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Water and vegetation in a changing environment: optimal adaptation, feedbacks and key trade-offs

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Vegetation responds to environmental change in many ways and at various time scales. For example, increasing atmospheric CO_2 concentrations can reduce stomatal conductance and, hence, transpiration at an hourly scale, whereas adjustments in leaf area, photosynthetic capacity and root distributions follow at the daily to seasonal scale. Evidence for root growth plasticity and adaptation to soil moisture conditions can be found in field and experimental data. However, the time scales at which roots respond to a sudden change in soil moisture are not well documented, and the dynamics of root allocation in response to soil moisture changes at daily time scales is not well understood. In addition, when looking at even longer time scales, shifts in tree density and species composition may happen over decades or centuries only. These responses give rise to feedbacks with soil water resources and atmospheric conditions, affecting the entire soil-vegetation-atmosphere system on a large range of spatio-temporal scales.

Reliable projections of long-term ecosystem response to environmental change require adequate understanding and quantitative representation of the physical processes and biological trade-offs related to vegetation-environment interactions. This includes answering the following questions:

1) What is the trade-off between canopy CO_2 uptake and water loss under given atmospheric conditions?

2) How much carbon do the plants need to invest into their root system, as well as water transport and storage tissues in order to achieve a certain water and nutrient supply for the canopy?

3) How quickly can root systems respond to changing conditions?

4) What are the trade-offs between carbon investments into foliage, stems and roots and returns in terms of carbon uptake by photosynthesis?

5) Do plants adapt to the environment in an optimal way in order to maximise their net carbon profit, i.e. the carbon uptake minus carbon invested into tissues needed for its uptake?

6) And finally, can vegetation behaviour be predicted by assuming a community-scale optimal adaptation for maximum net carbon profit?

Here we present promising results related to Question 6) based on the Vegetation Optimality Model (VOM), which was recently applied and tested along a precipitation gradient in Australia. We also explain the benefits of quantitative answers to Questions 1-4 and point to targeted experiments needed to address these questions, some of which will be presented separately.