

September 12, 2013/9/12

RE: Ms. Ref. No.: bgd-10-11583-2013

Dear Dr. Klein:

First of all, we would like to express our sincere appreciation to you for your kind attention and comments.

The title of the revised manuscript we submit to you is “CO₂ uptake of a mature *Acacia mangium* plantation estimated from sap flow measurements and stable carbon isotope discrimination”. The Paper was prepared by Hua Wang from Beijing Academy of Agriculture and Forestry Sciences, Ping Zhao, Lvliu Zou, Xiaoping Zeng, Guangyan Ni, Xingquan Rao from South China Botanical Garden, Chinese Academy of Sciences, and Heather R. McCarthy from University of Oklahoma. Our manuscript was numbered as Manuscript # bgd-10-11583-2013.

We revised the above referenced manuscript according to comments provided by your instructions. The contents of manuscript have been significantly improved. It is submitted herewith for consideration by you, and by Biogeosciences.

Interactive comment on “CO₂ uptake of a mature *Acacia mangium* plantation estimated from sap flow measurements and stable carbon isotope discrimination” by H. Wang et al.

T. Klein (Referee)

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The discussion paper under review presents a four-year study of carbon and water gas exchange dynamics in a subtropical *Acacia* forest plot in China. It applies a novel approach to calculate canopy-scale CO₂ uptake by combining sap flow measurements and ¹³C carbon isotope discrimination, and presents diurnal, monthly, seasonal, and annual variations in relation to main environmental determinants. The results are further compared to leaf gas exchange measurements and a sensitivity analysis is performed.

This is a timely, important paper, which presents a thorough, carefully planned study. The analyses and methodology are of the highest standards. The scientific results and conclusions are presented in a clear, concise, and well-structures way.

(Q) My only major concern regards with the general perspective of the scientific approach, which must consider the current status of the scientific field. Together with several smaller comments, this paper should be acceptable for publication in Biogeosciences.

Response

- (R) We carefully revised the manuscript according to the comments provided by your instructions. Especially, we revised it to put the study into the right perspective. Please see our responses to your comments as follows. The contents of manuscript have been significantly improved. It is submitted herewith for your consideration.

General comment

The paper presents a novel approach to the very important challenge of forest CO₂ uptake quantification. (Q1) However it overlooks the important role of forest CO₂ uptake measurement using the eddy-covariance method. To the best of my knowledge, over the recent decade this method has become the state-of-the-art in the field, and is being applied across hundreds of locations globally. The fluxnet network is one good example. To put the paper into the right perspective, this fact must be put upfront, and not hidden within the introduction (P11586 L12).

(Q2) In fact, the authors would have been able to present a much stronger case if their novel approach would have been compared, and agreed, with contemporary eddy covariance measurements. Nevertheless this does not reduce from the excellent scientific work that has been performed and carefully presented.

(Q3) Therefore, my advice is to put the study into the right perspective, and to highlight the significance of the approach: (1) ideal for plot-scale (the second paragraph in the introduction deals with this aspect, yet the distinction between canopy and whole-forest scales is not sufficiently explained); (2) a solution where the eddy-covariance method is limited. For example, as noted in the text, in mountainous sites. Another advantage could be in sites where wind regime is limiting for eddy-covariance application; (3) if this novel approach provides quantitatively valid estimates, the potential is huge considering the large number of sites with sap flow monitoring and the relatively easy sampling for carbon isotope analysis.

Response

- (R1) important role of forest CO₂ uptake measurement using the eddy-covariance method
We agreed with you in the fact of the importance of the eddy-covariance method in forest CO₂ uptake measurement. As you suggested, we revised our manuscript to put upfront this fact. Please see our response in (R2) and (R3).
- (R2) Comparison with eddy correlation (EC) observation system
We think it is difficult for comparison eddy correlation (EC) observation system with the SF/SI approach, since it is not easy to maintain such infrastructure for a 4-year

period without specific support. We didn't have such a facility in our sap flow site at that time.

We pondered on using an appropriate method. We think the SF/SI approach is proper than EC for our study, since it is suitable for upper-canopy species, and especially for single-species plantations, such as the *Acacia mangium* plantation in our study. EC application in measuring C uptake of forest faces some restrictions. Of them, the requirement on a flat landform restrains its application in mountain areas. Moreover, owing to high expense and low mobility, EC is not an appropriate observing system for our study. Additionally, this method is helpless in studying the contribution of different species to and the influence of population renewal on C balance within a mixed forest, since it is incapable of separating C fixation contribution by canopy from that by understorey and by soil, and unable to determine how these processes are affected by environmental factors as well. Herein, SF/SI is not comparable with eddy correlation (EC) observation system to some degree. CO₂ flux estimated from EC represents ecosystem-scale flux, while CO₂ flux from SF/SI represents canopy-scale flux.

It will be better to add this information in the Introduction section 'This SF/SI can cover the shortage of eddy correlation (EC) observation system. It could avoid low mobility of EC, and suitable for upper-canopy species, especially for single-species plantations, such as the *Acacia mangium* plantation in our study (Zhao et al., 2005a).' (P11585, L29).

(R3) The right perspective of our study

The significance of the approach was indicated as suggested. 'Recently, a novel approach combining sap flow measurement and stable carbon isotope techniques was proposed to estimate forest CO₂ uptake (Zhao et al., 2005a).' was revised as 'Recently, a novel approach combining sap flow measurement and stable carbon isotope techniques (SF/SI) was proposed to estimate forest CO₂ uptake (Zhao et al., 2005a). Firstly, it is ideal for plot-scale researches. Secondly, though EC is very important in forest CO₂ uptake measurement, SF/SI is a solution where the eddy-covariance method (EC) is limited. It could avoid low mobility of EC, and suitable for upper-canopy species, especially for single-species plantations, such as the *Acacia mangium* plantation in our study (Zhao et al., 2005a). Further, it is suitable for field measurement of forests in mountainous areas, and sites where wind regime is limiting for EC application. Lastly, its potential is huge considering the large number of sites with sap flow monitoring and the relatively easy sampling for carbon isotope analysis.' (P11585, L29).

Specific comments

(Q1) In the second paragraph of the introduction authors should clearly define 'canopy' (or

alternatively, plot), e.g. by size between 0.1 and 1 km². **(Q2)** Also, the comparison between water and photosynthesis fluxes must regard the simple fact that water fluxes are by three orders of magnitude (!) larger than CO₂ fluxes.

(Q3) In the methodology, it can be useful to show, for trees 1-4, whether the difference between the mean Js and North Js was significant. **(Q4)** In the development of delta (Eq. 13), the authors can improve accuracy of their estimates using the adjusted Farquhar equation (Seibt et al. 2008) that accounts also for mesophyll conductance and CO₂ compensation point effects. **(Q5)** Also, equation development can be more intuitive if an Ohm's law analogue is presented upfront, e.g. $F_c = g_c \times (C_a - C_i)$ or similar.

(Q6) In the discussion, section 4.3 could be elaborated to include a comparison of g_s vs. G_s . **(Q7)** Also, if leaf gas exchange measurements are representative of the entire canopy, then a simple multiplication by LAI should yield a rough estimate of F_c and G_s . Yet here this would yield values that are much higher than estimated by the applied method. Can this be settled? **(Q8)** Section 4.4 is central for the conclusion of the paper and needs to answer the following questions: Why was the Brazilian A. magnium F_c estimate so different? Age difference should not explain such a large gap. Needs to explore the differences closely, e.g. stand density, LAI etc. **(Q9)** Regarding the other literature presented, it seems that sap flow-based methods tend to yield lower estimates. Is there any underestimation involved?

(Q10) The conclusions section is repetitive and could be shortened. The tables and figures are informative, concise and well designed. **(Q11)** The authors must make sure that the final version presents a unified figure size: at the moment most figures are too small to read (Figs. 3-4 specifically) or appear too large (Fig. 1).

Response

(R1) We defined forest canopy, exemplified ranges of canopy structure descriptors, and added two related references as suggested. Please see the specific changes as follows.

‘Canopy is an important intermediate scale between leaf and ecosystem’ was revised as ‘Canopy is the combination of all leaves, twigs, and small branches in a stand of vegetation, is the aggregate of all the crowns (Parker, 1995). It was reported that ranges of leaf biomass, leaf area index, and leaf area density, which were important canopy structure descriptors, were 7-11 Mg ha⁻¹, 7-12 ha ha⁻¹, and 0.2-0.5 m² m⁻³ in evergreen broadleaf forest (Tadaki, 1966). Canopy is an important intermediate scale between leaf and ecosystem.’ as suggested (P11585 L13).

‘Parker, G.G.: Structure and microclimate of forest canopies, in: Forest Canopies, edited by: Lowman, M.D. and Nadkarni, N.M., Academic Press, San Diego, CA, 73–106, 1995.’ was added in the reference list (P11610 L30).

‘Tadaki, Y.: Some discussions on the leaf biomass of forest stands and trees, Bull. Govt.

For. Expt. Sta., Tokyo, 184, 135–61, 1966.’ was added in the reference list (P11611 L21).

- (R2) This sentence ‘Notably, comparisons between water and photosynthesis fluxes must regard the fact that water fluxes are generally much larger than CO₂ fluxes.’ was added as suggested (P11585 L18).
- (R3) We studied the variation in J_s at different aspects in detail, which has been published by Ma et al. in 2007. Hereby, the results on the difference between the mean J_s and North J_s were cited from the above mentioned reference.

Please see the specific information ‘Furthermore, the variation in J_s at different aspects was random for the studied trees (Ma et al., 2007). Hence, J_s at the north aspect was assumed to be representative of J_s of individual trees. For trees No. 1–No. 4, J_s was calculated as the mean of the values from four aspects, while for trees No. 5–No. 14, J_s was the value measured from north side’ in the following section “2.4 Stand transpiration and canopy stomatal conductance” (P11590 L4-8).

- (R4) We developed our equation based on the Farquhar equation. The parameter b stands for fractionation during carboxylation (27.5‰), which related to mesophyll conductance. As far as CO₂ compensation point effects were concerned, it is a molecular physiological process of high precision. Hereby, from the point of these views, we think it seems not so necessary to use using the adjusted Farquhar equation (Seibt et al. 2008) to further improve our accuracy (P11594 L7).
- (R5) The Ohm’s law analogue ‘ $F_{CO_2} = g_{CO_2} \times C_a \times (1 - C_i/C_a)$ ’ and its related specifications (P11594 L11-13) were presented upfront as suggested (P11593 L19). Equation (14) was turned into Equation (11). Hereby, equation sequence numbers were adjusted from Equation (11)-(13) to Equation (12)-(14). ‘Combining Eqs. (13) and (14), we then have:’ was revised as ‘Combining Eqs. (11) and (14), we then have:’.
- (R6) A comparison of g_s vs. G_s on both the pattern and value was added as suggested. ‘ G_s from SF/SI was 67.3% lower than g_s from gas exchange measurements, though their diurnal dynamics were similar’ was added (P11603 L15).
- (R7) Indeed, this multiplication would yield much higher values than estimated by the applied method, adding that F_{CO_2} from SF/SI were 27.0% lower than P_n from gas exchange. In our study, comparisons between gas exchange measurements and sap flux/stable isotope method (SF/SI) results were conducted, given that both estimates have taken LAI into consideration. Further, the differences may be attributed to high variation in gas exchange results that were variable by leaf position and age, and thus any one measurement was not representative of the entire canopy, and variability of the average response was high. Given that F_{CO_2} was calculated based on Δ and C_i/C_a averaged across a variety of age and light classes, this source of variation was reduced for the SF/SI results. The analysis of the differences between the gas exchange and SF/SI results heightened the advantages of the latter method (P11603 L16-22).

Also, if leaf gas exchange measurements are representative of the entire canopy, then a simple multiplication by LAI should yield a rough estimate of F_c and G_s . Yet here this would yield values that are much higher than estimated by the applied method. Can this be settled?

- (R8) The differences were explored more closely as suggested. It was revised as ‘Our lower estimates of GPP may be partly explained by an age-related decline in photosynthesis (20 yr-old vs. 4–6 yr-old). It was also probably the result of lower photosynthetically active radiation absorbed by the canopy, due to lower stand density (734 trees ha⁻¹ vs 1111 trees ha⁻¹), and lower LAI (1.95 m²m⁻² vs. 3.479 m²m⁻²) (Ma, 2008a; Nouvellon et al., 2012)’ (P11604 L18-19).
- (R9) Possible reasons for our lower estimate of F_{CO_2} for mature *A. mangium* plantation were analyzed. Please see the explanation ‘Our lower estimate was likely related to the lower mean canopy stomatal conductance, higher C_i/C_a , greater tree height, and aging’ (P11604 L2-15). The reasons for the inference that high C_i/C_a values leads to a decline in photosynthetic capacity of *A. mangium* are given in detail. The specific changes were listed as follows.
- The main text (P11604 L6-12)’ was deleted. The related content was rewritten and moved to the end of the paragraph (P11604 L15).

The reasons for the inference that high C_i/C_a values leads to a decline in photosynthetic capacity of *A. mangium* are given in detail as ‘The C_i/C_a ratio, which is maintained at a constant or near-constant value in many plant species, represents a balance between the rates of inward CO₂ diffusion (controlled by stomatal conductance) and CO₂ assimilation (controlled by photosynthetic light/dark reactions) (Ehleringer and Cerling, 1995). In our study, the C_i/C_a ratio varied from 0.76 to 0.84, which was higher than the ranges found in cottonwoods in a riparian woodland (0.75–0.78) (Letts et al., 2008), in 13-yr-old loblolly pine (*Pinus taeda*) trees (0.45–0.80) (Maier et al., 2002), and in nine well-watered conifer species (0.57–0.68) (Brodribb, 1996). Relatively high C_i/C_a ratios have also been found in tropical rain forest species (Lloyd and Farquhar, 1994; Ishida et al., 1996), a Canarian laurel forest tree species (*Laurus azorica*) (González-Rodríguez et al., 2001). There are three possible reasons for the inference that the C_i/C_a ratio may result in a decrease in photosynthetic rate of our study species. Firstly, high C_i/C_a values may suggest a relatively small stomatal limitation to net photosynthetic rate and non-conservative water use (González-Rodríguez et al., 2001; Ishida et al., 1996). Consistent with this inference, Cienciala et al. (2000) also observed no apparent limitation to water flux in *A. mangium*. High transpiration rates may reduce photosynthetic rates by lowering assimilation by reducing CO₂ availability, and effects on the photosynthetic capacity of the mesophyll (Sharkey, 1984). Secondly, non-stomatal limitations were may also be responsible for the decline in assimilation rates (Lauer and Boyer, 1992). Thirdly, the reduction in photosynthesis associated with leaf senescence should have high C_i/C_a values (Ponton et al., 2006).’ (P11604 L15).

The reference ‘Cienciala, E., Kučera, J., and Malmer, A.: Tree sap flow and stand transpiration of two *Acacia mangium* plantations in Sabah, Borneo, Journal of Hydrology, 236, 109–120, doi:10.1016/S0022-1694(00)00291-2, 2000.’ was added in the reference list (P11607 L12).

The reference ‘Ehleringer, J. R., and Cerling, T. E.: Atmospheric CO₂ and the ratio of intercellular to ambient CO₂ concentrations in plants, *Tree Physiology*, 15, 105–111, doi:10.1093/treephys/15.2.105, 1995.’ was added in the reference list (P11607 L18).

The reference ‘Ishida, A., Toma, T., Matsumoto, Y., Yap, S. K., and Maruyama, Y.: Diurnal changes in leaf gas exchange characteristics in the uppermost canopy of a rain forest tree, *Dryobalanops aromatica* Gaertn. F., *Tree Physiology*, 16, 779–785, doi:10.1093/treephys/16.9.779, 1996.’ was added in the reference list (P11608 L26).

The reference ‘Lloyd, J., and Farquhar, G.: ¹³C discrimination during CO₂ assimilation by the terrestrial biosphere, *Oecologia*, 99, 201–215, doi:10.1007/bf00627732, 1994.’ was added in the reference list (P11609 L20).

The reference ‘Ponton, S., Flanagan, L. B., Alstad, K. P., Johnson, B. G., Morgenstern, K. A. I., Kljun, N., Black, T. A., and Barr, A. G.: Comparison of ecosystem water-use efficiency among Douglas-fir forest, aspen forest and grassland using eddy covariance and carbon isotope techniques, *Global Change Biology*, 12, 294–310, doi:10.1111/j.1365-2486.2005.01103.x, 2006.’ was added in the reference list (P11611 L7).

The reference ‘Sharkey, T.: Transpiration-induced changes in the photosynthetic capacity of leaves, *Planta*, 160, 143–150, doi:10.1007/bf00392862, 1984.’ was added in the reference list (P11611 L21).

(R10) The conclusions section was shortened as suggested. Specific changes were listed as follows.

‘We concluded that mature *A. mangium* exhibited obvious diurnal, seasonal, annual, and inter-annual changes in canopy CO₂ uptake (F_{CO_2})’ was deleted (P11606 L6-7).

‘ F_{CO_2} ’ was revised as ‘canopy CO₂ uptake (F_{CO_2}) of *A. mangium* plantation’ (P11606 L8).

(R11) All the figures (.EPS) we uploaded were vector graphics. They can be zoomed to the sizes as requested by the journal.

Technical comments

(Q1) P11585 L7: Carbon is abbreviated as C without preliminary definition. **(Q2)** P11585 L10: ‘relatively rare’, more accurate: ‘less common’. **(Q3)** P11586 L9: ‘: : : sap flow measurement is non-destructiveness, easy, and low cost’, better: “: : : sap flow measurement is nondestructive, easy, and relatively low cost”. **(Q4)** P11586 L27-28: The sentence is repetitive; can omit. **(Q5)** P11587 L17: ‘*Acacia mangium*’, the genus name can be shortened. **(Q6)** P11587 L24: ‘The projected canopy area: : :’. The use of canopy here is confusing.

Perhaps can change to ‘crown’. **(Q7)** P11589 L10-13: This sentence can be shortened. **(Q8)** P11600 L11-12: This sentence refers to Fig. 6, and hence can be changed into: ‘: : values of both g_s and P_n were higher than: :’. **(Q9)** P11602 L17-21: This sentence reads strange. Perhaps rephrase. **(Q10)** P11603 L1: ‘ G_s stayed high at low $D...$ ’ Should this be ‘ G_s stayed high at high D ’ instead? **(Q11)** P11603 L 4-5: The sentence is redundant. **(Q12)** Fig. 1. ‘DBH ranks’ better DBH bins/categories. **(Q13)** Fig. 2. Values of annual precipitation amounts could be useful here. Stand transpiration seems to depend on SWC and not P . This is interesting since both SWC and stand transpiration are affected by some carryover effect, which can explain the inter-annual differences.

Response

- (R1)** ‘C’ was revised as ‘carbon (C)’ as suggested (P11585 L7).
- (R2)** ‘relatively rare’ was revised as ‘less common’ as suggested (P11585 L10).
- (R3)** ‘sap flow measurement is non-destructiveness, easy, and low cost’ was revised as ‘sap flow measurement is nondestructive, easy, and relatively low cost’ as suggested (P11586 L9).
- (R4)** ‘We expected that FCO_2 of a subtropical mature *A. mangium* plantation could be estimated by the sap flux/stable isotope combination’ was omitted as suggested (P11586 L27-28).
- (R5)** ‘*Acacia mangium*’, the genus name was shortened as ‘*A. mangium*’ as suggested (P11587 L17).
- (R6)** ‘The projected canopy area’ was revised as ‘The projected crown area’ as suggested (P11587 L24).

Similarly, the similar usages were all revised as follows.

- ‘canopy’ was revised as ‘crown’ as suggested (P11588 L22).
- ‘canopy’ was revised as ‘crown’ as suggested (P11588 L23).
- ‘canopy’ was revised as ‘crown’ as suggested (P11613 Table 1).
- (R7)** ‘One tree at the < 15 cm DBH class, four trees at the 15–20 cm DBH class, five trees at the 20–25 cm DBH class, two trees at the 25–30 cm DBH class, and two trees at the > 30 cm DBH class were selected for J_s measurement’ was shortened as ‘1, 4, 5, 2, 2 trees at the < 15 cm, 15–20 cm, 20–25 cm, 25–30 cm, > 30 cm DBH classes were selected for J_s measurement, respectively’ as suggested (P11589 L10-13).
- (R8)** ‘values of both G_s and FCO_2 were lower than those of g_s , and of P_n ’ was revised as ‘values of both g_s and P_n were higher than those of G_s , and of FCO_2 ’ as suggested (P11600 L11-12).
- (R9)** ‘Estimates of canopy conductance from the Penman–Monteith formula were very close to those obtained with the simplified equation by Köstner et al. (1992) (Ma, 2008) as would be expected given that the Köstner et al. (1992) equation is based on Penman–Monteith’ was rewritten as ‘It was reported that similar canopy conductance estimates of this *A. mangium* plantation were obtained from both the Penman–Monteith formula and simplified equation by Köstner et al. (1992) (Ma, 2008)’ as suggested (P11602 L17-21).

- (R10) ‘ G_s stayed high at low D ’ was revised as ‘ G_s stayed high at high D ’ as suggested (P11603 L1).
- (R11) ‘Comparisons between gas exchange measurements and sap flux/stable isotope method (SF/SI) results were conducted in this study (Figs. 6, 7)’ was deleted as suggested (P11603 L 4-5).
- At the same time, this information was added as follows.
- ‘SF/SI’ was revised as ‘sap flux/stable isotope method (SF/SI)’ (P11603 L 6).
- ‘results’ was revised as ‘results (Figs. 6, 7)’ (P11603 L 7).
- ‘measurements’ was revised as ‘measurements (Figs. 6, 7)’ (P11603 L 10-11).
- (R12) ‘DBH ranks’ was revised as ‘DBH categories’ as suggested (Fig. 1).
- (R13) ‘Further, lower annual F_{CO_2} and maximum monthly F_{CO_2} in May in 2005 may be due to the frequent rainfall occurred in June and July’ was revised as ‘Further, lower annual F_{CO_2} and maximum monthly F_{CO_2} in May in 2005 may be due to the frequent rainfall occurred in June and July, or to both SWC and stand transpiration are affected by some carryover effect’ (P11602 L 14-16).

We appreciate the opportunity of submitting our revised manuscript to Biogeosciences for consideration.

Sincerely,

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