

Interactive comment on “Drought effects on soil CO₂ efflux in a cacao agroforestry system in Sulawesi, Indonesia” by O. van Straaten et al.

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We kindly thank the reviewer for their constructive comments and thorough review of the manuscript. We have addressed each comment individually.

2.1. To test if there are statistical significant differences between the control and roof the authors use very often months of data. The differences are very often not significant but in my opinion the authors can use a moving window (for example of 2 weeks) and calculate the p-value in order to understand if and when the differences between the roof and control become significant. Also the differences during the CO₂ flush in April 2008 should be discussed better. At a first look it seems that the differences between control and roof are not so significant but maybe looking at the derivative of the time series the authors can justify this CO₂ flushing.

C4709

Author's response: Our objective was not to identify the exact moment when there were significant differences in soil CO₂ efflux between treatments but instead were to identify whether over an extended period of time there were statistical differences.

This was the reason why we separated the experiment into three time periods: pre treatment, treatment and post-treatment. In the revised version of the manuscript I have additionally separated the treatment period into two: 'treatment period #1' and 'treatment period #2'. During the first treatment period there are no statistical differences between the two treatments, and it is only in the second treatment period which was triggered by a natural drought and improved roof closure that CO₂ respiration from the roof plot were significantly lower than the control for approximately four months.

This articulation has been added to Fig 1a and Table 2.

2.2. In my opinion the linear regression between soil moisture and soil efflux is not completely correct since the response to drought can be confounded by the effect of productivity and temperature. One possible solution is the use of a model driven at least by soil temperature and soil water content. In this way it is possible to estimate the parameters describing the sensitivity to soil water content. Then look at the spatial variability of these parameters and add this information in the interesting Fig 2.

Author's response: The variation in soil temperature was very small during the 19 month experiment, fluctuating between 21.8 and 24.8°C (a range of 3.0 °C). Soil moisture range was however much larger and therefore more important in controlling CO₂ efflux.

Overall, soil temperature did not significantly contribute to the explanation of the observed variance in soil CO₂ efflux. Multiple linear regressions from three different moisture regimes (explanation described in comment 2.3) found that temperature could only significantly explain a small portion of the variation (9%) at the wet end of the moisture spectrum but none of the variation during either intermediate or dry soil moisture conditions.

C4710

On the reviewer's request I have run a multiple linear regression for the 18 individual roof plots chamber sites, where soil moisture (pF) and soil temperature were included as independent variables to predict soil CO₂ efflux. As was expected, soil temperature could only explain a very minor percent of the variation exhibited in soil respiration. At five chamber sites did soil temperature significantly improve the prediction model and explained 10%, 11%, 12%, 14% and 29% of the variation exhibited in soil respiration respectively.

After lengthy experimentation with Fig 2, I could not find a solution to present these results without overemphasizing this minor addition. Instead, I have opted to address the issue in the text in the context of the next comment (see below - comment 2.3).

2.3. The authors showed that the overall relationship of soil CO₂ efflux with temperature was not so strong. In my opinion this relationship should be tested stratifying the data in class of soil moisture (according for example with the quantile). The different water availability can confound the sensitivity to temperature (although the soil temperature seems really constant during the measurement period).

Author's response: As previously mention (comment 2.2), soil temperature fluctuations were minimal (3.0°C) during the 19 month experiment.

On the reviewer's suggestion we used a multiple linear regression to identify the controls (soil moisture and soil temperature) responsible for regulating temporal soil CO₂ efflux. Using the adjusted Fig 4 (see attached) we were able to stratify the data into three categories: wet, intermediate, and dry. Subsequently, for each class we determined the variability of CO₂ efflux explained by the two variables (coefficient of determination).

The correlation coefficient between soil temperature and moisture was calculated to make sure they were not correlated.

In this analysis we found: - At the wet end of the moisture spectrum, soil moisture could

C4711

explain 39% of the variation in CO₂ efflux, while soil temperature could explain 9%. - At intermediate water contents, neither soil moisture or soil temperature could explain the variation exhibited - At the dry end of the moisture spectrum, soil moisture could explain 73% of the variation in CO₂ efflux, while soil temperature was not significant.

2.4. The litter layer development as well as an indication (if available) of the time courses of the productivity of the plantation need to be included. These information are necessary to support the hypothesis of a reduction of autotrophic respiration due to the reduction of roots respiration of cacao plants induced by drought. The authors showed that chambers near tree stems (for cacao trees) were more sensitive to drought. Is there also an impact of litter accumulation and distribution under the roof?

Author's response:

We would have liked to make a more in-depth analysis as proposed by this reviewer; however, we unfortunately have little additional data to support the visual observations of the leaf litter accumulation and decomposition dynamics. It was only after the experiment was completed when we analyzed the data that we recognized the potential importance of the litter decomposition dynamics.

In the field we observed that: 1) Leaf litter was relatively evenly distributed between trees and across the experiment plots and not concentrated around the tree stems 2) Prior to roof opening leaf litter had accumulated in the roof plots.

Beyond these observations however we can only speculate. We suspect that the strong drought of the litter caused it to display hydrophobic properties, which may partly explain the lack of a strong soil CO₂ efflux flush following rewetting.

Specific and minor comments:

2.5. Title: I suggest to modify the title as: "Spatial and temporal effects of drought on soil CO₂ efflux in cacao agroforestry system in Sulawesi, Indonesia".

Author's response: I like the reviewer's suggestion. I have changed the title accordingly

C4712

Method section:

2.6. The positioning and displacement of the chambers should be described in detail.

Author's response: I have added two extra sentences in the Materials and Methods section describing the location the chambers in relation to 1) roof coverage and 2) to distance to tree stems. "In the roof plots, chamber bases were located under a range of roof closure conditions ranging from tightly closed to relatively open with more gaps. The chambers were established between 1.1 and 2.1 meters from the nearest tree."

2.7. The data analysis should be expanded and clarified a bit, in particular in the last part (from line 525 1151)

Author's response: The statistical analysis section has been improved upon: "We used a multiple linear regression analyses to establish predictive relationship between temporal soil CO₂ efflux, soil moisture and soil temperature. We stratified the data into three soil moisture classes: wet ($pF \leq 1.2$), intermediate ($1.2 < pF \leq 1.7$) and dry ($pF > 1.7$). Subsequently, for each class we determined the variability of CO₂ efflux explained by the two variables (coefficient of determination). Correlation coefficients for soil temperature and soil moisture were determined to test the strength of the correlation between the two independent variables. Additionally, to discern the extent of autotrophic respiration and belowground tree drought reactions, we tested how soil CO₂ efflux correlated with Gliricidia and cacao sap flux densities, solar radiation, and the chamber distance from adjacent trees respectively using simple linear regressions."

2.8. The reference R-development core team, 2008 is missing.

Author's response: Corrected

Results Section:

2.9. Pg. 11555 Lines 9-10: Please move this in the methods

Author's response: Corrected

C4713

2.10. Pg. 11559 Lines 5-10: Please reformulate this sentence

Author's response: We have reformulated this section so that it is easier to understand.

2.11. Table 2: A plot instead of a table can be more easy to interpret.

Author's response: I tend to disagree with the suggestion. The purpose of this table is to summarize average CO₂ efflux and soil profile CO₂ concentrations for different experiment periods and specifically to articulate the numbers. Incorporating the values into the text will make the text difficult to read, while presenting the data in a series of graphs is both a bit difficult and space consuming. The numbers presented for CO₂ efflux are a summary of fluxes reported in Fig 1a, while CO₂ concentrations are a summary of Fig 6.

Additionally, in the interest of future review papers that may require numeric information this table will be very valuable in its current form.

2.12. Table 3: In my opinion this table is not so interesting. The authors can consider the idea to plot the mean diurnal courses with error bars in place of the table.

Author's response: Table 3 was problematic for all three reviewers. We have therefore removed the table but modified the results section slightly adding values that were previously mentioned in the table. Specifically, we added: "A weak diurnal pattern was detected in soil respiration, whereby CO₂ efflux was lowest early in the early morning between 6 am and 8 am (107.6 ± 12.6 mg C m⁻² h⁻¹) and rose steadily throughout the day reaching a maximum in the mid-afternoon between 2 and 4 pm (142.0 ± 8.6 mg C m⁻² h⁻¹, mean \pm 1 SE)."

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C4714

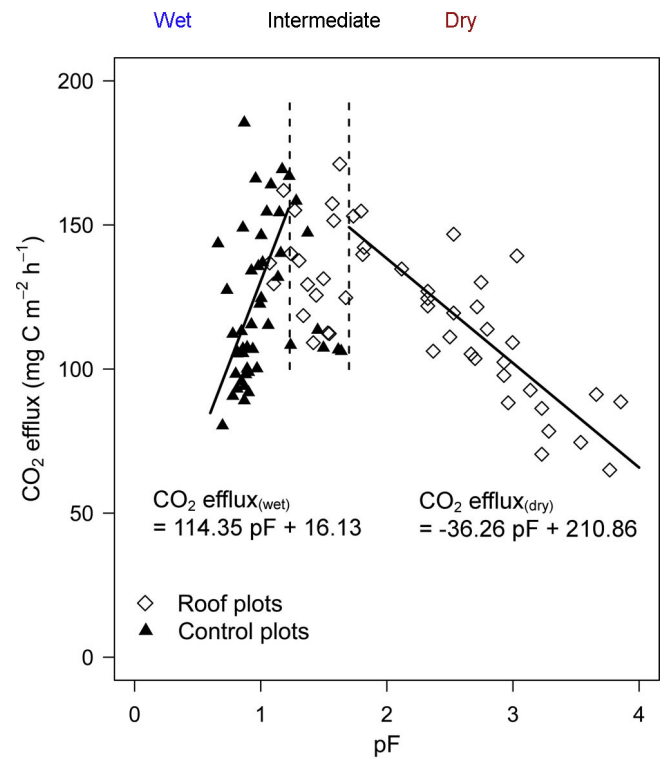


Fig. 1. Revised Figure 4 (response to comment 2.3, depicts the three soil moisture categories used for the multiple linear regression)