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Allocation based robust methodology for simultaneous reproduction of carbon fluxes, LAI, and forest biomass

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The terrestrial carbon flux and storage are influenced by many environmental and physiological factors, such as drought, windstorms, fire, human activities, vegetation types, forest age, or soil structure. To assess the terrestrial carbon flux and storage, terrestrial ecosystem models have been used for decades. Despite the long history of development and evaluation, however, there are still substantial uncertainties in their predictions. With the current state of performance, it is often the case that models need to be calibrated by adjusting predefined parameters for having agreement with observations.

Although calibration is necessary, seeming success of model based assessment of carbon flux often accompanies with the ill effect, substantial misrepresentation of storage. Because of its strong association with climate change, carbon fluxes have been more rigorously investigated by the terrestrial ecosystem modeling community. In practice, a number of model based analyses have paid attention solely on carbon fluxes and often neglected carbon storages such as forest biomass. As a result of this practice, model parameters are inevitably biased to carbon fluxes.

Against this ill practice, there are studies introduced methods for constraining both carbon flux and storage components. Richardson et al., 2010 is one of studies attempted to constraint both carbon fluxes and storages with the DALEC model using eddy covariance and multiple biometric observations. Although they successfully constrained model parameters, computational cost was significant with their approach: it involves several stage of model runs requiring 50,000 iterations for exploring parameter space for a single site. Their approach is effective for identifying physiological characteristics of a particular site, but is not ideal for analyzing multi-sites or large scale ecosystems. In that case, a more robust and simple methodology is needed.

Establishment of such a methodology may be more feasible by focusing on key physiological parameters. Such parameters have to be (1) strongly correlated to both carbon flux and storage so that simultaneous reproduction of carbon cycle components can potentially be achieved by manipulation of those parameters and (2) the fundamental backbone structure common to ecological modeling so that the same method can be applied to existing models. Ones that satisfy these requirements may be carbon allocation parameters. Carbon allocations can influence the plant growth by controlling the amount of investment acquired from photosynthesis, as well as carbon fluxes by controlling the carbon content of leaves (which turns into Leaf Area Index (LAI)) and litter, both are active media for photosynthesis and decomposition. Thus, LAI, gross primary productivity (GPP), ecosystem respiration (RE), and forest biomass can potentially be reproduced by allocation parameters.

Toward the full reproduction of carbon cycle, the present study explored the existence of such suitable balances of carbon allocations for several carbon flux and storage components: LAI, GPP, forest biomass, and the below- to above-ground biomass ratio. An experiment was performed with a widely used model, Biome-BGC. Through a process of testing the simultaneous reproducibility with the Biome-BGC, we evaluate and discuss consequences of commonly accepted practices in ecosystem modeling: (1) the carbon flux-oriented calibration and (2) application of fixed allocation parameter values for vegetation type. Appropriateness of fixed allocation parameter values was evaluated with a set of allocation parameter values estimated from the optimization.

Acknowledgments
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Reference

Richardson, A. D., et al., 2010. Estimating parameters of a forest ecosystem C model with measurements of stocks and fluxes as joint constraints. Oecologia, 164, 25-40.

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