Why vegetation modelling depends on luck.

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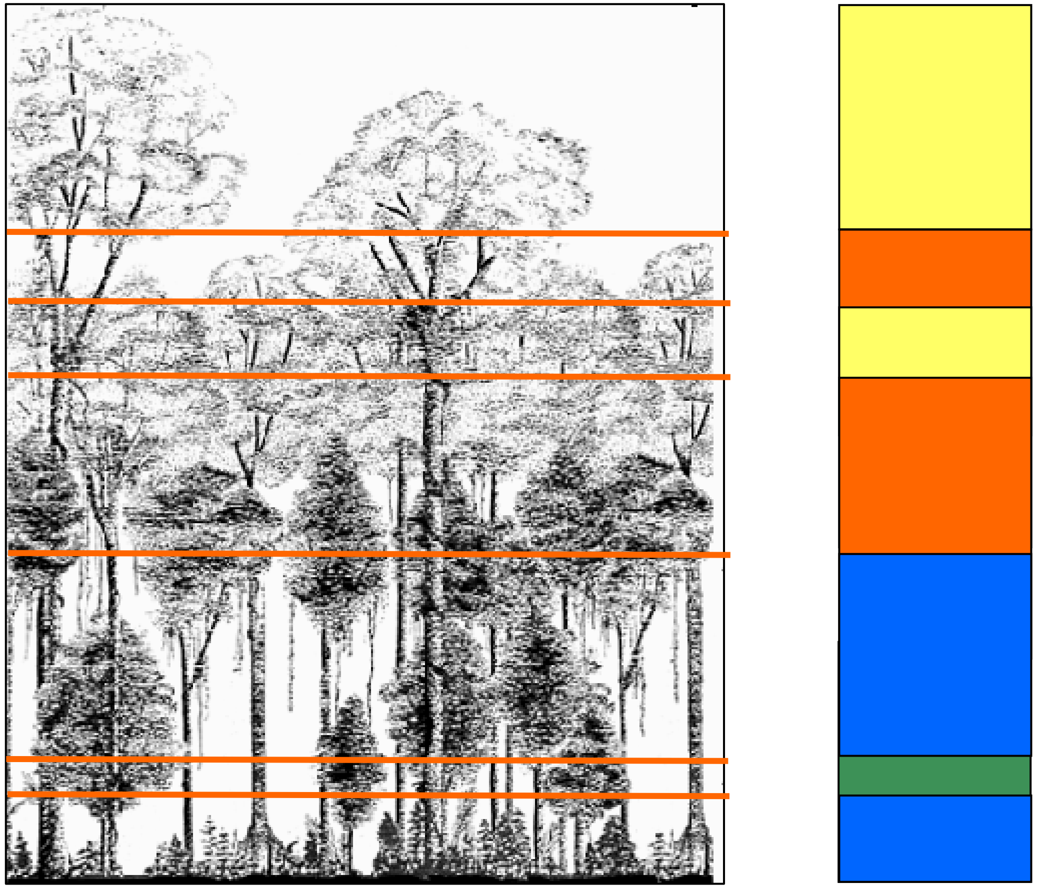
Content

- Short introduction to ED modelling strategy
- Challenges of modelling savanna ecosystems
- Predicting the future – mortality and vegetation distribution.

Ecosystem Demography Model (ED)

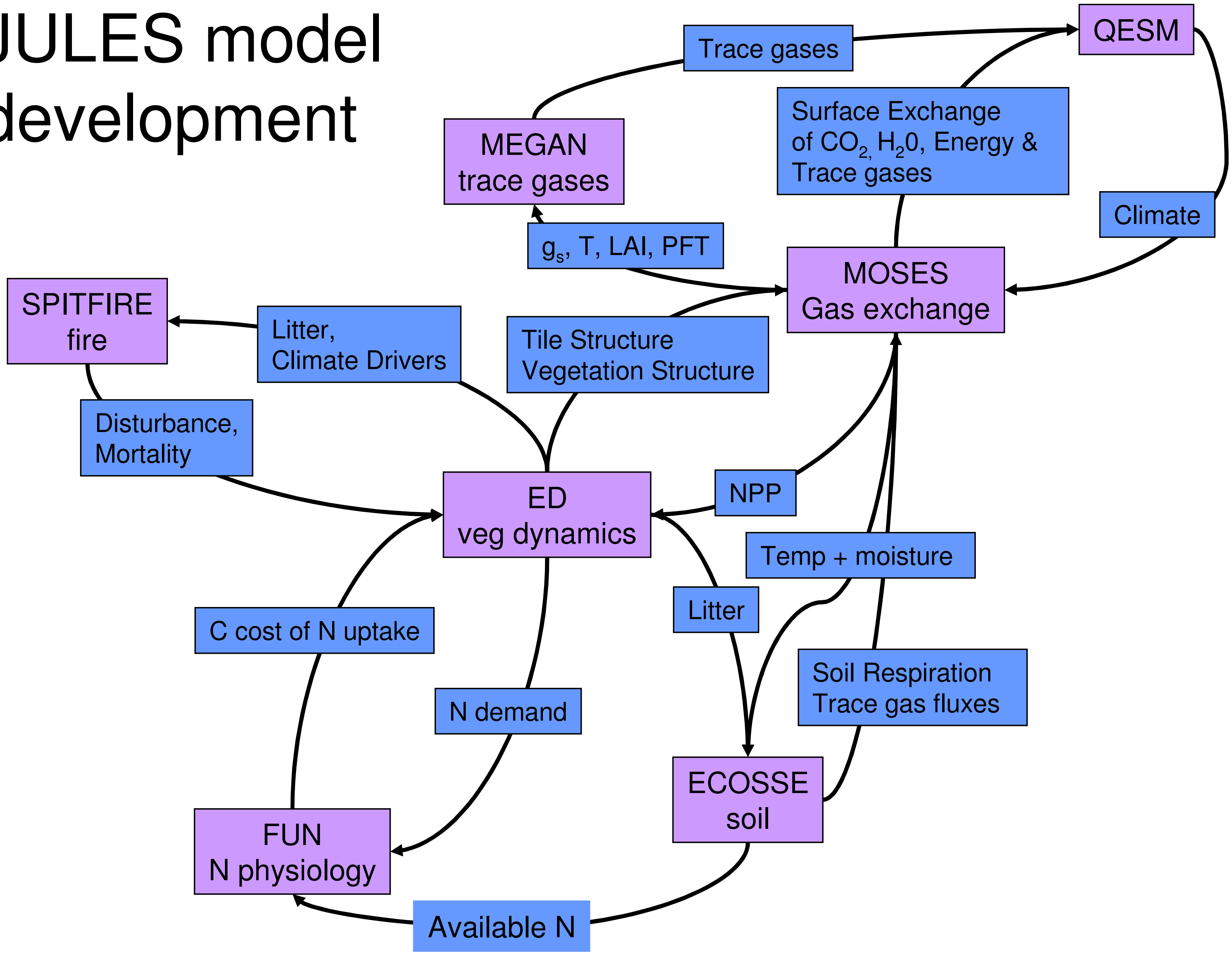
Moorcroft et al. (2001)



‘Cohorts’ of trees,
Binned according to:

1. Plant type
2. Height
3. Successional stage

JULES model development



Part 1: Savanna Modelling.

- Area-based DGVMs are not very good at modelling savanna…
- They tend to give dominance either by trees or by grass…

- Can the ED model generate a savanna?
- What do we mean by a savanna anyway?

Simple Observations

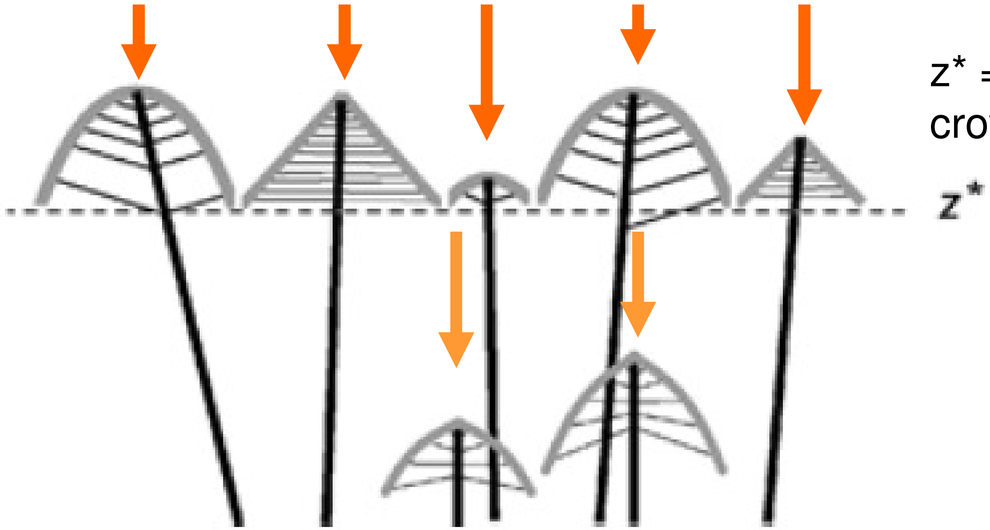
- 1. The canopy of savanna ecosystems is by definition, not completely closed by trees.
- 2. This arrangement is relatively stable through time. (as opposed to being the mid-point of a successional process).

Space in the Ecosystem Demography Model

- The original ED model has no concept of space
- Tree LAI is ‘spread out’ across the grid cell
- This is obviously a bad assumption.
- This model will never generate a savanna properly and must be changed.

Canopy Structure: ‘perfect plasticity’ solution

- New model considers space occupied by tree canopies
- Simulates canopy closure if canopy area = ground area
- Canopy trees get 100% light on top leaf surface
- Under-story trees all have the **same** light environment



z* = Height where crowns intersect

Purves et al., PLOS One 2007.

Plantations vs. nature and the tragedy of the commons.

- In a forestry plantation, lots of identical trees are planted at the same time
- They all grow at the same speed and all have access to some full light
- So none of them die
- So, the resulting density of trees is much higher than in a natural forest
- This is how ED works…

Limitations of cohort approach

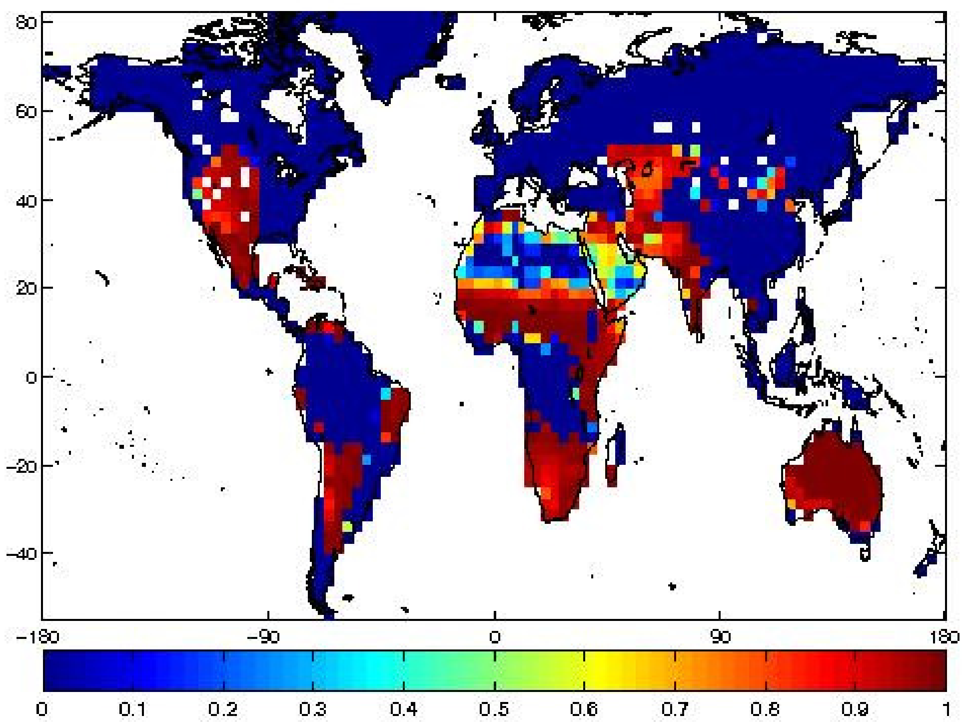
- ED is an **approximation** of a gap model
- It achieves this by **averaging** tree properties
- This means no trees are lucky or unlucky because of the circumstance of their birth(!)
- So, we have to introduce ‘luck’ (or asymmetry)
- If one cohort straddles the canopy intersection height z*, some are ‘lucky’ and make it into the canopy, and some are ‘unlucky’ and do not…

Model Results

In savanna areas, the model STILL tends towards canopy closure

- Why?

C4 Grass Fraction



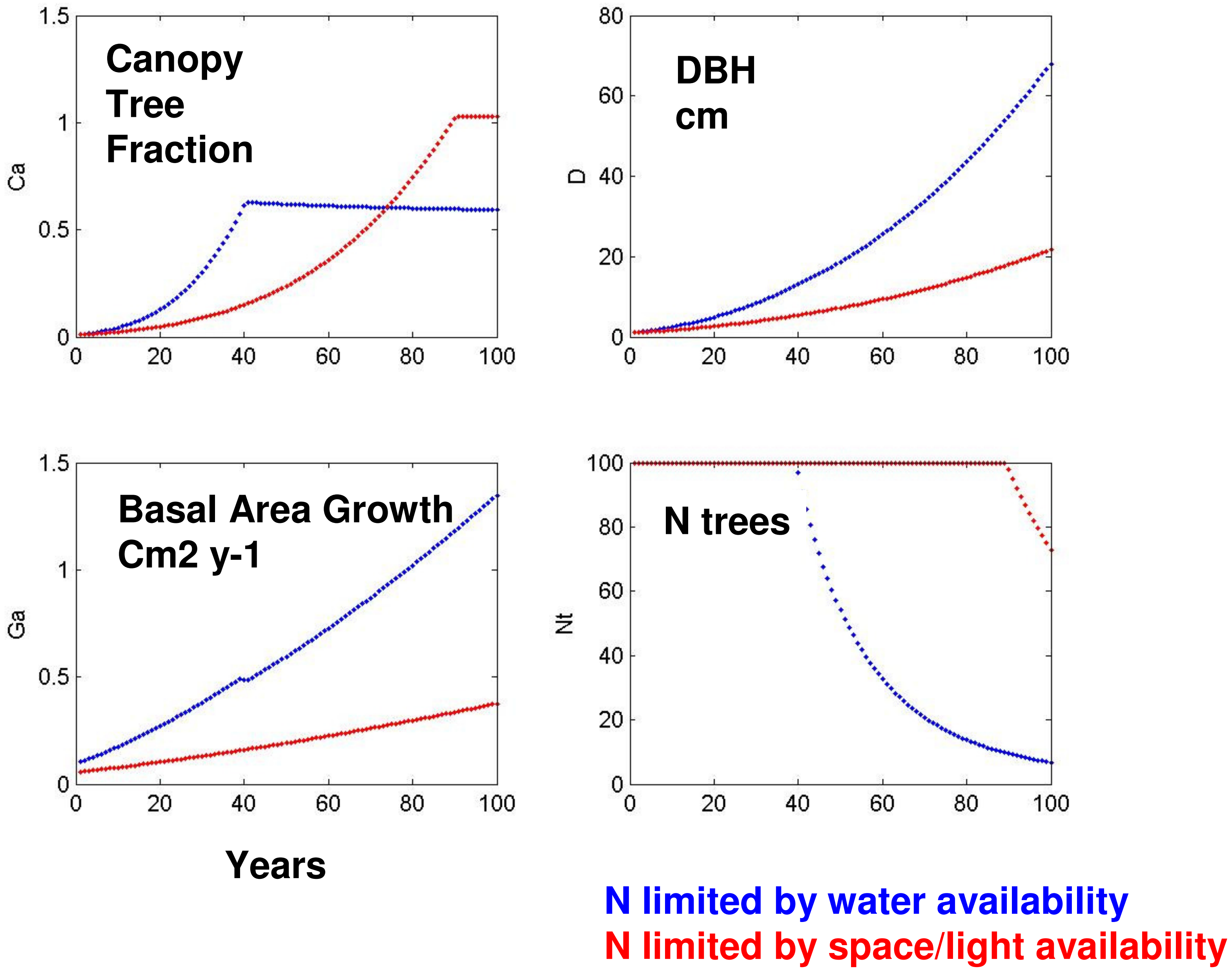
Soil water & symmetric competition

- Asymmetric competition for light.
- Symmetric competition for water.
- All trees get equal share of water.
- 2 Possible Outcomes
  - All die
  - All grow slowly

- We need asymmetry for water competition
  - or
- Root Closure Model.

‘Root closure’ model

- 1. Assume a given demand for water per unit crown area.
- 2. Plant initial seeding density
- 3. Trees all get the same water
- 4. If demand for water > supply
- 5. N = Area *Supply/Demand
- 6. Assume all the ‘unlucky’ trees die..;



Canopy
Tree
Fraction
Ca
DBH
cm
D
Basal Area Growth
Cm2 y-1
Ga
N trees
Nt
Years
N limited by water availability
N limited by space/light availability

Perfect asymmetry

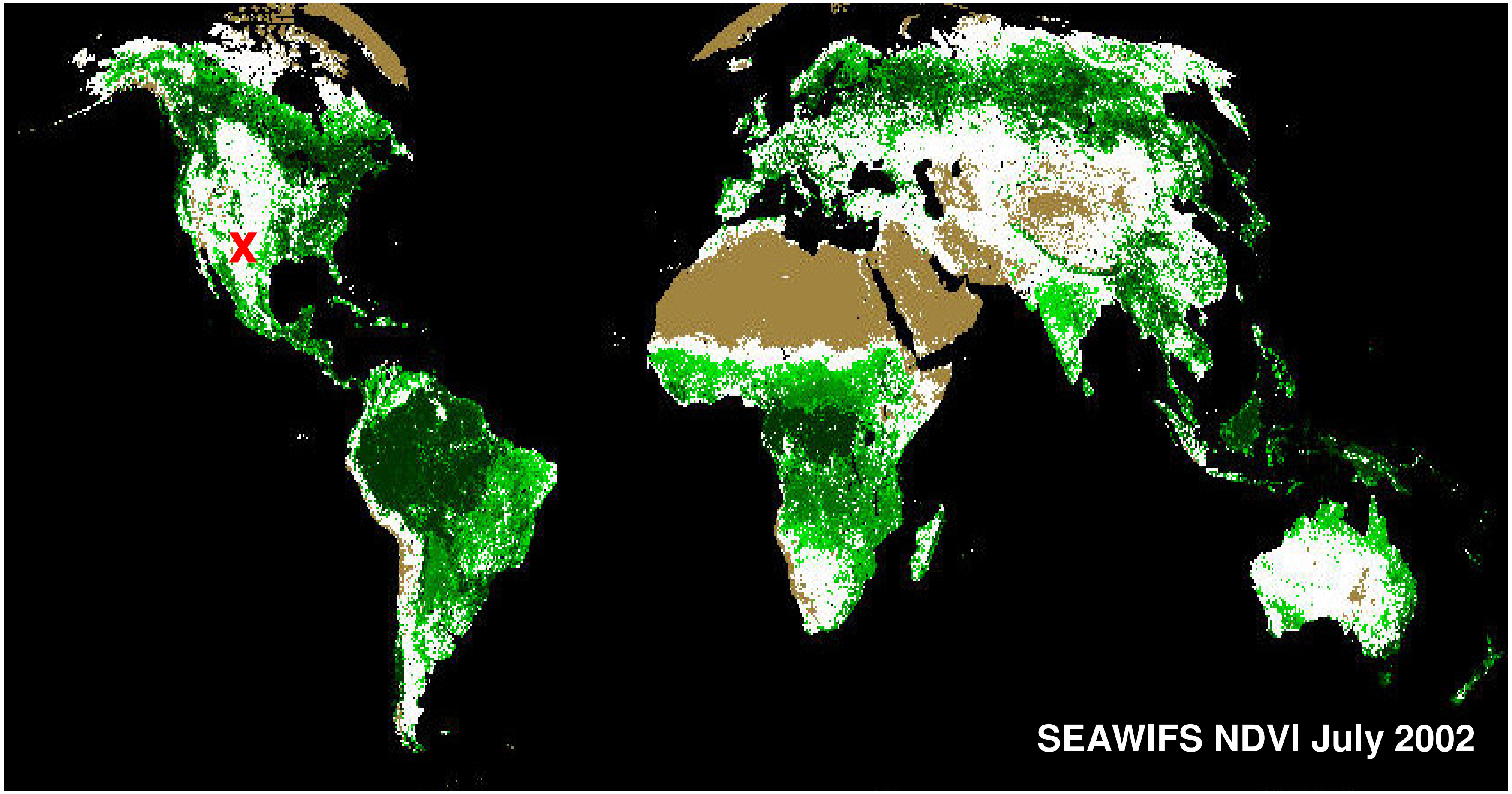
- How many trees _should_ we have?
- One extreme = few trees get maximum water
- Other extreme = many trees get minimum water

- Constraints?
- Minimum N = Maximum root area?
- Maximum N = Minimum possible water use.

- How effectively do large individual monopolie resources?

Part 2: The Future, some thoughts.

What is happening at the dry/hot margins of intact ecosystems?



Pinon mortality in New Mexico 2002-3

Jemez Mts., May 2004

Craig Allen USGS 2008

Pinon Mortality in SW USA

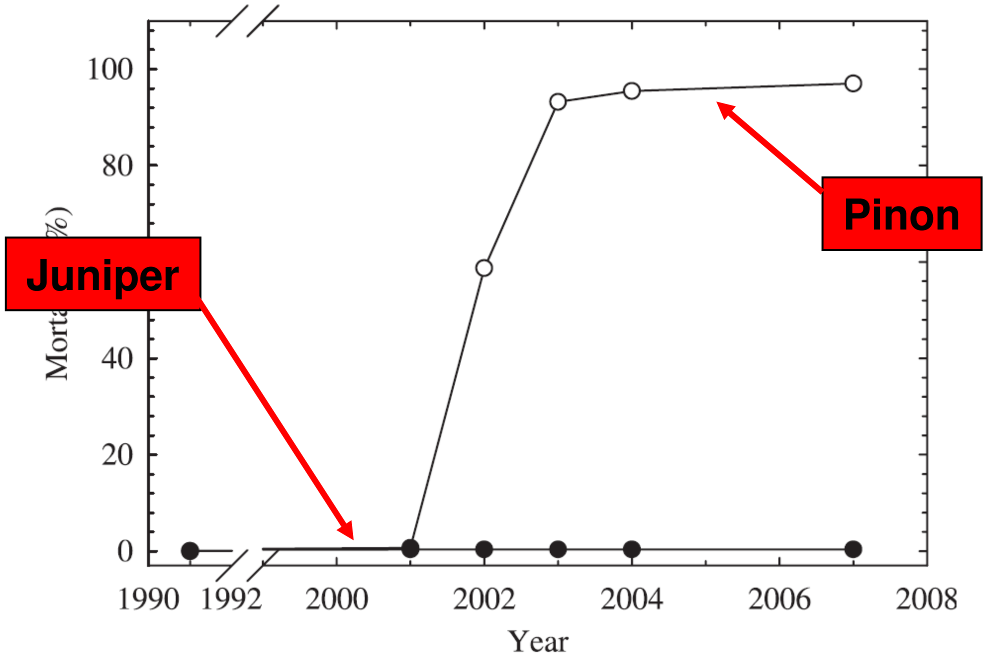
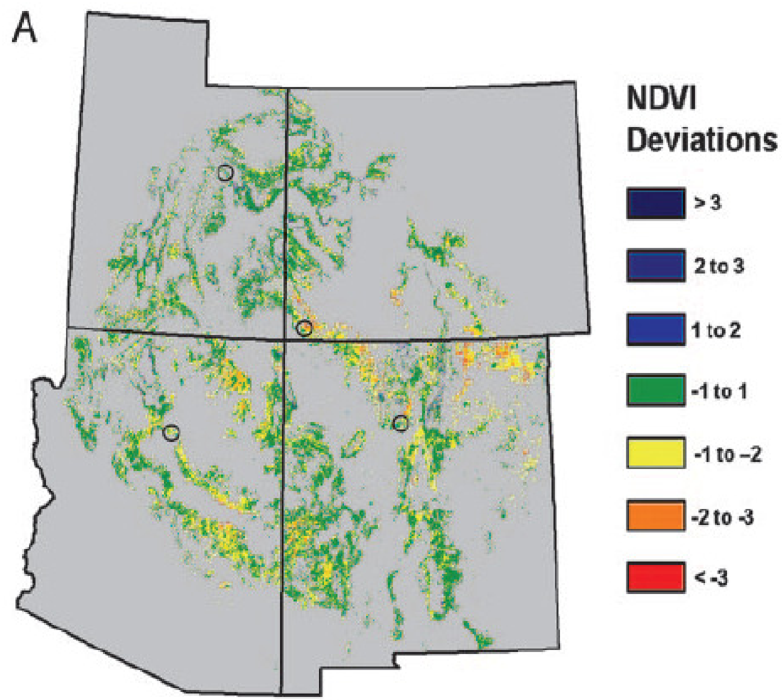


Fig. 2 Percentage mortality of piñon (open circles) and juniper (closed circles) trees at a 1.5 ha site, Mesita del Buey, near Los Alamos, New Mexico. For piñon, 16 of 484 trees survived (97% mortality), whereas for juniper, 559 out of 561 trees survived (< 1% mortality).



McDowell. New Phytologist 2007

Hydraulic resistance to drought

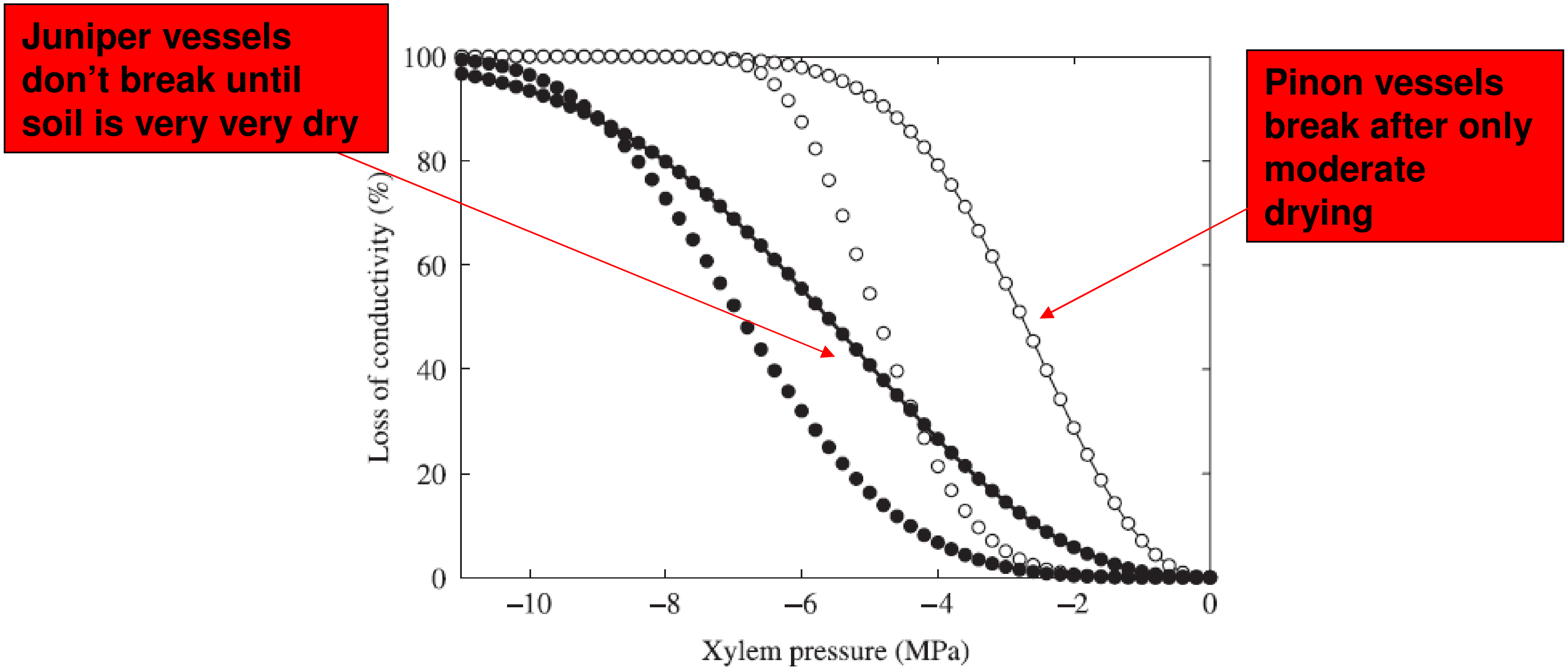


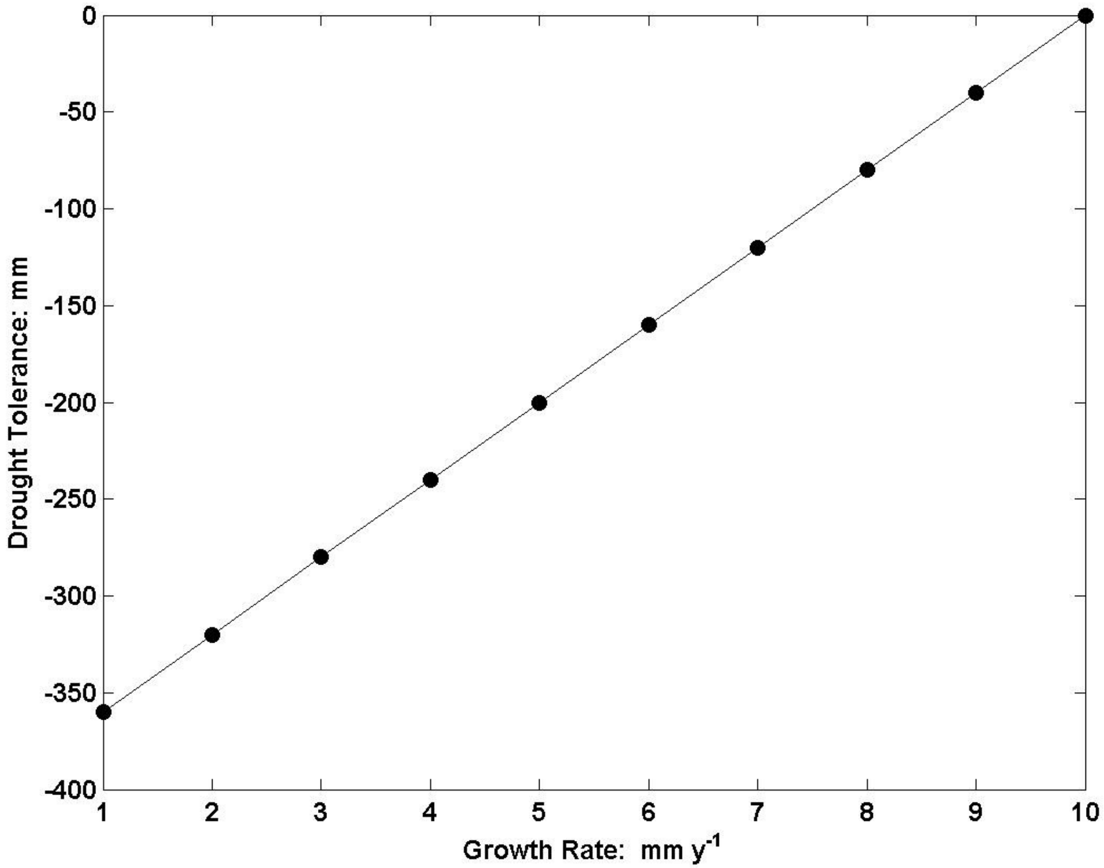
Fig. 4 The percentage loss of conductivity of excised root (connected circles) and stem (unconnected circles) segments of piñon (open circles) and juniper (closed circles) as a function of xylem pressure. These 'vulnerability curves' were obtained by the air-injection method (Linton *et al*., 1998).

McDowell New Phytologist 2008

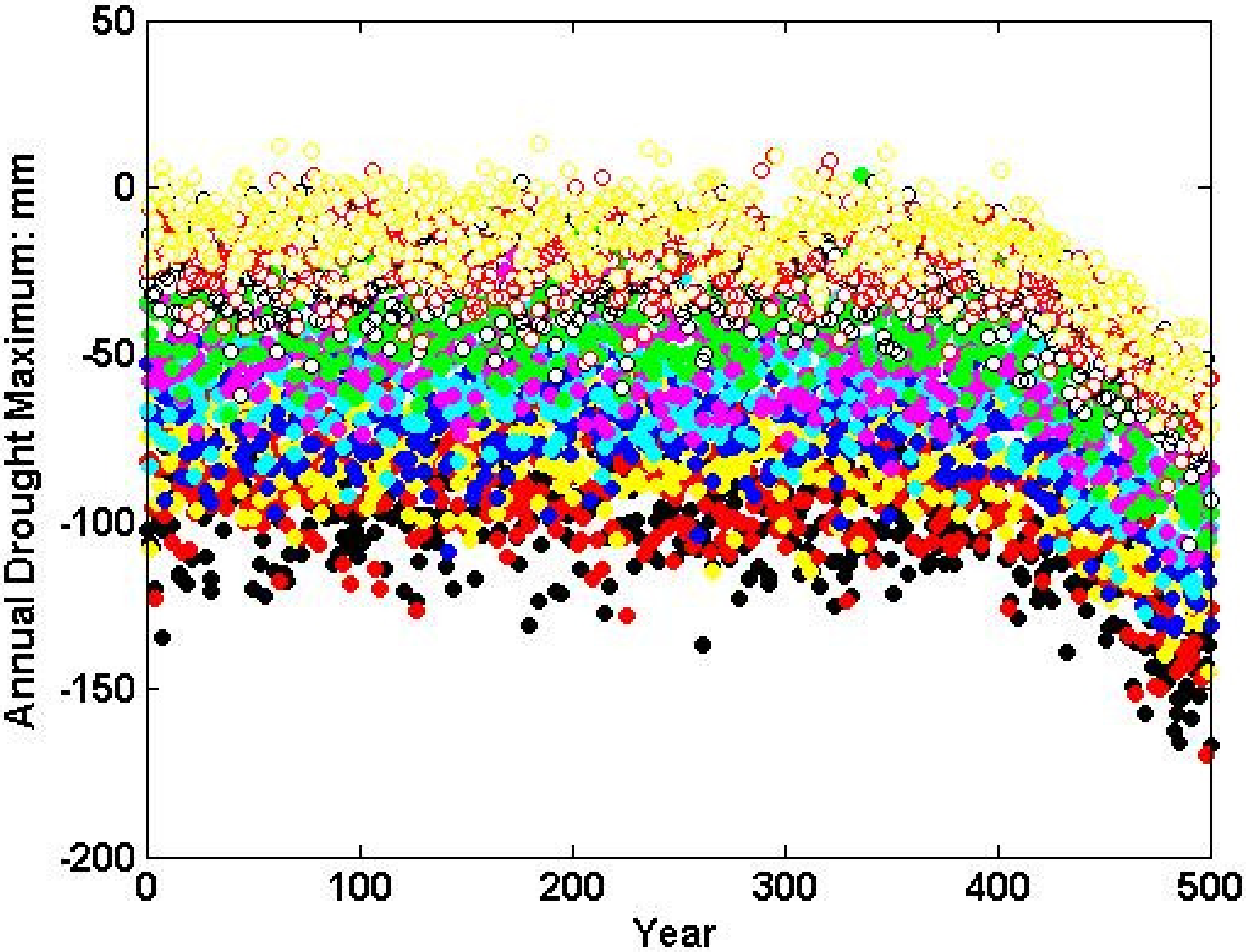
Juniper vs. Pinon

- Juniper: expensive vessels to deal with dry conditions
- It is **risk-averse**
- Pinon: bets droughts are long enough to starve to death…
- This **risk-taking** strategy was a good one, until now.
- Risk taking strategies are dominant in stable climates where magnitude of risk can be established
- How are risk-avoidance strategies distributed at present?

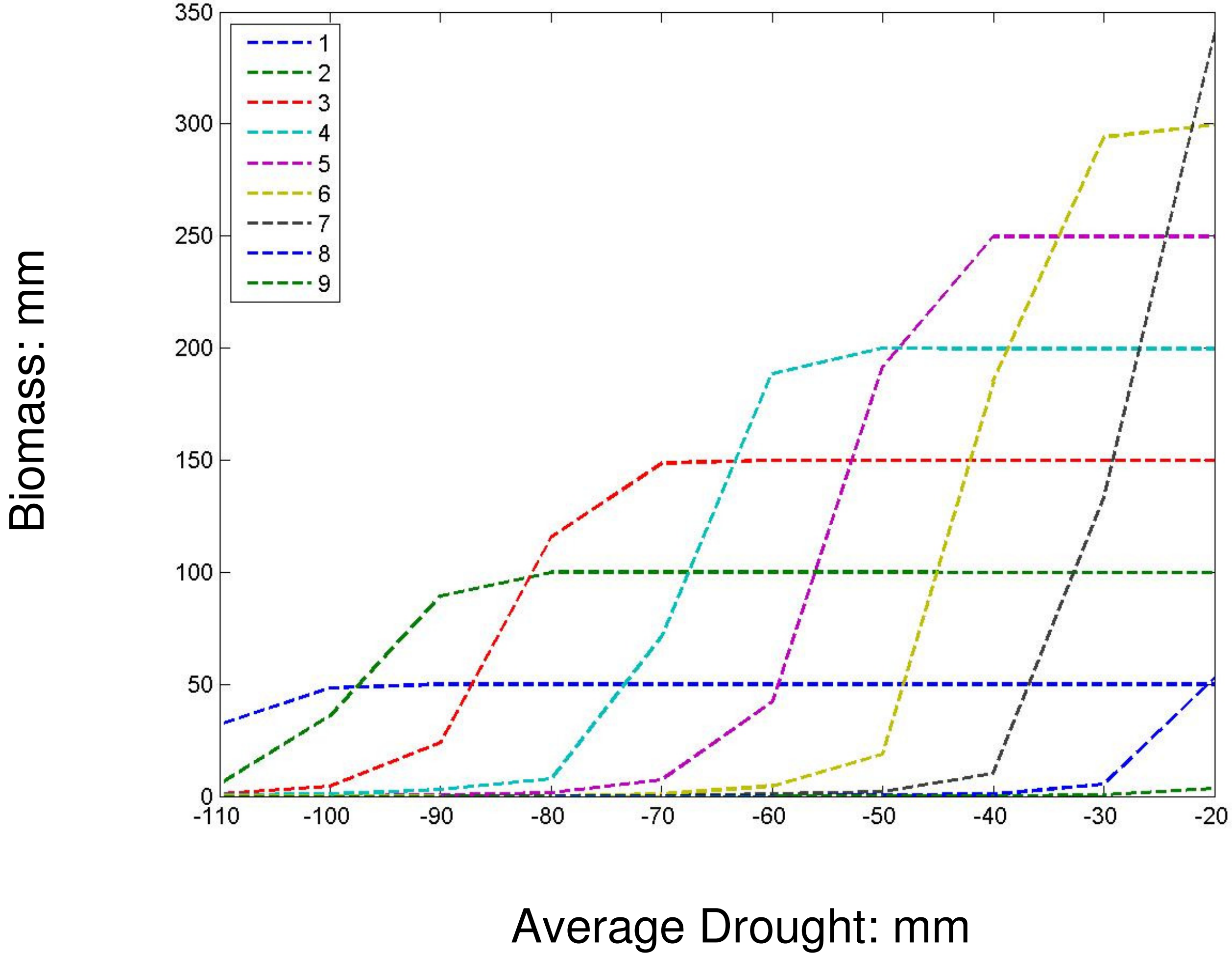
Define PFTs along functional trade-offs



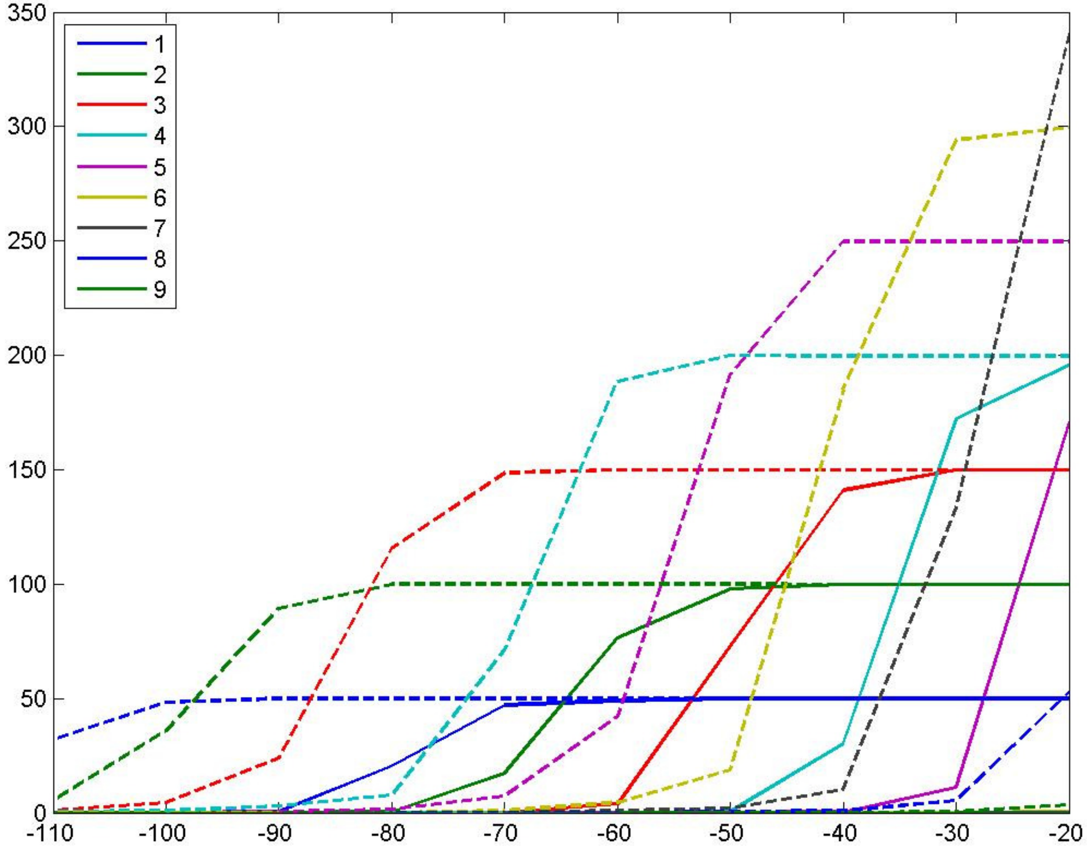
Climate Regime



Leads to distribution of PFTs along gradient.



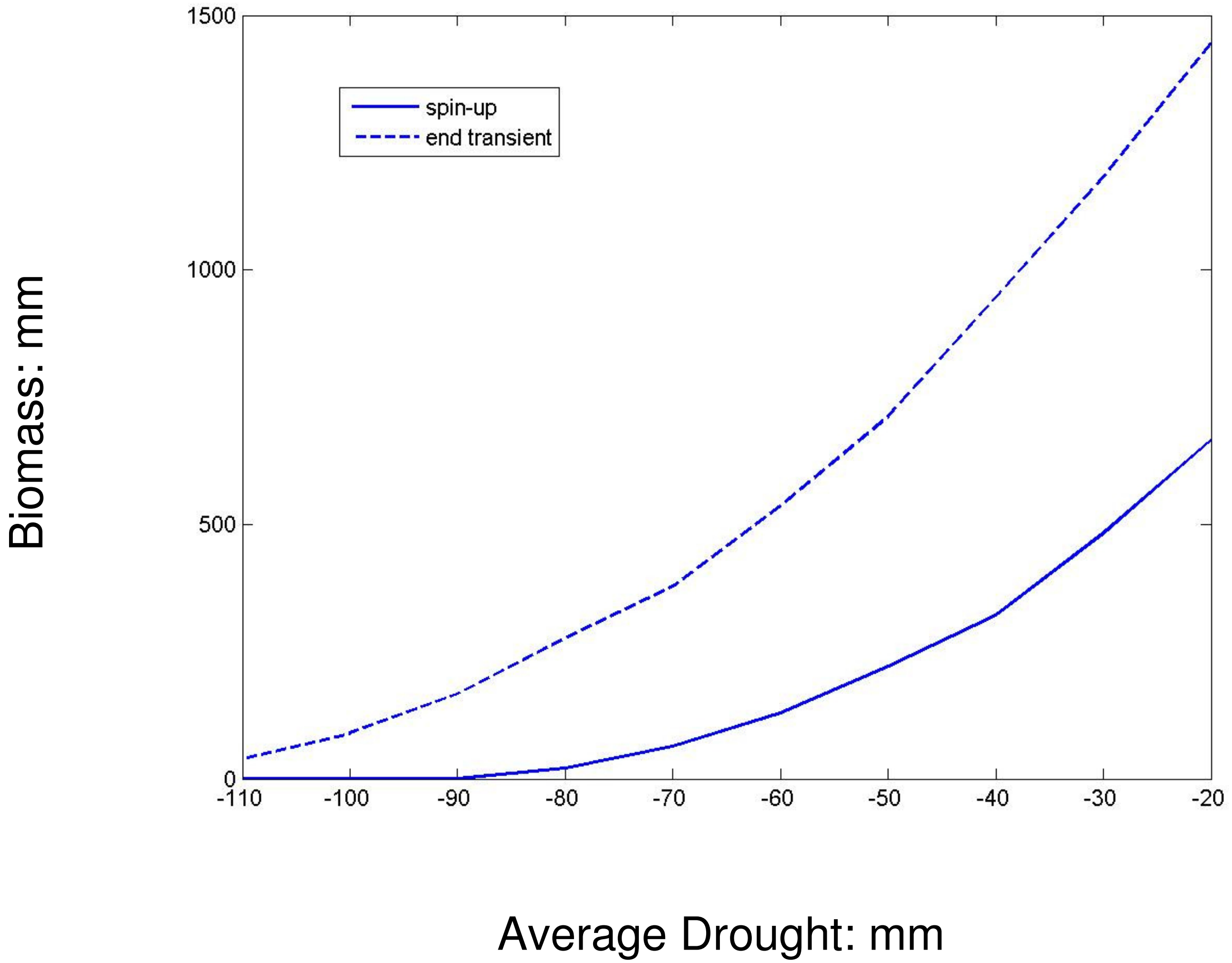
Climate Change pushes distribution rightwards



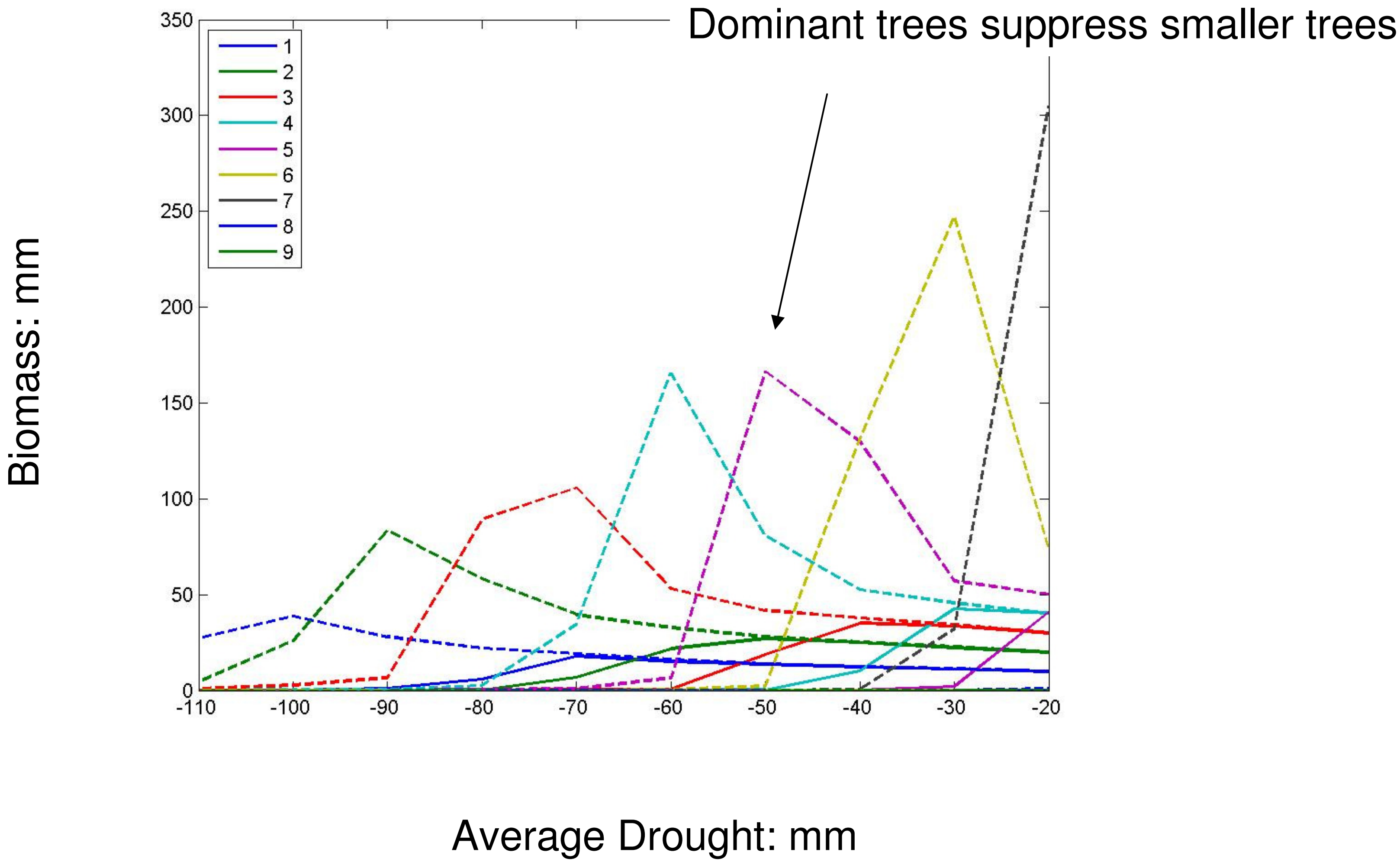
Biomass: mm

Average Drought: mm

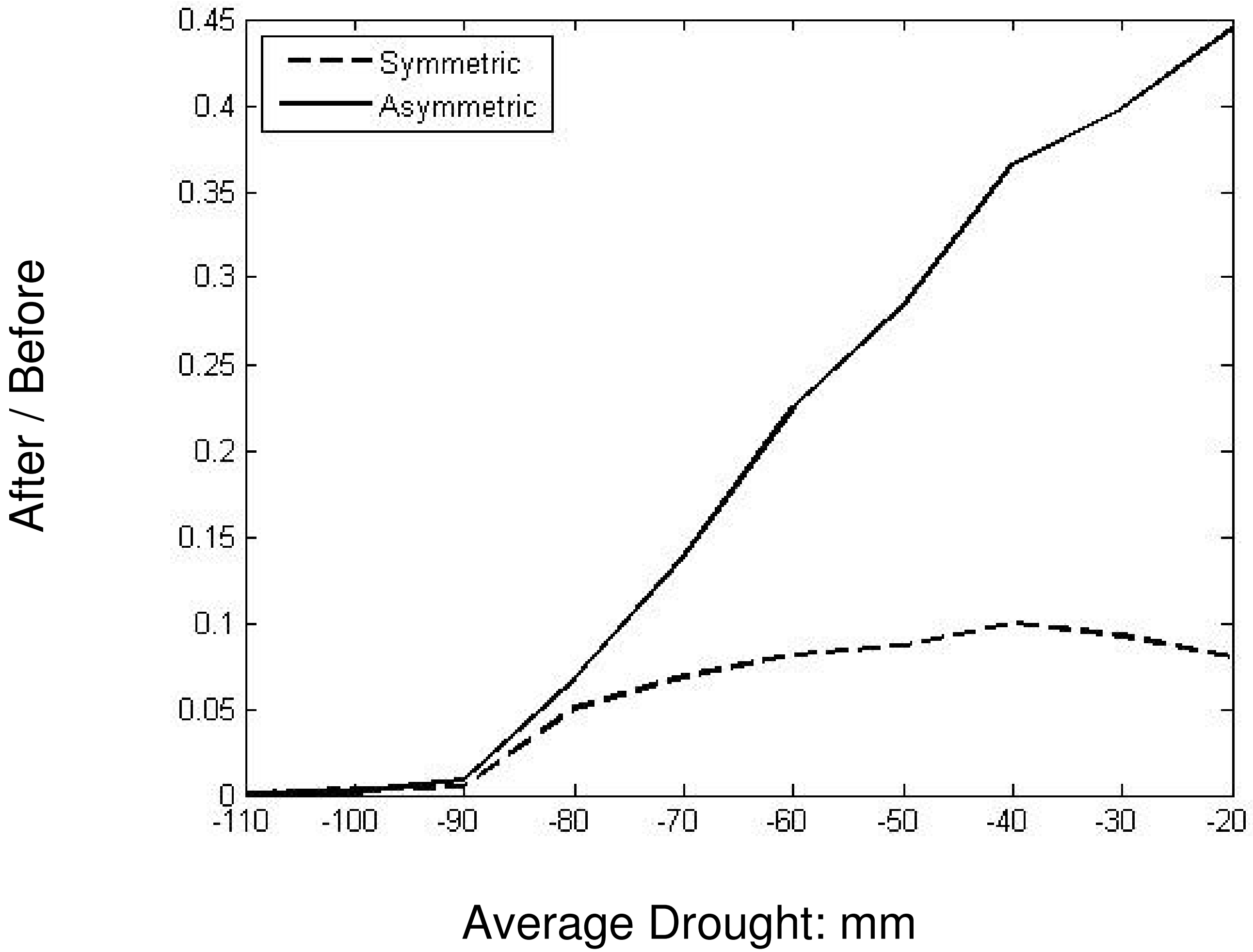
Climate Change leads to overall loss of biomass



Asymmetric competition changes impact of climate change



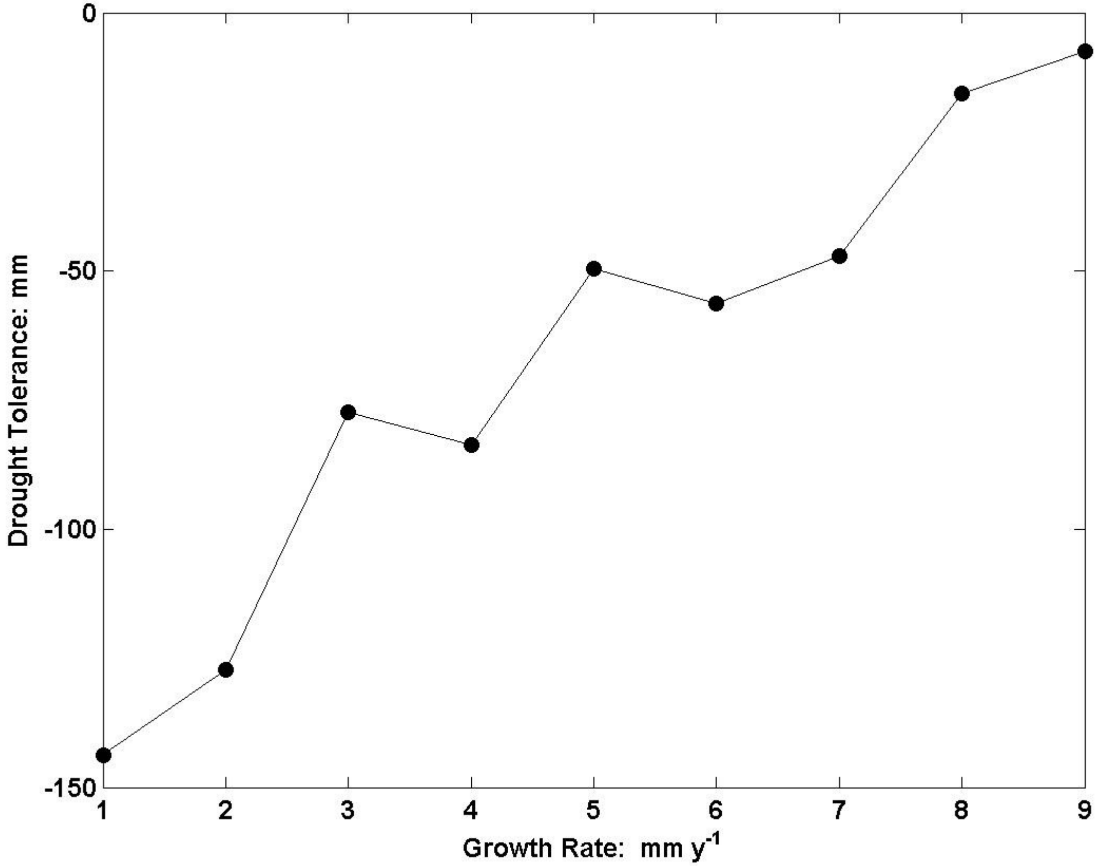
Impact of asymmetric competition on dieback
How do large individuals monopolise resources?



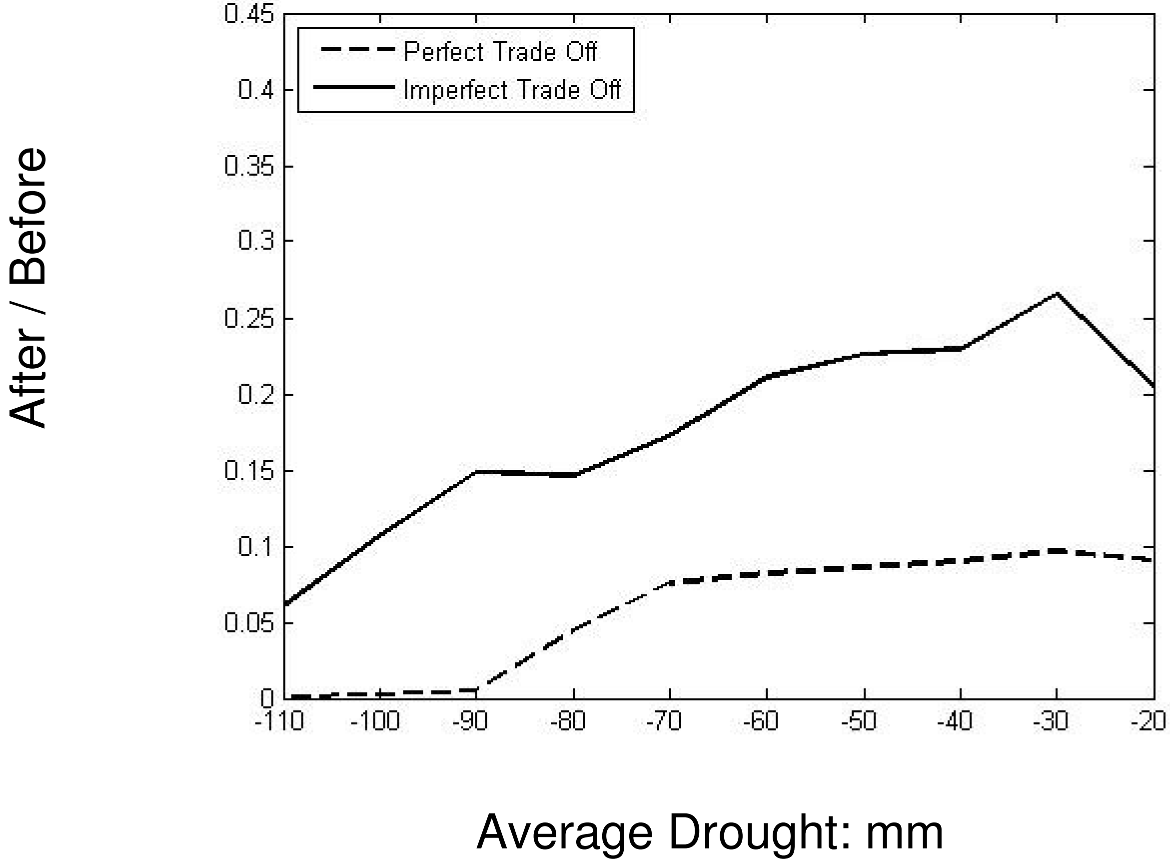
Conclusions

- Savanna modelling requires some kind of ‘closure’ for water, analagous to canopy closure
- An exact solution depends on the ability of big trees to monopolise water resources
- Similarly, asymmetric competition along a stress gradient increases the impact of climate change.
- We need to know
  - 1. How asymmetric is competition for light?
  - 2. How is diversity of strategy (not species) maintained?

Impact of imperfect trade-off surface



Impact of imperfect trade-off surface



So…

- We know ecosystems are diverse
- But are they diverse along the right axes?
  - We don’t know until it’s too late…
- Do other kinds of disturbance push the system towards a more resilient state
- Are different trade-offs correlated?
- Anything which increases the liklihood of resilient species already being in place will

Succession and ED

- What effect does the succession matrix have on dieback?
- This is disturbance driven, so, if anything, pushes the ecosystem towards a shorter time-frame
- BUT surviving other non-climatic disturbance MAY