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Discussions

# *Interactive comment on* "Drought impact on carbon and water cycling in a Mediterranean *Quercus suber* L. woodland during the extreme drought event in 2012" *by* A. Piayda et al.

**A. Piayda et al.**

arndt.piayda@ufz.de

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### General comments

*Reviewer comments in italic* — Author responses in normal text.

*Reviewer comment: Accurately modelling drought impacts on ecosystem gas exchange is a major challenge, so these data are a welcome addition. However I do have a number of comments about the analysis that I believe should be addressed before final publication.*

Authors' response: We are very thankful for the reviewer's evaluation of our manuscript. We have thoroughly studied the very constructive and detailed comments and revised the manuscript accordingly.

*The principal comment is that I cannot see why the data have been analyzed with a single-leaf model when they are clearly whole-ecosystem data, including a vegetation canopy and soil fluxes. The leaf scale model has been fitted to canopy-top eddy covariance measures. It is not appropriate to model a system like this using a single leaf model. Some of the results may be ecosystem-level effects rather than changes in leaf-level parameters. I suggest that an ecosystem-scale model should be applied. In particular, non-canopy fluxes need to be considered, as does the role of the atmospheric boundary layer conductance.*

We agree with the reviewer that ecosystem scale observations of gross primary productivity and transpiration can hardly be modeled with a simple leaf scale model if the observations are affected by other fluxes. Therefore, we tried to exclude all possible sources of interfering carbon and water fluxes for the modeling application:

- During the modeling period, understorey and soil water fluxes are small compared to the entire ecosystem fluxes (e.g., $\overline{ET_u}$ = 0.7±0.5 mmol m$^{-2}$ s$^{-1}$ compared to $\overline{ET_o}$ = 4.4±2.4 mmol m$^{-2}$ s$^{-1}$ for 2011, Fig. 4 b,c) and show no significant inter-annual differences (2012: $\overline{ET_u}$ = 0.7±0.4 mmol m$^{-2}$ s$^{-1}$), which can interfere the inter-annual comparison conducted in the manuscript.

- It is correct that changes in stem and branch transpiration of the tree layer have not been regarded here explicitly so that modeled stomatal conductance could be affected. However, stem and branch transpiration of *Quercus suber* (L.) trees are

strongly reduced due to the thick cork bark protection and play not a significant role in total ecosystem transpiration.

- Like transpiration, understorey gross primary productivity is comparably small with respect to the entire ecosystem (e.g., $\overline{GPP_u}$ = 1.5±1.2 compared to $\overline{GPP_o}$ = 10.8±3.0 $\mu$mol m$^{-2}$ s$^{-1}$ for 2011, Fig. 6 b,c) and inter-annual differences are not significant (2012: $\overline{GPP_u}$ = 1.2±1.0 $\mu$mol m$^{-2}$ s$^{-1}$). The remaining carbon fluxes from soil, understorey and tree stem respiration have been excluded from the modeling by partitioning the observed net carbon fluxes beforehand so that an influence of changes in respiration on the modeling results are avoided.

Following the recommendations of the reviewer, we increased model complexity to a sun/shade leaf model as described in De Pury & Farquhar (1997). The separation into sunlit and shaded leaves via $f_s = [1 - \exp(-K \cdot LAI)]/[K \cdot LAI]$ with $K = G(\alpha)/\cos(\alpha)$ could directly derived by measured $G(\alpha)$ and $LAI$ from Piayda *et al.* (submitted).

The influence of the atmospheric boundary layer on the transport from the Eddy Covariance sensor height to the leaf surface has been implemented via the aerodynamic conductance $g_a$ (Appendix B, Eq. B8, B9, B12, and B13), which comes directly calculated from turbulence and wind speed measurements $g_a = u_*^2/u$ with the measured friction velocity $u_*^2$ and horizontal wind speed $u$.

The necessary equations of the two-leaf model and the derivation of aerodynamic conductance are included into the revised manuscript.


**Specific comments**


*Please separate out the results from the discussion. Separating them would make the*

*results much clearer and the paper easier to read.*


We agree that a manuscript is usually more clear to the reader when results and discussions are separated in two sections. However, in this particular case we think that the manuscript gains clarity by drawing first the environmental conditions (section 3.1) and then separating it into a water related (section 3.2) and a carbon related (section 3.3, 3.4, 3.5) part. Both parts are consolidated finally in the model part (section 3.6).


*How many locations were used to measure soil temperature and moisture? One location only, or many?*


Soil temperature profiles (2, 4, 8, 16, 30, and 60 cm depth) were measured at two locations, an open and a tree-shaded location, two replicates each. Soil moisture profiles (5, 15, 30 and 60 cm depth) were measured as well at the open and tree-shaded locations but with 4 replicates each. The materials and method section of the revised manuscript was updated with this information.


*In the leaf-level model, what is the aerodynamic conductance ga? Note that this conductance should be corrected by a factor of 1.37 when being applied to CO2 rather than H2O (eqn A12).*


It is correct that $CO_2$ and $H_2O$ have different diffusion coefficients, thus, conductances through the stomata (factor: 1.56) and through the leaf boundary layer (factor: 1.37) are different for both molecules. The transport from the leaf boundary layer to the measurement height of the Eddy Covariance tower is purely turbulence driven, thus, aerodynamic conductivity is equal for both molecules (e.g. Wang & Leuning, 1998). So far, the boundary layer conductance was not treated separately for $CO_2$ and $H_2O$, but

only the observed aerodynamic conductance was used for both molecules (see above). To be more precise, the boundary layer conductance (including different factors for $CO_2$ and $H_2O$) was now included into the model explicitly according to Bonan et al. (2002). The model description in the appendix of the revised manuscript was extended by the full canopy conductance description.

*How is Tleaf calculated? Tleaf is mentioned on p10378 but it is not clear if this is measured or modelled, or what methods were used to estimate it.*

The leaf temperature is estimated using measured air temperature $T_a$ and measured sensible heat flux $H$ via $T_l = T_a + H/(g_a \rho_a c_p)$ with $\rho_a$ being the density and $c_p$ the heat capacity of the air. The inversion of sensible heat flux leads rather to an average surface temperature between leaf and soil because $H$ originates from both. However, the soil was highly comparable in both years (with respect to moisture, understorey vegetation cover and environmental conditions during the modeling period, compare e.g., Fig. 5), so that we can address the differences between both years purely to changes in leaf temperature. The description of leaf temperature calculation is included in the revised manuscript in the data treatment section (section 2.6)

*No information is given for how well the model fitted the data, nor are there errors given for the parameter estimates. Model fit statistics and parameter errors need to be given to assess the goodness of fit. For example, parameter standard errors might show us if the differences in parameter estimates between 2011 and 2012 are actually meaningful.*

We agree that a goodness of fit needs to be given to display how well the modeled carbon and water fluxes fitted the observations. Therefore, in section 3.6 (p. 20, l.

18) Nash-Sutcliffe model efficiencies were given as $\overline{\varepsilon_{GPP_o}}$ = 0.88 and $\overline{\varepsilon_{ET_o}}$ = 0.95 for 2011, and $\overline{\varepsilon_{GPP_o}}$ = 0.84 and $\overline{\varepsilon_{ET_o}}$ = 0.90 for 2012. The Nash-Sutcliffe model efficiency describes the goodness of fit with respect to correlation and to possible biases. According to the reviewers suggestion, we assessed the parameter uncertainty with respect to the measurements with bootstrapping (Efron & Tibshirani, 1993). The parameter uncertainty with respect to the model structure was not calculated, since the numerical estimation of the Hessian matrix delivered no reliable results due to discontinuous functions within the model and objective function. In the revised manuscript, uncertainty bands of the parameter standard error are drawn in Fig. 7 to display the significance of the described differences between both years. The stomatal conductance parameters $m$ and $D_0$ were the only ones showing strongly overlapping uncertainty bands so that their inter-annual differences were declared as not significant in the revised text.

*The actual values for the fitted parameters are not similar to values typically obtained from fitting to leaf data, which suggests there is a problem with applying the leaf-level model. For example, Ball-Berry model slopes $m$ are typically around 8 to 10, whereas Figure 7 shows estimates of 20 to 60, which seems unrealistic. Similarly the $T_{opt}$ for $J_{max}$ is generally 30 degrees or above (Kattge & Knorr 2007) so the estimated values of 20 degrees seem very low and suggest further investigation is needed.*

We are very glad for this advice of the reviewer, which caused us to go through all model equations. We found a unit error in the stomatal conductance description, which we corrected. The values for $m$ are now much lower, ranging on average from about 10 to 15 mol mol$^{-1}$. It is correct that literature values range around 30 °C for the optimum temperature $T_{opt}$ of $J_{max}$ but some species also vary around 20°C (June *et al.*, 2004). However, after thorough revision of the model code, no bugs could be found and values for $T_{opt}$ range on average between 20 to 25 °C. To our knowledge, no $T_{opt}$ values for evergreen oak species are reported so far preventing direct comparison.

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