Response to comments by Reviewer #1

A. Summary
This paper uses data from six eddy covariance flux sites distributed across the Sahel of West Africa to examine patterns in space and time of carbon fluxes (GPP) as characterized by two key canopy-scale parameters (maximum photosynthetic uptake, called Fopt in this paper, and initial quantum yield, termed alpha). The authors also explore the relationships between the two GPP parameters and a variety of satellite vegetation indices providing (in theory at least) opportunities for spatial upscaling of the site-based results. This is an interesting paper reporting useful results.

Response: Thank you very much, and also thank you for insightful comments that helped improving the manuscript.

B. Main Points
1. Regional GPP estimation. It is a pity the authors didn't take the final step to evaluate GPP across the region using the fitted models. At least, we don't see a map of these estimates, only point-based comparisons with the 6 field sites. In Section 2.4.1 the authors describe a "full model" for the regression tree used to characterize fluxes and predict Fopt and alpha at the field sites. In Section 2.4.2 they continue to describe an approach to derive parameters on a pixel-by-pixel basis where not all edaphic data (e.g. soil moisture) are available. However, we don't see the results of this analysis in the form of a map or other representation. Could this be added?

Response: We agree with the reviewer; in the previous version of the manuscript we did not include the full gridded map because the spatial up-scaling requires some very heavy computer processing. However, we have now borrowed computer power from the university, and in the revised version of the manuscript we have included a full gridded map of peak F_{opt}, peak α and an annual sum of GPP.

2. Prior work: The authors should refer to some considerable prior work that will be relevant to this analysis. See Global Change Biology 4, 523-538 (1998) and numerous HAPEX-Sahel papers in the J. Hydrology 1997 for earlier and quite detailed analysis of flux measurements in Sahelian vegetation. The GCB paper, for example, analyses Fopt and alpha as a leaf-level variable in considerable detail. Note that the canopy scale Fopt and alpha investigated here incorporate the effects of changing LAI during the season. This rather complicates the situation for this analysis, as the authors state on line 351.

Response: Thank you for this suggestion, we agree that it was a good idea to extend the comparison of the results of our analysis to the results of previously published research. This has been incorporated into the revised manuscript.

3. Peak uptake rates: the field measurements at some sites seem abnormally high. The earlier data in the GCB paper references above was for a southern Sahel site with LAI likely higher than any of these sites, but with maximum Fopt of only -15-20 umol m-2 s-1.

Response: 1) The leaf area index value of the HAPEX–Sahel West-Central fallow savanna site in (Hanan et al., 1998) is not larger than at the Dahra and Kelma sites, which are the two sites of our study with very high F_{opt} and α. Peak LAI is 2.1 for Dahra and 2.7 for Kelma, so it is considerably higher than 1.2 as given in (Hanan et al., 1998). The higher LAI can thereby explain parts of the higher F_{opt} estimates.
2) (Hiernaux et al., 2009) and (Dardel et al., 2014) showed above ground peak biomass in southwestern Niger which are comparable, and nowadays slightly lower than what is reported for the Gourma area (which in addition receives less rain).

Hanan et al 1997 (J Hydrology) report above ground peak biomass of 1000 and 1500 kg/ha for the grass and shrub fallow sites, which is much lower than what is reported for the Dahra site (Mbow et al., 2013), which also receives less rainfall. This is in line with a productivity gradient over these 3 sites, possibly caused by soil fertility and fallow management in southwestern Niger.
3) The reason for the high estimates of F_{opt} and α are the very high net CO2 fluxes measured by the eddy covariance systems. For the Dahra field site, we have performed a rigorous quality check of the data, please see (Tagesson et al., 2016) and we are certain that the measured values are correctly measured. Tagesson et al. (2016) have tried to explain the high net CO_2 flux values by that there is a combination of dense herbaceous C4 ground vegetation, high soil nutrient availability, a grazing pressure resulting in compensatory growth and fertilization effects, and the West African Monsoon bring a humid layer of surface air from the Atlantic, possibly increasing vegetation productivity for the most western part of Sahel. This info has been included in the revised manuscript.

4. Possible unit issues: this is an impertinent question, but looking at the massive multipliers between the author's estimates and independent estimates in Figures 2 (incoming PAR) and 3 (GPP) I couldn't help wondering if there might be some unit issues. In the case of PAR the conversion of PAR in W/m2 to umol m-2 s-1 varies somewhat based on solar angle and atmospheric conditions but is typically 4.2 umol/W. This is more than the 3.09 of the fitted slope, but is it really possible that the ERA PAR product is underestimating actual incoming PAR so consistently by a whopping 70% ! Similarly for Figure 3, if the MODIS product is in units of g/m2/day carbon and the authors have retained their data in units g/m2/day CO2 this would give an inherent slope in Figure 3 of 12/44 = 0.273. Again this doesn't entirely account for their calculated slope of 0.17, but might be worth double-checking.

Response: Yes, we absolutely understand your concern here, and we have been looking at these conversions many times to make absolutely sure that the conversions are correctly done:

1. **PAR values:**

The average raw in-situ PAR = 483 μmol m-2 s-1

The average raw ECMWF PAR = 350503 (J m-2 summed for 3 hours)

To get ECMWF PAR to (W m-2): raw ECMWF PAR was divided by (60sec*60 minutes*3 hours) =>
Average ECMWF PAR (W m-2) =350503/(60*60*3)= 32 W m-2.

To convert ECMWF PAR (W m-2) to μmol m-2 we multiplied with 4.57 (Sager and McFarlane, 1997):

Average ECMWF PAR (μmol m-2 s-1) =32*4.57= 148 μmol m-2 s-1

Average in-situ PAR (μmol m-2 s-1)/ Average ECMWF PAR (μmol m-2 s-1) = 483/148 = 3.2

So we think that the PAR conversion is correctly done. We recently found out that the issue is related to a major bug in the code of ECMWF surface PAR:
"The surface incident value (code 58) seems erroneously low. For example, in locations in the Celtic Sea, surface PAR is typically around 20% to 25% of the clear sky value (code 20), and about a third of in-situ measurement of surface PAR. Cause: We have shortwave bands that include 0.442-0.625 micron, 0.625-0.778 micron and 0.778-1.24 micron. PAR is coded as if it was intending to sum all of the radiation in the first of these and 0.42 of the second (to

account for the fact that PAR is normally defined to stop at 0.7 microns. However, PAR is in fact calculated from the sum of the second band plus 0.42 of the third." (ECMWF, 2016).

This indicates that the ERA-interim surface PAR product is actually not PAR, but rather incoming red and near infrared. However, we still intend to use this data source since we relate the gridded ECMWF PAR to in-situ measured PAR and used this relationship to convert ECMWF PAR to the proper level. The relationship should be ok, even if it is relating in-situ PAR to a different part of the spectrum; the final product is still PAR at a reasonable level. The issue is now described in the revised manuscript.

2. **MODIS GPP:**

An example for GPP of Agofou:

Average in-situ GPP -1.34 µmol CO2 m-2 sec-1

Convert it to g CO2 m-2 and s-1:

1 mol=44 g CO2 and micro=µ=10^{-6}

- ⇨ **Average in-situ GPP =0.000059 g CO2 m-2 s-1**

Convert it to g CO2 m-2 and 8 d-1:

8 days = (8*24*60*60) seconds

0.000059 g CO2 m-2 s-1 * (8*24*60*60)

- ⇨ **Average in-situ GPP =40.7 g CO2 m-2 and 8 day-1:**

Convert it to g C m-2 and 8 d-1:

1 g CO2 = 0.27 g C

Average in-situ GPP = 40.7*0.27= 11.0 g C m-2 and 8 day-1:

Average raw MODIS GPP for Agofou: 24.1

Scaling factor: 0.0001 =>

Modis GPP (kg C m-2 and 8 day-1)=0.00241 kg C m-2 and 8 day-1

Modis GPP (g C m-2 and 8 day-1)=0.00241 *1000 = 2.41 g C m-2 and 8 day-1.

Again, we agree that this major underestimation is strange, but we believe that all conversions are correctly done.

C. Minor Points

Line 42: While it is appropriate to mention that significant inter-annual variability in global carbon cycle arises in semi-arid regions relating to rainfall variability and fire (particularly in the mesic savannas, more so than the Sahel; eg. Williams et al Carbon Balance and Management 2007), it would be an exaggeration to state that the semiarid regions are "driving long-term trends".

Response: We agree with the reviewer that this was not a very clear sentence. But still, according (Ahlström et al., 2015) semi-arid region are driving the long term trends. We have clarified this in the revised manuscript:

"Vegetation growth in semi-arid regions is an important sink for human induced fossil fuel emissions. The mean carbon dioxide (CO_2) uptake by terrestrial ecosystems is dominated by highly productive lands, mainly tropical forests; wheras semi-arid regions are the main biome driving its inter-annual variability (Ahlström et al., 2015; Poulter et al., 2014). Semi arid regions also contribute to 60% of the long term trend in the global terrestrial C sink (Ahlström et al., 2015; Poulter et al., 2014)."

Line 52: "continuous cropping" is very rare in the Sahel (outside of areas with irrigation opportunities, anyway). In the drier northern regions pastoralist communities may attempt a dryland crop, but with little expectation of success. Even in the wetter southern Sahel where the crop site in this paper is located, most fields are fallowed. In the highly populated regions near the capital city of Niger, rotations have reduced, but it would be wrong to imply that "continuous cropping is practiced" widely.

Response: Thank you for noticing this, this sentence has been removed.

Line 107: "find evidence" is awkward here. Perhaps substitute "characterize".

Response: Yes, we fully agree. Characterize is much better. Thank you very much.

References

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