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Plant functional types for world vegetation models applied in Australia

Current-generation DGVMs express the variety of plant behaviours through a smallish number (~10-20) of plant functional types. Factors that have kept this number small include

- Absence of clear evidence that increasing the number would improve the predictive capacity, and absence of parameter-estimates for further PFTs
- Computing costs, for vegetation models that are dynamically linked to climate models on ~15 min timescales
- Failure of nerve on the part of the vegetation ecology research community; over 20 years we have been unable to agree coherent recommendations

Three parallel strategies can be recommended towards improving the representation of plant types in DGVMs.

1. Improving parameterization of existing PFTs

Over the past 10 yr large datasets (thousands to tens of thousands of species, with worldwide coverage) have been assembled for several ecological-strategy traits, including leaf photosynthetic and lifespan traits, seed size and dispersal morphology, leaf size, sap, wood density and hydraulic anatomy, potential height, leaf decomposition rates, and fire response. There has been Australian participation or leadership in much of this activity. These data show clearly that existing PFTs include a very wide range of parameter-values, and that variation is continuous not categorical for quantitative traits. These data (and more are accumulating quickly) can provide a basis for

- Improving parameter estimates for PFTs
- Checking whether PFT-sets reflect the trait-correlation patterns that are actually observed in nature
- Modulating the parameters attributed to PFTs depending on the physical environment or on other traits

Some work has begun along these lines in collaboration with QUEST-UK. Rapid progress could potentially be made beginning immediately.

2. Adding further PFTs.

Further PFTs could be added for several reasons. For aspects that are dynamically coupled to atmosphere behaviour, proliferation of PFTs poses computing demands that may be difficult to meet. But for aspects that are only updated once every few months, there is no real limit to the numbers of PFTs that could be recognized.

a) Subdividing PFTs which span a particularly wide range on some parameter. For example, woody evergreen plants could be subdivided to reflect a wider range of tolerable leaf water potential.

b) Subdividing PFTs to reflect fire response and fuel properties, given the importance of fire in shaping vegetation worldwide and in Australia.

c) Adding PFTs for particular taxa that are thought to be both important and distinctive. Examples might be Triodia (hummock-grasses or spinifexes), an arid-zone sclerophyll grass that accumulates as above-ground fuel; and the eucalypts.

d) Adding PFTs that reflect differences in nutrient acquisition strategies, including the different mycorrhizal types, cluster roots, and nitrogen-fixation. This would need to be combined with better treatment of the phosphorus status of landscapes and of the nitrogen cycle.

e) Adding crops. These would not be PFTs as such, since they would not compete in mixtures with other PFTs. Nevertheless accurate representation of the land-surface properties of crops could be of substantial value.

There should be noted also the development of “ecosystem demography” models. These are models where a single disturbance type is identified, and time-since-disturbance becomes a niche axis. The models group individual trees into size-and-age classes, allowing growth and succession processes to be followed within PFTs while restricting the computing load. ED models increase the differentiation among plant types without formally increasing the number of PFTs. ED is currently being implemented into JULES and thence into HADGEM3.

3. Evolutionary ecology vegetation model (EEVM).

In an EEVM, traits would be allowed to “float” until they settled, giving a predicted PFT. The PFT-mixture would be predicted at evolutionary and ecological equilibrium. Therefore an EEVM would not be coupled to an earth system model. It would not be a replacement for a DGVM, but rather a complementary intellectual activity. It would not deal with “transients”, progressive change as the environment changes. It would, however, build scenarios for the end-points towards which selection might be heading.

There exist a wide range of evolutionary-ecology models for how particular traits should be positioned by natural selection under various circumstances. One strand of activity towards an EEVM would be to gather together this scattered collection of theory, and assess its overall capacity to predict the world’s vegetation successfully.

The other strand of activity would focus on the observable fact that there is not a single best winning strategy in most vegetation types. Theoretically there could be several reasons for this, but in my opinion the only one worth spending time on is frequency-dependent or game-theoretical competition among strategies; for example the mixture of height strategies observed in most vegetation types. Adaptive dynamics theory identifies conditions when two strategies should replace one. It is possible to solve numerically for the mixture of strategies that should be competitively successful at evolutionary and demographic equilibrium, but the equilibrium is slow and computing intensive. Currently Falster (unpublished) is working towards a “fast solver” for this problem.

Timelines:- Improving parameterization for existing PFTs, and adding further PFTs, are both activities currently under way to some extent. They can continue indefinitely. An evolutionary ecology vegetation model is a longer-term proposition. Given funding, it might be achievable over 4-8 years.