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Abstract

Crop yield is sensitive to climate change and has been projected to be negatively affected by future climate. To reduce yield loss and ensure food security in the context of climate change, it is critical to understand how climate variables interact with crop growth in agroecosystems. One important and widely used tool to study yield responses to climate is process-based modeling. However, using process-based models to simulate the climate impacts on crops is becoming challengeable as the future climate is characterized by more and more frequent extreme events, such as heatwaves, unpredictable rainfall, and droughts. Most existing crop models may not be capable of characterizing the impacts of such extreme events on crops simply because they usually do not simulate some critical processes that climate variables directly affect crop growth such as photosynthesis. Instead, they use a simplified approach--radiation-use efficiency (RUE) which is a coefficient to describe empirical relationships between intercepted radiation and biomass. The usage of RUE has simplified computation but also limited our understanding of interactions between climate variables (e.g., temperature, CO2, rainfall) and crop growth. Thus, we developed a module combining processes of radiative transfer and photosynthesis (RP) within the canopy to account for the impacts of climate variables on crop growth dynamically. Then, we integrated the RP module into a popular agricultural system model—the Environmental Policy Integrated Climate (EPIC) to assess its performance. The results show that its capabilities of predicting crop yield are comparable to the traditional RUE method. The correlation between observed and simulated biomass is 0.77 for the RUE method, while 0.76 for the RP method. But the RP method could show responses of biomass accumulation to changes in climate factors, which is almost overwhelming for RUE. For instance, the RP module could simulate how extremely high temperatures (which usually last several hours during a day) affect crop growth and also allow the EPIC to distinguish elevated CO_2 impacts on C3 and C4 crops, while the default RUE method could not. Therefore, the RP module is promising to improve capabilities and extend functionalities of current process-based models, which is not only beneficial to the community of crop modeling but also enhances our ability to evaluate the impacts of climate change on the agroecosystem.

Keywords: Crop modeling, process-based models, climate change, crop yield, photosynthesis, agricultural system modeling

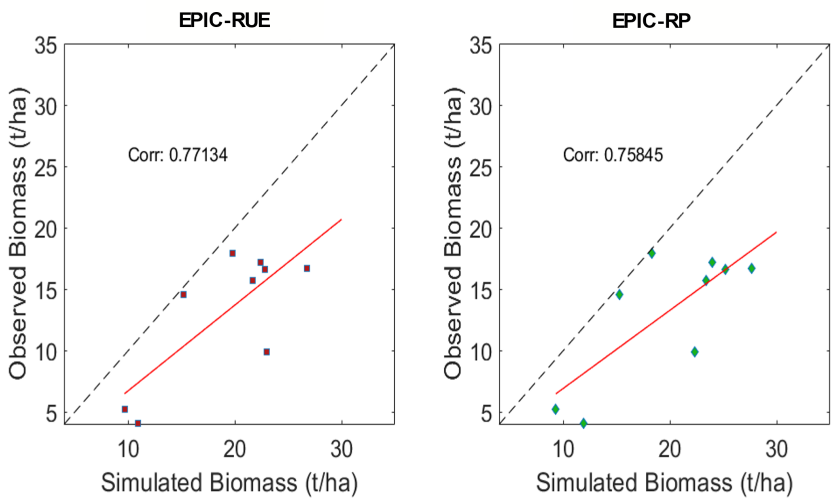

Figure 1. Comparison of simulated biomass and observed biomass by EPIC using the default RUE (left) method and the RP module (right).

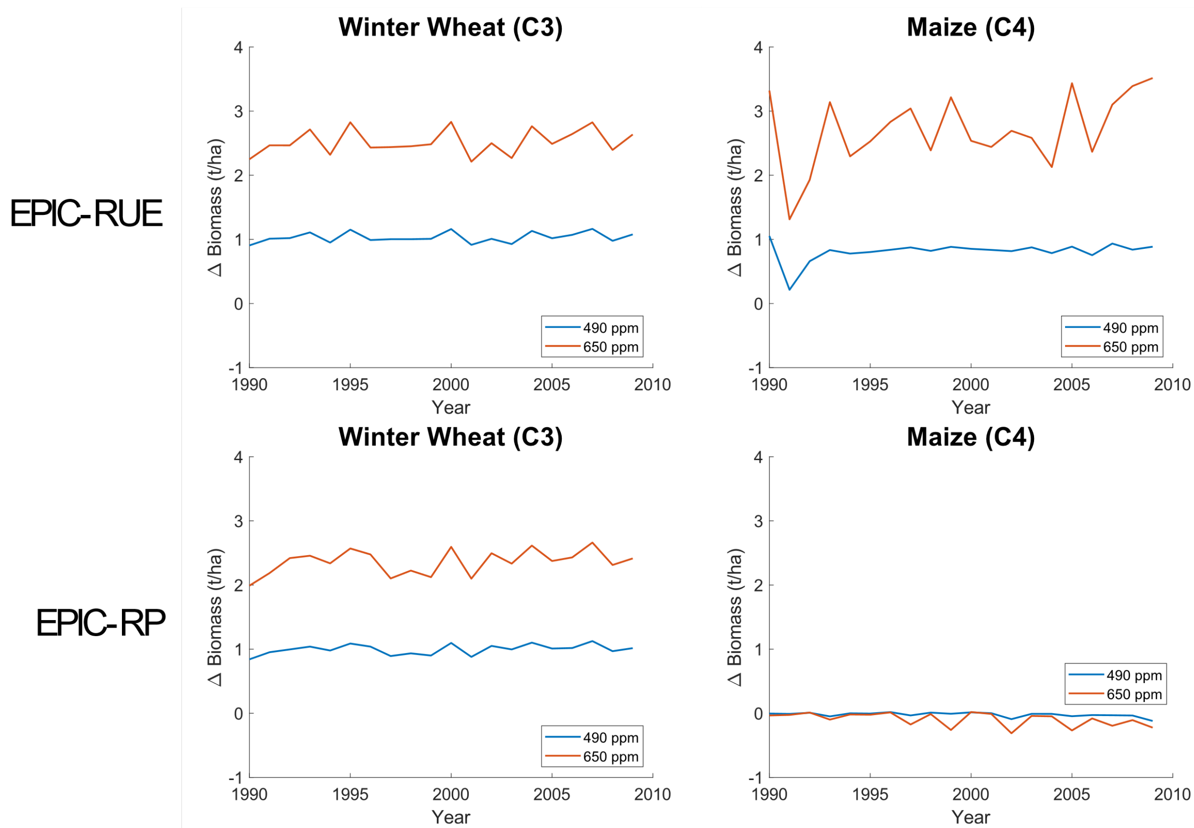

Figure 2. Simulating the impacts of elevated CO_2 on biomass accumulation of C3 and C4 crops with the RUE method and RP module. The results of the RUE methods show an increment in yield for both C3 and C4 crops. But the RP module shows different responses of C3 and C4 crops to elevated CO2 concentrations, which is consistent with that from field experiments.