Disentangling drought-induced variation in ecosystem and soil respiration using stable carbon isotopes

Stephan Unger · Cristina Mágua · João S. Pereira · Luis M. Aires · Teresa S. David · Christiane Werner

Received: 11 April 2009 / Accepted: 25 January 2010 / Published online: 10 March 2010
© Springer-Verlag 2010

Abstract Combining C flux measurements with information on their isotopic composition can yield a process-based understanding of ecosystem C dynamics. We studied the variations in both respiratory fluxes and their stable C isotopic compositions (δ13C) for all major components (trees, understory, roots and soil microorganisms) in a Mediterranean oak savannah during a period with increasing drought. We found large drought-induced and diurnal variations in isotopic compositions of soil, root and foliage respiration (δ13Cres). Soil respiration was the largest contributor to ecosystem respiration (Reco), exhibiting a depleted isotopic signature and no marked variations with increasing drought, similar to ecosystem respired δ13CO2, providing evidence for a stable C-source and minor influence of recent photosynthate from plants. Short-term and diurnal variations in δ13Cres of foliage and roots (up to 8 and 4‰, respectively) were in agreement with: (1) recent hypotheses on post-photosynthetic fractionation processes, (2) substrate changes with decreasing assimilation rates in combination with increased respiratory demand, and (3) decreased phosphoenolpyruvate carboxylase activity in drying roots, while altered photosynthetic discrimination was not responsible for the observed changes in δ13Cres.

We applied a flux-based and an isotopic flux-based mass balance, yielding good agreement at the soil scale, while the isotopic mass balance at the ecosystem scale was not conserved. This was mainly caused by uncertainties in Keeling plot intercepts at the ecosystem scale due to small CO2 gradients and large differences in δ13Cres of the different component fluxes. Overall, stable isotopes provided valuable new insights into the drought-related variations of ecosystem C dynamics, encouraging future studies but also highlighting the need of improved methodology to disentangle short-term dynamics of isotopic composition of Reco.

Keywords Keeling plots · Respired carbon dioxide · Ecosystem respired carbon dioxide stable isotopic composition · Drought · Mediterranean ecosystem

Abbreviations
δ13C Isotopic composition (of respired CO2)
R Respiratory flux
Reco Ecosystem respiratory signal
res Respiratory signal of ecosystem components
S Soil
C Canopy
T Trees
U  Understory plants
SMO  Soil microorganisms
r  Roots and associated symbionts