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**Title: Mapping trends in woody cover throughout Namibian savanna with MODIS seasonal phenological metrics and field inventory data**

**Author(s): Vladimir R. Wingate et al.**

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**MS Type: Research article**

Dear Ms Töper, dear Ms Rammig,

We are grateful for the opportunity to resubmit a revised version of our paper “Mapping trends in woody cover throughout Namibian savannah with MODIS seasonal phenological metrics and field inventory data”, and would like to thank you for your assistance in the submission process. We would also like to thank the anonymous reviewer for providing a very constructive review that has resulted in a strengthened manuscript.

Please find attached a response to the reviewer comments, which provides a point-by-point response to each of the referee’s comments, and where we have endeavoured to concisely address each point raised.

The manuscript has undergone the Major and Minor Revisions suggested by the reviewer, including the re-structuring sections, the correction of figures and alteration of text. These changes are noted in the response file (below) together with the page and line number, and are highlighted in yellow.

Since every review comment was highly appropriate and valuable, we have followed the recommendation of the reviewers as much as possible.

I hope that you continue to find this research engaging and much look forward to hearing back from you in due course.

Best regards,

Vladimir Wingate

On behalf of Prof Nikolaus Kuhn, Prof Stuart Phinn, Dr Cornelis van der Waal

# Interactive comment on “Mapping trends in woody cover throughout Namibian savanna with MODIS seasonal phenological metrics and field inventory data” by Vladimir R. Wingate et al.

**Anonymous Referee #1**

Received and published: 20 March 2019

I think this is an interesting topic but the current weak structure, somewhat sloppy writing and lacking information makes the reporting of the study weak, even if it may be OK when done. In general consider the following points for major revisions before it can be reconsidered.

* Don’t write longer than needed. Keep it precise, clear and brief.

As per the reviewers suggestions (minor revisions), certain sentences and words have now been omitted.

* Make sure the methods are described in such detail that an informed colleague can repeat the study based on the information provided in the met-section. This is not the case at the moment.

As per the reviewers recommendations (minor revisions), the Methods section has now been amended in order that the study may be repeated in full.

* Use SI units

Since the spatial resolution of Corona imagery was report in feet on the USGS Earth Explorer websites, the authors have chosen to retain the original unit.

Please refer to this website: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-declassified-data-declassified-satellite-imagery-1?qt-science_center_objects=0#qt-science_center_objects

* Better illustrations and captions needed. The reader should be able to get the context by looking at the figure and reading the caption, with no need to consult the bulk text. Examples: Figure 3. Explain abbreviations used in figures (DSINT etc.) Figure 4. Replace x and Y with real variables and units. Confidence interval for the regression line? Figure 5. Percentage tree cover range from 0-0.8% i.e. very low. Should be 0-80%? Figure 6. Add units to the colour bars (Slope%, woody cover %) Figure 7. Unclear content and message.

Figure 3: captions have now been expanded as per the reviewers recommendation, and now reads: “Figure 3. Predictor variable importance (2008) generated using the Random Forest algorithm, evaluated using Mean Standard Error (MSE) (a) and node purity (b): here, predictor variables associated with woody vegetation are consistently (i.e. DSINT) are consistently more importance that those associated with herbaceous vegetation (MaxWS). In addition, Mean coefficient of variation is mapped for the study area, and revealing greater uncertainty in arid coastal regions.”
Figure 4: x and y axes have now been replaced with real variables as per the reviewers suggestion, in addition, a confidence interval (0.95) has been included for the regresdsion line.

Figure 5: Percentage tree cover range has now been modified to 0-80% as per the reviewers recommendations.

Figure 6: Units and colour bars (Slope%, woody cover %) have now been added as per the reviewers recommendations and read: “Slope% km2 yr-1.”

Figure 7: Unclear content and message:

As per the reviewers recommendations, the caption has been developed to better describe the content and message of Figures 7 and 8.

P20L1: The text now reads: “Figure 7. A qualitative assessment of what the observed trends represent on the ground, in terms of land cover changed, was undertaken by visual assessment of multi-temporal, high resolution imagery and random sampling. Here, a randomly sampled point for an area exhibiting a significant negative slope (≥-25%) is presented and found to manifest as land clearing for small-scale agriculture and indicative of direct land cover change. These are identified using a 1972 Corona image (a) and a 2010 aerial othrophoto (b).”.

P22L1: Figure 8. A qualitative assessment of what the observed trends represent on the ground, in terms of land cover changed, was undertaken by visual assessment of multi-temporal, high resolution imagery and random sampling. Here, a randomly sampled point for an area exhibiting a significant positive slope(≥25%) is presented and found to manifest as no apparent change that can be identified from a 1972 Corona image (a) and a 2010 aerial othrophoto (b). Results may be indicative of indirect change.

* Let each section (Methodology, results etc.) contain information related to that section only, i.e. don’t mix methods and background etc.

As per the reviewers suggestion, certain paragraphs and sections found on the methods which give background information have been moved to the Introduction section, specifically, the following paragraph introducing trend analyses using EO data was moved to the introduction P2L18: “Key aspects surrounding trend estimation from Earth Observation (EO) time-series include temporal and spatial resolution, as well as data quality (Badreldin and Sanchez-Azofeifa, 2015; Sulkava et al., 2007). Although trend estimation using linear regression analysis is widely employed, it contravenes several statistical assumptions (deBeurs and Henebry, 2004; Eklundh and Olsson, 2003). Hence, non-parametric tests which overcome these limitations were applied (i.e. Mann-Kendall and Median Theil Sen trend analyses) (deBeurs and Henebry, 2004; Forkel et al., 2013). Furthermore, limitations are incurred by temporally aggregating, for example, to the annual scale, by diminishing temporal resolution. On the other hand, annual aggregation may strengthen trend analysis by eliminating seasonal cycles, which have been found to add seasonal correlation structures and thus augmenting uncertainties (Forkel et al., 2013).”.

* Provide some justification for using NDVI and what it measure, Saturation effects due to higher LAI etc. Why not EVI or PPI?

As per the reviewers suggestions, the authors have elaborated on the justification for using NDVI and what it measures. Spefically:

L5P3: This sentence now reads “These indicators are often derived from spectral vegetation indices of satellite imagery, which are related to the vegetation density of canopies”.

The issue of NDVI saturation is occurring at higher LAI is not applicable to this study, although this issue is discussed in L33P27.

We now address why NDVI was used rather than EVI:

P3L8: For this study, the authors have chosen to use NDVI rather than the Enhance Vegetation Index (EVI), since it has been shown to effectively capture vegetation density in savannah environments (Brandt et al., 2016a; Olsson et al., 2005; Wagenseil and Samimi, 2007).

Some additional comments in attached PDF

L18P2: scale is not suitable (1:1000 is a scale). Perhaps "extent"?

This sentence has been changed as per the reviewer’s recommendation.

“Thus, there is an inadequate understanding of the extent of woody vegetation change in relation to environmental and socio-economic and environmental drivers”.

L27P2: Unclear. What is VHR? Spatial resolution? Temporal resolution? spectral resolution? Specify.

This sentence now reads: “These products use very high spatial resolution scenes to train a vegetation cover algorithm based on high to moderate resolution imagery”.

L5P3: What is photosynthetic potential? Define. What about NDVI saturation occurring at higher LAI? Can it be a problem here?

L5P3: This sentence now reads “These indicators are often derived from spectral vegetation indices of satellite imagery, which are related to the vegetation density of canopies”.

The issue of NDVI saturation is occurring at higher LAI is not applicable to this study, although this issue is discussed in L33P27.

L29P3: Ref to support this?

This sentence now reads: "For example, a pre-rainfall leaf flush and synchronized flowering is commonly observed in three tree/shrub species which are widespread in the northeast, in particular, Terminalia sericea, Ochna pulchra and Pterocarpus angolensis (Childes, 1988)".

L1P4: Unclear which literature support these statements.

The following references have now been included: "The annual growth of herbaceous biomass relies on the first precipitation events to initiate photosynthesis and remains photosynthetically active during the rainy season, as it is largely dependent on the spatio-temporal distribution of annual precipitation (Mendelsohn and el Obeid, 2005a). Senescence of herbaceous vegetation then takes place at the onset of the dry season once the plants have completed their annual life cycle, while in addition, intense grazing pressure throughout the country contributes to promptly grazing the pasture throughout much the country (Mendelsohn and el Obeid, 2005a). Importantly, this results in woody vegetation remaining photosynthetic during part of the year, while herbaceous vegetation is entirely desiccated (Verlinden and Laamanen, 2006b)."

1.3 Aims: Le this section include the aim only. Add the motivation above.

As per the reviewrs suggestion, this section has been renamed to "Motivation and aims".

L29P4: extent

"Regional scales" is acknowledged by the authors to be accepted terminology in global ecological studies, and has therefore not been changed, please refer to this article: http://science.sciencemag.org/content/241/4873/1613

L32P4: reviewer deleted: "In addition, vegetation change processes, including deforestation and woody encroachment are reported to be widespread in Namibia, yet their spatial and temporal dynamics remain little studied.".

This sentence has now been removed as per the reviewer suggestion.

L6P8: Give enough details on the S-G filter that it can be repeated by another user.

L8P8: This sentence now reads: “A Savitzky-Golay (SG) smoothing filter was then applied (using the default SG filter settings available in TIMESAT) to each pixel of the time-series to interpolate missing values, smooth outliers and minimize the effects of low quality data resulting from noise and cloud cover, and the time-series was aggregated to mean monthly values”.

L6P8: THeera re some issues with the quality data according to https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod13q1_v006

Known Issues

The following issues have been detected:

Unexpected missing data in the last cycles of each year.

Incorrect instances of "NoData" and spikes in NDVI values.

VI Usefulness Bits are not correctly assigned.

For instances where the VI Quality (bits 0-1) is flagged as good and the VI Usefulness (bits 2-5) indicates the same pixels have the lowest usefulness score, users are advised to disregard the usefulness score.

Corrections will be implemented in Collection 6.1 reprocessing in 2019.

Make sure the Quality data handling is clear enough so it can be repeated based on provided information. Provide some detail on the processing of the QI data.

L7P8: This issue has now been addressed: “Pixels flagged as low quality were masked; here, only values with a pixel reliability summary QA of 0 were used (where is equal to good data which can be used with confidence).

Why was not EVI used/tested?

It has frequently been shown to perform better than NDVI in semi arid regions.

For this study, the authors chose to use NDVI, since it is still frequently used to monitor vegetation change globally using MODIS, in addition, it allow for comparison with previous studies.

L21P8: reviewer deleted “values”

P8L19: This sentence now reads: The post-processing and sampling effort was also different for the 2016 dataset, in which data were processed to fractional cover.”

L5P9: And how was this homogeneity assessed? Visual inpsection?. It is very hard to select a homogenous are for a 250x250 meter pixel when on the ground, at least if there are trees and shrubs in the area. Describe.

This sentence now reads: “We justify this assumption since the field plots were sampled in homogenous vegetation strata (Baccini et al., 2007). Homogeneity was assessed via visual inspection

of high resolution imagery and where possible extensive field observations of vegetation cover and composition"

L8P9: Give URL, ref and data set used. Valid for which time period?

P9L8: This sentence now reads: "Biomes distribution was downloaded from the Food and Agricultural Organization Global Forest Resources Assessment (http://www.fao.org/3/ad652e/ad652e00.htm); for Namibia, they comprise tropical desert, tropical dry forest, tropical mountain system and tropical shrub land, the latter two being very similar (Simons et al., 2001)."

L10P9: Population density for which time period)s)?

L9P10: This sentence now reads: "Population density data were obtained from the Worldpop, high resolution global gridded dataset at 100 m resolution, which gives an estimation of the number of people per km2 in 2015 (Lloyd et al., 2017)"

L17P9: give resolution im as well. The homepage (https://climatedataguide.ucar.edu/climate-data/cmorph-cpc-morphing-technique-high-resolution-precipitation-60s-60n) says 0.25X0.25 deg.

L9P16: This sentence has been changed to: "Monthly precipitation was computed using the Climate Prediction Center Morphing technique (CMORPH) dataset, in which precipitation estimates are from satellite-derived passive microwave and infrared data, and available at a resolution of 0.25° (Joyce et al., 2004)."

L18P9: how? Reference period? (anomalies)

L18P9: This sentence now reads: "The CMORPH dataset was aggregated to mean annual values and converted to anomalies, based on the overall mean of the time-series."

L19P9: with data for the same year or lagged?

P9L18: This sentence now reads: "To evaluate the correlation between rainfall and modelled woody cover, the CMORPH anomalies time-series was regressed, as the independent variable, against the time series of annual percentage woody cover anomalies (no time lag were used)".

L17P10: reviewer deleted Eklundh reference.

L17P10: As per the reviewers suggestion the Jönsson and Eklundh et al has now been removed.

L25P10: reviewer deleted "two accuracy metrics, namely, the"

L27P10: As per the reviewer suggestion, this sentence now reads: "The paired observed and predicted values were used to compute the Root Mean Squared Error (RMSE) and the coefficient of determination (R2) (Stehman et al., 2012; Willmott, 1982)

L3P11: And how many of these are located in Namibia? (sample plots Bastin)

All sample plots are located in Namibia.

This has now been specified in the text:

L5P11: “Finally, model predictions were compared to the recently published 4,684 sample calibration/validation dataset of percentage tree cover from Bastin et al. (2017) (all plots located in Namibia)”

L27P11: describe how this was done (how we converted to anomlaies)

The anomalies calculated the deviation from the mean.

P11L29: This has now been specified in the text: “The time-series was first converted to anomalies (deviation from the mean) before applying the trend analysis (Eastman, 2009).

L17P12: This need to be clarified. (1000*1000)/(250*250) = 16, not 1.6?

Equation should read: 100, 0000, and the expansion factor should be 16.

In consequences, the necessary amendments have been made throughout the text and tables.

L25P12: per year?

This sentence has been changed and now clarifies that:

P12L25: “Two classes were created representing areas mapped as either positive or negative trends, with slopes ≥25% (≥-25%), using the final Theil-Sen slope image.”

In addition, the “%” in (≥-25%) has now been included.

L26P12: Please useSI units-

Since the spatial resolution of Corona imagery was report in feet on the USGS Earth Explorer websites, the authors have chosen to retain the original unit.

Please refer to this website: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-declassified-data-declassified-satellite-imagery-1?qt-science_center_objects=0#qt-science_center_objects

L1P13: this term is not mentioned before and not in the met section. What is it. Explain and define. Does it include MSE and Node purity? How? (predictor layer importance).

Predictor variable importance evaluation is introduced in the Results section 2.9 Model accuracy and comparison: “Two measures are used to assess predictor variable importance, including percent increase in Mean Standard Error (MSE) following random permutation, and increase in node purity resulting from all the splits in the forest based on a particular variable, as computed using the gini criterion (please refer to Breiman, 2001 for details).”

L6P13: What is the difference between variable importance and predictor importance? Explain.

This sentence has now been changed to: “predictor variable importance”

This sentence now reads: “Predictor variable importance (2008) is plotted in (Figure 3); two measures are used to assess predictor variable importance …”

L7P13: Explain and define. (gini)

This sentence now reads: "…and increase in node purity resulting from all the splits in the forest based on a particular variable, as computed using the gini criterion (please refer to Breiman, 2001 for details)"

Figure 3 P13: Label subfigs a,b,c so they can be identified.

Labels in the sub-figure have now been changed as per the reviewers suggestions.

Figure 4: observations >10% wooduyt cover was removed? Not visible here. Add 1:1 line and make the graph quadratic so

This should read: observations >1% removed.

P8L24: This sentence now reads: Samples with a measured percent woody cover <1% were excluded (n=25) from this analysis in order to apply log transformations, which otherwise would have resulted in negative values, this resulted in a total of 458 available for model calibration.

L4P14: Figure 4 reports and R2 of 0.467!? And RMSE of 14.47%

This sentence now reads: "Figure 5 illustrates the linear relationship between percentage woody cover at 5% increment classes (2016), and percentage tree cover, yielding an R2 of 0.77 and an RMSE of 3.94%"

Figure 5: this is a very low percentage with max at 0.8% Should be 80%?

Figure has now been updated and reads 80%

L6P15: How is this to be interpreted? [% km2 yr-1]

Slope (percentage change in NDVI) per Km2 per year)