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Interactive comment on "Deriving seasonal dynamics in ecosystem properties of semi-arid savannas using in situ based hyperspectral reflectance" *by* T. Tagesson et al.

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Response to Anonymous Referee #2

The manuscript describes an interesting study using multi-angular hyperspectral data collected from a tower at a semi-arid savanna. Overall the study seems to have been undertaken in a scientifically appropriate manner and makes a valuable contribution to scientific progress. The scientific quality is high. And the presentation of the manuscript is of excellent quality.

While the data analysis is sound I have the following questions, comments and suggestions which should be addressed to improve the manuscript:

Response: We would like to take the opportunity to thank the reviewer for valuable comments that we believe helped improving the revised version of the manuscript.

The analysis of effects of varying sun / sensor geometry has been done over 15 days (of which 3 have been removed) during the peak of the growing season. This misses the highest zenith angles and times of different vegetation conditions. I suggest to repeat the analysis for other time periods as well to gain a full picture of sun / sensor geometry effects. Furthermore, why have only NDSIs been investigated and not the reflectances themselves? This information would help to understand the behaviour of the NDSIs and would support the claim in the discussion that NDSIs reduce angular effects.

Response: The reason for not doing the analysis of the varying sun/sensor conditions at the point in time with the highest zenith angles, is that this occurs during the dry season (two months prior to the onset of the growing season) where there are no vegetation (herbaceous) influencing the reflectance spectrum in the measured area. The focus of the manuscript is to investigate how NDSI is coupled with vegetation parameters, and we hence choose to use the point in time with most vegetation on the ground. We agree that it would make a very interesting study to investigate how sun/sensor geometry influences NDSI differently across the year. However, this is not a minor task and this manuscript is long as is. We therefore feel that this is beyond the scope of this manuscript. But it is a very good idea for a future manuscript to investigate seasonal dynamics in anisotropy of both the reflectance spectrum on its own and on NDSI estimates. This is something that will hopefully be possible to do in a not too distant future. The reason for focusing on NDSI, and not on the anisotropy on the reflectance values themselves is that it has already been done (Huber et al., 2014; Tagesson et al., 2015). The focus of the paper by Tagesson et al. (2015) is to present all research activities at the Dahra field site. Among them, a section of the anisotropy of the reflectance spectrum is presented. The aim of the paper by Huber et al. (2014) is to present the ASD set-up and investigate the quality of the measurements. A second aim is to study the effects of varying sun/sensor geometry on the reflectance spectrum. Therefore, in order not to present the same information two times, the effects of varying sun/sensor geometry part of this paper focus on the effects on the NDSI. However, the comment is relevant and in the revised manuscript we have included a discussion regarding the behaviour of the NDSI in relation to the behaviour of the reflectance spectrum and referred to figures in Huber et al. (2014) and in Tagesson et al. (2015).

Why has the analysis of the relationship between reflectance / NDSI and ecosystem variables been restricted to a linear relationship? E.g. other studies found a non-linear relationship between reflectance and biomass due to saturation effects. Also why have only daily median reflectances / NDSIs been used when GPP, LUE and FAPAR were daily integrals? Averages would be more appropriate in these cases. And why have the off-nadir views not been analysed?

Response: In case the linear relationship is strong, it indicates limited issues with saturation. For wavelength regions where there are issues with saturations, exponential and logarithmic regressions could fit better. However, in case the aim is to find wavelength regions which are as sensitive as possible for investigating seasonal dynamics in an ecosystem property, wavelength regions with saturtion issues should be avoided. Therefore linear models are better to use than non-linear models. This was the main reason for fitting linear rather than non-linear regressions. There is also a practical aspect to it, fitting the reduced major axis linear relationships using the bootstraping methodology required a full month of processing for these 4 variables (GPP, LUE, FAPAR and biomass). In case we would try several other regression models, these would require several months of processing. Median values were used in order to minimise the influence of errors in the analysis. Median provides the most common model output and it is thereby more robust against outliers than average values. This info was provided in the manuscript, but it was not mentioned the first time that median values were used. Thank you for pointing this out to us, it has been corrected in the revised

manuscript. We have investigated the seasonal dynamics in the off-nadir views as well, but as seen in the figure below, there was no difference in seasonal dynamics for the different viewing angles. We thereby choose to only use the nadir one, as it would not make any difference in the analysis.

Some minor more specific comments:

page 3318, line 22: “Environmental conditions” usually mean variables like temperature, humidity, rainfall, etc. Do you mean reflectance in different wavelength regions have different sensitivity to “environmental conditions”? Or do you really mean “vegetation condition”?

Response: Thank you for pointing this out. We meant variables like stand structure, health status of the vegetation, direct/diffuse radiation, vegetation and soil water content. This has been clarified in the revised manuscript.

page 3320, section 2.1: It would be good to provide some information on the height of the grasses, trees and shrubs and the tree and shrub cover to get a better idea about the vegetation structure at the site.

Response: In the revised manuscript information regarding the height of the trees and the herbaceous layer is included. Much more information regarding the footprint and the vegetation in the instantaneous field of view of the spectroradiometers are provided in the revised manuscript.

page 3320, line 6: “(3%, of the land cover)”. remove comma.

Response: This has been taken care of.

page 3320, line 12: “rainfall (mm) was measured at 2m height”. Is the height relevant? Rainfall always has to be measured with the rain gauge not obstructed by any obstacles. What would be more interesting here is to know at what interval rainfall has been collected, i.e. daily, hourly, etc.

Response: All sensors were connected to a CR-1000 logger in combination with a multiplexer (Campbell Scientific Inc., North Logan, USA) and data were sampled every 30 s, and stored as 15 minute averages (sum for rainfall). This info has been included in the revised manuscript.

page 3320, equation 1: Please define “albedo_soil”. Has it been measured?

Response: Albedosoil is defined as PAR albedo of the soil, and it has been been measured as 0.20 (Tagesson et al., 2015). This info is included in the revised manuscript.

page 3321, line 19: Please define “VPD” on first use.

Response: This has been taken care of.

page 3322, section 2.4: The authors refer to Huber et al. (2014) for more detail on the spectrometer setup. However, the manuscript should provide some of the more fundamental information: 1. Were foreoptics used? 2. What are spectral resolution and spectral sampling of the spectrometers? 3. Have the seven different viewing angles been measured simultaneously? Or has a rotating or moving head been used? Was always the same target in the field of view? Or did the target change because of the rotating head? 4. How have solar irradiance measurements been made? Transmissive or reflective diffusor? 5. If multiplexing setup how long does it take to go through a whole measurement sequence? 6. Has solar irradiance been measured for each view angle measurement separately?

Response: Thank you very much for pointing this out. Much more information about the spectroradaiometer set-up is given in the revised manuscript, including information regarding all the points raised above.

page 3322, line 22: Why have daily median reflectances been used? Why not an average over a certain time interval?

Response: As mentioned above. We consider median values being more robust as they are not as sensitive to outliers and hence less affected by errors in the data set.

page 3323, line 6: “median” over what? The 15 days?

Response: Yes the median of the 15 days. This has been clarified in the revised manuscript.

page 3323, lines 19-22: I suggest to move the last sentence to the start of the paragraph, i.e. before line 13 as the NDSI has to be calculated before the ANIF can be calculated.

Response: Thank you for this suggestion, it has been taken care of.

page 3325, line 5 + 22: Change “in the end” to “at the end”.

page 3329, line 15: Change “accurate and extra” to “additional”.

page 3329, line 25: Change “the majority” to “most”.

Response: Thank you for these suggestions, they have been taken care of.

page 3330, line 12: “Peak” suggests it is lower again at very high biomass. Rephrase.

Response: We meant that the absorption of red light saturates at higher biomass loads. This has been changed in the revised manuscript.

page 3330, lines 11-14: This is not the reason for the saturation of the NDVI. The NDVI saturates at high biomass because the NIR reflectance is much larger than the red reflectance. NDVI therefore reduces to R_NIR / R_NIR which equals 1.

Response: We agree with you, and we are talking about the same thing, we are just using different phrasing, where you consider it from an equation point of view, we consider it from a leaf optical property point of view. All vegetation indices using red will suffer from saturation problems. The reason for this is related to the fact that there are only so many photons striking a plant leaf and at a certain point, the chlorophyll absorbs nearly all the red energy to the point where no matter how much vegetation you add, more photons cannot be absorbed because they are already all absorbed. It is normally the red band that saturates. So any index using the red energy will suffer from the same limitation. For example, the Enhanced Vegetation Index (EVI) is not supposed to saturate as badly because in the equation empirical constants have been added to put more weight in the NIR spectrum that preserves sensitivity to higher loads of biomass (more layers of leafs) because here much more radiation is transmitted and reflected from the leaves.

page 3330, lines 14-17: Again this is wrong. The saturation is not necessarily reduced with narrower bands. Narrow bands might even cause saturation earlier. Saturation can be reduced by selection of bands that show a smaller difference therefore avoiding the NDVI equation becoming 1 (see above).

Response: Thank you for pointing this out for us. You are correct, it is not the narrowness of the band which results in that saturation is avoided, it is which wavelength region that is chosen. This has been clarified in the revised manuscript.

page 3331, line 17-18: "As fluorescence is competing with photochemical conversion : : :" suggests high fluorescence equals low photochemical conversion. The reality is more complex. And it looks like often the opposite is true. So either remove this sentence or formulate differently.

Response: Thank you again, this sentence is removed in the revised manuscript.

page 3331, line 19-20: ": : : should have very spectral high resolution (0.05-0.1nm)". This is not true. Fluorescence has been measured successfully with a spectral resolution of about 10nm. Whether very high spectral resolution is necessary depends on the method applied.

Response: Thank for this comment; this also explains why we see such a strong peak even though the spectral resolution of the ASDs are 3 nm. This has been changed in the revised manuscript.

page 3332, lines 1-7: The whole discussion only focuses on what is happening at the

leaf level, i.e. reduced pigment contents. What about changes in vegetation cover?

Response: Ok thanks. It has been clarified in the revised manuscript that the discussion is on the canopy level.

page 3342, Figure 2. Why are there gaps in the reflectance time series? Black vertical lines at the start and end of the rain seasons should be in all diagrams.

Response: The gaps are caused by technical issues due to loss of power supply, broken sensors or filtering of data due to bad weather conditions. This info is included in the revised manuscript. The black lines are included in all subplots in the revised manuscript.

References Huber, S., Tagesson, T., and Fensholt, R.: An automated field spectrometer system for studying VIS, NIR and SWIR anisotropy for semi-arid savanna, Remote Sens. Environ., 152, 547–556, 2014. Tagesson, T., Fensholt, R., Guiro, I., Rasmussen, M. O., Huber, S., Mbow, C., Garcia, M., Horion, S., Sandholt, I., Rasmussen, B. H., Göttsche, F. M., Ridler, M.-E., Olén, N., Olsen, J. L., Ehammer, A., Madsen, M., Olesen, F. S., and Ardö, J.: Ecosystem properties of semi-arid savanna grassland in West Africa and its relationship to environmental variability, Global Change Biol., 21, 250-264, doi: 10.1111/gcb.12734, 2015.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/12/C1836/2015/bgd-12-C1836-2015-supplement.pdf

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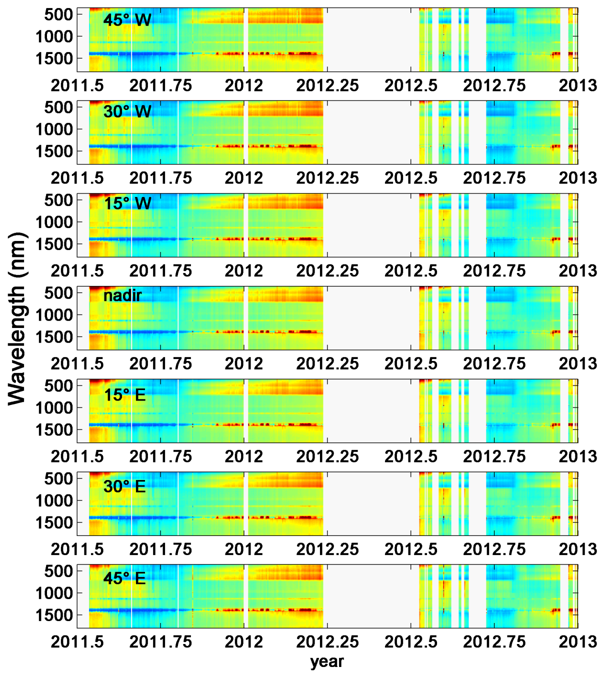
45° W
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15° W
nadir
15° E
30° E
45° E
500
1000
1500
Wavelength (nm)
2011.5
2011.75
2012
2012.25
2012.5
2012.75
2013
year

Fig. 1.