学 位 論 文 審 査 の 要 旨

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学 位 論 文 題 名

The impact of non-structural carbohydrate production on the forest dynamics under climate change estimated by spatially explicit individual-based global dynamic vegetation model
（空間明示的個体ベース動的全球植生モデルを用いた気候変動下における非構造性炭水化物の生産が森林構造に与える影響の将来予測）

The doctoral thesis consists of 4 chapters, including 137 pages, 52 figures, 7 tables based on 1 reference paper. The aim of the study is to model the non-structural carbohydrate (NSC) accumulation process and simulate the impacts of NSC-induced tree mortality on global forest dynamics under climate change. I incorporated a new module to estimate NSC concentrations into an individual-based ecosystem model and simulated the impacts of tree mortality using the new model with global climate model outputs as inputs.

NSCs are essential for plant growth, metabolism, and buffering against environmental stressors such as drought and insect outbreaks. NSCs are closely linked to tree mortality, which is difficult to estimate based solely on ground measurements, particularly under climate change. Carbon starvation, resulting from an imbalance between NSC supply and demand, is one of the mechanisms driving drought-induced tree mortality. Therefore, modeling NSC dynamics in an ecosystem model is crucial for accurately estimating the impact of tree mortality on the global carbon cycle.

I used SEIB-DGVM (Spatially Explicit Individual-Based Dynamic Global Vegetation Model) for this study. I developed a new module to estimate NSC dynamics based on observational data. The NSC accumulation process differs across climate regions (boreal, temperate, and tropical). I validated the modeled NSC concentrations against observations at both point and global scales. Secondly, I simulated the new model under Shared Socio-Economic Pathway (SSP) scenarios and compared the forest dynamics to those of the previous model. Additionally, I included a condition where tree mortality rates increased as NSC concentrations decreased. I analyzed the impacts of NSC-induced tree mortality on global forest composition from 2015 to 2100.

Chapter 1 explains the role of terrestrial ecosystems in estimating the global carbon cycle and emphasizes the importance of modeling research for understanding terrestrial ecosystems' contributions. It also introduces NSCs, their interaction with tree mortality, and the significance of modeling NSC dynamics.

Chapter 2 provides a detailed description of the newly developed model, SEIB-DGVM-NSC, which simulates NSC dynamics. It describes how I developed the module for estimating NSC dynamics based on observational data, the validation methods used, and the input climate data. The chapter also includes validation results. NSC seasonality was validated at four sites representing different biomes: Canada (boreal), Austria and Switzerland (temperate), and Panama (tropical). When applying the same parameters used for point-scale validation to the global scale, the simulated mean NSC concentrations closely matched observed data across different biome types.

Chapter 3 examines how forest composition differs under rising CO_2 levels between the new model and the previous model across Asia, Europe, and North America. Under SSP scenarios, the new model predicts a bimodal distribution of trees, with taller, thicker trees dominating northern regions and shorter trees in southern regions, particularly in Europe. This pattern aligns better with observed trends, highlighting the sensitivity of trees to warm and dry conditions. The model also incorporates a carbon starvation mortality process. Carbon starvation reduces tree density, allowing surviving trees to grow taller. While shorter trees are more affected, taller trees remain unaffected and thrive under these conditions. Tree age is consistently younger under carbon starvation, demonstrating its impact on tree lifespan.

Chapter 4 concludes the thesis by summarizing the potential of SEIB-DGVM-NSC and emphasizing the importance of calculating NSC concentrations for understanding the global carbon cycle in terrestrial ecosystems.

These results demonstrate the high accuracy of predicting NSC concentrations globally using terrestrial ecosystem models. This success highlights the potential to simulate other tree mortality events caused by changes in NSC dynamics on a global scale in the future.

よって，審査員一同は，二宮秀輝が博士（食資源）の学位を受けるのに十分な資格を有するものと認めた。