result in unique carbon isotopic compositions in leaves ($\delta^{13}\text{C}_{\text{leaf}}$). Many studies rely on globally averaged C₃ and C₄ $\delta^{13}\text{C}_{\text{leaf}}$ end member values and simple linear mixing models to track transitions from forests to C₃ grasslands and the emergence of C₄ grasses. However, within a biome, the distribution of $\delta^{13}\text{C}_{\text{leaf}}$ values are complex and often poorly resolved due to variations in the vegetation assemblage of that biome. This poses a challenge for assigning appropriate ranges in $\delta^{13}\text{C}_{\text{leaf}}$ values to estimate confidence intervals in paleovegetation reconstructions. Selecting appropriate end-member values based on mean global $\delta^{13}\text{C}_{\text{leaf}}$ values versus biome or climate-specific $\delta^{13}\text{C}_{\text{leaf}}$ values will also influence interpretations for the presence and abundances of C₃ and C₄ vegetation in the geologic record.

Here we provide a new carbon isotopic framework for investigating how C₃ and C₄ vegetation assemblages change across landscapes and through time. We compiled modern published data sets of $\delta^{13}\text{C}_{\text{leaf}}$ values based on biome, photosynthetic pathway, growth form (i.e., trees, shrubs, grasses, forbs), plant function type (evergreen versus deciduous), and various climatic parameters (i.e., mean annual precipitation, mean annual temperature). From this compilation, we provide ranges of C₃ and C₄ $\delta^{13}\text{C}_{\text{leaf}}$ values as a function of biome and these other climatic parameters. The resulting $\delta^{13}\text{C}_{\text{leaf}}$ distributions help to isotopically define closed-canopy forests, savannas, and treeless grasslands in modern biomes and provide a reference for future paleovegetation reconstruction studies to better approximate the range of uncertainty in mixing models and to select biome-specific end member values for investigating how landscapes evolve through space and time.