Final response to the reviewers comment from Anonymous Referee #1 on the manuscript bg-2020-171: "Evapotranspiration over agroforestry sites in Germany"

We thank you for your feedback, suggestions and helpful comments on the manuscript. In the current document we give a point-by-point answer on above referee report.
We show first the referee comments **(RC)** and second the authors answer **(AR)**. Specific changes in the revised manuscript are marked as green text as part of the authors response.

0. RC: *This paper presents ET measurements from paired monoculture/agro-forestry sites throughout Germany. The results indicate insignificant differences in ET between the land use types, which appears to be a positive result. The writing is adequate, but I personally feel that the document overemphasizes the statistical comparison between the paired sites to the extent that the important message of the paper is obscured. The content of the paper is fine, but the text needs further refinement.*

0. AR: Thank for very much for your positive feedback and the detailed and valuable comments. We reduced discussions on the statistical significance of the differences between ET from the different land-uses both in Abstract as well as in the main text. We are confident that the quality of the manuscript will improve after considering your suggestions.

1. RC: *Page 1 line 23: Direct comparison of ET between wet and dry years is not very relevant because the available energy is likely different between the two years.*

1. AR: We used this comparison to test if we can detect the effect of a wet and a dry year on ET fluxes with the used methods. With this analysis we showed that both methods (ECEB and EC-LC) were suitable to detect differences in ET due to different ambient conditions. But, we also showed that differences in ET between the two land-uses and between the two methods were of similar magnitude and of the same sign (ET_AF > ET_MC; ET_ECEB>ET_EC-LC). This makes it difficult to decide whether differences in ET between AF and MC are caused by the presence of the trees of the AF system, or if the differences are an effect of the methodological uncertainties. We clarified this in the abstract, as also shown in the **2**. **AR** below.

The aforementioned discussions refer to Figure 10 of the initially submitted manuscript. We added a second figure next to the existing one and zoomed into the centre of the plot to indicate the trends. See the new figure with the extended caption below:

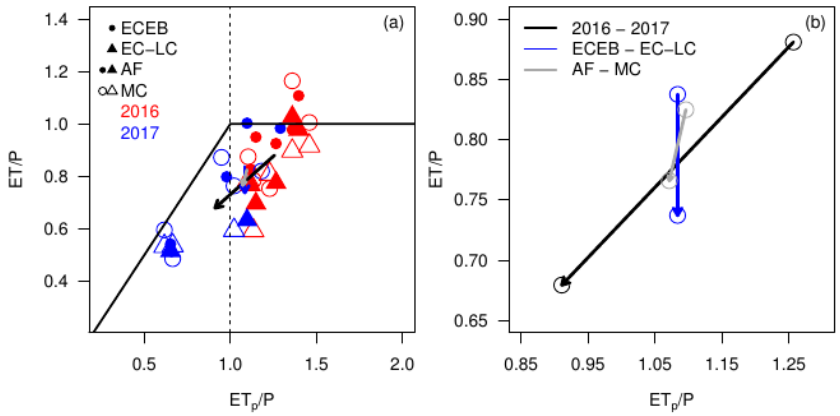

Figure 9. (a) Evapotranspiration index (∑ET/∑P) versus the dryness index (∑ET$_p$/∑P) for both land-uses (AF: filled triangles and dots; MC: empty triangles and dots), both set-ups (ECEB: dots; EC-LC: triangles) and both years (2016: red; 2017: blue). The bold black line describe regions of an energy limitation (ET$_p$/P<1) and a water limitation (ET$_p$/P>1). The arrows indicate mean trends of ET for the effect of different years (black arrow), different methods (blue arrow) and different land-uses (grey arrow). **(b)** Trends of the mean evapotranspiration index (∑ET/∑P) versus the mean dryness index (∑ET$_p$/∑P) for the effect of different years (black), different methods (blue) and different land-uses (grey).

2. RC: *Page 1 lines 16-26: This is the most important point of the paper. However your description does not speculate or give guidance as to whether you expect higher ET at the AF or MC locations, no hypothesis.*

2. AR: → we formulated the main objective of this work in the first paragraph of the abstract (Page 1 line 5-6), which was to assess if AF systems have higher ET compared to monoculture systems

We clarified the hypothesis and the objective in the abstract as: "[...] Therefore we hypothesize that short-rotation coppice agroforestry systems have higher water losses to the atmosphere via ET, compared to monoculture agriculture without trees. In order to test the hypothesis the main objective was to measure actual evapotranspiration of five AF systems in Germany and compare those to five monoculture systems in close vicinity to the AF systems.[...]"

In addition, we extended the discussion in the abstract in the particular lines with a more precise conclusion:

"With respect to the annual sums of ET over AF and MC, we observed small differences between the two land-uses. We interpret this as an effect of compensating small-scale differences in ET next to and in between the tree strips for ET measurements on system-scale. Most likely, differences in ET rates next to and in between the tree strips are of the same order of magnitude but of opposite sign and compensate each other. Differences between annual sums of ET from the two methods were of the same order of magnitude as differences between the two land-uses. In contrast, we observed higher mean evapotranspiration indices ($\sum$ET/$\sum$precipitation) across sites for a drier than normal year (2016) compared to a wet year (2017) independent of the land-use or method. This indicates that we were able to detect differences in ET due to different ambient conditions with the applied methods.

We conclude that agroforestry has not resulted in an increased water loss to the atmosphere indicating that agroforestry in Germany can be a land-use alternative to conventional agriculture."

3. RC: *Page 2 line 8: You note that SRC are comparable to monoculture (forestry) but you don't indicate what aspects are comparable - are you refering to energy partitioning and water use?*

3. AR: we refer to the geometrical structure of those systems, rather than energy partitioning or water use; SRCs are not mixed systems like agroforestry (trees and crops), they consist only of one tree species, which is similar to monoculture systems with only one crop species, we changed it in the text as follows:

"SRC plantations are monoculture systems with a single tree species grown."

4. RC: *Page 2 Intro: Most of your references are relatively recent, you might gain some insights by reviewing earlier work. See references in Cleugh.*

4. AR: we will look through the older literature and extend the introduction in the revised version of the manuscript

5. RC: *Page 3 line 10: The ECEB method is not really limited by closure of the energy budget because this is the default assumption for ECEB. It is, however, limited by the accuracy of your estimates of senible heat flux, net radiation, soil heat flux and change in storage terms.*

5. AC: indeed, we changed this as follows:

"The ECEB method is limited by the accuracy of the energy balance components (the net radiation, the sensible heat flux, the ground heat flux and storage terms), typically leading to an overestimation of latent heat fluxes."

6. RC: *Page 3 line 20: Why do your partition the residual energy budget between just H and LE and not between H,LE and G - or possibly even Rn*

6. AC: Despite substantial research into the partitioning of the energy balance residual (*i.e. Mauder et al. (2017): 'Evaluation of energy balance closure adjustment methods by independent evapotranspiration estimates from lysimeters and hydrological simulations'*) there is no general consensus how to partition the energy balance residual, and the partitioning is likely site and case specific and would require additional information beyond the typical set of measurements we had available. However, research (*Foken et al. (2008): Micrometeorology*) seems to suggest that the largest fraction of the residual is related to the turbulent fluxes (H + LE), rather than to the measurement of available energy. Therefore, we partition the residual only to LE and H.

7. RC: *Page 3 line 21: I would suggest being more specific in your hypothesis. Specify short-rotation copice agro-foresty, as your results may not extent to other systems.*

7. AC: we changed the hypothesis in the introduction and added the hypothesis to the Abstract as well as a related objective:

"The main hypothesis of the current work was that short-rotation coppice agroforestry systems have higher water losses to the atmosphere via ET, compared to monoculture agriculture without trees."

8. RC: *Page 5 line 4: How did you know if precipitation data were missing?*

8. AC: we sampled the meteorological data every 10 seconds; for our analysis we checked how many 10 second values per day were available and compared those to the theoretical number → 10 sec values available/10 sec values theoretical

9. RC: *Page 5 line 10: Did you use the precipitation data from the AF plots? and if so how did you use them?*

9. AC: we did not use the precipitation data from the AF, as the data were strongly affected by interception and not really representative for the AF system, as the precipitation in between the tree strips is expected to be higher than within the tree strips, we used only precipitation from the monoculture system; the annual sums in precipitation between AF and MC differed substantially (AF<<MC), which would have affected the ratios between ET and P. We used only precipitation from the MC sites under the assumption that the mean annual sum of precipitation between AF and MC do not differ due to the small size of the agroforestry systems and no small scale effects on precipitation formation. We added further explanations in the text:

"[...]Therefore, we used the precipitation measurements from the MC system to compute ratios of annually summed actual and potential ET to precipitation at both AF and MC systems. We assume that the annual sum of precipitation at the AF and the MC systems do not differ, due to the relatively small size of the agroforestry systems and no expected local effects of the agroforestry systems on the precipitation formation.[...]"

10. RC: *Page 7 equ 4: Technically, this conversion gives you units of mg/m2 not mm/30 min. (assuming your lambda value is using milligrams and not the more usual grams. This needs to be explicit to avoid readers from incorrectly applying this equation. (i.e. give units for your variables)*

10. AC: we corrected the formula as shown below:

Half-hourly evapotranspiration rates in units of $\mathrm{mm\,30\,min^{-1}}$ were calculated from LE as

$$ET = \frac{LE_{ECEB}(\mathrm{J\,kg^{-1}\,s^{-1}})}{L(\mathrm{J\,kg^{-1}})} \cdot 1800(\mathrm{s\,30min^{-1}}) \cdot \frac{1}{\rho_{H_2O}}(\mathrm{m^3\,kg^{-1}}) \cdot 1000\,\mathrm{mm\,m^{-1}} \quad (4)$$

with L ($\mathrm{J\,kg^{-1}}$) the latent heat of vaporization (Dake, 1972) depending on air temperature T (°C)

$$L = (2.501 - 0.00237T) \cdot 10^6, \quad (5)$$

and $\rho_{\mathrm{H_2O}} = 1000\,\mathrm{kg\,m^{-3}}$ the density of liquid water.

11. RC: *Page 8 line 9-10: This sentence needs to be fixed. Also, it is an assumption that lack of energy budget closure reduces ET. That assumption is not necessarily true.*

11. AC: we reformulated the sentence:

"[...] We corrected \unit{ET_{ECEB}} for the average energy balance non-closure, which we estimated from direct LE measurements by EC during measurement campaigns of minimum four weeks duration. In the current study we found that considering the energy balance residual reduces \unit{ET_{ECEB}}. [...] "

12. RC: *Page 10 line 2: Your Big-Leaf assumption may be appropriate for the MC sites but less so for the AF sites, can you address the potential effects.*

12. AC: The big-leaf assumption might be violated over AF due to the heterogeneity of the system, this could potentially be a problem. In this discussion heterogeneity refers to the different plant species (crops/grasses and trees) of different heights. The trees infer a shaded area in terms of wind and incident radiation in the quiet zone. On the one hand the reduction in incident radiation might lead to reduced ET due to a different leaf stomata regulation from sunlit and shaded leafs both from trees and crops as well as due to reduced wind velocities. On the other hand trees and crops in the windward site are affected by increased wind velocities and varying incident radiation. So, the big-leaf assumption might even be valid over agroforestry systems due to the compensation of the effects in the lee and at the windward site of the tree strips.
Therefore, the canopy resistance derived from meteorological measurements at our flux tower (one flux tower over AF and MC, respectively) might still be representative for the agroforestry system, as the mean meteorological conditions are recorded. We added some more explanations+discussions in the Mats+Methods section 2.6 ("Canopy resistance") of the revised manuscript:

"Effects of structural differences between AF and MC on ET were studied in terms of the relationship between the aerodynamic and canopy resistances (\unit{s\,m^{-1}}) and half-hourly ET. The canopy resistance was calculated from the rearranged Penman-Monteith equation (Eq. (\ref{equ:PM_equ})) for evapotranspiration, which depends on the canopy conductance, g_c (\unit{m\, s^{-1}}), and the aerodynamic conductance for heat, g_{ah} (\unit{m\, s^{-1}}). The canopy conductance follows the big leaf assumption, assuming that the whole canopy response to environmental changes equals the response of a single leaf. This assumption is valid for the monoculture system with a single crop type of similar height. For the agroforestry systems this assumption is violated due to the different plant species (trees and crops) of different heights. In the lee of the tree strips the reduced wind speed and incident radiation might lead to reduced ET due to a different leaf stomata regulation of sunlit and shaded leafs. In the windward site of the tree strips trees and crops are affected by increased wind velocities and varying incident radiation, thus opposite conditions compared to the lee of the tree strips. However, we assume that the meteorological data from our flux tower represent the mean state of the meteorological conditions within the agroforestry system. Therefore, we are confident that the big-leaf assumption is also valid for agroforestry systems."

13. RC: *Page 10 Equ 11: Here and elsewhere in the paper you use 'lambda' as the latent heat of vaporization but in the text you use 'L'. Best to use one or the other, not both.*

13. AC: we changed it from 'lambda' to L

14. RC: *Page 10 line 9: is 'ppp' a variable, if so it should be shortened to a single character.*

14. AC: we changed it from ppp to P_A

15. RC: *Page 10, equ 14: don't use VPD as a variable name, reduce it to a single character (e.g. 'D', or a single character variable with a subscript or superscript (e.g. 'e_D')*

15. AC: we changed VPD to D

16. RC: *Page 11 line 2-3: Did you account for wind direction. The AF site is inherently non-homogeneous, and similar to other row-structured crops may have strong directional dependencies.*

16. AC: no, we neither account for any wind direction, nor will we include a new analysis

17. RC: *Page 11 sec 3.1: This information might be more succinctly incorporated as a table - only referring in text to any atypical conditions.*

17. AC: we kept this section and shortened it; we added Table A2 to this section as follows:

3.1 Meteorological conditions and plant physiological stages during the campaigns

For the meteorological conditions during the campaigns we refer to time series of relevant meteorological parameter in Figure 2 and mean values in Table 3.

Table 3. Mean air temperature, T_A, vapor pressure deficit, D, global radiation, R_G, and the cumulative precipitation, P, for the respective site and campaign period.

Site	T_A (°C)	P (mm)	D (hPa)	R_G (Wm^{-2})
Dornburg AF	19.0	57.1	6.41	200.7
Dornburg MC	18.6	2.1	7.35	212.6
Forst AF	21.4	18.9	12.02	358.8
Forst MC	21.2	14.8	11.88	371.5
Mariensee AF	18.54	40.6	6.2	258.9
Mariensee MC	16.93	163.5	4.7	172.8
Reiffenhausen AF	19.31	26.3	8.02	219.1
Wendhausen AF	16.6	48.6	5.4	235.0
Wendhausen MC	15.5	90.7	5.2	239.9

18. RC: *Page 14 line 24-25: Water vapour concentrations are not a good indicator of spectral response - many other factors come into play.*

18. AC: We changed the text to reflect that the spectral response characteristics of the two analyser were similar as follows:

"[...] fluctuations were attenuated. The spectral response characteristics of the gas analyser and the thermohygrometer set-up were similar. Therefore, the correction of high-frequency losses is expected to be higher for the compromised gas analyser at the respective MC systems, than for a fully functional gas analyser."

19. RC: *Page 15 fig 4: Why is there no nocturnal data for some sites?*

19. AC: There was not enough power available to cover the power needs, due to the solar power supply of the station. Therefore, we had larger data losses during night.

20. RC: *Page 17 sec 3.4: Instead of using "LE from EC", "LE from EC_LC", "LE from ECEB", might I suggest using subscripts LE_a = LE from EC LE_b = LE from ECEB LE_c = LE from EC_LC It will make reading the paper much easier.*

20. AC: it is a good suggestion, we changed the text as follows

LE_{ECEB}, LE_{EC} and $LE_{EC\text{-}LC}$ for LE and
ET_{ECEB}, ET_{EC} and $ET_{EC\text{-}LC}$ for ET

21. RC: *Page 20 line 6-14: This is really interesting. I would cut down on the amount of stats provided and focus on the underlying concepts of what be causing this - which obviously is on scales much bigger than the individual sites*

21. AC: Indeed, we discussed partly in the manuscript that circulations bigger than the individual sites might cause the observed pattern. If this is really the case, we would require additional information beyond the typical set of measurements we had available. Therefore, we did as suggested and cut down the amount of statistics.

"[...]Interestingly, the diel pattern of the EBR from \unit{LE_{EC}} at both land-uses at all sites are equal. Additionally, the differences between the median diel cycle EBRs (between 6 am and 6 pm) at the AF and the MC system were small, with differences of minimum -0.09 and maximum 0.13 across sites. As both flux towers located at the AF and the MC system at one site are separated by approximately 100 to 500 m and the diel patterns look similar, we suspect that the non-closed surface energy balance at one site is caused by local effects of longer wavelength than the commonly applied averaging period of 30 minutes and beyond the individual site level.[...]"

We will further discuss possible reasons for the observed pattern in the revised version of the manuscript.

22. RC: *Page 20 line 17-18: This seems inconsistent with your preceding paragraph.*

22. AC: in addition to discussions in above lines we changed the phrase 'loss of energy in the morning' to 'lack of energy in the morning'

23. RC: *Page 20 sec 3.4.3: Not so sure about the usefulness of this section. As presented it is a simple algebraic exploration assuming linear relationships. In reality, changing one or more the components by +/- 20% may have non-linear effects on the other components, which can not be accurately captured by the your current analysis method.*

23. AC: We removed this section from the paper

24. RC: *Page 22 line 15: This is perhaps expected, by definition Rn is the sum of the other components.*

24. AC: Yes, this is correct. We removed this section from the paper.

25. RC: *Page 22 line 27-30: Is it correct that this is an assumption and you did not measure evaporation and transpiration separately.*

25. AC: yes, this is an assumption and we changed it accordingly:

"We assume that after the ripening of the crops evaporation contributed the most to the measured ET at the MC plot, whereas at the AF plot both evaporation from the crop fields between the tree strips and transpiration from the trees contributed to the measured flux."

26. RC: *Page 24 sec 3.5.2: Even though ET was measured by EC only for campaigns, it might be useful to compare sums of ET by all three methods for those campaign periods.*

26. AC: we included a new sub-section 3.5.2 'Sums of evapotranspiration during the campaigns' and a figure:

3.5.2 Sums of evapotranspiration during the campaigns

Sums of evapotranspiration for all three methods and all sites indicate higher sums of ET_{ECEB} relative to ET_{EC}, except for D-AF (Fig. 8). The difference between sums of ET_{ECEB} and ET_{EC} reflect the unaccounted correction of ET_{ECEB} for the energy balance non-closure. The large difference between sums of ET_{ECEB} and ET_{EC} at M-AF correspond to the low energy

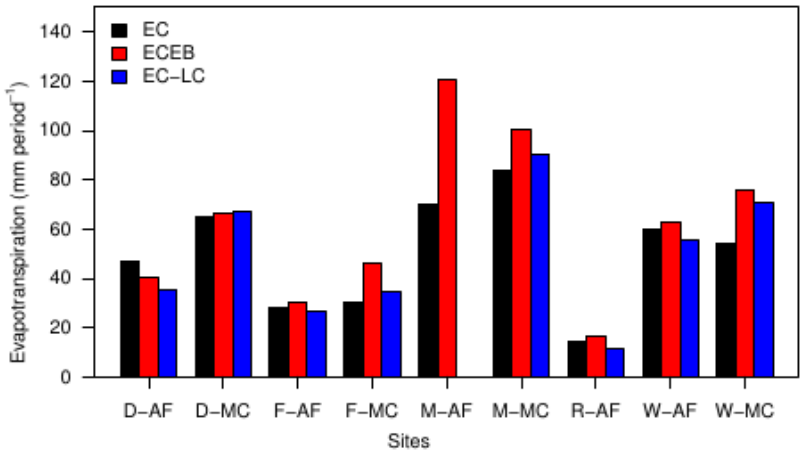

Figure 8. Sums of uncorrected and not gap-filled half-hourly evapotranspiration for all three methods and all sites during the campaign periods. Incomplete records with either ET_{EC}, ET_{ECEB} or ET_{EC-LC} missing were omitted.

balance closure of 65% at the site. Differences between sums of ET_{EC-LC} and ET_{EC} correspond to higher sums of ET_{EC-LC} than ET_{EC} over the AF systems and lower sums of ET_{EC-LC} than ET_{EC} over the MC systems (Table 4).

27. RC: *Page 27 line 3: how do you get a displacement height of 7 m with a canopy height of 5 m?*

27. AC: yes, this is a typo and we changed it in the text to:

"[...] a displacement height d of 0.7 m and 3.5 m for canopy heights of 1 m and 5 m, respectively."

28. RC: *Page 27 line 7-8,13-14: Is these relationship inherent from the derivation of canopy conductance from ET?*

28. AC: The canopy resistance was derived as the inverse of the canopy conductance with $ET_{EC\text{-}LC.}$ Small differences in canopy resistance between the two land-uses are an artefact from small differences in ET between the two land-uses. We did change the title of the derivation of r_c and r_ah from 'Canopy conductance' to 'Canopy resistance' to make this more clear. Additionally, we moved the whole derivation of the canopy resistance and other formulas to the Appendix to keep the overall length of the manuscript short.