

1 We appreciate the comments and suggestions from two referees on our manuscript “MODIS vegetation
2 products as proxies of photosynthetic potential: A look across meteorological and biologic driven
3 ecosystem productivity”. These have greatly contributed to improved scientific rigor and clarity and
4 have enriched the presented discussion. We have addressed all comments and proposed significant
5 changes to the manuscript, in particular to the Introduction and Conclusion sections, details follow:

6

7 **Reviewer 2.**

8 General comments: The authors tested whether seasonality of GEP and photosyn-
9 thetic potential could be captured by MODIS VIs, GPP, LAI and FPAR products across
10 four Oz flux towers. Although this is an important topic to link satellite remote sensing
11 data with in-situ land surface observations, I found this manuscript requires substantial
12 improvements.

13

14 The authors should stress the novelty of this manuscript and make a compelling con-
15 clusion. The authors showed a series of figures and tables, which did not converge
16 towards conclusion which is actually unclear. I think the conclusion is that MODIS V
17 captured seasonality of GEP when key meteorological variables and vegetation phe-
18 nology were synchronous. If this is the conclusion, this is not new as reported from a
19 series of previous papers (e.g. Gamon et al., 1995 Ecological Applications). If this is
20 not the conclusion, then the authors failed to deliver clear, compelling conclusion. Also
21 I see there is no clear linkages between the title (MODIS VI as proxies of photosynthetic
22 potential...) and conclusion.

23

24 R2C01: We propose changes to our Conclusions section (see at the end of this response) to highlight
25 the originality and emphasize the compelling nature of our research and findings of the manuscript, that
26 include the following:

27

28 1. Our results revealed three different environmental conditions, to be viewed as a continuum,
29 consisting of (1) primarily meteorological-driven (solar radiation, air temperature and/or precipitation)
30 systems (e.g. sclerophyll forests), with no statistically significant relationship between *GEP* and
31 satellite derived measures of greenness; (2) biologically-driven ecosystems, where changes in the

1 vegetation status represented by tower based measures of photosynthetic capacity drive *GEP* (e.g.
2 tropical savannas); and (3) locations where meteorology and vegetation phenology are synchronous
3 (e.g. *Acacia* woodland).

4
5 2. In contrast to past and current literature studies that link ecosystem productivity (*GEP*) and VIs at
6 phenologically driven ecosystems (Chen et al., 2004; Guan et al., 2015; Huete et al., 2008; Maeda et al.,
7 2014; Rahman et al., 2005; Toomey et al., 2015), we argue that satellite derived biophysical measures
8 and other greenness indexes are not a measure of *GEP*; but rather a proxy for ecosystem structure (e.g.
9 leaf area index - quantity of leaves) and function (e.g. leaf level photosynthetic assimilation capacity -
10 quality of leaves). Our results should extend to other greenness measurements from remote sensing
11 sensors, including phenocams, satellites, and *in situ* spectrometers.

12
13 3. We propose the parameterization of the light response curve from EC fluxes as a novel tool to obtain
14 measures of photosynthetic potential (a proxy for vegetation structure and function) as the appropriate
15 link to satellite derived measures of greenness. We find VIs to be statistically correlated to long term
16 measures of phenology such as *Pc* and *LUE* rather than to variables subject to the short term responses
17 to environmental conditions (e.g. *GEP* at saturation, GEP_{sat} and quantum yield, α). This has important
18 implications for earth system models that rely on RS products to determine maximum *GEP* (GEP_{max} -
19 the GEP_{sat} in our study) or quantum yield (α), as they may misrepresent vegetation seasonality and
20 phenology.

21
22 4. We identified the main seasonal drivers of productivity over four key ecosystem types: vegetation
23 structure and function, meteorology, or a combination of both. Moreover, we included ecosystems
24 where the MODIS *GPP* product has been questioned for not being able to capture the absolute value of
25 *GPP*, its' annual cycle, or in getting the right answer for the right reasons (Kanniah et al., 2009;
26 Leuning et al., 2005). We quantified how much of the *GEP* seasonality could be explained by different
27 variables (incoming radiation, temperature precipitation, or vegetation status) and then presented
28 seasonal profiles that showed when vegetation photosynthetic potential and climate were synchronous
29 or out-of-phase.

30
31 5. We used satellite derived vegetation indices and meteorological variables rather than *in situ*

1 measurements; therefore, our findings (e.g. regressions) can be extrapolated to regional and continental
 2 scales.

3

4 6. Reviewer 2 is correct in pointing out that our findings build upon previous work by Gamon et al.
 5 (1995) and others (Huete, 2012; Peng and Gitelson, 2012; Sims et al., 2006); however, there are clear
 6 differences between our approach and Gamon et al. (1995) (see Table 1 of this response for a cross-
 7 study comparison).

8

9 Table 1. Differences between Gamon et al. (1995) and Restrepo-Coupe et al. (2015)

10

	Gamon et al. (1995)	Restrepo-Coupe et al. (2015)
Time period	1-year	EC: 3+ years RS: 15+ years
Spatial scale	In situ measurements	250+ m
Proxy for photosynthetic potential and activity (method)	<ul style="list-style-type: none"> • Leaf-level photosynthetic activity (<i>A</i>): gas exchange • LAI, biomass: biometry 	Parameterization of the EC light response curve
	<p>Note that the leaf level <i>A</i> measurements presented by Gamon et al were scaled up to represent the ecosystem. Scaled <i>A</i> and <i>GEP</i> may or may not be related as other ecosystem components, different from leaves can contribute to <i>GEP</i> (e.g. soil biological crusts, branches), which can be significant (e.g. semi-arid ecosystems). Methodologically, <i>A</i> is a time intensive measurement and requires a high sampling that includes leaves from different age cohorts, canopy levels (shaded versus full light) if been used to scale to ecosystem level.</p>	
Vegetation indices and other photosynthetic potential drivers	<i>NDVI</i> and simple ratio (<i>SR</i>) (portable spectroradiometer	<i>NDVI</i> , <i>EVI</i> , <i>LAI_{MOD}</i> , and <i>fPAR_{MOD}</i> (remote sensing -

(method)	sampled to mimic AVHRR reflectances)	MODIS). Satellite derived meteorological variables: LST_{day} , SW_{down} and $Precip_{TRMM}$.
Measures of productivity	NPP (restricted to above ground primary productivity). Later scaled to represent green leaf fraction.	GEP : photosynthetic activity. Includes above and below ground primary productivity and CO_2 used on photorespiration (Waring and Running, 1998).
Findings	The ability of $NDVI$ to predict A is linked to a LAI threshold. Where at sparse canopies, $LAI < 2$, $NDVI$ is highly correlated to A . In contrast, at high LAI ecosystems, $LAI > 2$, $NDVI$ was insensitive to canopy structure.	We argue the ability of VIs to represent GEP is restricted to those sites where phenology is synchronous to photosynthetic activity. Thus, in sites where photosynthetic potential was asynchronous or aseasonal to meteorological drives, RS products were unable to explain GEP independently of site biomass or LAI .
	Highest correlation between $NDVI$ and maximum daily photosynthetic rates.	We found the short term response of the ecosystem (e.g. restricted by high values of VPD) showed lower correlations (GEP_{sat} a proxy of maximum daily photosynthetic rates) compared to other measures of potential (LUE and Pc).

- 1
- 2 The role of photosynthetic potential is unclear. In Abstract, the authors stated
- 3 "...through comparisons of ecosystem photosynthetic activity (GEP) and potential (e.g.

1 ecosystem light use efficiency and quantum yield) with MODIS vegetation satellite
2 products...”;
3 however, the authors did not report anything related to photosynthetic potential in the abstract.
4

5 R2C02: We will modify the Abstract to distinguish ecosystem photosynthetic activity from measures
6 of potential addressing the reviewer's comments (see at the end of this response).
7

8 We used the term photosynthetic potential to refer to four variables obtained from the light response
9 curve parameterization: ecosystem light use efficiency (*LUE*), photosynthetic capacity (*Pc*), *GEP* at
10 saturating light (*GEP_{sat}*), and quantum yield (α). These variables were calculated to remove the effect
11 of day length, changes in radiation environment, cold/warm periods, among other non-optimum
12 meteorological conditions from *GEP* (*Pc* and *LUE*), or to normalize the conditions under which the
13 measurements are made (e.g. α as indicator of vegetation response under diffuse radiation) –thus, they
14 represent the canopy's ability to do photosynthesis independently of the meteorological conditions (see
15 Section 2.2.3.).
16

17 In TBR site, EVI did not agree well with *GEP* (Figure 5). Then the authors compared EVI with
18 photosynthetic potential in Figure 6, which again did not show correlation between EVI and
19 photosynthetic potential in TBR site. Thus photosynthetic potential did not provide any insight to
20 understand why EVI failed to capture seasonality of *GEP* in this site.
21

22 R2C03: At the evergreen wet sclerophyll forests, there were no relationships between *GEP* and
23 satellite derived measures of greenness (e.g. *GEP* and *EVI_{SZA30}*, $R^2 < 0.01$ and $p = 0.93$, Figure 5b).
24 However, p-values showed that the regression between *Pc* and *EVI_{SZA30}* and *NDVI_{SZA30}* were
25 statistically significant and that the null hypothesis was false -the relationship is not the result of chance
26 ($R^2 = 0.16$, $p < 0.01$; Figure 6 and Supplement Table 4). Low R^2 values can be explained by the small
27 dynamic range of both seasonal measures of photosynthetic potential and *EVI_{SZA30}* (cf. Figure 4 and
28 Figure 6). Moreover, we showed how at this site incoming solar radiation explained 60% and a multi-
29 linear model driven by *SW_{down}* and *EVI_{SZA30}* explained 70% of the variability in *GEP*, indicating that
30 this is a meteorological driven ecosystem.
31

1 Across sites we observed strong correlations among VIs and P_c . The positioning of each ecosystem
2 along a continuum of MODIS-derived variables representing phenology confirms the usefulness of
3 satellite products as representative of vegetation structure and function.

4
5 The title says “MODIS vegetation products as proxies of photosynthetic potential”; however, the
6 abstract did not tell anything about photosynthetic potential and the conclusion included only a bit,
7 which was marginal.

8
9 R2C04: We propose to modify the Abstract (highlighted in yellow) to clearly define photosynthetic
10 potential as parameters of the light response curve, thus, to address the reviewer's comment:

11
12 “... In this study, we re-evaluate the connection between satellite and flux tower data at four contrasting
13 Australian ecosystems, through comparisons of ecosystem photosynthetic activity (GEP) and measures
14 of potential (via parameterization of the light response curve: ecosystem light use efficiency (LUE),
15 photosynthetic capacity (P_c), GEP at saturation (GEP_{sat}), and quantum yield (α) with MODIS
16 vegetation satellite products, including VIs, gross primary productivity (GPP_{MOD}), leaf area index
17 (LAI_{MOD}), and fraction of photosynthetic active radiation ($fPAR_{MOD}$). We found that satellite derived
18 greenness products constitute a measurement of ecosystem structure (e.g. leaf area index - quantity of
19 leaves) and function (e.g. leaf level photosynthetic assimilation capacity - quality of leaves) **represented**
20 **by P_c and LUE , rather than GEP ...**”

21
22 Inconsistent terms should be corrected. I found photosynthetic potential is unclear and
23 confusing.

24 R2C05: We propose to modify the Introduction text to address the reviewer's comment

25
26 “Our second objective was to derive **using the light response curve** different ground-based measures of
27 vegetation photosynthetic potential: quantum yield (α), photosynthetic capacity (P_c), GEP at saturation
28 light (GEP_{sat}), and ecosystem light use efficiency (LUE) in an attempt to separate the vegetation
29 structure and function (phenology) from the climatic drivers of productivity. **We explored the**
30 **seasonality of the four measures of photosynthetic potential (α , P_c , LUE , GEP_{sat})** and aimed to
31 determine if EVI was able to replicate absolute value and **their annual cycle** rather than photosynthetic

1 activity (*GEP*), based on linear regressions....”

2
3 The authors used this term to indicate LUE and quantum yield (P2 L7-8)
4 or LUE, quantum yield, GEPsat, and Pc (P11 L11). I think “potential” is not related to
5 LUE; probably, it might be related to LUEmax. In P16 L6, the authors defined poten-
6 tial as “biophysical drivers of productivity”, which seems not related to GEPsat or Pc.
7 Ecosystem photosynthetic activity is another confusing term. It corresponded to pho-
8 tosynthetic activity, productivity, or gross ecosystem productivity (*GEP*). I recommend
9 using *GEP* consistently across the manuscript.

10
11 R2C06: *GEP* and photosynthetic activity are currently used synonymously in the literature. At times,
12 in the text we used photosynthetic activity to differentiate the term from photosynthetic potential by
13 indicating that one is the ability to do photosynthesis (potential) and differs from the activity (the result
14 of radiation, H₂O, and CO₂ used by the vegetation to attain carbon uptake).

15
16 Uncertainty in photosynthetic potential should be incorporated. Fig 2 clearly shows the
17 relationship between PAR and *GEP* is not straightforward. I can see all parameters
18 (quantum yield, GEPsat, Pc, and LUE) showed large variability around the mean values. The
19 uncertainties in each parameters might explain little correlation between EVI
20 and photosynthetic potential in TBR site, and might help better interpret Fig 6.

21
22 R2C07: Uncertainty in estimates of photosynthetic potential and RS products were incorporated by use
23 of Type II linear regressions that account for uncertainty in both variables. We propose to add the
24 following text in Section 2.5 (highlighted in yellow) to address the Reviewer's comments

25
26 “We fitted Type II (orthogonal) linear regressions that account for uncertainty in both variables
27 (satellite and EC). We obtained an array of very simple models of productivity and photosynthetic
28 potential...”

29
30 Please note we present confidence intervals (CI) for all coefficients used on the regressions (Table 3)
31 and other measures of statistical significance (e.g. AIC) to determine if the RS greenness indices

1 represent the absolute value, the amplitude and timing of the seasonal cycle, rather than assuming non
2 uncertainty. on the parameterization of the light response curve or the satellite product.

3
4 MODIS LST suddenly appeared in Fig 7 and 8. I understand the authors used LST
5 which could constrain GEP reported by Sims et al.; however, it is out of context. See
6 the title again: “MODIS vegetation products as proxies of photosynthetic potential.”

7
8 R2C08: We understand the concerns of the reviewer, thus as incorporating LST_{day} versus P_c may
9 distract the reader from one of the key objectives of the study -to demonstrate RS greening indices to
10 be measurements of photosynthetic potential. We propose to modify Fig. 8 by removing the
11 corresponding panel LST_{day} versus GEP .

12
13 Specific comments:

14 P2 L2: measured -> estimated

15
16 R2C09: Done

17
18 P2 L10-12: I do not think the authors provided results on this argument. I expected
19 comparison between in situ LAI with satellite greenness index, and between in situ
20 V_{cmax} or A_{max} with satellite greenness index.

21
22 R2C10: LAI measurements at a temporal resolution longer than a year (i.e., seasonal) are difficult to
23 obtain due to missing periods and restricted access to some of our remote sites. We wish to emphasize
24 that is not merely the ‘quantity’ of leaves, but rather, jointly ‘quality’ (e.g. leaf-level photosynthetic
25 capacity) and ‘quantity’ (e.g. LAI) that drives the potential of the ecosystem to do photosynthesis.

26
27 We understand the parameterization of the net CO_2 assimilation rate (A) versus leaf internal CO_2
28 concentrations (C_i) represents the mechanistic basis behind many plant physiology models, and their
29 parameterization (e.g. via maximum Rubisco activity or V_{cmax}) is key in determining the effects of
30 elevated atmospheric CO_2 concentration on growth (Harley et al., 1992; Medlyn et al., 1999).

31 However, scaling from leaf to ecosystem introduces additional uncertainty and assumes sufficient

1 sampling from leaves from different species, age cohorts, and canopy levels (shaded versus full light).
2 Moreover, at woodland and savannas, C3/C4/base soil percentage cover changes over the year
3 increasing the difficulties of scaling up leaf-base measures. Some of the site locations are remote and
4 difficult to access, thus leaf-measurements may be only available for a few periods of the year. Our
5 study takes advantage of available eddy covariance data, as it offers *continuous ecosystem level* data.

6
7 P3 L25: x -> multiplication symbol

8

9 R2C11: We used \times as multiplication symbol throughout the document

10

11 P11 L25: GEP to PAR -> GEP to APAR?

12

13 R2C12: $LUE = GEP/PAR$

14

15 Please see response to Reviewer's comments R1C07 for an extended discussion.

16

17 P13 L16: Eq 3 was not related to filtering.

18

19 R2C13: Manuscript needs to be corrected, should have stated Eq 8.

20

21 P14 L6-16: I am curious why the authors used coarse resolution satellite estimates of SW and
22 precipitation instead of tower based observations.

23

24 R2C14: Our intent is to construct relationships that can be scaled to regional and continental scale;
25 therefore, we used satellite derived meteorological variables: SW_{down} , precipitation and LST_{day} . We
26 propose the inclusion of text to the Section 2.3.2. (highlighted in yellow) to address the Reviewer's
27 concern:

28

29 "...No quality control was performed on the rain ($Precip_{TRMM}$) or short wave (SW_{CERES}) satellite derived
30 time series. We used satellite derived meteorological variables instead of in situ measurements as the
31 independent variable in GEP models (see Section 2.5), thus, our findings (e.g. regressions) can be

1 extrapolated to regional and continental scales.”

2

3 P19 L27: remove a comma

4

5 R2C15: Done.

6

7 P28 L20-22: This conclusion is not true in TBR site which showed EVI did not correlate
8 with LUE and Pc.

9

10 R2C16: Please refer to R2C03 of this response.

11

12 P43 Figure 2 caption: define Pc. Also, remove the equation of Pc in the figure which
13 disrupts readership. The colors of dots look different. If this is true, then define; other-
14 wise, use one colour.

15

16 R2C17: Please see uploaded figure

17

18 P44 L5: There was no “grey dashed line” in the figure

19

20 R2C18: Please see uploaded figure

21

1 **Reviewer 1.**

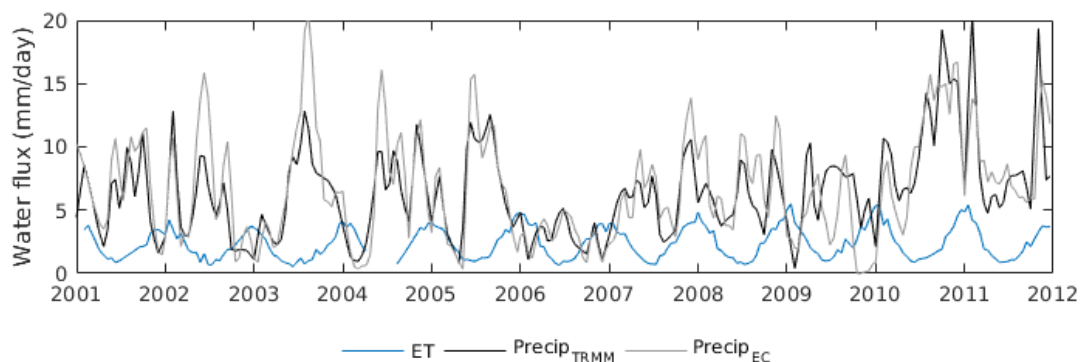
2 The authors investigate the potential of MODIS vegetation indices (VIs) to predict gross primary
3 production in semi-arid ecosystems of Australia. This is an important topic
4 since GPP of such ecosystem types are indeed difficult to capture by VIs and this
5 deserves an in depth analysis. Overall, the paper contains several interesting aspects
6 that are worth being published. But I agree with referee #2 that the manuscript requires
7 substantial sharpening and streamlining.

8

9 The first objective was ‘to gain understanding of ecosystem behaviour’ but it is not clear
10 what is meant by that. In that regard I had expected more insights on the role of **water limitation** (VPD
11 and soil moisture) on GPP and to what extent VIs can capture that
12 or not. Water limitation is in my view perhaps the most critical point on why VIs may
13 not ‘see’ the productivity response properly.

14

15 R1C01: We appreciate the reviewer's comments as they introduce the issue of water availability (soil
16 moisture and *VPD*) to the discussion. We observed the greater discrepancies between VIs and *GEP* at
17 Tumbarumba (AU_Tum), a site that does not show signs of water limitation (Figure 1). In this
18 sclerophyll forest, only 3% of the 10-year time series corresponds to *VPD* values greater than 3 kPa, a
19 threshold identified for a 50% reduction in *LUE* (Ogutu and Dash, 2013). Mean seasonal
20 evapotranspiration (*ET*) at AU_Tum was 2.4 mm/day (standard deviation of 1.23 mm/day), which is



21 substantially less than the 2001-2012 average of 6.4 mm/day *Precip_{TRMM}* (*Precip_{EC}* = 6.4 mm/day)

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Figure 1. Water fluxes at Tumbarumba (AU_Tum) sclerophyll forest: Evapotranspiration (ET , blue lines), satellite derived ($Precip_{TRMM}$, black lines) and flux-tower ($Precip_{EC}$, grey lines) precipitation (mm/day).

We acknowledge the difficulties in separating the meteorological from the biophysical contributions (photosynthetic potential) to GEP based on radiation and VPD (e.g. derivation of P_c), particularly in woodlands as these ecosystems can be highly controlled by access to soil moisture (Cleverly et al., 2013). For example, at Alice Springs Mulga site (AU-ASM), Eamus et al. (2013) reported an increase in transpiration at moderate values of VPD , whereas the rate of photosynthesis remained unaffected, signalling the complexity of the controls on carbon exchange. However, we argue that VIs represent the ‘ecosystem potential’ seasonality that can later be translated to photosynthetic activity if driven by water, temperature, light, and CO_2 availability. At seasonal time scales (e.g. 16-days, monthly), our analysis looks at the biotic drivers of productivity (parameterization of the light response curve); by contrast, at shorter time scales (e.g. hourly, daily) ecosystem photosynthetic potential should be scaled to reflect resource limitations (i.e. access to soil moisture), availability (e.g. incoming radiation) and the correspondent ecosystem responses (e.g. stomatal closure, CO_2 fertilization) that determine GEP .

We propose to add the following text (in yellow) at section 4.1. *Derivation of measures of photosynthetic potential at tropical savannas, sclerophyll forests and semi-arid ecosystems*, as follows :

“In this study we were able to separate the biological (vegetation phenological signal) from the climatic drivers of productivity using eddy-covariance carbon exchange data. Using the parameterization of the light response curve we derived different measures of vegetation photosynthetic potential (α , LUE , GEP_{sat} and P_c). At seasonal time scales (e.g. 16-days, monthly), our analysis looks at the biotic drivers of productivity, whereas at shorter time scales (e.g. hourly, daily), photosynthetic potential can be limited or enhanced by meteorological controls, thus GEP was linked to resource limitation (i.e. high VPD), availability (e.g. access to soil water) and corresponding ecosystem responses (e.g. stomatal closure, photoinhibition, and CO_2 fertilization).”

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Additional text is also proposed to be inserted into Section 4.2. Seasonality and comparisons between satellite products and flux tower based measurements of carbon flux: photosynthetic activity (productivity) and potential (phenology):

“Similar to Mediterranean ecosystems (AU-Cpr), in wet sclerophyll forests (AU-Tum) without signs of water limitation, the VIs were unable to replicate seasonality in *GEP*...”

Using precipitation from a coarse scale product does not seem appropriate to capture water availability. I’m wondering why not observed soil moisture or simple ecohydrological metrics like cumulative water deficit (from measured precip and ET) has been used here.

R1C02: It is our intent to obtain continental-wide relationships independent from biome classification or EC drivers (e.g. *ET*). Thus, as we want to offer an understanding and relationships that are able to capture spatial (e.g. ecotone) and temporal changes in land cover type (e.g. drought impact). The reviewer is correct about other measures of water availability (e.g. soil moisture) being more robust as the timing and intensity of precipitation will have an important effect on whether water is available to plants. However, issues related to the identification of threshold values (e.g. not all soil moisture increases translate in a phenological response at AU_ASM (Cleverly et al., 2016)), time scales and other issues beyond the scope of this study may have an equal effect upon whether photosynthetic potential translates into activity (*GEP*). We believe that robust *GEP* models will incorporate: 1) satellite derived VIs as proxies for photosynthetic potential, 2) meteorological drivers, and 3) a mechanistic response from the vegetation to the short term variations in weather and climate, but we found the present MODIS *GPP* and other models to perform poorly across Australia. Future work should aim to look into different satellite products as, for example the Gravity Recovery and Climate Experiment, GRACE-total water storage (*TWS*), and the Soil Moisture Active Passive, SMAP-soil moisture values, among others as *GEP* drivers and to refine the derivation of measures of photosynthetic potential.

It has been argued that dur-

1 ing water stressed conditions the yellowing of the herbaceous understory may act as
2 a ‘drought indicator’ which might drive the VI in the ‘right’ direction (Sims et al 2014,
3 GCB; Jung et al 2008, GCB). If so, the capacity of VIs to reflect GPP response would
4 depend on the presence and density of herbaceous vegetation and the openness of the
5 forest canopy. The colour of the leaves is influencing the VIs and this could also indicate
6 changes of LUE.

7
8 R1C03: We agree with the reviewer that the presence and density of herbaceous vegetation and the
9 openness of the forest canopy can drive the VI signal at savannas and open woodlands at certain times
10 of the year (e.g. AU_How and AU_ASM, see Chen et al. (2003); Cleverly et al. (2016, Submitted); and
11 Hutley et al. (2000). Moreover, we agree that VIs constitute a signal dominated by chlorophyll (red
12 reflectance) and cellulose content (NIR), thus will indicate changes in *LUE*. However, we argue that
13 satellite derived biophysical measures and other greenness indexes are not a measure of *GEP*. Instead,
14 VIs and other biophysical products are proxies for ecosystem structure (e.g. leaf area index - quantity
15 of leaves) and for function (e.g. leaf level photosynthetic assimilation capacity - quality of leaves). Our
16 results should extend to other remote sensing sources, including phenocams and *in situ*
17 spectroradiometers.

18
19 The authors mention repeatedly that ‘understanding’ is more impor-
20 tant than ‘well-fitting models’ but the authors present a systematic analysis on which
21 regression models work best (which I like!). Investigating the coefficients of these re-
22 gression models shows often unexpected signs, e.g. GPP decreasing with VI, or the
23 presence of intercept terms, which conceptually makes little sense. Discussing and ex-
24 plaining these things may be a chance to make the point why ‘understanding’ is impor-
25 tant.

26
27 R1C04: We propose to incorporate the reviewer's suggestion into to section 4.3. Considerations for the
28 selection of RS data to be used on *GEP* models and phenology validation studies, here highlighted in
29 yellow:

30
31”The fact that a brighter soil background results in lower *NDVI* values than with a dark soil

1 background for the same quantity of partial vegetation cover (Huete, 1988; Huete and Tucker, 1991)
2 may have a positive effect in the all-site Pc versus $NDVI_{SZA30}$ regressions (increase R^2). Thus as
3 darkened soils following precipitation generally result in higher $NDVI$ values for incomplete canopies
4 (Gao et al., 2000) and may similarly suggest higher vegetation or soil biological crust activity. On the
5 other hand, soil brightness and moisture may have a negative effect on the confidence interval of the x-
6 intercept for the proposed relationships (e.g. Pc versus $NDVI_{SZA30}$, for $NDVI_{SZA30} \sim 0$). Moreover, at
7 certain times the AU-ASM and AU-Cpr sites were at the low end of the vegetation activity range, and
8 the observed RS signal may have been dominated by soil water content rather than by photosynthetic
9 potential.”

10
11 The second objective was to disentangle the seasonality of ‘vegetation structure
12 and function from climatic drivers of productivity’. The authors derive 4 metrics here
13 (α , Pc , LUE, GEP_{sat}). I agree with referee #2 regarding the (non-optimal) nomen-
14 clature of ‘photosynthetic potential’ vs ‘activity’. I also see a conceptual problem here
15 because all 4 metrics are actually confounded by changes in light harvesting (reflected
16 by VIs) such that vegetation structure and functioning cannot be disentangled from eco-
17 physiological effects.

18
19 R1C05: See R2C02

20
21 In my opinion the authors should have used $PAR * VI$ in the light
22 response curve fitting to account for that. I’m also wondering about the usefulness of Pc
23 – first it seems redundant given α and GEP_{sat} , and second it requires somewhat
24 arbitrary thresholds and site specific knowledge to compute it.

25
26 R1C06: While other more refined biophysical measures of photosynthetic potential would be ideal (e.g.
27 chlorophyll fraction of absorbed PAR), the parameterization of the light response curve offers an
28 insight of seasonal ecosystem form, function and phenology (Hutyra et al., 2007; Restrepo-Coupe et al.,
29 2013; Wu et al., 2016). Pc was calculated to remove the effect of day length, changes in radiation
30 environment, cold/warm periods, among other non optimal meteorological conditions from GEP —thus,
31 Pc represents the canopy's ability to do photosynthesis. We assumed optimal radiation to be equivalent

1 to the site annual mean daytime $PAR \pm 100 \mu\text{mol m}^{-2} \text{s}^{-1}$ and $VPD \pm 1$ standard deviation. By contrast,
2 α and GEP_{sat} , would be characteristic of the vegetation response under conditions dominated radiation
3 (diffuse and direct) and VPD , respectively (see Section 2.2.3).

4

5 I'm wondering why the
6 authors did not employ the 'classical' approach ($GPP=APAR*LUE$) here to disentangle
7 'biophysical' ($APAR=VI*PAR$) from 'ecophysiological' (LUE) components, which seem
8 more straightforward and would do the job (?).

9 For example, given $GPP=VI*RAD*LUE$

10 it derives that GPP scales with VI if a) the product of RAD and LUE is nearly constant
11 (compared to the variability of VI), or b) product of RAD and LUE is in phase with VI. I
12 guess I'm lacking a more clear presentation and justification of a clear framework and
13 motivation of the analysis strategy.

14

15 R1C07: For context:

16

17 $GEP = APAR \times \varepsilon$ as in Yuan et al., (2007) (Equation 1)

18

19 or

20

21 $NPP = APAR \times \varepsilon$ as in Gamon et al. (1995) (Equation 2)

22

23 where ε is the efficiency with which absorbed radiation is converted to fixed carbon (also referred as
24 LUE by some authors), NPP is net primary productivity, where $NPP = GEP$ - autotrophic respiration,
25 and APAR is the absorbed fraction of PAR.

26

27 $APAR = PAR \times fPAR$.

28

29 where $fPAR$ is defined as the fraction of PAR absorbed by the canopy (leaves and woody tissue) and
30 has been correlated to NDVI (Gamon et al., 2013; Myneni and Williams, 1994).

31

1 We consider $fPAR$ and ϵ to be similarly representative of the canopy structure and function; therefore,
2 separating ϵ and $fPAR$ would be problematic as both variables would be considered similar measures of
3 photosynthetic potential. In general, models that use Eq1 assume ϵ to be constant and biome-dependent
4 (Yuan et al., 2007). Moreover, the determination of ϵ continues to be a major challenge in ecological
5 research (Field et al., 1998; Running et al., 2004). Our analysis offers a ground-based measure of
6 vegetation photosynthetic potential and constitutes an attempt to derive all-site regressions between the
7 satellite products and ecosystem form and function independently of biome type. Thus, so that
8 ecotones and sudden land use changes such as flooding or fire may not be misrepresented when
9 extrapolated to regional and continental scales.

10

11 Minor points: -

12 Why were coarse scale products of radiation and precip being used?

13

14 R1C08: We used satellite derived vegetation indices and meteorological variables rather than in situ
15 measurements; therefore, our findings (e.g. regressions) can be extrapolated to regional and continental
16 scales.

17

18 We propose to add text to section 2.3.2. Satellite measures of precipitation (TRMM) and incoming
19 solar radiation (CERES), to address the Reviewer's concerns:

20

21 ...No quality control was performed on the rain ($Precip_{TRMM}$) or short wave (SW_{CERES}) satellite derived
22 time series. We used satellite derived meteorological variables rather than in situ measurements as the
23 independent variable in GEP models (see Section 2.5), therefore, our findings (e.g. regressions) can be
24 extrapolated to regional and continental scales.

25

26 Why

27 monthly if those are available daily? -

28

29 R1C09: We are interested on the seasonal response of the ecosystem (e.g. monthly or 16-day), away
30 from short term responses (e.g. hourly or daily). The 16-day window is a time scale representative of
31 important ecological processes; in particular, leaf appearance to full expansion (Jurik, 1986; Restrepo-

1 Coupe et al., 2013).

2

3 Page 19234, line 6: R²=0.16 does not suggest a

4 ‘strong’ relationship to me -

5

6 R1C10: We observed a clear improvement in the ability of the model to predict *P_c* and *LUE* rather
7 than *GEP*. At the evergreen wet sclerophyll forest of AU_Tum, there were no relationships between
8 *GEP* and satellite derived measures of greenness (e.g. *GEP* and *EVI_{SZA30}* or *NDVI_{SZA30}* R²<0.01 and
9 p=0.93, Figure 5b). In contrast the regression between *P_c* and VIs were statistically significant,
10 meaning the regression was significantly higher than zero (R²= 0.16, p<0.01; Figure 6 and Supplement
11 Table 4), low R² values can be explained by the small dynamic range of both seasonal measures of
12 photosynthetic potential and VIs (cf. Figure 4 and Figure 6). Thus, we would change strongly to
13 significant on the text as we showed how at this site incoming solar radiation explained 60% and a
14 multi-linear model driven by *SW_{down}* and *EVI_{SZA30}* was able to explain 70% of *GEP* indicating a
15 meteorological driven ecosystem.

16

17 At Section 3.3. Relationship between *EVI_{SZA30}* and measures of photosynthetic potential (α , *LUE*,
18 *GEP_{sat}*, and *P_c*):

19

20 “At the sclerophyll forest site (AU-Tum) the *EVI_{SZA30}* was able to predict vegetation phenology rather
21 than productivity. For example we observed that *P_c* (but not α) was significantly related...”

22

23 Page 19240 line 23: I’m not sure but I thought a brighter soil

24 (or snow) increases ndvi (?). In any case, this is an interesting section of **discussion**

25 which might be expanded (‘understanding’ why things work or not)

26

27 R1C10: We quote Huete (1988) who found “Soil brightness influences have been noted in numerous
28 studies where, for a given amount of vegetation, darker soil substrates resulted in higher vegetation
29 index values when the ratio vegetation index (RVI= NIR/red) or the normalized difference vegetation
30 index[NDVI-(NIR- red)/(NIR+ red)= (RVI-1)/(RVI+1)] were used as vegetation measures (Colwell,
31 1974; Elvidge and Lyon, 1985; Huete et al., 1985)”.

1
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7

We added text to the discussion to address the Reviewer's suggestion see R1C04

Please note we were requested by Fluxnet and OzFlux to change the site abbreviations.

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Abstract

1
2 A direct relationship between gross ecosystem productivity (*GEP*) estimated by the eddy covariance
3 (EC) method and Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation indices (VIs)
4 has been observed in many temperate and tropical ecosystems. However, in Australian evergreen
5 forests, and particularly sclerophyll and temperate woodlands, MODIS VIs do not capture seasonality
6 of *GEP*. In this study, we re-evaluate the connection between satellite and flux tower data at four
7 contrasting Australian ecosystems, through comparisons of ecosystem photosynthetic activity (*GEP*)
8 and measures of potential (via parametrization of the light response curve: ecosystem light use
9 efficiency (*LUE*), photosynthetic capacity (*Pc*), *GEP* at saturation (*GEP_{sat}*), and quantum yield (α))
10 with MODIS vegetation satellite products, including VIs, gross primary productivity (*GPP_{MOD}*), leaf
11 area index (*LAI_{MOD}*), and fraction of photosynthetic active radiation (*fPAR_{MOD}*). We found that satellite
12 derived greenness products constitute a measurement of ecosystem structure (e.g. leaf area index -
13 quantity of leaves) and function (e.g. leaf level photosynthetic assimilation capacity - quality of leaves),
14 rather than *GEP*. Our results show that in primarily meteorological-driven (e.g. photosynthetic active
15 radiation, air temperature and/or precipitation) and relatively aseasonal vegetation photosynthetic
16 potential ecosystems (e.g. evergreen wet sclerophyll forests), there were no statistically significant
17 relationships between *GEP* and satellite derived measures of greenness. In contrast, for phenology-
18 driven ecosystems (e.g. tropical savannas), changes in the vegetation status drove *GEP*, and tower-
19 based measurements of photosynthetic activity were best represented by VIs. We observed the highest
20 correlations between MODIS products and *GEP* in locations where key meteorological variables and
21 vegetation phenology were synchronous (e.g. semi-arid *Acacia* woodlands) and low correlation at
22 locations where they were asynchronous (e.g. Mediterranean ecosystems). Although, we found a
23 statistical significant relationship between the long term measures of photosynthetic potential (*Pc* and
24 *LUE*) and VIs, where each ecosystem aligns along a continuum, we want to highlight that EC data offer
25 much more than validation and/or calibration of satellite data and models. Knowledge of the
26 conditions in which flux tower measurements and VIs or other remote sensing products converge
27 greatly advances our understanding of the mechanisms driving the carbon cycle (phenology and
28 climate drivers) and provides an ecological basis for interpretation of satellite derived measures of
29 greenness.

30

1 5. Conclusions

2 Remote sensing vegetation products have been widely used to scale carbon fluxes from eddy
3 covariance (EC) towers to regions and continents. However, at some key Australian ecosystems
4 MODIS GPP and VIs may not track seasonality of gross ecosystem productivity (*GEP*). In particular,
5 we found EVI_{SZA30} was unable to represent *GEP* at the temperate evergreen sclerophyll forest of
6 Tumbarumba (AU-Tum) and at the Mediterranean ecosystem (Mallee) of Calperum-Chowilla (AU-
7 Cpr). This result extends across satellite products overall: MODIS GPP_{MOD} , LAI_{MOD} , $fPAR_{MOD}$, and
8 other VIs.

9
10 We aimed for a greater understanding of the mechanistic controls on seasonal *GEP* and proposed the
11 parametrization of the light response curve from EC fluxes, as a novel tool to obtain ground-based
12 seasonal estimates of ecosystem photosynthetic potential (light use efficiency (*LUE*), photosynthetic
13 capacity (*Pc*), *GEP* at saturation (GEP_{sat}), and quantum yield (α)). And by photosynthetic potential we
14 refer to the presence of photosynthetic infrastructure in the form of ecosystem structure (e.g. leaf area
15 index- quantity of leaves) and function (e.g. leaf level photosynthetic assimilation capacity - quality of
16 leaves) independent of the meteorological and environmental conditions that drive *GEP*. Based on
17 basic linear regressions, we demonstrated that MODIS derived biophysical products (e.g. VIs) were a
18 proxy for ecosystem photosynthetic potential rather than *GEP*. We reported statistically significant
19 regressions between VIs (e.g. $NDVI_{SZA30}$ and EVI_{SZA30}) to long term measures of phenology (e.g. *LUE*
20 and *Pc*), in contrast to ecosystem descriptors subject to short term responses to environmental
21 conditions (e.g. GEP_{sat} and α). Our results should extend to other methods and measures of greenness,
22 including VIs and chromatic coordinates from phenocams and in situ spectrometers.

23
24 We found that the linear regressions between MODIS biophysical products and photosynthetic
25 potential converged on a single function across very diverse biome types, which implies that these
26 relationships persist over very large areas, thus improving our ability to extrapolate in situ phenology
27 and seasonality to continental scales, across longer temporal scales and to identify rapid changes due to
28 extreme events or spatial variations at ecotones. We further found that saturation of $fPAR_{MOD}$ and
29 $NDVI_{SZA30}$, restricted their usefulness, except in comparatively low biomass ecosystems (savannas and
30 arid and semi-arid savannas and woodlands).

31

1 We quantified how much of *GEP* seasonality could be explained by different variables: radiation
2 (SW_{down}), temperature (T_{air}), precipitation ($Precip$), or phenology (VIs as proxy). Our analysis showed
3 the relationship between RS products and *GEP* was only clear when productivity was driven by either:
4 (1) ecosystem phenology and climate, synchronously driving *GEP*, as was observed at Alice Springs
5 Mulga woodland (AU-ASM), and similar to many temperate deciduous locations, or (2) solely by the
6 vegetation photosynthetic potential, as observed at the tropical savanna site of Howard Springs (AU-
7 How). At AU-How, radiation and temperature were constant across the year, although ecosystem
8 photosynthetic activity (*GEP*) and potential (e.g. Pc and LUE) fluctuated with the highly seasonal
9 understory. However, RS products do not follow *GEP* when: (3) phenology is asynchronous with key
10 meteorological drivers such that *GEP* is driven by one or the other at different times of the year, as we
11 observed at AU-Cpr; or when (4) *GEP* is driven by meteorology (SW_{down} , T_{air} , soil water availability,
12 VPD , or different combinations) and photosynthetic potential is aseasonal, as observed at AU-Tum. At
13 AU-Tum, changes in productivity were driven by SW_{down} , while the ecosystem biophysical properties
14 remained relatively constant across the year, represented by the small amplitude of the annual cycles in
15 Pc and LUE (true evergreen forest). An understanding of why satellite versus flux tower estimates of
16 *GEP* relationships hold, or do not hold, greatly contribute to our comprehension of carbon cycle
17 mechanisms and scaling factors at play (e.g. climate and phenology, among others).