26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Ecological forecasting to support experimental design: the EucFACE experiment as a case study

Belinda Medlyn[1], Mingkai Jiang[2], Bin Wang[2], He Lyu[2], Xueqian Zhang[2], David Wårlind[3], Jürgen Knauer[4], Katrin Fleischer[5], Daniel Goll[6], Stefan Olin[3], Xiaojuan Yang[7], Lin Yu[5,8], Sönke Zaehle[5], Haicheng Zhang[9], Kristian Schufft[5], David Ellsworth[1], Ben Smith[1]

[1] Hawkesbury Institute for the Environment, Western Sydney University, Richmond, NSW, Australia
[2] State Key Laboratory for Vegetation Structure, Function and Construction (VegLab), College of Life Sciences, Zhejiang University, Hangzhou, Zhejiang, China.
[3] Department of Physical Geography and Ecosystem Science, Faculty of Science, Lund University, Sweden.
[4] University of Technology, Sydney, NSW Australia
[5] Max Planck Institute for Biogeochemistry, Jena, Germany.
[6] Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ-Université Paris-Saclay, Gif-sur-Yvette, France.
[7] Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee,USA.
[8] Department of Earth System Sciences, Hamburg University, Hamburg,Germany.
[9] Carbon-Water Research Station in Karst Regions of Northern Guangdong, School of Geography and Planning, Sun Yat-Sen University, Guangzhou, China.

Email: b.medlyn@westernsydney.edu.au

Abstract: Ecosystem-scale experiments represent a major opportunity to improve terrestrial ecosystem models. Applying models in advance of an experiment to forecast the potential outcomes maximises the value of the experiment for modelling by identifying critical areas of uncertainty, guiding experimental design, and prioritising measurements. Here we illustrate the effectiveness of an iterative forecasting approach, using sequential model intercomparisons at the large-scale Eucalyptus Free-Air CO_2 Enrichment (EucFACE) experiment.

The response of terrestrial vegetation to rising atmospheric CO_2 concentrations has been highlighted as one of the key uncertainties in the coupled Earth-system models underpinning climate change projections. In particular, it is unclear how soil nutrient limitation – particularly the low phosphorus (P) availability in subtropical and tropical soils – constrains any potential CO_2 fertilisation effect. The EucFACE experiment was established in 2012 in a mature eucalypt woodland in western Sydney and is the first large-scale experiment to test the response of P-limited vegetation to CO_2 enrichment.

A suite of seven models was applied to forecast experimental outcomes at the start of the experiment. There were significant disagreements among the models in their forecasts, and these disagreements were used to target measurement campaigns in the experiment. Results from the experiment showed no response of above-ground productivity of the woodland to the CO_2 enrichment, and analysis of whole-ecosystem carbon (C) and P budgets indicated that P availability was constraining additional growth.

To further test this conclusion, the entire EucFACE experiment was fertilised with P in 2023. A suite of eight ecosystem models was applied to predict the outcome of P fertilisation at several different application rates. Comparison of the model predictions in the advance of the experiment has highlighted major knowledge gaps, allowing experimental hypotheses to be refined and measurements to be targeted to these gaps. Our results provide a clear demonstration of the advantages of iterative forecasting of experiments as an important strategy to improve model predictive capacity.

Keywords: *Ecological forecasting, Terrestrial ecosystem models, Carbon dioxide, Phosphorus limitation, Soil nutrient cycling*

