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Comparing methods to estimate annual soil CO_2 fluxes in spruce forests on incomplete temporal data series

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Abstract

The annual CO_2 flux from soils across different biomes plays a crucial role in developing global climate models and analyzing carbon cycles in terrestrial ecosystems. However, significant gaps remain in regional-scale studies due to the large labor intensity. Conventional soil respiration measurements are typically conducted just 1-2 times per month and only during snow-free periods, resulting in highly discontinuous data series that complicate annual flux estimations.

Our study addressed this challenge by analyzing 2,760 soil respiration measurements from spruce forests at the Ural-Carbon supersite (Middle Urals, Russia), collected by chamber method during autumn 2021 and from April to October 2022. We employed both classical regression approaches and machine learning techniques to model annual soil respiration patterns, while evaluating how model complexity (number of predictors) and methodological choices (including Random Forest extrapolation and hybrid approaches for winter CO_2 flux estimation) affected the results.

A simplified 7-predictor RF model showed only marginally lower accuracy compared to the full 21-predictor model (R^2 = 0.89, MSE = 0.22 vs R^2 = 0.92, MSE = 0.31). Remote sensing-derived predictors contributed more to model accuracy than field-measured variables. However, annual extrapolation using this model overestimated fluxes relative to the Soil Respiration Database (ver. 5) averages and disagreed with classical regression methods for fragmented datasets. After incorporating literature-based winter respiration values into the Random Forest model and averaging hybrid approaches, we obtained consistent annual flux estimates: Random Forest: 830.3 ± 6.4 g C/m²/year, hybrid approach: 851.6 ± 8.0 g C/m²/year.

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Categories

Forests

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soil respiration, random forest, forests, annual flux