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Interactive comment on "Underestimation of boreal soil carbon stocks by mathematical soil carbon models linked to soil nutrient status" *by* B. Ťupek et al.

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Dr Leonid L. Golubyatnikov's (Referee's) comments are highlighted by bold font.

 # Symbol and font used to indicate Author's reply.

Authors evaluated soil organic carbon stock for Swedish forest using models Yasso07, Q, CENTURY and compared the model results with the Swedish forest soil inventory data. They described the obtained results very accurate and comprehensively.

#Thank you for your comments! We appreciate and considered them all, and below we reply to each in detail. Based on your comments we have presented 1 new biomass/

litterfall figure and redrawn 2 original biomass modelling figures (attached at the end); and reformulated text by following your remarks and clarifying Sections "2.1.1 Biomass and litterfall estimates" and "5 Conclusions" of our Biogeosciences Discussion (BGD) paper (the marked up version is in the supplement of this comment).

Remarks:

1. Is phrase "i.e. samples with SOC stock below 0.01 and 99.9 percentile" (line 103) correct?

 # We reformulated the sentence "SOC stock below 0.01 and above 99.9 percentile"

2. It's not necessary to reintroduce the abbreviations (for example, line 102).

 # We removed "(SOC)" from line 102, "(CEC)" from lines 198, 283, 287,"(SFSI)" from line 321,"(SMHI)" from line 533

3. Units for turnover rate are necessary (lines 159-164).

 # We added short description of TR on the line 153 where it was first introduced "(TR, the fraction of living biomass that is shed onto the ground per year, unitless)"

4. Section 2.2 duplicates the information from lines 64-80.

 # We reformulated section 2.2 by removing information which was previously mentioned in the introduction. The sentence on lines 226-238 was reformulated: "The Yasso07 model (Tuomi et al., 2009; 2011) is one of the most widely applied SOC models. *The sentence on lines 232-235 was deleted. The sentence on lines 247-248 was reformulated:* "The CENTURY is also one of the most widely applied models."

Authors used linear functions for biomass of vegetation types. According to Tabl.C1 all (!!!) functions for aboveground biomass have R2<0.5 and only one function for belowground biomass has R2>0.5. Therefore, these functions do not reflect the realistic interdependences and increase the model mistakes.

 # We are sorry for your possible misunderstanding on the extent in which we used the linear functions for the long-term mean forest biomass and litter input modelling for the soil carbon models. What we meant to describe in Section "2.1.1 Biomass and litterfall estimates" and in Appendices A, B, and C was that we used these linear functions (1) only for the litter input from the understory vegetation, (2) only for the long-term mean conditions "steady state forest", and that (3) the understory vegetation types affected the total understory litterfall with different weights according to their proportion of the total understory litterfall (better models for largely abundant dwarf-shrubs shared most influence than poorer models of scarcer herbs, grasses and lichens).

Firstly, it is evident that the forest understory represented the minor part of the total litter input (Fig. 1 of this comment), and that the major part of the litter input originated from the tree stand biomass components which were modeled by the non-linear functions with R^2 values close to 0.9 (Fig. 2 of this comment, redrawn Fig. B1, Appendix A and B, Tables A1 and B1). Therefore, when compared to the tree stand whose high model precisions governed the estimated total litter inputs for soil carbon models, and the understory had only small influence on the performances of soil carbon models.

Secondly, the variation of observed understory data for the plots close to estimated long-term mean conditions was largely reduced (as juvenile and declining forest phases were excluded) in comparison to the low proportion of explained variance for models presented in Table C1 for forest plots with high variance in understory data due to all stages of forest development. Our application of linear understory models for these plots resulted in much stronger fit between the observed and predicted values (Fig. 3 of this comment as redrawn Fig. S9, mean, min, and max R^2 were 0.69, 0.38, and 0.91,respectively).

Thirdly, the contribution of understory types to total understory litterfall was largest for the major part of total understory litterfall originating from dwarf-shrubs and mosses

(Fig. 1c). Dwarf-shrubs and mosses were predicted for the steady state forest with high R^2 values between 0.7 and 0.9 (Fig. 3). The understory vegetation types with the lower R^2 values (between 0.38 and 0.66, for herbs, grass, and lichens, Fig. 3) contributed little to total understory litterfall (Fig. 1c). When aiming to evaluate the impact of understory models on performances of SOC models for steady state forests, as in our application, it is correct to consider the larger R^2 values of Fig. 3 (especially totals with R^2 values close to 0.9, as total understory biomass or litterfall modeled for each functional type separately or in one model highly correlated).Therefore, the influence of these poorer understory models was small on predictions of the understory litter and marginal on predictions of the total forest litterfall and simulated SOC stocks.

Note, that SFI observations of forest floor vegetation coverages were not available for 3230 SFI plots with soil data. For the comparison between the understory and the stand biomass based on measurements (Fig. 1), we estimated biomasses for 2440 plots SFI plots which contained the understory data. In order to remove the age class effect on the understory biomass, which was also removed in our BGD paper for plots with soil data by estimating the forest biomass only for steady state, we selected from the 2440 SFI plots only those plots whose estimated fraction of absorbed radiation (f_{APAR}, Appendix A) was close to steady state f_{APAR} (f_{APAR70}) "steady state forest plots". In order to remove the effect of the actual stand development, which was crucial for estimating long-term mean litter input accurately, we developed functions based on f_{APAR} (Appendices A and B).

When regarding the nature of the understory coverage SFI data (visual observations), the lower precision (R^2 values below 0.9) of estimated biomasses could be expected even with the most sophisticated ecological models, but the significant p-values of our model parameters with predicted and observed values showing approximately 1:1 relation indicated that the estimates were accurate. Our aim here was to produce accurate biomass/litterfall estimates representing the mean long-term conditions (defined by es-

timated steady state) for small regions (defined by degree of latitude and productivity class for dominant species) as attempts for high precision of the estimates applied for the period of the last few thousands of years are uncertain due to high variation of data and factors affecting plot history.

For an improved understanding of the biomass models we reformulated Section 2.1.1 and Appendix C (see the marked up version of our BGD paper in the supplement of this comment). We also replaced Fig. B1 and S9 by Fig. 2 and 3 of this comment and added the component biomass and litter contribution Fig. 1 into the supplement as Fig. S10.

We noticed the erroneous unit in the original caption of Fig. B1 where the units "tons ha^{-1}" in scatterplots of the non-linear models were instead described as "kg ha^{-1}". We have redrawn Fig. B1 and S9 using "tC ha^{-1}" (Fig. 2) and added R^2 values.

Interestingly your comments on validity of our understory models complemented on previous comments from Prof Göran Ågren who was interested whether our stand biomass models based on f_{APAR70} accurately reflected Swedish regional differences in nutrient status and Nitrogen deposition (as possible reason for biased estimates of SOC stock on fertile sites). Note,that based on Prof Göran Ågren comments we have redrawn Fig. A1 and added new Fig. S11 in the supplement of the BGD paper. You are most welcome to interact with Prof Göran Ågren and us replying to him on the discussion page of our paper. http://www.biogeosciences-discuss.net/bg-2015-657/

It is not clear what authors wanted to show by this manuscript. From the presented results it follows that models of some processes do not accurately reflect these real processes. But it is evident and not new! Another conclusion of the article is also obvious: data for model essentially impact the model results.

 # In the view of the above mentioned general conclusions, we (1) clarified the novelty

of our study by highlighting the connection between the soil nutrient status and performance of widely applied soil carbon models (see reformulated Conclusions), and (2) mentioned that the use of the long-term mean litter input, instead of using litter from the actual state forest measurements, has mainly contributed for accurate modelling of SOC stocks (see reformulated Section 2.1.1). The second was obviously necessary for accurate analysis and it is not meant to be a conclusion of our study, therefore it was removed from conclusions (see reformulated Conclusions).

What we meant to describe in our Yasso07, Q, and CENTURY model intercomparison with Swedish soil carbon inventory data was that process based soil carbon models with the current formulation lacking nutrient status related controls of decomposition and soil carbon accumulation would underestimate for conditions where the high nutrient status predominate, in our application for medium-highly productive sites of Southern Sweden. Thus, the main message of our study is the modelling SOC stock bias related to the application of the Yasso07, Q, and CENTURY soil carbon models on productive sites in Sweden, which have not been published by other scientists and that is new to a wide community of modelers or other users of these models. As mentioned in our BGD paper and described further in detail in above discussion, our simulation is based on the widely used process based SOC models, accurate driving data including litter inputs, and massive SOC data points (Swedish inventory data, N=3230). Through the intercomparison of three different widely-used SOC models with massive data points, we identified that re-evaluating of the impact of nutrient status would improve the model development towards their accuracy on estimation of SOC stocks. Therefore, our study is very useful for developing accurate soil carbon and Earth system models, needed for accurate estimation of feedback of global warming on SOC stock temperature sensitivity and soil CO2 efflux, for the accurate national reporting of soil carbon stock changes for United Nations Framework Convention on Climate Change (UNFCCC), and implications of decisions mitigating the climate change effects on soil carbon stocks.

For an improved clarity of the main message we reformulated Conclusions (see the marked up version of our BGD paper in the supplement of this comment).

I think this manuscript can not be published

 # We are aware of your concerns about the low R2 values of our understory biomass models presented in Table C1, and about the clarity of the main message. However, as we thoroughly clarified above, the use of these models in our application is reasonably accurate and does not introduce bias on the estimated SOC stocks of soil carbon models and onto their relations to site nutrient status. In sections describing biomass models, we improved the description of the influence of litter input components onto total litter input and SOC stock results. In above response and in improved conclusions we also highlighted the main message of our study.

We hope that you could reconsider this statement after improvements made into the paper, and that if needed you would give us further comments suggesting necessary improvements.

FIGURE CAPTIONS:

Fig. 1. (Fig. S10.) The tree stand and understory forest (a) biomass, (b) litterfall, and (c) understory litterfall (all in $\mathrm{tC\,ha^{-1}}$) for Swedish Forest Inventory plots with available understory coverage observations and in their actual state close to the estimated long-term mean conditions “steady state”.

Fig. 2. (Fig. B1.) Scatter plots for the dry weight tree biomass components ($\mathrm{tC\,ha^{-1}}$) between "modelled" (estimated based on fraction of absorbed radiation,f_{APAR}, and our f_{APAR} models) and "measured" (estimated based on basic tree stand dimensions and allometric biomass models). The r^2 values represent the coefficient of determination indicating how close the modeled values fit the measured values.

Fig. 3. (Fig. S9.) Scatter plots for the dry weight biomass ($\mathrm{tC\,ha^{-1}}$) of the functional types of understory vegetation for Swedish Forest Inventory plots in actual state being close to the estimated long-term mean conditions “steady state”. On the x-axis is the biomass modelled by the understory vegetation dry weight biomass ($\mathrm{tC\,ha^{-1}}$) models and on the y-axes is the observed coverage multiplied by the coverage/biomass conversion functions. The abbreviations “abv”, ”belw”, and ”tot” mean aboveground, belowground and total. The last panel for “understory total” shows high agreement between the sums of each modeled functional types and the sums of all functional types. The r^2 values represent the coefficient of determination indicating how close the modeled values fit the observed values.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/bg-2015-657/bg-2015-657-AC2-supplement.pdf

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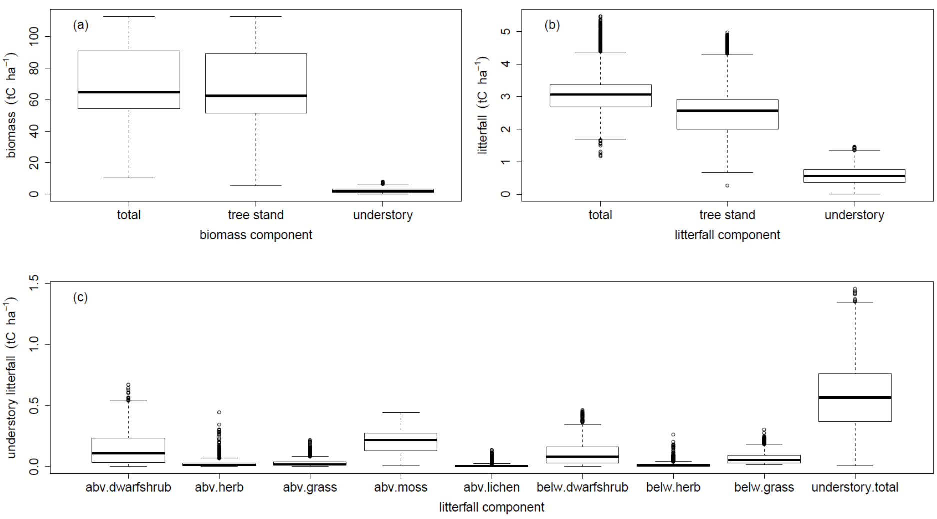
(a)
biomass (tC ha−1)
0
20
40
60
80
100
total
tree stand
understory
biomass component
(b)
litterfall (tC ha−1)
0
1
2
3
4
5
total
tree stand
understory
litterfall component
(c)
understory litterfall (tC ha−1)
0.0
0.5
1.0
1.5
abv.dwarfshrub
abv.herb
abv.grass
abv.moss
abv.lichen
belw.dwarfshrub
belw.herb
belw.grass
understory.total
litterfall component

Fig. 1.

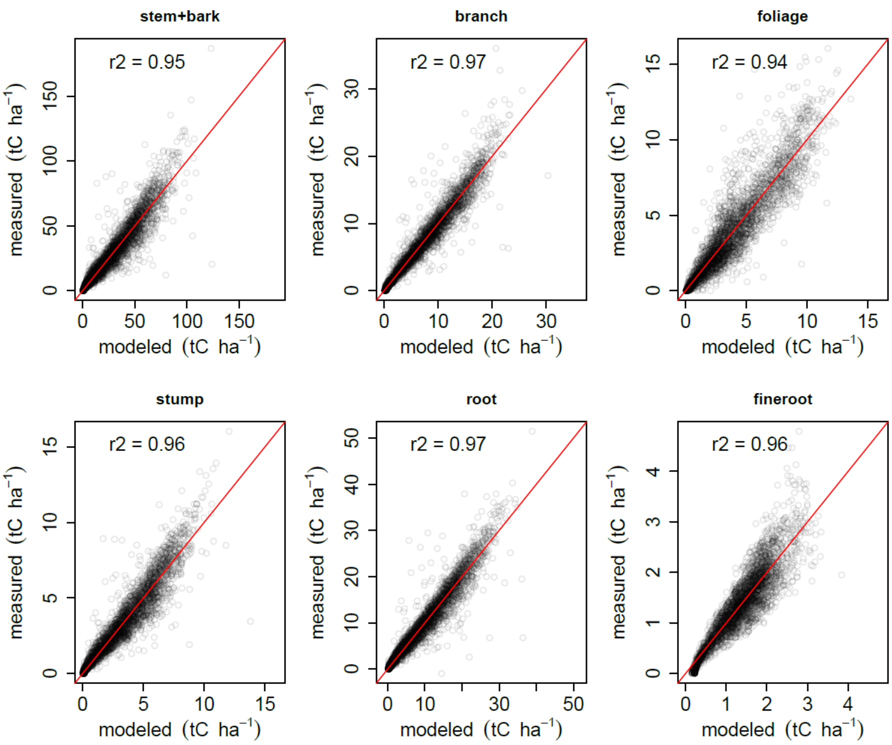
stem+bark
r2 = 0.95
branch
r2 = 0.97
foliage
r2 = 0.94
stump
r2 = 0.96
root
r2 = 0.97
fineroot
r2 = 0.96
measured (tC ha−1)
modeled (tC ha−1)

Fig. 2.

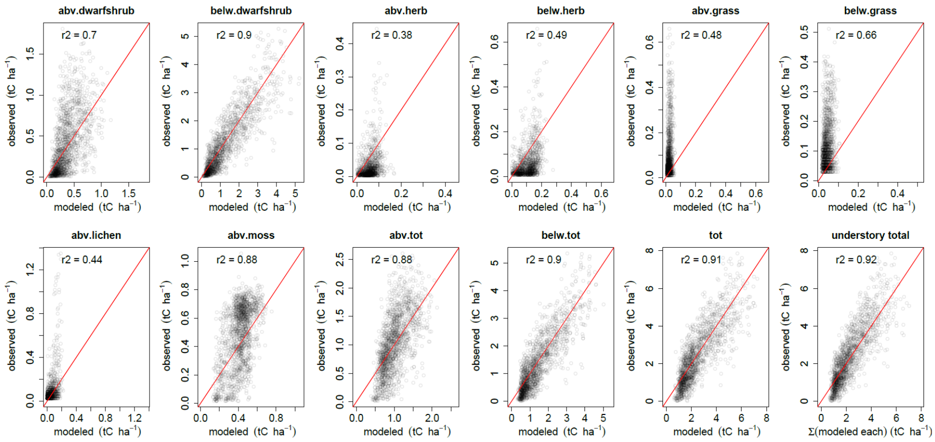
abv.dwarfshrub
r2 = 0.7
belw.dwarfshrub
r2 = 0.9
abv.herb
r2 = 0.38
belw.herb
r2 = 0.49
abv.grass
r2 = 0.48
belw.grass
r2 = 0.66
abv.lichen
r2 = 0.44
abv.moss
r2 = 0.88
abv.tot
r2 = 0.88
belw.tot
r2 = 0.9
tot
r2 = 0.91
understory total
r2 = 0.92
observed (tC ha^{-1})
modeled (tC ha^{-1})
Σ(modeled each) (tC ha^{-1})

Fig. 3.