plant functional types

"How can the diversity of species and their responses to climate change variables be effectively simplified for modelling purposes?"

Version for use toward synthesis document: with unpublished data removed

Two main sources of information

- Macquarie Uni comparative ecology group, including
  - Ian Wright, trait correlations and leaf physiology
  - Fiona Scarff, flammability
  - Dan Falster, height and strategy mixtures
  - Anna Richards, C-N relations
- ARC-NZ Research Network for Vegetation Function
  - Collaborating with UK-QUEST (Quantifying and Understanding the Earth System) for vegetation modeling
  - Various working groups synthesizing data

In LPJ there are ~10 basic PFTs, differentiated on

- Photosynthetic and respiration traits: V_{cmax}, J_{max}, etc
- Woody vs herbaceous; evergreen vs raingreen vs winter-deciduous; C3 vs C4
- climate zone restrictions: GDD, cold-month T, warm-month T
- Scaling relations among dbh, height, total leaf area, crown width
- LMA, leaf lifespan
- C_i/C_a, E_{max}

Three styles of development

- Improved parameters for existing PFTs
- Add more PFTs
  - Further subdividing the range of responses
  - Ecosystem Demography
  - Fire and fire-response PFTs in Australasia
- Evolutionary Ecology Vegetation Model
  - Derive ecol and evol stable strategy mixture

PFT-trait parameterization: key traits vary continuously, often as correlated axes

- E.g. “leaf economic spectrum”
- leaf N, A_{max}, R_d, leaf lifespan, leaf mass per area
- Nearly 80% of worldwide variation is along the main axis

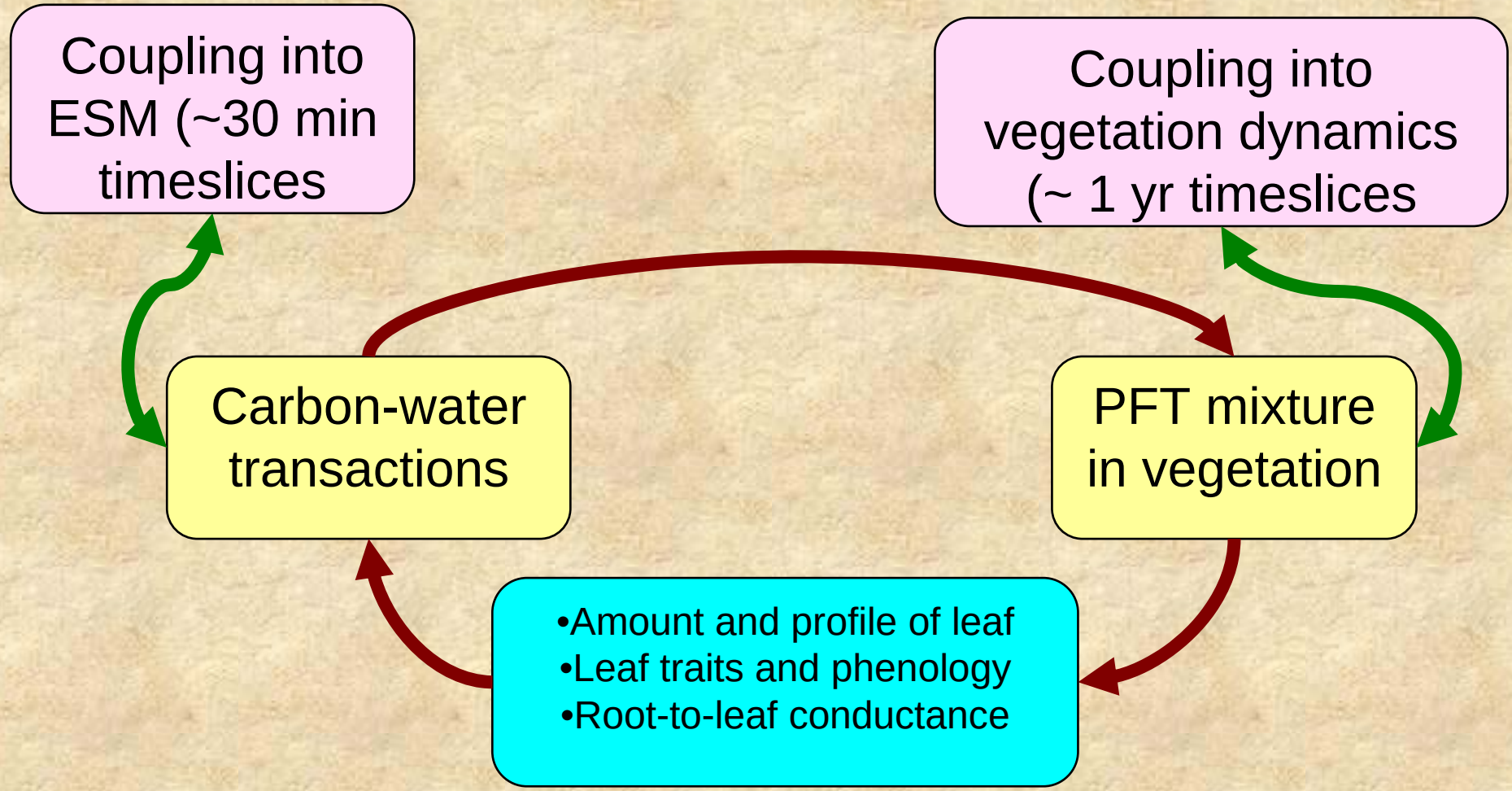
Image unavailable

Wright et al (2004)

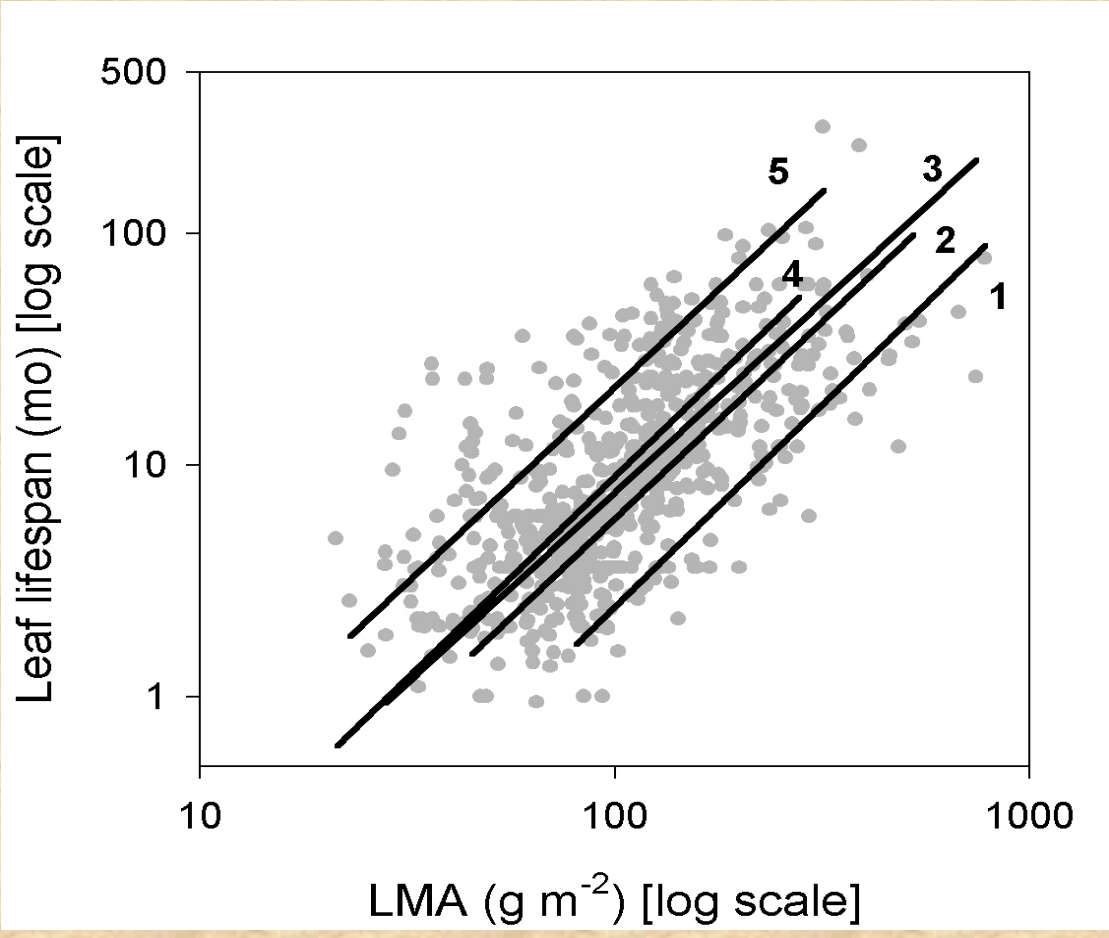
Squares show Sheffield DGVM PFTs, against background of actual species mainly from Glopnet

- Correlation across PFT's loosely reflects correlation across real species
- PFT traits are sometimes near centroid of species, sometimes not
- note wide range within each PFT, and continuous variation

PFTs could be much more numerous for vegetation dynamics, but would need to be condensed for coupling to ESM



Some pairwise trait relationships are modulated by climate; could replace parameters with appropriate equations



Wright et al 2005, Global Ecol Biog 14: 411-421

Replacing set parameters for each PFT by appropriate equations in DGVMs

- Coordination between traits
- Modulating with physical environment
- Trials in Sheffield DGVM
  - in collaboration with Rosie Fisher (UK-QUEST)

Ecosystem Demography

- 'size and age structured approximation': method of grouping similar trees together, to reduce computational load
  - Trees grouped into classes by **PFT**, **height**, and **age since last disturbance**
- being implemented by Rosie Fisher (Sheffield) into JULES, for gap-phase succession in Amazon
- Veg Function Network and QUEST are collaborating to assemble test data sets in a wide range of vegetation types

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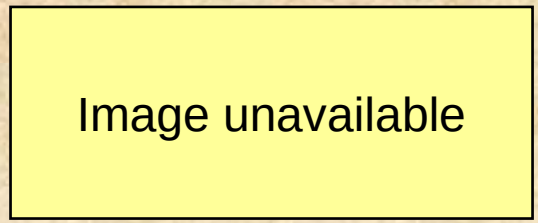
Mortality vs wood density, as implemented into ED for Amazon forests by Rosie Fisher

Other parameters: decomposition and fire

WG20 meta-analysis of multi-species decomposition trials



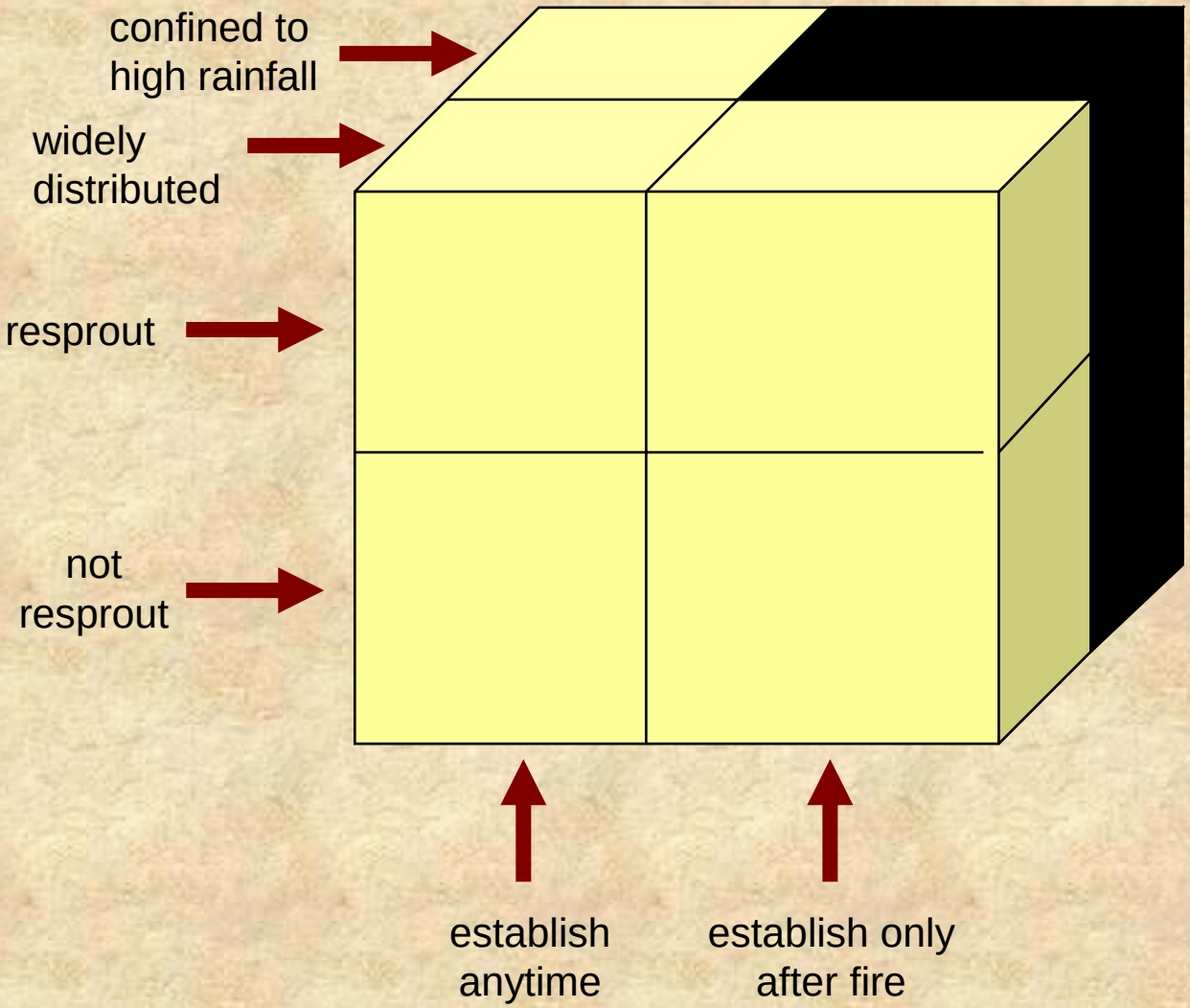
Diameter shows range across climate zones within species

Diameter shows range across species

WG24 Fire, vegetation and climate change in Australasia (collab with QUEST-UK)

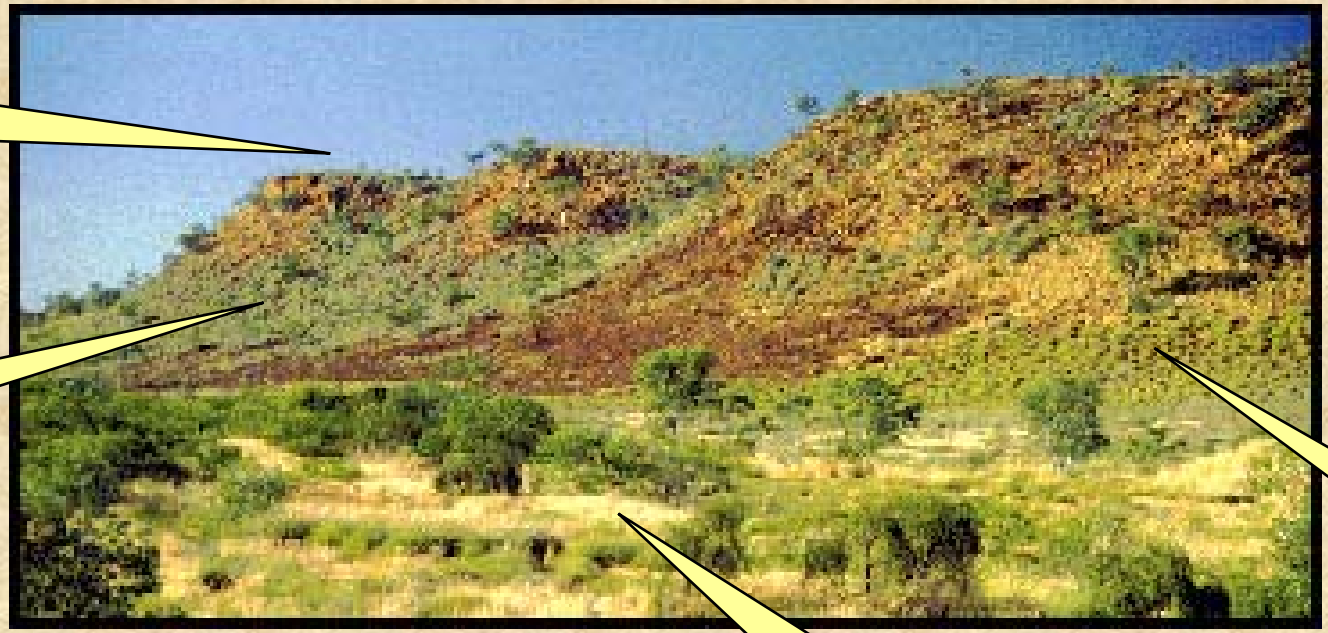
- Compile palaeo database for Australasian quaternary vegetation
- New set of PFTs for fire modeling in Australian vegetation
- Classify Australian pollen-types into PFTs
- Apply into LPJ-Spitfire, simulate fire and vegetation at various key times in the past, compare to maps from palaeodatabase

WG24 currently adopting 2 x 2 x 2 classification for woody plants in relation to fire



PFTs for Australia?

- Triodia
  - grasses that accumulate as fuel generating fire-regimes like shrub-dominated vegetation

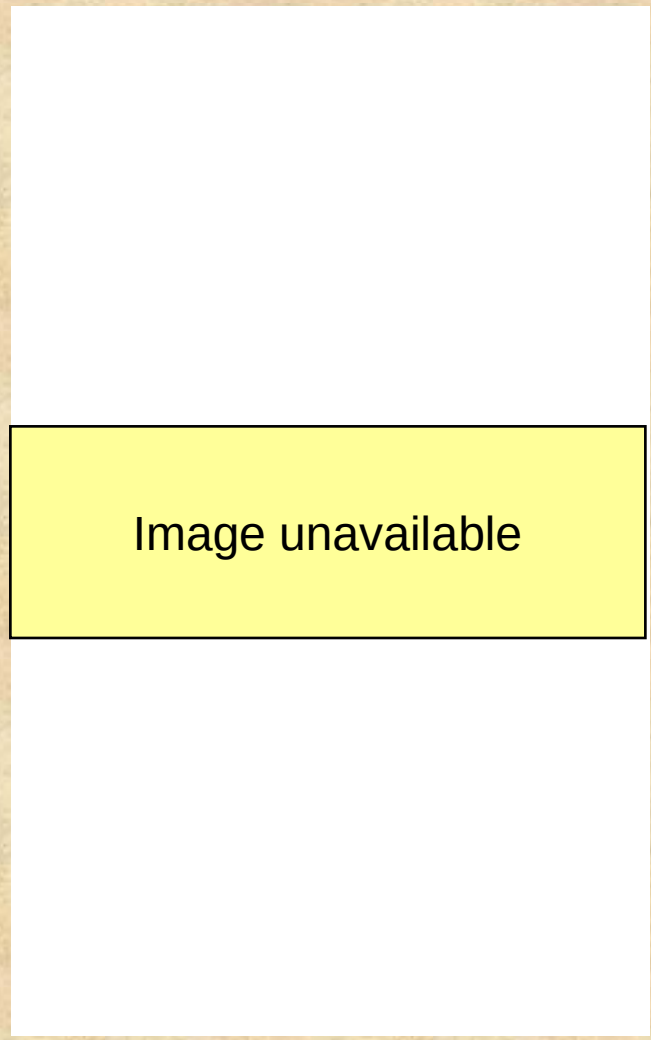


PFTs for Australia (cont)?

- Eucalypts
  - Maintain fast transpiration even during dry season?

PFTs for Australia (cont)?

- Nutrient acquisition strategies (cluster-roots, AM/Ecto/Ericoid, N-fixers)
  - Become relevant when models have better soil landscapes or nutrient cycles
  - Old, low-P soils generally seen as a key feature of Australian ecology
    - And an opportunity to improve representation also of other substantial parts of the world



PFTs for Australia? (cont)

- Crops?
- Vegetation types rather than PFTs
- Dynamics of coverage not decided by competitive growth
- Still, there could be several benefits from including in modeling

Evolutionary Ecology Vegetation Model (EEVM)

- Current DGVMs have PFTs with fixed traits
- An EEVM would instead evolve plants with whatever trait-combinations were most successful
- Potential benefits include
  - Flexible and continuous variation across modeled plants
  - Follow evolutionary response to changing conditions
  - Including evolutionarily novel conditions such as high CO_2

nature of an Evol Ecol Veg Model

- Traits would be allowed to “float” under natural selection until they settled, giving predicted PFTs
  - integrated test of scattered collection of theory about how trait-values are positioned by natural selection
- The PFT-mixture would be predicted at evolutionary and ecological equilibrium
  - Not coupled to an earth system model
  - Does 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
- Complementary to DGVMs rather than replacing them

Two strands

1

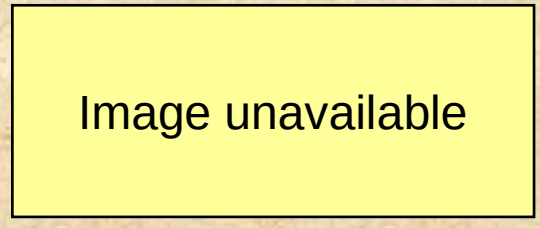
Strategy-mixture along a single tradeoff

- need a “fast solver” based on adaptive dynamics

Apply to different tradeoffs, e.g. height, time since disturbance

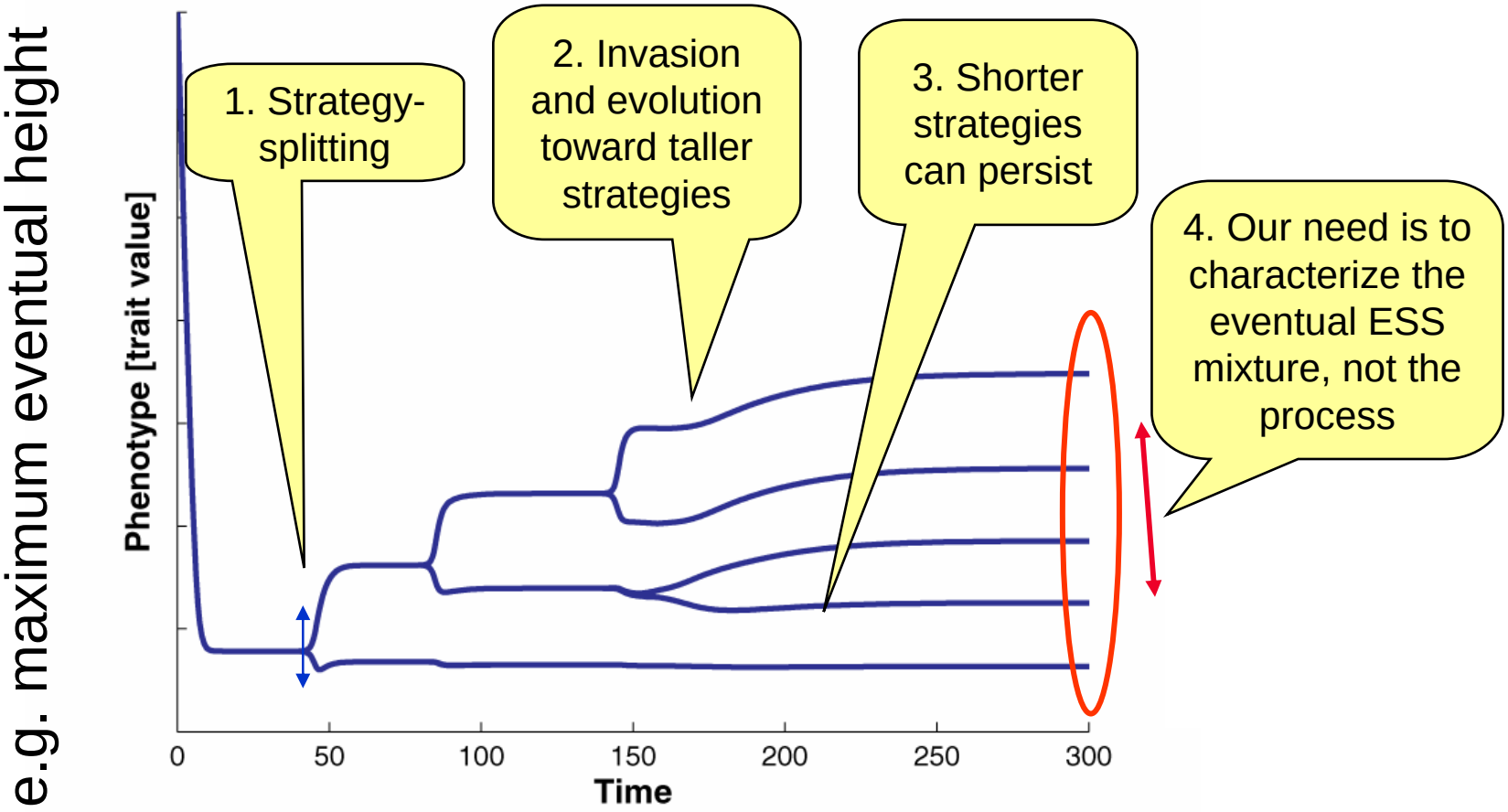
2

Optimization of traits where there should be a single best solution under given irradiance, VPD etc



Optimum sapwood area per leaf area in relation to physical-environment variables (Westoby, Falster, Cornwell in prep). What has been optimized here is [revenue - cost] per leaf area.

Emergence of an ESS strategy-mixture through “adaptive dynamics”



Doebeli, M. & Dieckmann, U. (2000) Evolutionary branching and sympatric speciation caused by different types of ecological interactions. *American Naturalist,* 156, S77-S101.
de Mazancourt, C. & Dieckmann, U. (2004) Trade-off geometries and frequency-dependent selection. *American Naturalist,* **164,** 765-778.

Timelines for different styles of development

- Improved parameters for existing PFTs
  - Possible over next 1-2 years, continuing thereafter
- Add more PFTs
  - Possible over next 1-2 yr, continuing thereafter
- Evolutionary Ecology Vegetation Model
  - Maybe 5-8 years off?