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# Drought impact on carbon and water cycling in a Mediterranean *Quercus suber* L. woodland during the extreme drought event in 2012

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Savannah-type ecosystems account for 26–30% of global gross primary productivity $GPP$, with water being one of the major driving factors. In Europe, savannah-type woodlands cover an area of about 1.5 million ha. Here, the recent past has shown a significant decrease in precipitation $P$ in winter and spring as well as a decrease in total annual precipitation. Strong effects on local water balance and carbon sink strength have thus been reported due to changes in precipitation regime.

The objective of this study is to quantify the impact of the extreme drought event in 2012 on the water balance, gross primary productivity and carbon sink strength of a typical Portuguese cork-oak woodland (montado) compared to the wet year of 2011. Physiological responses of the dominant tree species *Quercus suber* (L.) are disentangled employing combined photosynthesis and stomatal conductance modelling.

Precipitation effectiveness $ET/P$ increased from 86% in 2011 to 122% in the 2012 dry year due to deep soil or groundwater access of the *Q. suber* trees leaving no water for groundwater replenishment. Understorey and overstorey $GPP$ were strongly reduced, by 53 and 28%, respectively, in 2012 compared to 2011, due to the late onset of the autumn rains in 2011 and an additional severe winter/spring drought. However, the ecosystem was still a carbon sink in both years, but with a 38% reduced sink strength under extreme drought in 2012 compared to 2011. The combined photosynthesis–stomatal conductance model yielded the best results if it was allowed to adjust photosynthetic and stomatal parameters simultaneously. If stomatal response was modelled with the Leuning approach, which allows for a different sensitivity to vapour pressure deficit, the stomatal model parameters were highly coupled. A change in either of the parameters needed to be compensated by the other to guarantee a stable sensitivity of stomatal conductance to assimilation, independent of variations in vapour pressure deficit. The *Q. suber* trees showed a 37% reduced stomatal conductance during the drought period of 2012 compared to 2011, due to water supply limitations. In response to reduced leaf-internal $CO_2$ availability, the trees strongly reduced the apparent maximum carboxylation rate by 43% in 2012 compared to 2011. Unexpectedly, the optimum temperature of the maximum electron transport rate decreased during the drought period, enhancing the susceptibility of the trees to high temperature stress during the summer.

Our results suggest that, if the trend of decreasing annual precipitation and changed precipitation patterns on the Iberian Peninsula continues, sustained effects on local groundwater reservoirs, understorey species composition and tree mortality have to be expected in the long term. To model the effect of drought on the montado ecosystem successfully, variable apparent maximum carboxylation rate $V_{c,max}$, stomatal conductance parameter $m$ and vapour pressure deficit sensitivity parameter $D_0$ need to be incorporated into photosynthesis–stomatal conductance modelling.