



HAL
open science

Source Water Isotope Identification Toolkit ‘SWIIT’ for detecting historical water use by forest trees

Christopher Sargeant, Michael Bliss Singer, Christine Vallet-Coulomb

► To cite this version:

Christopher Sargeant, Michael Bliss Singer, Christine Vallet-Coulomb. Source Water Isotope Identification Toolkit ‘SWIIT’ for detecting historical water use by forest trees. University of St Andrews; University of California Santa Barbara. 2016. hal-04550213

HAL Id: hal-04550213

<https://hal.science/hal-04550213>

Submitted on 17 Apr 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L’archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d’enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Copyright

Source Water Isotope Identification Toolkit 'SWIIT' for detecting historical water use by forest trees

Résumé :

The hydrological limitations on vegetative health are particularly complex in environments where multiple sources of water are potentially available to trees in lowland riparian zones. To anticipate how subsurface hydrological partitioning may evolve in the future, the dynamics of tree water source usage and the potential impacts to overlying vegetation, we require a robust, quantitative framework that is constrained by historical data. Here, we outline a toolkit (SWIIT- 'Source Water Isotope Identification Toolkit') to retrospectively investigate the dynamics of tree water uptake. SWIIT utilizes tree-ring isotopes ($\delta^{18}\text{O}$) in combination with a biomechanistic fractionation model to predict the isotopic signature of water utilized during any particular period of growth (seasonal/annual). Through comparisons with measured $\delta^{18}\text{O}$ in local endmember water sources, and climatic and hydrological variables, this methodology can be used to reconstruct and inform on past ecohydrological interactions. We provide a comprehensive overview of the theoretical basis behind the modelling component and assess the data requirements to constrain its predictions. The toolkit's utility is demonstrated for several riparian field studies characterized by differences in climate, geomorphic and hydrological complexity. Whilst our examples are for riparian areas, we suggest that SWIIT can be applied to a range of forested environments where distinct isotopic endmembers exist. To aid application of SWIIT for data-poor environments, we present a set of tool groups, which can be applied over a gradient in data availability and output resolution. We emphasize that it is possible to make scientific progress in retrospective understanding water use by vegetation under varying degrees data availability.

Objectifs du projet et mise en contexte :

- Develop a toolkit for retrospective analysis of source waters to riparian trees.
- Assess the variability of water source utilization at different temporal resolutions (subannual and annual) for species with contrasting rooting depths.
- Investigate the variation of water source utilization across a strong hydroclimatic gradient along the Rhone River, SE France.

Méthodologies :

Tree coring, water collection, dendrochronology, cellulose extraction, isotopic analysis of cellulose and waters, back-calculation of water source used by trees, development of time series of water source utilization.

Principaux résultats :

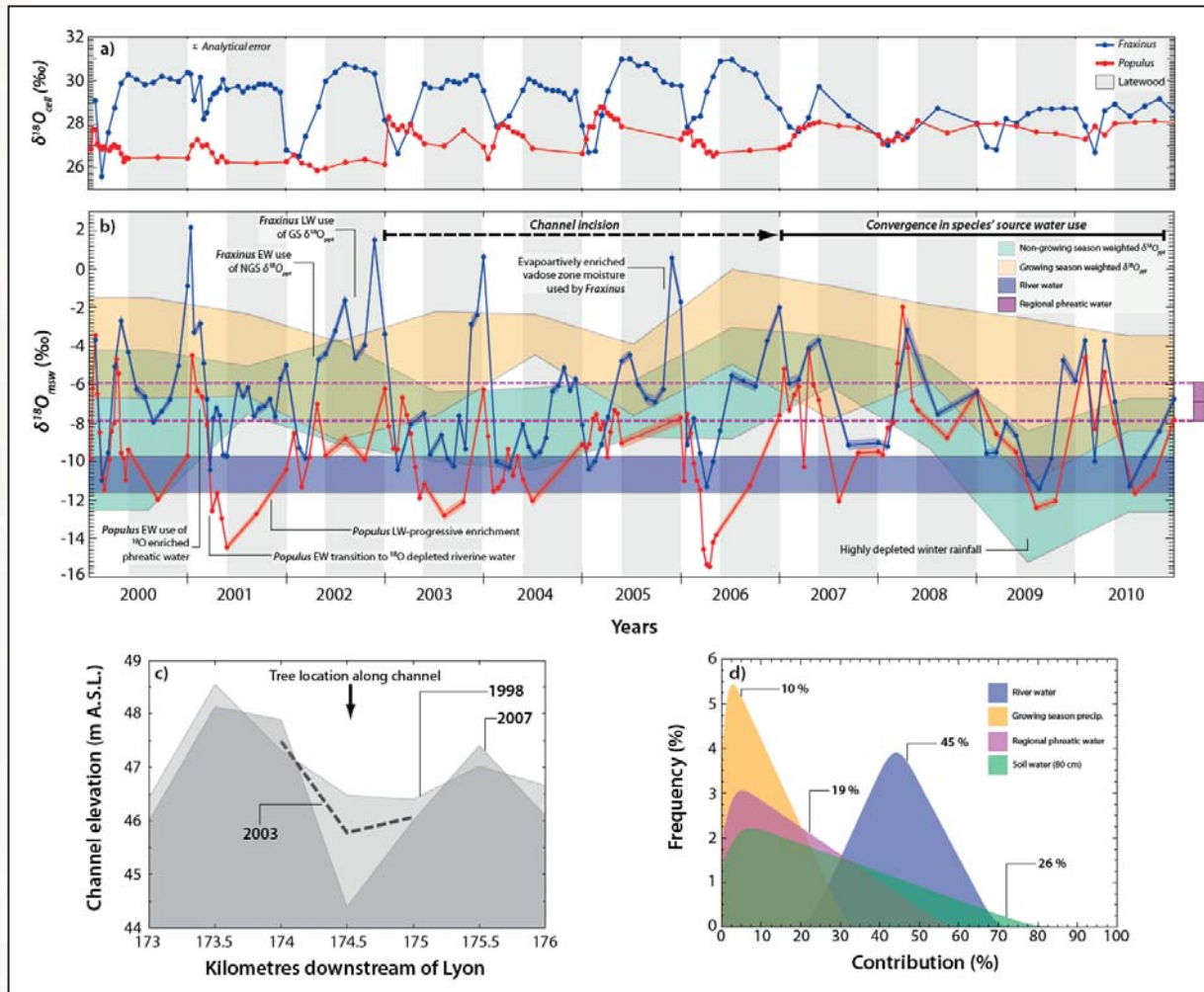


Figure 1: Time series of *Fraxinus excelsior* and *Populus nigra* sub-annual $\delta^{18}O_{cell}$ record at Donzère-Mondragon (a), the respective $\delta^{18}O_{msw}$ in relation to potential endmember $\delta^{18}O_{sw}$ (b), Rhône channel bed elevation data (unpublished thesis of Elsa Parrot, ENS-Lyon, 2015) (c) and the feasible water source contributions to *Populus* $\delta^{18}O_{xy}$, using by the 'IsoSource' mixing model (Phillips & Gregg, 2003) (d). Coloured banding around each $\delta^{18}O_{msw}$ is $\pm 2SE$ based on 1000 Monte-Carlo simulations (plus analytical error in $\delta^{18}O_{cell}$ measurements) and that of endmember water sources is $\pm 1SD$. Figure 1d distributions reflect 5946 water source solutions determined by the IsoSource software.

- Shallowly rooted *Fraxinus* utilizes non-growing season precipitation for earlywood ($U=847$, $p=0.407$) growth and growing season precipitation for latewood growth ($U=1596$, $p=0.080$) (vadose) (Fig 1b) for the 2000-2006 period. From 2007 onwards non-growing season precipitation.
- *Populus* utilizes a relatively more depleted (phreatic) $\delta^{18}O_{msw}$ than *Fraxinus* ($U=10273$, $p<0.001$) for both (2000-2006). *Populus*' seasonal pattern of water-use over this period suggest a reliance on both Rhône and Massif Central derived phreatic waters, which may result from a 'bank storage' effect (Fig. 1b).
- Post-2007: convergence in the seasonal water sources used by both tree species. *Populus* $\delta^{18}O_{msw}$ becomes more similar to that of *Fraxinus* ($U=949.5$, $p=0.700$). This is likely due to a reduction in water table height associated with channel incision (Fig 1c).
- Comparison $\delta^{18}O$ of xylem water extracted from *Populus* (September 2014) with local water sources suggests that the principle water source used by the tree is of Rhône origin (Fig. 1d).

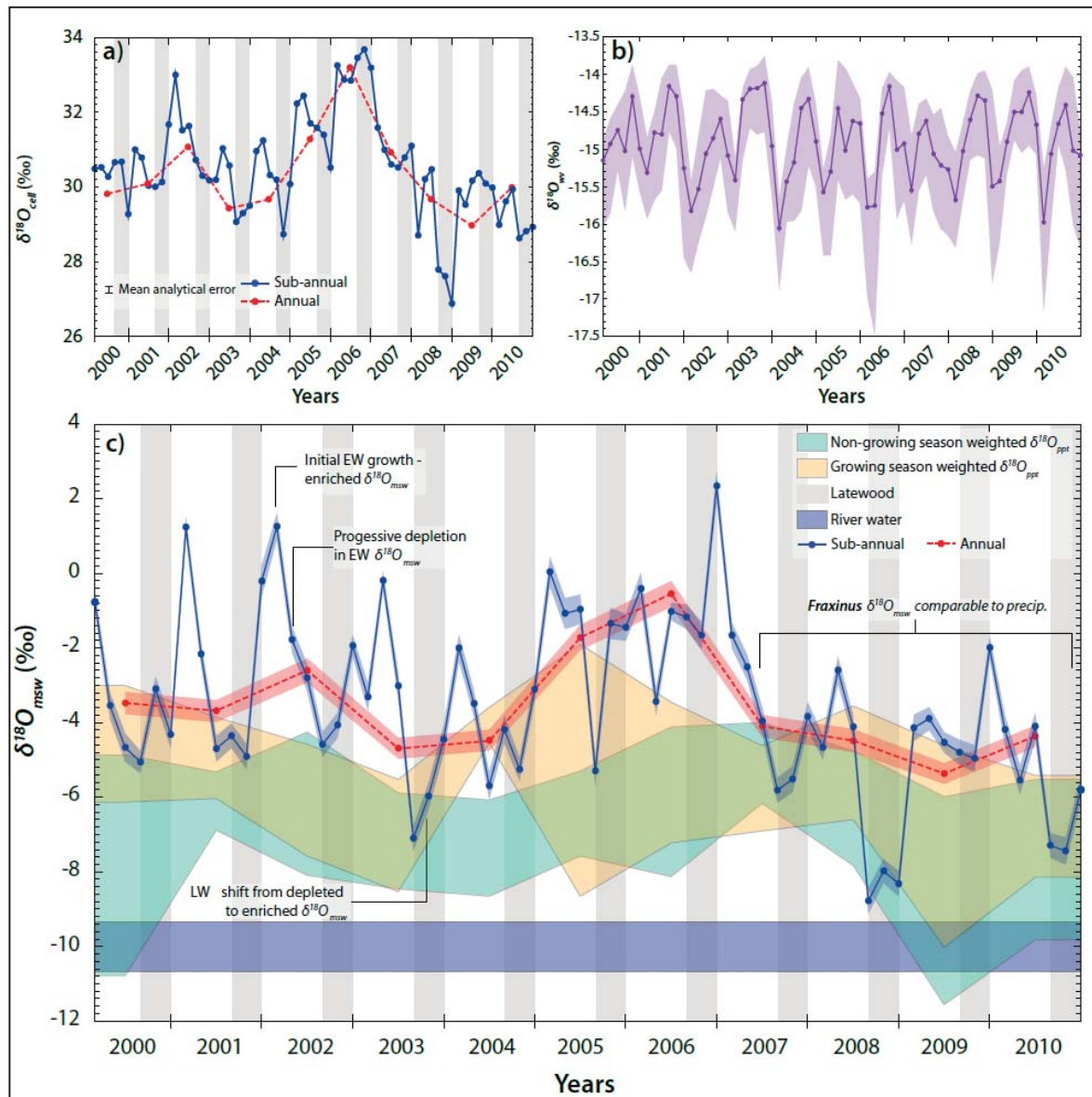


Figure 2: Time series of annual and sub-annual $\delta^{18}\text{O}_{\text{cell}}$ for *Fraxinus excelsior* at Mas Tibert (a), the reconstructed $\delta^{18}\text{O}_{\text{wv}}$ (unpublished data, Vallet-Coulomb) utilized in $\delta^{18}\text{O}_{\text{msw}}$ calculations (b) and the annual and sub-annual $\delta^{18}\text{O}_{\text{msw}}$ in relation to potential endmember $\delta^{18}\text{O}_{\text{sw}}$ (c). Coloured banding around each $\delta^{18}\text{O}_{\text{msw}}$ is $\pm 2\text{SE}$ based on 1000 Monte-Carlo simulations (plus analytical error in $\delta^{18}\text{O}_{\text{cell}}$ measurements) and that of endmember water sources is $\pm 1\text{SD}$.

- Sub-annual $\delta^{18}\text{O}_{\text{cell}}$ shows high variability around the whole-ring (annual) $\delta^{18}\text{O}$ suggesting more information about the water source used by a tree is available through high resolution sampling (**Fig. 2a**).
- This idea is supported by the $\delta^{18}\text{O}_{\text{msw}}$ results (**Fig. 2c**) produced from reconstructed $\delta^{18}\text{O}_{\text{wv}}$ (**Fig. 2b**) based on local $\delta^{18}\text{O}_{\text{wv}}$ measurements. *Fraxinus* sub-annual $\delta^{18}\text{O}_{\text{msw}}$ can range up to 6.91 ‰ (2003).
- *Fraxinus* earlywood is more enriched than the latewood ($T_{64}=3.10$, $p=0.003$). This pattern of seasonal water source use is the reverse of what was documented at Donzère-Mondragon (**Fig. 1b**).
- *Fraxinus* does not appear to utilize phreatic water despite the absence of a gravel layer.
- For 2007-2010 there is a shift in $\delta^{18}\text{O}_{\text{msw}}$ ($T_{64}=4.17$, $p<0.001$) compared to 2000-2006 (mean difference of -2.2 ‰). This shift is not as apparent for annual $\delta^{18}\text{O}_{\text{msw}}$ (mean difference of -1.55 ‰).
- 2000-2006 *Fraxinus* earlywood uses evaporatively enriched vadose moisture, whilst latewood is similar to growing season $\delta^{18}\text{O}_{\text{ppt}}$ ($F_{3,52}=13.68$, $p<0.001$). For 2007-2010 earlywood is similar to growing season $\delta^{18}\text{O}_{\text{ppt}}$ and LW is using a combination of both growing and non-growing season precipitation ($F_{3,28}=6.51$, $p=0.002$).

Perspectives :

Hydrological regimes are being perturbed globally under climate change, with many regions forecast to become warmer and drier. Given that water availability is a primary determinant of vegetative health and productivity, alterations in the spatial and temporal distribution of this critical resource are expected to significantly impact forest ecosystems.

Plus-value pour les praticiens :

- Flow restoration can be designed to benefit riparian forest access to subsurface water.
- Retrospective analysis of tree water use can aid understanding of riparian forest responses to fluctuations in water availability.
- Managers can assess trends in forest health in response to climate change.

Références :

Sargeant CI, Singer MB. *Sub-annual variability in historical water source use by Mediterranean riparian trees. Ecohydrology. 2016, 9 (7):1328-45.*

Singer MB, Stella JC, Dufour S, Piégay H, Wilson RJS, Johnstone L. *Contrasting water-uptake and growth responses to drought in co-occurring riparian tree species. Ecohydrology. 2013, 6 (3):402-12.*

Singer MB, Sargeant CI, Piégay H, Riquier J, Wilson RJS, Evans CM. *Floodplain ecohydrology: Climatic, anthropogenic, and local physical controls on partitioning of water sources to riparian trees. Water Resour Res. 2014, 50 (5):4490-513.*

Contacts :

Christopher Sargeant, cs456@st-andrews.ac.uk

Michael Singer, bliss@eri.ucsb.edu

Christine Vallet-Coulomb, vallet@cerege.fr

