Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2019-37-RC1, 2019

Biogeosciences Discussions

Interactive comment on "Global variability of carbon use efficiency in terrestrial ecosystems" *by* Xiaolu Tang et al.

Anonymous Referee #1

Received and published: 6 April 2019

Tang et al. investigate the global variation in carbon use efficiency (CUE), a carbon cycle property that is determined by the ratio of net to gross primary production (NPP / GPP), and thus essentially by autotrophic respiration. Based on a collection of in-situ NPP and GPP measurements and climate, vegetation and soil variables, they apply a machine learning algorithm (random forest) to derive a spatial CUE map. Subsequently, spatial gradients in this map are presented and compared to CUE simulated by dynamic global vegetation models.

Estimating vegetation CUE at the global scale is definitely urgently required to better understand and predict climate-carbon cycle feedbacks. Currently, observation based spatial estimates of CUE are lacking, mainly due to difficulties in measuring NPP even at local scales.

Unfortunately, the methods underlying the work presented here involve several important shortcomings and it is thus hardly possible to draw robust conclusions. A list of the most important issues is presented below. Apart from methodological shortcomings, also phrasing and English grammar are on a very poor level throughout the manuscript. To my mind, in its current form this study is not meeting the criteria for publication in Biogeosciences.

Major issues

1. The compiled database of in-situ NPP and GPP measurements is presented nowhere in the manuscript. Which are the additional studies other than Luyssaert et al. (2007) and Campioli et al. (2015) that are included? They should be listed in a table and properly referenced in the main text. It is thus also not evident which time span is covered by the measurements, and if temporal changes in climate or other conditions may have an effect on the compiled measurements that is neglected in this study. Moreover, is this database substantially different from or similar to the CUE data presented in Collalti and Prentice (2019, https://doi.org/10.1093/treephys/tpz034)?

2. The spatial representativeness of measurements included in this study is insufficient (see Figure 1). The complete lack of measurements in e.g. Africa and Russia can potentially lead to biases in CUE, and does not allow to robustly model global relationships between CUE, climate, vegetation, soil and management variables, since the variance and interaction of these variables cannot be covered sufficiently. It does not allow for a detailed representation of major biomes, for instance not for a division into tropical/temperate/boreal biomes. Only 5 measurements for tundra are not significant. It is also not clear how the division of the so-called "ecosystems" that are distinguished here (Forest, Grassland, Wetland, Cropland, Tundra), which are rather biomes, is implemented. For instance, how are wetlands defined?

3. It is extremely difficult to measure all NPP components in the field. NPP can hardly be estimated "directly" or in a very "robust" way (as stated in Line 69-70). What

about root NPP, herbivory, carbon allocated to reproductive parts, root exudates or VOC emissions? These can make up quite substantial percentages, depending on the ecosystem. It must be shown that NPP measurements used in this study account for all relevant NPP components and are comparable. See for instance Luyssaert et al. (2007, https://doi.org/10.1111/j.1365-2486.2007.01439.x) or Clark et al. (2001, https://doi.org/10.1890/1051-0761(2001)011[0356:MNPPIF]2.0.CO;2) for detailed discussions of this issue.

4. It is completely unclear how the measurements of CUE can be related to the independent variables used for spatial modelling. There must be an important scale mismatch that cannot be neglected (this is also indicated in the last sentence of the main text, Line 380). While NPP and GPP can only be measured for small areas (there is not even a hint on the spatial scale of measurements anywhere in the manuscript), the climate, vegetation (satellite products) and soil variables are certainly measured at a resolution of 50 km or even coarser (the spatial resolution of these variables is also not stated in Table S1). How do you account for this scale mismatch? The climate, vegetation and soil variables must be measured at the same location (and time) as the NPP and GPP measurements to allow establishing relationships and their subsequent upscaling. Moreover, why has this set of variables been selected (Table S1)? Why not including GPP or biomass estimates (according to the theory that Ra may be proportional to GPP or biomass)? Why are differences between species not taken into account? Because of the above reasons, it is not surprising that only 49% of the variance in CUE can be explained by the 6 most important variables, which is not even the majority of the variance (Line 187). The scale mismatch between the other independent variables and CUE measurements may also contribute to the finding that ecosystem type is the by far most important independent variable (Line 244, Fig. S5).

5. It is not apparent how this work leads to new insights regarding the understanding of processes shaping CUE, which would also be very relevant for a better representation of CUE in process-based models. The presented approach is designed to derive a

global CUE map based on a machine learning approach (random forest), but does not analyse processes leading to differences in observed CUE.

Specific comments

What are the main conclusions of this study? This is not evident from the abstract. E.g. Line 42: More precise main results (values of CUE) required

Line 42-43: CUE actually increases with latitude

Line 55-57: “Gross primary production (GPP), net primary production (NPP) and autotrophic respiration (Ra) are the most important and highly related components to carbon cycling.” What do you mean here? Are turnover, decomposition and heterotrophic respiration less important?

Line 96-98: “Previous studies, based on individual observations or process-based model estimates, indicate that site fertility and management are important drivers of CUE by increasing resource availability for plants (Vicca et al., 2012; Campioli et al., 2015).” The studies referred to here did not use any process-based model estimates.

Line 66-68: Bradford and Crowther (2013) did certainly not invent the term “CUE”. Other literature has to be cited here.

Line 69-70: I totally disagree here (see major issue 3).

Line 72-73: How is Ra measured then? I also wonder why you do not mention the possibility to measure GPP by eddy covariance and flux partitioning methods.

Line 80: What is geographic allocation?

Line 81-84: If this shall be an example calculation, what exactly is the effect of 20% error in CUE on the carbon cycle (value!)?

Line 85-86: Please explain in more detail the GPP and NPP available from MODIS or DGVMs, including more appropriate references.

Line 90: TRENDY needs to be explained (and requires a reference).

Line 109: Why are only studies until February 2017 included? 2 years have passed since then already.

Line 137-139: This is a result and does not fit in the methods section.

Fig. 2: Please double-check your ANOVA results. For instance, why is the observed CUE in Tundra grouped into AB (what does AB mean actually?), while the observed CUE in Cropland and Wetland is grouped into B despite very similar mean values. Or: Why is the observed and modelled CUE in Wetland not significantly different despite much larger differences than between observed and modelled CUE in Forest, which in turn shall be significantly different? These results seem questionable.

Line 227-234: Which selection criteria have been applied by Campioli et al. (2015)?

Line 248-249: Where do you show MODIS based CUE and how does this relate to Ryan et al. (1994)?

Line 250-256: It is not clear which temperature range is covered by the CUE measurements in your data set. In addition, another main limitation of this study is that you only account for the relation between CUE and temperature for annual mean conditions, but not the response of CUE to temperature variation during the course of the year.

Line 272: Not only different definitions of PFTs are responsible for differences in CUE simulated by TRENDY models.

Line 280: Again, how do you account for the mismatch in spatial scale between observed and modelled CUE?

Line 333: What is Jung's GPP? This needs to be introduced in detail.

Line 338-339: Where do you show this, and what exactly do you mean by "prediction accuracy of global C cycling"?

Line 339-340: "thus using a constant CUE derived NPP may lead anthropogenic bias for NPP estimate." Impossible to understand this sentence.

Line 345: "Third, our NPP estimate indicates the improvement of MODIS algorithms." How do you indicate the improvement of MODIS algorithms?

Line 350: How exactly can representations or parameterizations of processes in models be improved by your work? As far as I can see, you try to derive spatial patterns in CUE, but this work does not allow drawing conclusions on the underlying processes (see major issue 5).

Line 357: "our global CUE map facilitated ground-truthing NPP estimation". I do not understand what ground truthing and your global CUE map have in common.

Line 360: It is extremely bold to refer to your NPP estimate as "the actual value".

Line 365: As mentioned above (major issue 4), a valid upscaling of relationships between CUE and climate etc. is not achieved by this study either.

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Table S1: What does "Publications" mean? Which ones?

Fig. S12/S13: The chosen colour scale makes it hard to see the spatial differences.

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