Final Authors Response

We thank both reviewers for their extensive and insightful feedback.

Anonymous Reviewer #2

Major concerns:

Generally, the language needs to be improved and the manuscript must be much more concise. This goes for all sections. A large section of the results is about testing different partitioning methods, but it is not included as an aim in the introduction. In case an aim of the study is to investigate different partitioning methods, please clarify this already in the introduction. Otherwise, I would recommend using the one that works the best. I fully understand why the night-time methods are not working well, since it has generally been seen that at a diurnal time scale respiration is not strongly linked to temperature for savanna ecosystems. But I cannot understand why the daytime method is working so poorly. Are you sure that you fitted the equation correctly? After putting a lot of effort into partitioning of the data, the partitioned data is not even shown except in the format of monthly averages. Please, show the partitioned data as well.

Authors' response: The testing of partitioning methods was not a major goal of this study. The method comparison has been removed and the Lloyd and Taylor (1994) model was used for fitting the night-time respiration data. The manuscript was made more concise and the language was improved.

Why did you use monthly averages in the investigation of seasonal variation? I cannot see any reason for not using daily sums or averages. By using monthly estimates you hide a lot of the variability and it is more difficult to see the relationship to the environmental variables.

Authors' response: The kind of analysis we had done would be very difficult to do at daily time scale because the daily data is noisier and the data covered three years.

There is no statistical testing of relationships of the fluxes to the environmental variables. It is just stated that high flux values can be explained by some variables. But you do not explain how you have tested for this.

Authors' response: Results of linear regression analysis between NEE and environmental drivers were added to the section 3.3.

Specific comments:

L19-20. There is a contradiction in this sentence: are the balances yearly or are they for the growing season,please rephrase.

Authors' response: Corrected.

L23-24 Please clarify in the abstract why: This study underlines the difficulty in establishing a functional relation between the total ecosystem respiration and the environmental drivers in savanna ecosystems.

Authors' response: Sentence removed.

L24-25 There must be something that explains the inter-annual variability, even though it might be that you have not seen any explanations in your data sets.

Authors' response: Sentence removed.

L32 reference for the 20% of global area please.

Authors' response: Same reference.

L35. Please rephrase, it sounds like the humans are grazing.

Authors' response: Corrected.

L42 reference please

Authors' response: Added.

L45 . instead of ,

Authors' response: Corrected.

L51 This is not correct: Tagesson, Ago and Quansah is all sites affected by either grazing or agriculture, there are also EC towers in Wankama Falls, Agofou, and Demokeya, which are all affected by grazing or agriculture; see (Tagesson et al., 2016a)

Authors' response: Corrected.

L55 please include (Tagesson et al., 2016a) that investigated annual budgets for 6 different sites across the Sahel.

Authors' response: Included.

L61 I do not understand why you use NDVI as a proxy for GPP. You have EC measurements, why not use them directly? Please clarify.

Authors' response: This was done to assess the long-term (in this case 12 years) productivity at the measurement site.

L70 Do you have any data on number of sheep and cattle?

Authors' response: We added a paragraph to the site description about the farm management which is a typical commercial farm in South Africa.

"The measurement site is located at a commercial farm which has about 1300 head of cattle which varies +- 300 depending on the year. During a wet year there are more animals than during a dry year. The cattle are grazing on approximately 6000 hectars, which consists of natural grazing (e.g. at the measurement site), planted grazing and maize/sunflower fields that are grazed after harvesting. This form of farming is considered large-scale commercial farming. Due to the semi-arid climate, the carrying capacity of the grazing fields tends to be low and thus the grazing area is large. The farmers cannot keep track on the grazing patterns but they do move the cattle around to optimize grazing and protect the field against overgrazing."

L86 please give exact sampling dates.

Authors' response: Exact sampling dates were added to the Table 3.

L91 What do you mean, did you count all plants inside the 100m2 plot or did you identify all species?

Authors' response: *"All of the plant species were counted and identified up to species level,and their major growth form was recorded."*

L101 Are not all these measurements relevant to Ecosystem dynamics? Please use a different word than ecosystem dynamics.

Authors' response: Carbon cycle dynamics.

L103 At 2 and 8 m height or at several heights between 2 and 8 m? What was the height of the tipping buckets?

Authors' response: Rephrased. Tipping bucket was installed at 1.5 m height.

L102 What sensors were used for the meteorological measurements?

Authors' response: Corrected.

"The meteorological measurements included air temperature (Rotronic MP 101A) and pressure (Vaisala PTB100B), wind speed (Vector A101ML) and direction (Vector A200P/L), relative humidity and temperature gradient (Vaisala PT-100) between two points (2 m and 8 m height)"

L108 What sensor? what did it measure?

Authors' response: Soil moisture sensor at 5 cm depth.

L115 Why 20 m when height of the sensor was only 9m, should be possible to have a much shorter tube than this. What sort of tube did you use, inner diameter? No filter between the IRGA and the incoming air?

Authors' response: The gas analyzer is located inside a trailer that is some distance away from the measurement mast. The gas sampling tube was PTFE (ID 4mm, OD 6mm) and it had a filter.

What was the separation length between the inlet tube and the anemometer?

Authors' response: 20cm

L137-140 and Figure 2. The footprint is never this uniform for different wind directions, if you have estimated the footprint for each 30 min period; it would be easy to show an average for the different wind directions.

Authors' response: Added contour of the mean 80% cumulative footprint.

L140 If the footprint is homogeneous thornveld, why do you report vegetation sampling for all other vegetation types? Looking at figure 2 with the footprint, is seems like the only vegetation cover which is affecting the EC measurements are the thornveld. If you want to present all the other data as well, I think you should you must incorporate a reason for this in the introduction, and a link to the EC data.

Authors' response: The reviewer is correct: thornveld clearly dominates the flux footprint and that is the vegetation type we focus on. For clarity, Section 2.2 on vegetation sampling and the tabulated soil data, which are included to characterize a larger area, were moved to Supplement.

L145-151 Please give equations for the all partitioning models.

Authors' response: The method comparison has been removed and the Lloyd and Taylor (1994) model was used for fitting the night-time respiration data.

L163 Why in two steps? Why give E0 an annual value and not using the moving window?

Authors' response: This makes the fitting procedure more robust.

L166 What is Fp? Why fitting this at all? Why not using the light response function that was used in the "daytime method"?

Authors' response: Fp is GPP. The fitting was done following the method by Kutsch et al. (2008).

L170 This is probably a good choice, but why not always use 1 September to 31 August or something similar? Why only estimating the growing seasons?

Authors' response: Rephrased the sentence. The analysis covered the whole years.

L174 This is incorrect MCD43A4 is not an NDVI product, it is a BRDF product, please rephrase. Why using monthly averages, when data is available as an 8 day product? It is not clear if you extracted the values of one single pixel, or did you use an average of several pixels?

Authors' response: Rephrased. Monthly average value of one 500 m pixel was used.

L176 What do you mean by that NDVI is better to use than the LAI and GPP product for vegetation structure? First, you are not studying vegetation structure, you are studying fluxes. Different products are good for different things. I agree that NDVI is a useable parameter, but it is not a real value like LAI and GPP. You cannot claim that it is better to use than these other parameters for studying vegetation dynamics. It is so far very unclear what you are going to use these data for. Please clarify. I would state that NDVI is a proxy for vegetation phenology.

Authors' response: Removed the last sentence. The NDVI was used to study long-term productivity at the measurement site.

L180 please give sum of rain

Authors' response: Corrected.

L192 In figure 4, it does not look like a linear increase until the saturation level. It is rather asymptotic

Authors' response: Removed "linear".

L197 How could the parameters get unrealistically high? In case data looks like in Figure 4, parameters should be fine. In case the relationship is very linear, the saturated GPP level gets unrealistically high, but this does not really matter for the partitioning as long as the equation is well fitted to the data. As the manuscript is written now, it seems like you want to test several different partitioning methods, if this is the case then you must show how all these different partitioning methods differ in their output. In the results section, you do not show the output of the different methods at all.

Authors' response: The method comparison has been removed.

L209 I would not say that it was fitted successfully in case the R2 value is 0.11.

Authors' response: This result was removed.

L210-215, in case you want to make a proper comparison of the different partitioning methods, you should give statistics for all methods. Please also show a figure with modelled versus measured values. In order to make a proper comparison you must separate a part of the data set to be used for the model parameterisation and one part for the model evaluation. A suggestion would be to use a bootstrapping simulation methodology.

Authors' response: The method comparison has been removed and the Lloyd and Taylor (1994) model was used for fitting the night-time respiration data. The modelled respiration rates correlated with the measured respiration (R^2=0.56, p-value < 0.01).

L216 Where did this suddenly come from. If you want to write a section about the effect of one point and two point measurements of the storage term this should be given a section of its own. Please clarify in the method section how the one point and two point storage terms were estimated. This has nothing to do with partitioning.

Authors' response: This paragraph was moved to the section 3.4.

Section 3.2

What about the partitioned GPP and ecosystem respiration data? Why did you not show the diurnal cycle of them? Additionally, what was the environmental variables controlling the diurnal dynamics. You set out in the introduction to investigate which environmental variables that affect the diurnal, seasonal and interannual dynamics, but there is no proper description of what controls the diurnal dynamics.

Authors' response: The diurnal cycle of GPP, ecosystem respiration and VPD was added to the section 3.2 and their relation to the diurnal cycle of NEE was analyzed.

Section 3.3

L235 Why did you analyse using monthly averages? Is there any reason for not using daily averages? A lot of dynamics can be hidden in case you average like that. How did you test for all these things that you claim? You state that rainfall and low VPD causes the seasonal dynamics, but there is absolutely no statistical tests done to show that these variables are determining the fluxes? A large part of the section is rather about interannual dynamics than about seasonal variation.

Authors' response: The kind of analysis would have been very difficult to do at daily time scale because the daily data is noisier and the data covered for three years. Linear regression analysis between NEE and the environmental variables was added to the section.

L266 from which date to which date?

Authors' response: from 1st of September to 31st of August

Why is NDVI included as an own section and not just incorporated in the other sections as an explanatory variable giving the phenology of the vegetation?

Authors' response: It is used to assess the long-term productivity at the measurement site. *"Based on the NDVI data, the year 2010-2011 represents a common pattern at this site, whereas the years 2011-2012 and 2012-2013 have lower NDVI peak values."*

L274 The Merbold study is rather in the spatial domain than in the temporal domain, and it is comparing sites from tropical rain forest to semi-arid savanna ecosystems so it is not strange that they see a spatial relation to rainfall.

Authors' response: Removed the sentence.

L275 Which results show this?

Authors' response: The sentence was removed.

What about interannual variation in respiration?

Authors' response: The relation between the annual respiration and environmental drivers was not clear.

L285 Demokeya has approximately 7% tree cover, i.e. about half of Welgegund. This is not a similar canopy cover.

Authors' response: Corrected.

L287 Why is it that NDVI over and underestimates at different parts of the season?

Authors' response: The sentence was removed.

L309 The strong grazing pressure cannot explain the difference as there is a very strong grazing pressure at the Dahra field site as well. Please see (Tagesson et al., 2016b). How come that the missing data of Tagesson et al can explain the difference between Dahra and Welgegund? The uncertainty estimates of Tagesson et al indicate that the missing data should not be a reason for huge uncertainty in the annual budgets?

Authors' response: Removed the sentence and added "The large difference in the carbon balance is due to much larger carbon uptake at Dahra during the rainy seasons which might be explained by moderately dense C_4 ground vegetation and high soil nutrient availability."

Have you tried to make any uncertainty estimate of the annual budgets?

Authors' response: New subsection about error estimation was added to the methods section and the uncertainty of annual carbon dioxide balance was estimated.

Table 1, please explain what the abbreviations under Species are? Example what does P.J.H.Hurter mean?

Authors' response: Specified. The plant species names include the name of the publishing author.

Table 3 and 4, please give exact sampling dates instead of column 1-4, it seems like Table 3 and 4 can be combined.

Authors' response: Exact sampling dates were added and Table 3 and 4 were combined.

Figure 1, please include error bars.

Authors' response: Corrected.

Figure 2. Why did you use a different point for the NDVI comparison? If this is the case, then it is more important to show the MODIS pixel surrounding that point. In case you want to present the results for all different vegetation types, please show the transects used for the vegetation samplings.

Authors' response: The NDVI for the measurement site was calculated at the 500 m pixel indicated by the red square in Figure 2. The NDVI comparison point in Figure 2 indicates the moist sandy grassland area which is not grazed. The NDVI signal between these two areas were compared.

"From September 2001 to August 2013, the yearly maximum values of the measurement site NDVI were 0.02 units smaller on average than a nearby moist sandy grassland area which is not grazed (land-use class 6 in Figure 2). This difference is most probably due to heavy grazing at the measurement site."

Figure 3 please include GPP and respiration

Authors' response: Time series of daily sums of NEE, GPP and respiration was added to the Supplement (Figure S5).

Figure 4 Why was the data binned and what was the size of the bins? When was this data used?

Authors' response: To better visualize the light response curves during the wet and dry seasons. The figure shows 2814 values and each bin has about 100 values.

Figure 5 how come that soil moisture is up to 20% during the dry season, this is very high.

Authors' response: There was a 22 mm precipitation event in 7th of June 2011. During that time the soil moisture peaked at 18 %.

Figure 6 I like this figure, except why monthly sum per hour, it is just a confusing unit. Why not hourl average, it would make more sense?

Authors' response: Correct to mean NEE for each hour of day.

Figure 7 why not include all months? Again why hourly per month. February with 28 days will be different than January just because of # of days in the month.

Authors' response: All months were included. Changed units to mean diurnal cycle of NEE.

References

Kutsch, W. L., Hanan, N., Scholes, B., McHugh, I., Kubheka, W., Eckhardt, H. and Williams, C.: Response of carbon fluxes to water relations in a savanna ecosystem in South Africa, Biogeosciences, 5(6), 1797–1808, doi:10.5194/bg-5-1797-2008, 2008.