Discussion on egusphere-2022-835

Anonymous Referee #1

Referee comment on "Modeling of non-structural carbohydrate dynamics by the spatially explicitly individual-based dynamic global vegetation model SEIB-DGVM (SEIB-DGVM-NSC ver1.0)" by Hideki Ninomiya et al., EGU sphere, https://doi.org/10.5194/egusphere-2022-835-RC2, 2022

I really appreciate your help and comments.

First of all, you said that “it appears to be logic that a model constrained by field data will produce simulations that fall within the range of that data.” As you can imagine, whether a model can achieve the initially planned concept depends heavily on parameterization in the case of process-based material cycling modeling. Unlike a large amount of observational data, such as eddy correlation fluxes, NSC, which is the focus of this paper, is not accumulated a lot, making it difficult to model. However, to predict tree mortality caused by future events such as drought, an explicit calculation of NSC in DGVM that can handle process-based and population dynamics is necessary, and we expect the model accuracy to improve as observational data accumulates in the future. This paper provides the basic concept and initial validation of the model and is expected to provide a foundation for future use.

Secondly, regarding the term “NSC” used in the paper, I know that the term NSC refers to two types of NSCs in plants: soluble sugar and starch. Starch plays a role in long-term carbon storage, while soluble sugar is used for immediate energy needs. In this paper, we use the term NSC to refer to the mixture of both soluble sugar and starch. I apologize if this caused any confusion. Each type of NSC has a different role but we observed that the mixture of both types of NSC are explicitly accumulated by using assimilated carbon through photosynthesis, and the stored NSC is used for metabolism, bud flush, and other processes. We chose to use the NSC data in our study because we had more data on the mixed NSC than on each type separately. I used the term “carbon storage” to refer to NSC in previous manuscript, but I realize that this may have confused readers. Therefore, in the new manuscript, I will only use the term NSC to avoid any ambiguity.

Thirdly Figure 1 shows the NSC pool model to represent explicit NSC accumulation. The concept of a "pool model" is often used in modeling research. The amount of NSC fluctuates in the pool, increasing up to the maximum (determined by eq. (10) and (11)) by the assimilated carbon through photosynthesis and sometimes decreasing due to metabolism and bud flush. I apologize for any confusion caused by the lack of caption in Figure 1. Perhaps you misunderstood from Figure 1 that the NSC in trunks feeds into NSC in other organs. This understanding is incorrect. The carbon from the trunk to the leaf is not in the form of NSC. The assimilated carbon satisfies the NSC trunk pool, and then the rest of assimilated carbon satisfies the next NSC leaf pool. The outflow of carbon as NSC is only used for metabolism and bud flush, as shown in the square below the NSC pool.

The inflow and outflow of NSC are represented by the pool model, where each leaf, trunk, and root has its own NSC pool as Figure 1 shows. The maximum pool size depends on the biomass of each organ. However, I agree with you, the NSC pool model does not represent all the processes of carbon allocation in real plants. In reality, trees allocate leaf-generated soluble sugar to other organs to support their physiological activity, and NSC in one organ may flow into another. In SEIB-DGVM ver 1.0, we did not consider the translocation because, although leaves have a high soluble sugar concentration, they account for a small proportion of the total NSC amount of trees and trunk account for the largest NSCs pool due to the largest biomass, so the flow of NSC from leaves to trunk is small compared to the NSC in trunks (Cho et al., 2022, Ecol. Inform.). In ver 2.0, I will try to include this process. However, in ver 1.0, this process does not affect the results much, and the key point of the study is to develop an explicit NSC pool model for each organ that matches the observed seasonality and total NSC. The carbon flow within organs may be important for further model development.

Answers for Specific Comments

47-48 "decrease of wild animal habitat, altered hydrological and carbon cycles, and increased vulnerability to sudden invasions by exotic species"

Answer: I deleted "decrease of wild animal habitat and increased vulnerability to sudden invasions by exotic species".

61 "when little recently assimilated carbon is available"

Answer: I appreciate you pointing out my mistake. I have made the necessary modification: 'when sink strength exceeds source activity.

75 "the amount of NSC depends"

Answer: I changed "the amount of NSC storage or remobilization depends". Thank you for helping me make the sentence clearer.

84 "and xylem"

Answer: Thank you for checking my mistakes. I changed "girdling of the phloem and xylem" to "girdling".

85 “recovery of trees”

Answer: I appreciate the additional information you provided. If I understand correctly, the speed of recovery of trees under stress depends on the severity of the stress and the specific plant processes that are impaired. I have decided to delete the explanation 'delay recovery trees' as it may be misleading to readers and is not necessary to explain the indirect effects that lead to tree mortalities.

88 “supply leads to carbon starvation”

Answer: I am sorry, I did not understand your concern. Embolism may be main cause of tree mortality from drought. However, carbon starvation is considered the process when stomatal closure precludes photosynthesis relative to carbon demand for abnormally prolonged periods. I have read the recent review by McDowell et al. published in 2022. Could you tell me the question that you had?

108-109 “the growth, competitive interactions, and mortality of each tree are calculated based on environmental conditions.”

Answer: SEIB-DGVM calculate competition between individuals, without interactions between individuals, the competitive interactions are not calculated.

117 “flagship”

Answer: Yes, I shared the judgement by modeler, but it seems to make others confused, so I deleted it.

121, 133 “simulate NSC dynamics” “reserves”

Answer: I appreciate you bringing this important points to my attention. I failed to mention the reason for the need to include the NSC process in SEIB-DGVM. NSC plays a critical role in tree metabolism and the overall health of forest ecosystems, but SEIB-DGVM lacks the capability to accurately calculate NSC. This limitation hinders the ability of SEIB-DGVM and MIROC-ESM to simulate the impacts of NSC imbalances on forest disturbance patterns.

146 “disturbances”

Answer: In SEIB-DGVM, wildfires and high temperature stress are calculated as disturbances.

147-148 “carbon stock in leaves and roots”

Answer: It means NSC in leaves and roots.

Carbon stock and NSC are same meaning, so I will unify the term.

151-152 “even though the carbon stock of the trunk depends on the leaf mass from the previous day”

Answer: I am sorry for misunderstanding you. The carbon stock means NSC, so I wrote briefly how to calculate the NSC in original SEIB-DGVM, but the sentence is too brief to be understood. Therefore, I deleted the sentence, and I added further information about the NSC in original SEIB-DGVM into section 2.2.1 NSC pool.

157 “NSC pools”

Answer: I am sorry if I confuse you.

First of all, stock means NSC, so I change to use only NSC.

Pools mean pool model as Figure 1 shows that stock NSC from assimilated carbon and emit NSC for metabolism.

Mass means biomass including NSC storage, e.g., leaf mass.

159-160 “growth of leaves”

Answer: I am sorry for misunderstanding you. I wrote how to calculate NSCs in the original SEIB-DGVM. The NSC in trunks is supplemented from the litter after seed establishment and is based on the existing leaf biomass after the first 30 days of the growing season.

200-201 “overflowing carbon”

Answer: The maximum of NSC in each organ is defined as $NSC_{organ,\ max}$. The next paragraph explains $NSC_{organ,\ max}$, so I replaced the previous paragraph with it. Firstly, the surplus carbon that remains after respiration is assigned to $NSC_{trunk\ t}$. The overflowing carbon means the rest of assimilated carbon after NSC in trunks reaches $NSC_{trunk,\ max}$. The term "overflowing carbon" may cause confusion among readers, so I have changed it to "the rest of assimilated carbon.

203 “maximized”

Answer: The total NSC is maximized in relation to the total biomass. The maximum of total NSC is defined in Table 1.

206 “volume”

Answer: It is not percentage. For example, if a temperate tree is 200kg, the maximum of total NSC storage is 10kg.

The value is average for total NSC included in trees collected in each reference of Table 1.

These values means total NSC (soluble COH + starch), so it included both soluble COH and starch.

211 “covered whole seasons”

Answer: It means several data points per season.

219 “three NSC types”

Answer: It means three NSC seasonality: tropical, temperate, and boreal.

247 “assimilated carbon is inadequate”

Answer: Yes, it means insufficient. When stomata are closed during a drought, the tree cannot photosynthesize, but it still needs to respire. In such cases, the tree cannot produce enough carbon to be used for respiration.

248 “NSC”

Answer: I am sorry for misunderstanding you. NSC and storage have the same meaning, so I used only NSCs in the manuscript. But, assimilated carbon and NSC have different meaning in this model.

The assimilated carbon is used for plant growth and other expenditures and all carbon are consumed on the day. While, the NSC is mainly carbon storage, so sometimes used for expenditures when the assimilated carbon is less than the expenditures, and the NSC pool is not used for plant growth, therefore, all NSC is not consumed on the day

248 “loss is allocated”

Answer: I am sorry if it confuses you.

When assimilated carbon < respiration, the NSC storage compensates for the shortage.

So, the total NSC storage (NSC_{leaf} + NSC_{trunk} + NSC_{root}) decrease by the shortage.

For example, in boreal forests, NSC_{leaf} is decreased by 20% of the shortage, NSC_{trunk} is decreased by 60% of the shortage, and NSC_{root} is decreased by 20% of the shortage. The allocation is shown in Table 2.

264 “boreal in Table2”

Your response

“I understand that species behavior has to be binned according to region, to some degree. This, however, also means that boreal conifers and broadleaf store similar amounts of NSC in leaves. Not sure this is realistic.”

Answer:

Yes, different species exhibit varying degrees of NSC behavior. However, it is challenging to model different NSC processes for each species due to a lack of observational data. The synthesis paper by Martínez-Vilalta et al. (2016) demonstrates the NSC seasonality in each climate region by averaging the NSC of samples collected from various field sites containing different species. In this study, we used the paper as a basis to define the amount of NSC depending on daily photosynthesis and the biomass of each organ in eq. (11) ($NSC_{organ, max} = (a + b \times \text{daily GPP}) \times \text{Biomass}$). We applied the equation into 1 PFT in point-scale simulation. Then, we expand the scale into global simulation to apply into 14 PFTs.

You mentioned that "boreal conifers and broadleaf store similar amounts of NSC in leaves," but this model shows that the amount of NSC depends on daily GPP and biomass, which are influenced by leaf seasonality. As a result, boreal conifers and broadleaf actually store different amounts of NSC in this model.

268 “deciduous PFTs”

Answer: In SEIB-DGVM, to represent tree fall leaves during winter, the dormant phase is incorporated into deciduous PFTs, while evergreen PFTs do not have the phase because they do not need to lose leaves. From the dormancy phase to growth phase, NSCs are used for deciduous PFTs in both the original and new model.

299 “Site descriptions”

Answer: Yes, the measurement was reported from other studies, so I made the description more concise by removing some sentences.

301 “point-scale”

Answer: The study involves two validation process: point-scale and global-scale. I added further explanations into section 2.3 Validation of NSC for local and global simulations.

In modelling studies, we often differentiate between 'point-scale' and 'global-scale' simulations. In this study, we used the term 'point-scale' to refer to simulations conducted at specific field sites.

371 “global scale”

You mentioned “There is so little data available to make this global-scale validation useful”. However, we used all available NSC data from the given climate zone.

The study involves two validation process: point-scale and global. Firstly, we selected 4 filed sites with different climate zone, where only 1 PFT was present. Next, the NSC module was validated to determine the accuracy of the equations used to estimate NSC. Secondly, the NSC module was

applied into a global simulation using all available NSC data. This simulation is key aspect of this study, as this model is designed to simulate how changes in NSCs of trees will affect global carbon in future scenarios.
I added further description into section 2.3 Validation of NSC for local and global simulations.

390 “Parameterization of NSC functions”
Answer: Thank you for giving me advices. I added further information about where the data were collected.

406 “The parameter *a* was then adjusted so that the fluctuations of the NSCs did not exceed”
Answer: I apologize for confusing you. First of all, the parameter *a* in Eq. (10) controls the initial amount of photosynthetically fixed carbon mobilized for the NSC pools. The parameter *b* in Eq. (10) controls the seasonal fluctuations of the NSCs from the parameter *a*. The NSC seasonality in our model is determined by these two parameters. For example, in temperate and boreal forests, NSC in leaves typically increases from spring to summer. To reflect this trend, we set parameter a to a value lower than the observed mean seasonal NSCs, while parameter b represents the increasing trend. Therefore, only by changing *a*, it is not expected that the model provides estimates within the range of observations.

423 “Schematic model”
Answer: I apologize if the figure has caused confusion.
When carbon is assimilated, it enters the NSC pool, which has a maximum capacity. So, I mean that the carbon that exceeds the NSC pool capacity is considered not form of NSC, but assimilated carbon. NSC from the trunk is not transported to the leaves and roots. The model does not consider the translocation of NSC within organs because the amount of NSC translocated within organ is not big and it has minimal impact on the results. I agree with you, the NSC pool model does not encompass all physiological processes. However, SEIB-DGVM-NSC ver. 1.0 is the first basic model that can compute NSC in each organ. Further data on NSC translocation within organs can enhance the model's development.

430 “Canada”
Answer: I changed the name of paragraph: Boreal, Temperate, and Tropical.

Figure 2
Answer: Thank you for your help. I added data source in caption.
The data generated from point-scale simulations do not have confidence intervals because they

represent simulations at a specific time and location based on given latitude and longitude data. For instance, in the case of Canada, the modeled data depict the seasonal variation in 2000, which was calculated using the same latitude and longitude coordinates as the Canadian field site data that were used for validation.

Figure 5 “Caption”
Answer: I am sorry for confusing you. The mean refers to time period, and it means percentage of total NSC (leaf+trunk+root) to total dry woody biomass.
I changed the caption to this “The global map of percentage of total NSC concentration relative to total dry woody biomass averaged during 1976–2005 (%) (a) from the new model (b) from the original SEIB-DGVM”.

546 “on a point scale”
Answer: I am sorry for writing shortly, I wanted to write “point-scale simulation”.

579 “has a high potential to simulate various biotic effects on terrestrial ecosystems”
Answer: I agree with you. We cannot make the claim of a “high potential to simulate”. Instead, I revised to say that the new model can be used to simulate the biotic effects on terrestrial ecosystems compared to the original SEIB-DGVM because the original SEIB-DGVM cannot calculate the NSC in all organs.

585 “NSC concentrations in leaves”
Answer: Thank you for pointing out the mistakes. I wanted to say that NSCs in trunk and root are good indicators of carbon balances as well as NSC in leaves. I revised it.

590-598
Answer: I agree with you. I did not mention the findings of the study in the entire paragraph. I revised the paragraph to state that the new model can accurately simulate the total NSC in temperate and tropical forests at a global scale. Therefore, the model can be used to estimate the effects of carbon starvation and insect pests on forest ecosystems. Regarding carbon starvation, as you pointed out, it is not the main cause of plant death during drought. Therefore, I have modified the statement to say that carbon starvation is one of the causes.

602 “depicted the NSC changes in the trunk especially well”
Answer: I mean that Table 5 shows that the model accurately calculates the amount of NSC in the trunk at a global scale, which constitutes a significant portion of the total NSC. I revised it.

613 “decline of phloem conductance”

Answer: I agree with you. NSC dynamics are of secondary importance to plant function and survival under water ceases. I thought that the mention about phloem transport is not appropriate to explain the limitation of the new model. Therefore, I changed to mention temperature and short radiation rather than precipitation and soil properties, which affect photosynthesis rate and plant growth.