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Modelling future gross primary productivity in Australia

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Abstract: Achieving net-zero emissions by 2050 is a top priority for the Australian government. A critical aspect of reaching this goal is modelling vegetation photosynthesis, or gross primary productivity (GPP), at a large scale, as this is the only flux that the terrestrial carbon sink uses to absorb carbon emissions. However, the unique challenge in Australia is that it is dominated by arid and semi-arid ecosystems where the coupling between carbon and water plays a crucial role in the photosynthesis process. It is unclear how hydrologic characteristics such as hydroclimate variability and hydrological connectivity impact carbon modelling, and whether existing carbon models can adapt to dynamic plant traits under a changing climate.

In this study, we tested two competing parsimonious carbon models, including a conceptual eco-hydrological model (HYMOD-BGM) that uses water use efficiency, and a deep learning approach (a Long Short Term Memory network, LSTM) using various inputs. Our results showed that the LSTM performed better, but the water-carbon coupling was not explainable in this model, whereas HYMOD-BGM was able to explain the coupling. To further evaluate the Water-Carbon coupling in the model, we tested these models against a detailed virtual catchment based on the process-based model, RHESSys(Tague, 2004). This virtual catchment test allowed us to predict and assess the impact of Water-Carbon coupling on vegetation dynamics. Our findings revealed that Water-Carbon coupling is a dominant factor when water availability is low.

Building on these findings, we used three bias-corrected global climate models (GCMs), ACCESS, MIROC6, and MPIESM, to drive both HYMOD-BGM and LSTM models. Our results showed that under the worst CMIP6 carbon emission scenario SSP585, LSTM was unable to respond to increasing temperatures, and the prediction of GPP remained constant. In contrast, HYMOD-BGM simulated decreased GPP due to water stress caused by increasing temperature. Our study identified appropriate parsimonious modelling approaches for quantifying carbon budgets and highlighted the importance of considering water-carbon coupling in carbon modelling efforts.

REFERENCES

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