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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.

B. Ťupek et al.

boris.tupek@luke.fi

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Author's reply to Prof G. I. Ågren (Referee):

!Referee: referee's comments #Authors: author's reply

GENERAL COMMENTS

!Referee: This is an interesting paper.

#Authors: Thank you, we appreciate all your comments, considered them carefully, and reply below to each of them! In addition the PDF version of our reply and the marked up manuscript with highlighted changes is provided in the supplement of our comment.

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Discussion paper

!Referee:Three structurally quite different soil carbon models give very similar predictions of forest soil carbon stocks when they are driven by the same litter inputs and differ also similarly from observations. The critical question is why they fail in their predictions for 22% of the test sites. The authors attribute the failure to weaknesses in how the models handle soil nutrient status. This might well be the case, but such a failure can come from two quite different sources. On one hand, is the litter input correctly calculated?

#Authors: Yes the litter input is calculated correctly, as we are aware that the correct calculation of the litter input is essential for the simulation of the soil carbon sequestration and the estimation method has large influence on the sequestered soil carbon. E.g. see SOC and litter relations in supplement figure FS6 and results lines 306 - 310.

!Referee:The procedure used to generate litter input is not transparent.

#Authors: We are aware that our description of the novel approach of litter input estimation may not be transparent in general concept in Sect. 2.1.1 “Biomass and litterfall estimates”, therefore we added detailed descriptions for reproducing the methods to appendices (Appendices A, B, and C, Tables A1, B1, and C1, and Figures A1, B1, and S9). At first, the novel method could seem complicated compared to the estimation by using only the allometric biomass models. However, the measurements of actual state forest could not be applied directly to biomass models in order to derive the long-term litter inputs due to differences in stand age classes and our method to remove the effect of the actual stand development was crucial for estimating long-term mean litter input correctly.

!Referee:The calculation is based on fAPAR (the fraction of absorbed photosynthetically active radiation) but the maximum/potential value of absorbed radiation seems to be ignored. However, both the potential production and fAPAR vary with the nutrient status of the stand. In the end, it seems to me that the procedure generates tree biomasses and thus litter production only depending on latitude;

#Authors: We are sorry that you partly misunderstood whether the maximum/potential value of absorbed radiation was taken into account. What we meant to describe was that fAPAR was based on the field data, the maximum observed fAPAR was certainly taken into account, and it was specific for latitude and nutrient status, and served as a prerequisite for the estimated 70th percentile of fAPAR (fAPAR70). The nutrient status was in our data represented by a productivity class (H100, height of the dominant trees at the age of 100 years in meters). Both latitude and the H100 data were used in estimation of the fAPAR70 values (Appendix A1 lines 508 - 513, Table A1 and Fig. A1). We think that adding panels showing the relation between modeled fAPAR70 and H100 data into Fig. A1 will clear the confusion about relation between fAPAR and site productivity/nutrient status (see attached updated Fig. A1).

!Referee: this will ignore the large regional differences in nitrogen deposition that play an important role in tree productivity, likely leading to an underestimate of litter production in high deposition areas.

#Authors: Figure 2 in this reply shows that productivity class (H100) of deciduous, pine, and spruce forests used in this study for the long-term litter input modelling was well correlated with Nitrogen deposition data (panels a, b, and c). However if using the actual state forests measurements directly, with only the allometric biomass models approach, the forest stage development masked the relationship between the nutrient status and the litterfall estimates (actual state forest litter in panels d, e, and f). In our approach with the stage development set to a 70th percentile of the maximum production potential, the litterfall estimates (long-term mean litter) reflected well the differences in Nitrogen deposition (panels g, h, and i).

!Referee: On the other hand, it is clear that soil nitrogen modifies the carbon use efficiency of decomposers; increasing nitrogen availability increases CUE, which increases soil carbon stocks (Ågren et al. 2001, Franklin, et al. 2003). In all three models, inclusion of either of these two factors would improve the model performance at the high nutrient sites.

#Authors: We added your comment into discussion, by reformulating sentence on lines 343-345, complementing on studies of Fernandez-Martinez et al. 2014, and Manzoni et al. 2012. “Larger net soil carbon accumulation in nutrient rich sites could be attributed to the relative differences in litterfall components (relatively more leaves and branches with higher N content than fine roots), and to higher N availability and carbon use efficiency of decomposers, reduction of respiration per unit of C uptake (Ågren et al. 2001, Manzoni et al. 2012, Fernandez-Martinez et al., 2014).” Manzoni, S., Taylor, P., Richter, A., Porporato, A. and Ågren, G. I.: Environmental and stoichiometric controls on microbial carbon-use efficiency in soils, New Phytol., 196, 79-91, 2012.

#Authors: We also added citation of Franklin et al. (2003) after the sentence on line 347. “The soils with large N deposition were also highly productive and showed high to exceptionally high SOC stocks (Fig. 2, Fig. 3, soil groups 7 and 8). This was in agreement with fertilization and modelling study of Franklin et al. (2003) showing an increase in soil C accumulation with N addition.”

SPECIFIC COMMENTS

!Referee: 1. Line 78. effects should be affects

#Authors: Effects was changed to affects

!Referee: 2. Line 221. It is not clear what is meant by “the 2012Q model”. Should it be 2011 or 2013? #Authors: We changed it to 2011, because 2011 was the calibration of the model and 2013 was an application on larger regions, no calibration.

!Referee: 3. Line 343. Why should decreased microbial demand for nitrogen lead to increased soil carbon?

#Authors: We reformulated sentence on lines 343-345 as described in general comments

!Referee: 4. Line 387. Why should inorganic nutrient uptake by mycorrhiza lead to underestimated SOC stocks on medium-highly productive sites?

#Authors: In lines 386-388 based on finding of Orwin et al. (2011) we suggest that not accounting for the available nutrients from the organic (not inorganic) uptake by models contributes to their underestimation of SOC stocks on sites with higher nutrient status. We reformulated the sentence.

"Expanding on the CENTURY model structure, the MySCaN model incorporating the organic nutrient uptake by mycorrhizal fungi estimated positive effect on SOC accumulation, relatively larger in poor than in fertile sites (Orwin et al.,2011). Therefore, not accounting for the organic nutrient uptake by mycorrhizal fungi by the Yasso07, Q, and CENTURY models probably led to the underestimation of SOC stocks in sites with higher nutrient status."

Orwin, K. H., Kirschbaum, M. U., St John, M. G. and Dickie, I. A.: Organic nutrient uptake by mycorrhizal fungi enhances ecosystem carbon storage: a model-based assessment, Ecol. Lett., 14, 493-502, 2011.

!Referee: Cited literature Franklin, O., et al. (2003)."Pine forest floor carbon accumulation in response to N and PK additions - Bomb 14C modelling and respiration studies." Ecosystems 6: 644-658. Ågren, G. I., et al. (2001). "Combining theory and experiment to understand effects of inorganic nitrogen on litter decomposition." Oecologia (Heidelb.) 128: 94-98.

#Authors: Thank you for providing these references.

#Authors: Figure captions

Figure 1. or Figure A1 in our BGD paper. Actual state fraction of absorbed radiation (fAPAR, estimated as in Härkönen et al., 2010) (actual fAPAR) and steady state fAPAR (modeled fAPAR70) which was set to 70th percentile of maximum fAPAR for given species, latitudinal degree, and site productivity class. Panels a), b), and c) show relation between fAPAR and latitude (°) for forest stands dominant by Scots pine, Norway spruce and deciduous species, whereas panels d), e), and f) show relation between

fAPAR and site productivity class (H100, height of dominant trees at 100 years in meters).

Figure 2. Scatterplots between the Nitrogen deposition (kg N ha-1 y-1) and a), b), c) site productivity class (H100, which is the height of the dominant trees at the age of 100 years in meters) , d), e), f) actual state forest litterfall (t C ha-1 y-1), and g), h), i) long-term mean “steady state” forest litterfall (t C ha-1 y-1) for deciduous species, Scots pine, and Norway spruce dominated stands.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/bg-2015-657/bg-2015-657-AC1-supplement.pdf

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Discussion paper

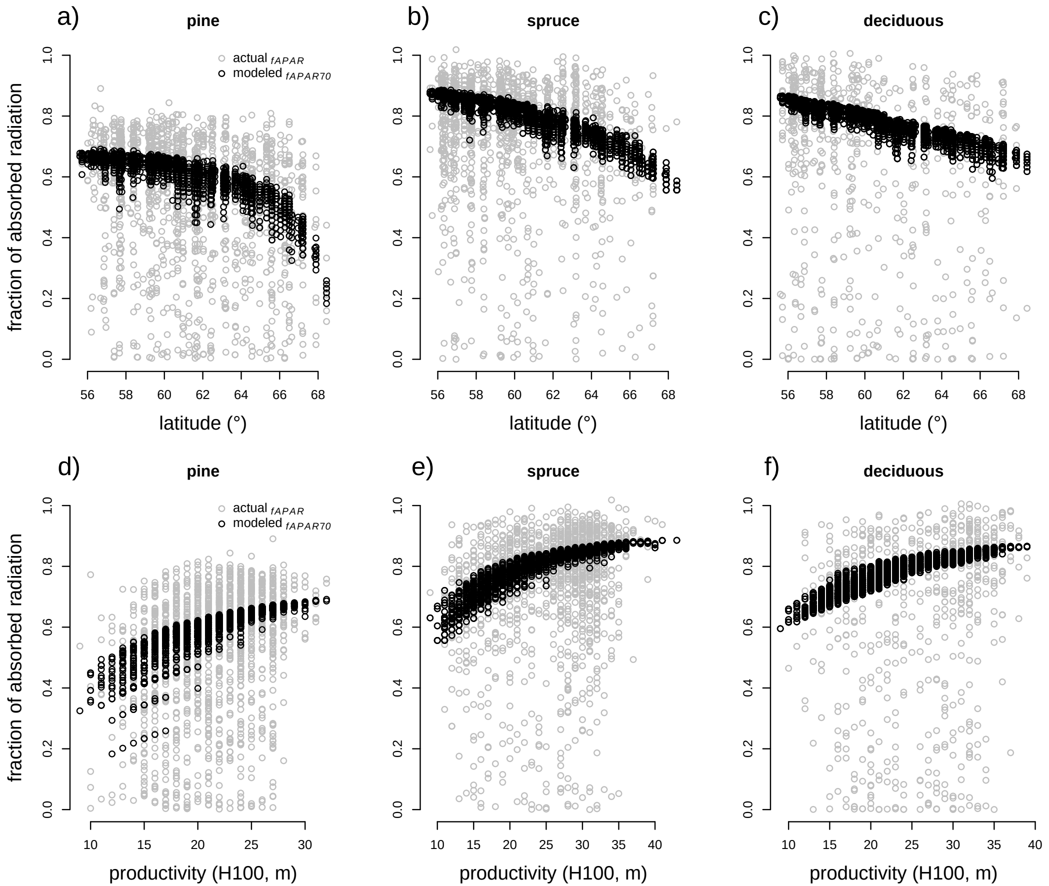

Fig. 1.

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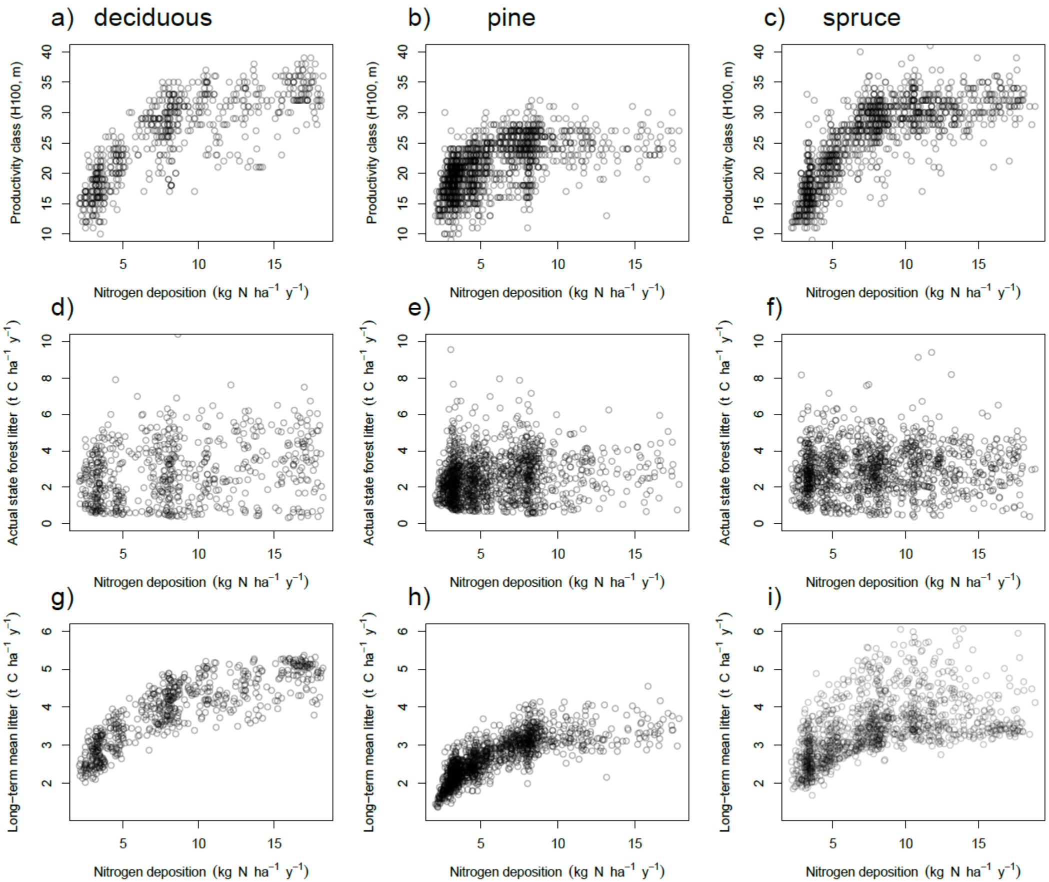
a) deciduous
b) pine
c) spruce
Productivity class (H100, m)
Actual state forest litter (t C ha⁻¹ y⁻¹)
Long-term mean litter (t C ha⁻¹ y⁻¹)
Nitrogen deposition (kg N ha⁻¹ y⁻¹)
d)
e)
f)
g)
h)
i)

Fig. 2.