Geophysical Research Abstracts
Vol. 20, EGU2018-18983, 2018
EGU General Assembly 2018

Ecohydrological study of a refugial Fagus sylvatica population using stable isotopes

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Climate refugia are expected to act as important reservoirs of biodiversity under future global warming. Great efforts have recently been made to identify refugia in the landscape using fine-scale meteorological data and models. However, predicting the viability of refugial plant populations in a future warmer and drier climate requires an in-depth understanding of the diverse processes related to their water use.

In trees, stable isotope techniques are often used to quantify water use, taking advantage of the distinct isotopic composition of each water pool (i.e. rainfall, fog water, soil water or groundwater) and following its signal in xylem water. However, recent studies have shown that isotopic fractionation may occur during plant water uptake.

In this study, we investigated the plant water sources used by an emblematic refugial population of beech (Fagus sylvatica) in the Ciron river gorge in SW France. It has been demonstrated that this population survived the last glacial maximum, since fossil charcoal dated it to 40000 years BP. However, it is unclear whether its particularities will allow beech trees to survive in a future warmer climate. We analysed the stable isotopic composition of all potential tree water sources and xylem water through an entire growing season at bi-weekly intervals, in order to reveal potential ecohydrological processes enabling the persistence of this refugia. By applying Bayesian isotope mixing models (MixSIAR), we quantified the contribution of top and deep soil water and streamwater to xylem water of F. sylvatica and the more regionally common Quercus robur.

Both species used mostly a mixture of top and deep soil water all throughout the season, with Q. robur using relatively more deep soil water than beech trees. For both species, water uptake from deep soil was slightly more important than from shallow soil, and increased progressively as the soil dried after rain periods. Streamwater use appeared to be residual despite the proximity of trees to the stream, as previously reported for other riparian forests. Other potential sources such as fog did not seem to contribute to tree water at all. This may indicate that this refugial population is endangered under future climatic scenarios because there are not specific eco-hydrological processes at play that would buffer the negative impact of a warmer and possibly drier climate.

In addition, although the isotopic signal of xylem water tracked well that of soil water, a pervasive isotopic offset between soil and xylem water was also observed. Xylem water was consistently more depleted in [U+F064]2H than soil water, and this offset was larger the drier the soil, possibly reflecting the occurrence of isotopic fractionation during root water uptake. This is in agreement with recent experiments on potted plants, and also an increasing number of isotope field studies. After ruling out all potential methodological reasons for such an offset, possible mechanisms behind the discrepancy between soil and xylem water isotopes will be proposed and discussed.