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Climate change and Australian vegetation: where are we headed?

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Abstract: From the wet tropical rainforest to the saltbush plains, the Australian vegetation has been shaped by climate over millennia. Now, as anthropogenic climate change accelerates, we are likely to see significant impacts on the function and distribution of native vegetation, but it is not yet clear what form those impacts will take. Detection, attribution, and prediction of changes in vegetation remains a large challenge, particularly in Australia. Notable shifts that have been reported to date include: significant greening in some regions, likely associated with CO2 fertilisation; shifts in timing of pasture grass productivity, associated with changing rainfall patterns; tree dieback, associated with hotter droughts and pest outbreaks; and increased fire frequency, associated with increases in fire weather. Such changes in vegetation function have major implications for our land-based natural capital, and there is a critical need for predictive models to assess risks to ecosystem services.

A key challenge for prediction is to capture the interactions and feedbacks among environmental drivers (e.g. rising CO2 concentrations, increasing temperatures, changes to rainfall patterns) and vegetation processes (e.g. productivity, carbon sequestration, water use, nutrient cycling, flammability). Mechanistic vegetation models simulate the interactions among these major processes, and their responses to environmental drivers, in order to predict vegetation growth and dynamics over time.

Typically, however, there is significant disagreement across models, reflecting the considerable scientific uncertainty involved in attempting to describe and quantify the key biological processes. The use of model intercomparisons to identify major areas of disagreement and target experimental design to reduce uncertainty has proved to be a valuable way forwards, providing new scientific insight as well as improved confidence in model predictions.

One notable example of this approach has been the iterative application of vegetation models to Free-Air CO2 Enrichment (FACE) experiments. These experiments fumigate patches of vegetation to elevate atmospheric carbon dioxide (eCO2) and track changes in ecosystem processes over time. Several large-scale FACE experiments commenced in the late 1990's and ran for over a decade. The experimental data were then used to evaluate the responses to eCO2 predicted by a range of vegetation models. The data were able to discriminate among some sets of model assumptions – for example those related to water-use efficiency, carbon allocation, and tissue stoichiometry – but were not sufficient to constrain other model assumptions. Thus, for new FACE experiments, there has been a concerted effort to run model intercomparisons in advance of the experiment. At the Eucalyptus FACE experiment (EucFACE) experiment in western Sydney, for example, model intercomparison was used to identify a priori the major competing hypotheses causing disagreement among models, enabling data collection to be targeted at discriminating among these assumptions. Data emerging from the first five years of the experiment's operation are now being used to constrain and develop the next generation of vegetation models.

Similar approaches are being applied to advance model representations of processes leading to drought mortality, fire frequency, and vegetation distributions. The iterative model-data integration approach described here is a powerful way to advance scientific understanding and our capacity to predict, and plan for, future vegetation dynamics.

Keywords: *Dynamic vegetation model, carbon sequestration, carbon dioxide, climate change, model intercomparison*