Review of 'Simulating carbon fluxes in boreal catchments: WSFS-Vemala model development and key insights '

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Reviewer 2:

This work quantitatively predicts the dynamics of carbon flux at the scale of the river-lake aquatic ecosystem. The Vemala model was integrated into a hydrological model to simulate carbon flux driven by water flows. The evidence strongly supports their conclusions, and the findings hold great potential for providing new insights into the carbon cycle in river-lake systems.

Answer: We thank reviewer 2 for the positive comment on the overall manuscript.

The reviewers only raised minor concerns for the authors to consider in the revised version:
1. Details regarding observation data collection are insufficient, such as the methods for collecting water/soil samples and measuring target parameters.

Answer: Thank you for this comment. We agree that the description of observational data should be clarified in the manuscript. The WSFS-Vemala model is developed and applied using long-term hydrological and water quality observations from national monitoring programmes maintained by the Finnish Environment Institute (Syke). Discharge data are obtained from the HYDRO dataset, which consists of continuous flow measurements from gauging stations across Finland. Water quality data, including total organic carbon, total inorganic carbon, alkalinity, pH, nitrogen, and phosphorus, are obtained from the VESLA dataset, which is based on routine grab sampling and laboratory analyses following standardized national protocols. Sampling frequency typically ranges from monthly to seasonal, depending on site and variable.

These observational datasets are used for model calibration and validation at the national scale. In addition, the targeted sampling campaign conducted in 2023 at Lake Tuusulanjärvi was used to support this study particularly. The sampling procedures and analytical methods for these measurements are described in detail in lines 290–292.

We will revise the Methods section accordingly to improve the clarity of the observational data description. As the current Methods section is already relatively long and detailed, we will also reconsider its overall structure and assess whether some technical details can be moved to Supplementary Materials. This will allow us to keep the main manuscript focused while still providing full methodological transparency. At the same time, we will ensure that all essential information regarding the observational datasets, sampling approaches, and analytical methods is clearly described in the main text.

HYDRO dataset / Syke, https://metadata.ymparisto.fi/dataset/%7B86FC3188-6796-4C79-AC58-8DBC7B568827%7D

VESLA dataset / Syke, https://ckan.ymparisto.fi/dataset/%7BB1444E19-0F36-49F5-A849-01A3D2083A11%7D

2. Only a single reference is provided for Eqs. 13–14 in the text. Additional references should be added to solidify the selection of coefficients.

Answer: Observations from the Vesla data management system of the Finnish Environment Institute (Syke) have been used. A reference to the database will be added to these equations.

3. Time series plots comparing simulated and observed TOC/TIC are missing in Sections 4.1.2–4.1.3, which undermines the validity of the NSE values presented in Table 3.

Answer: We agree that a reference to the appropriate figure already in the manuscript presenting TIC/TOC time series at the outlet of Vantaanjoki (suppl figure 3) is missing from this section 4.1.2. and 4.1.3. We will revise it accordingly.

4. The limitations of the modeling approach require further discussion, such as the underlying assumptions of the dozens of sub-models.

Answer: We agree that clarifying the assumptions and limitations is important. In the revised manuscript, we will discuss the need for further development of the model towards a combined inorganic/organic carbon soil model to take into account mineralisation in the soil as a source of inorganic carbon. Presently, the model simulates the inorganic carbon loading associated with rock weathering using alkalinity and soil types rather than accounting also for mineralisation of organic carbon in the soil. This model is seen as a first step towards a more integrated inorganic and organic carbon terrestrial model capable to simulate GHG from soils and TIC leaching from mineralisation and rock weathering. The lack of TIC data available for model development is the reason for the development of a separate TIC terrestrial sub-model. The strength of this sub-model is to use alkalinity data available at the national scale. Another limitation of the model is its applicability to areas dominated by carbonate soils. In boreal environments with rare carbonate soils, most of TIC and TOC are under a dissolved form. For the application of this model in carbonate soils, sedimentation processes of carbon should be added to the model.
The aim of this modelling approach is not a single lake but national scale modelling of TIC and TOC loading to the aquatic environment and to the Baltic Sea and to provide GHG from aquatic environments to be added to national estimates of GHG. We therefore focused our modelling development to the most important processes affecting TIC and TOC in boreal environments at the Finnish scale.

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