Climate Change and the Ecohydrology of Australia: Future Research Needs

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The question

Modified wording:

"*How will changed patterns of rainfall and other climate features influence landscape water balance and hence plant distribution*?"

What ecohydrological processes link climate change to changes in distribution?

UNDERLYING HYPOTHESIS

Changes in

- Rainfall
- evaporative demand
- $[CO_2]$

⇨ changes in catchment water balance via changes in

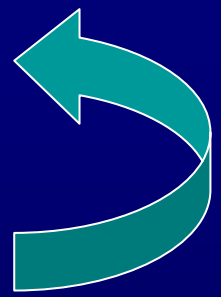
- LAI
- light interception
- G_c and root depth

⇨ change in site water balance

⇨ changes in species distribution

Issue 1: Fire

- How will flammability change and how will probability of fire (frequency, intensity, distribution) change?
- How will these changes influence vegetation distribution?
- How will changed fire regime affect catchment water budgets across Australia?



Issue 2: Rainfall

- Which attributes of changing rainfall patterns are important ….
  - magnitude ?
  - frequency?
  - duration
  - timing (especially across seasons) ?

Each of these contribute to spatial patterns of Ψ_{soil} …. which determine veg behaviour

Rainfall

- We need to know which rainfall events are significant and which aren't (pulse size)
- Different veg classes have been identified in terms of their response to pulses of rain

Rainfall

An experimental methodology?

- Manipulative rainfall experiments (amount and timing), supported by ecophysiological measurements and a modelling framework

Issue 3: Rainfall - veg interactions

- Species differences in response to changing rainfall patterns … explained by differential root distribution? But Australian data inadequate
- Need assessment of sensitivity of recruitment to change in rainfall. Incorporate this information into forest succession models

Rainfall – veg interactions

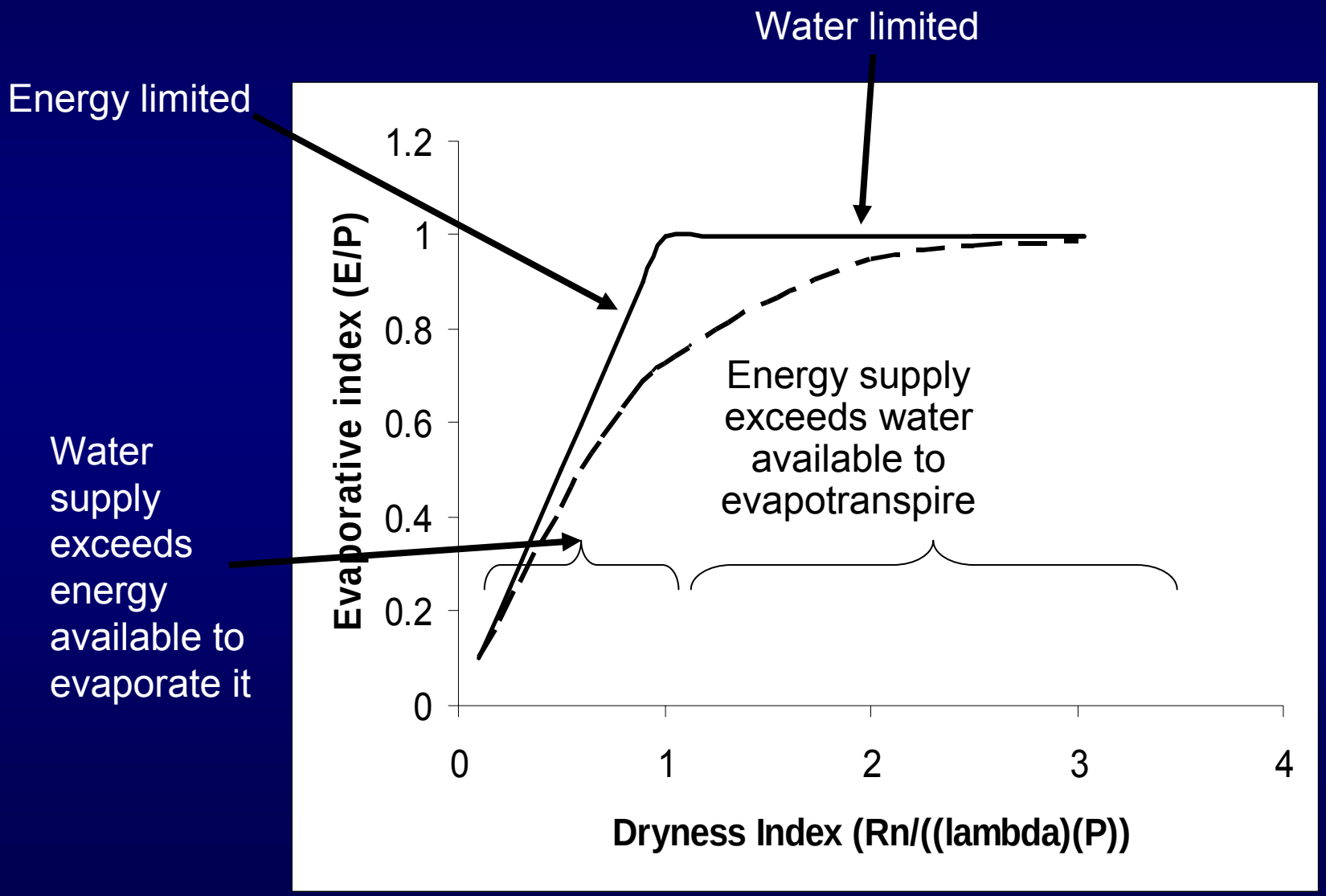
- Are future radiation and rainfall patterns synchronised or out-of-phase ?

Rainfall – veg interactions

A way forward *(from Donahue et al 2007)*:

- Develop a better formulation of the Budyko hydrological model – especially focusing on *f*PAR as a principle vegetation attribute, at small and intermediate scales (A< 1000 km^2)
- Need to include GW use

Budyko's curve



Issue 4: Vegetation and water balance

- What is the relationship between rainfall and catchment water balance, i.e. what is a good measure of catchment water balance?

Issue 5: Veg function and modelling

- Why is the relationship between ANPP and rainfall lower for Australian evergreen forests than northern hemisphere evergreen forests? Is it:
  - weather (e.g. high VPD, temp) ?
  - eucalypt physiology ?
  - low soil fertility ?
  - a consequence of high below-ground C allocation?
- How will the relationship be affected by high CO_2 and altered climate ?

Veg function and modelling

LAI, G_c and root depth are pivotal !

- What regulates LAI? LAI determines site productivity, but also influences site water status, that is, GW recharge and stream flow

Veg function and modelling

LAI, G_c and root depth are pivotal !

- How does G_c respond to changes in [CO_2], D, LAI and site water status across Australia?

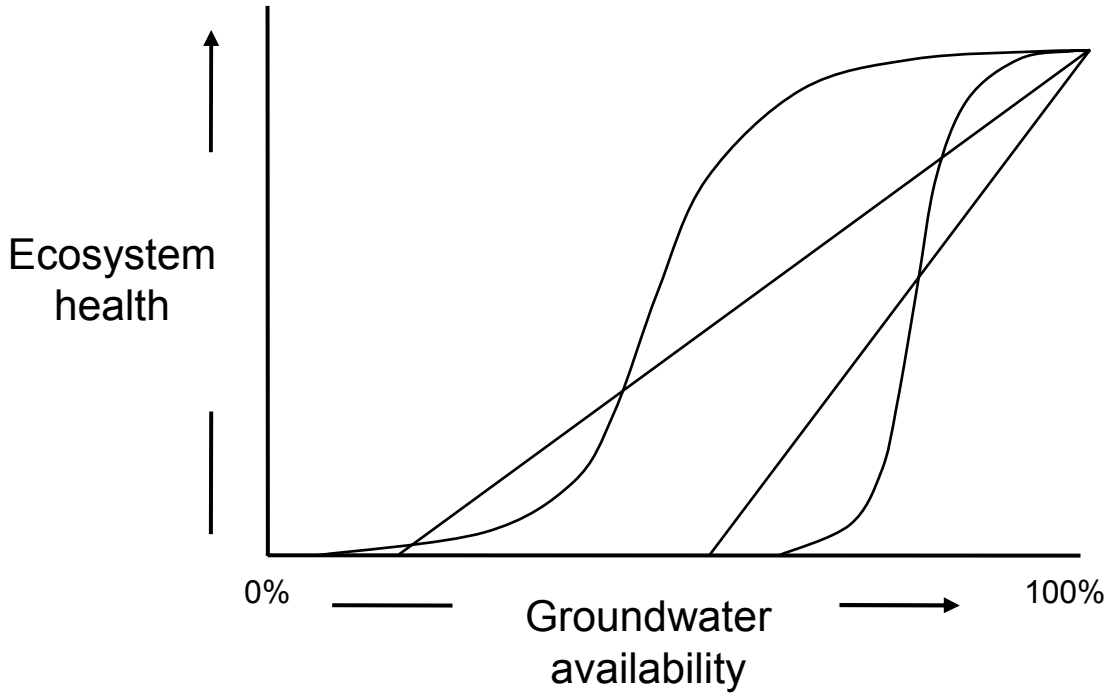
- Are there simple rules linking root depth and catchment water status?

Issue 7: Groundwater dependent ecosystems

Key questions for these systems:

- How will recharge change under altered rainfall/vegetation patterns, across Australia?
- What is the response function of a GDE to a change in GW availability?

Theoretical ecosystem responses to changing GW availability



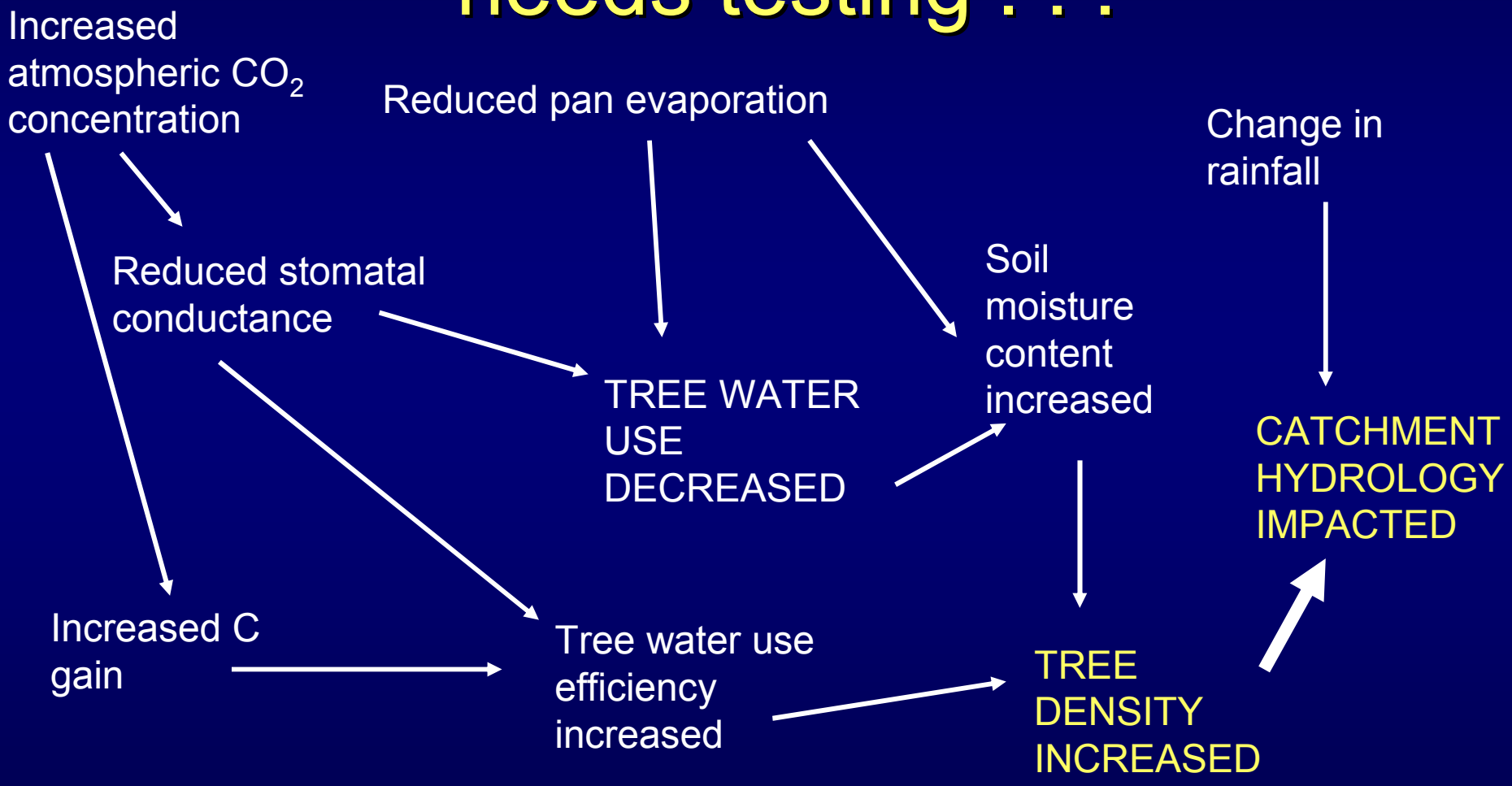
Issue 8: Woody thickening

- How would an increase in woody biomass affect catchment water balance?
- Should we be planting more trees to capture C or cutting them down to release water and storing the C in some other way?

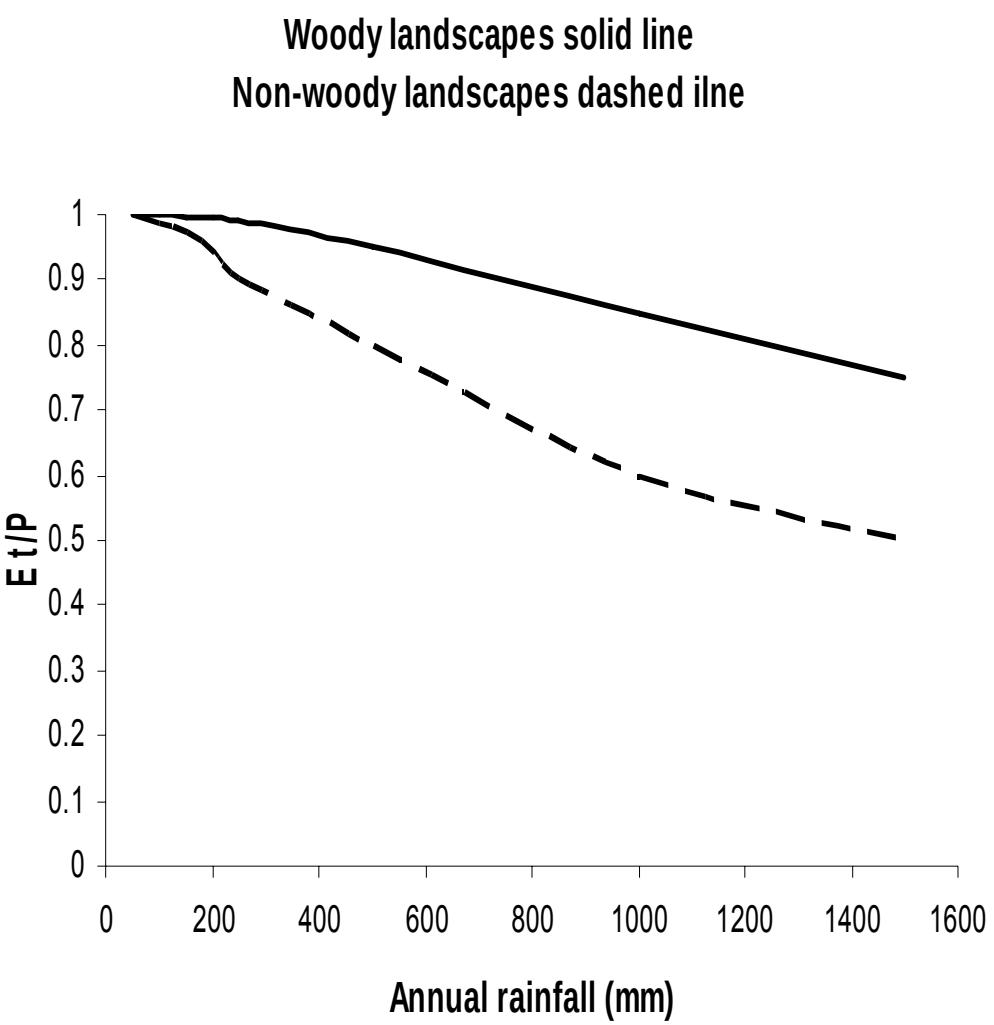
Relationship between climate change, woody thickening and hydrology

- In humid/mesic landscapes, as forest cover increases, stream flow decreases
- In arid and semi-arid landscapes, woody component is a very small part of the water balance
- But is this changing as climate changes?

A simple conceptual model: needs testing . . .



Issue 9: Modelling (Zhang et al 2001)



In arid zones (P<300 mm) all P is lost as Et, increased tree density has no effect on water balance

In semi-arid zones (300mm<P<800mm) effect of increased tree density increases with rainfall

In mesic zones, the impact of increased tree density is constant

Is this true for Australia?
Australia occupies the semi-arid zone mostly and this is where data are scarce

Does the Zhang model explain Australia ?

- Zhang model based on winter-rain sites where E_{pan} and rain are out of synchrony
- Unknown whether this analysis works in summer rainfall zones

Issue 10: Rangeland degradation – a commentary

- Poor understanding of impacts of changes in land use on ecohydrology

- Lack of long-term streamflow and groundwater depth data across Australia

- Why are savannas so poorly represented in global models – is it poor representations of
  - (a) root depth
  - (b) seasonality of grass LAI
  - (c) proper measures of soil moisture at depth?

Issue 11: Veg type and water budget

- Need to establish the link between veg type and water budget for semi-arid and arid zones
- Globally, water yield increases in response to decreases in woody cover, and we see:
  - Rainfall winter dominated
  - Infiltration and drainage and sub-surface lateral flow rates are high
- Is this true in Australia?

Veg type and water balance

- How does recharge vary with rainfall intensity, duration and frequency in arid and semi-arid zones?
- How important is vegetation cover to this process? Deep drainage absent in some arid and semi-arid zones for the past 10,000 years
- Need to identify hydrologically sensitive areas in the landscape

Issue 12: Trading C for Water

- We need to investigate trade-offs between C sequestration and water yield

Contributors to this talk

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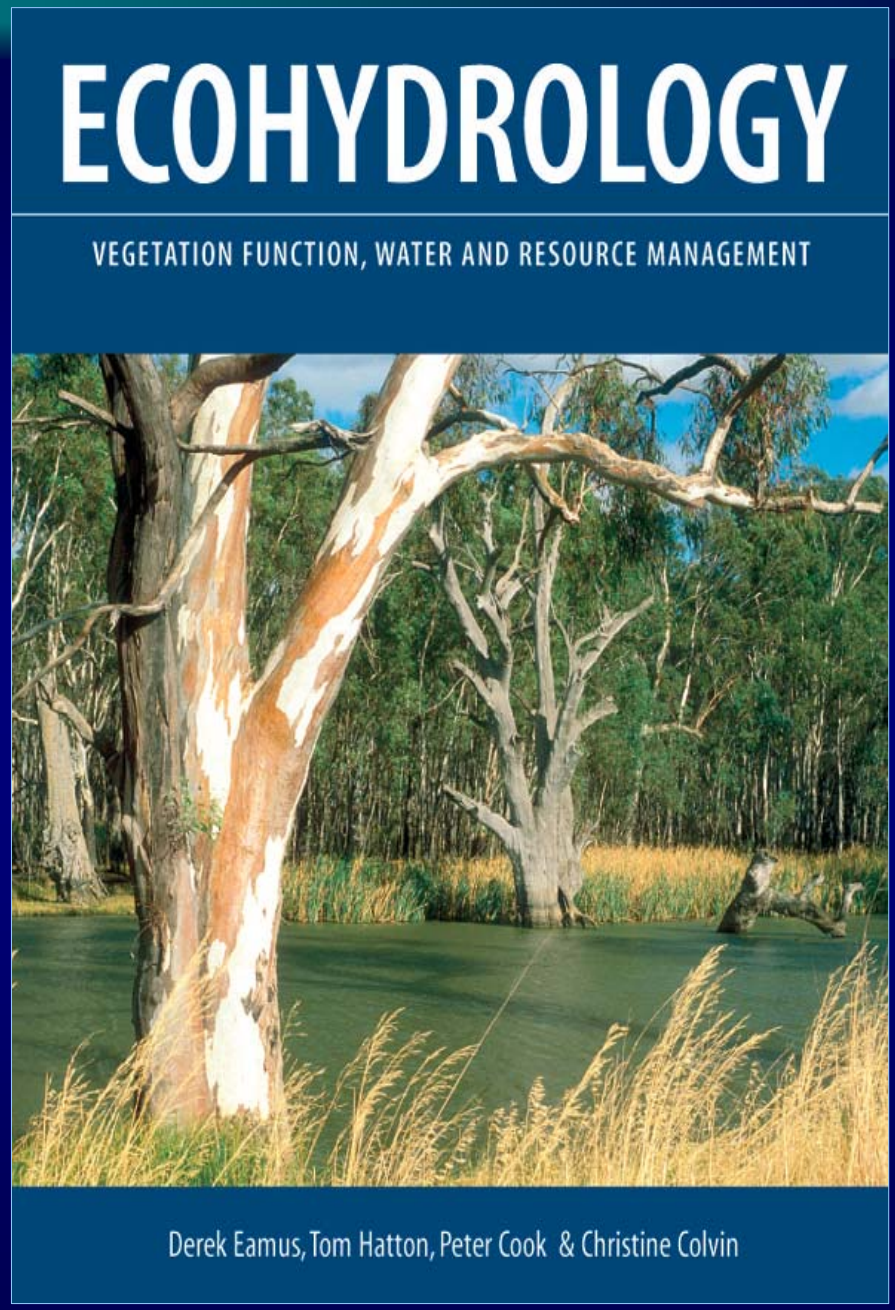
THANK YOU!

ANY QUESTIONS?



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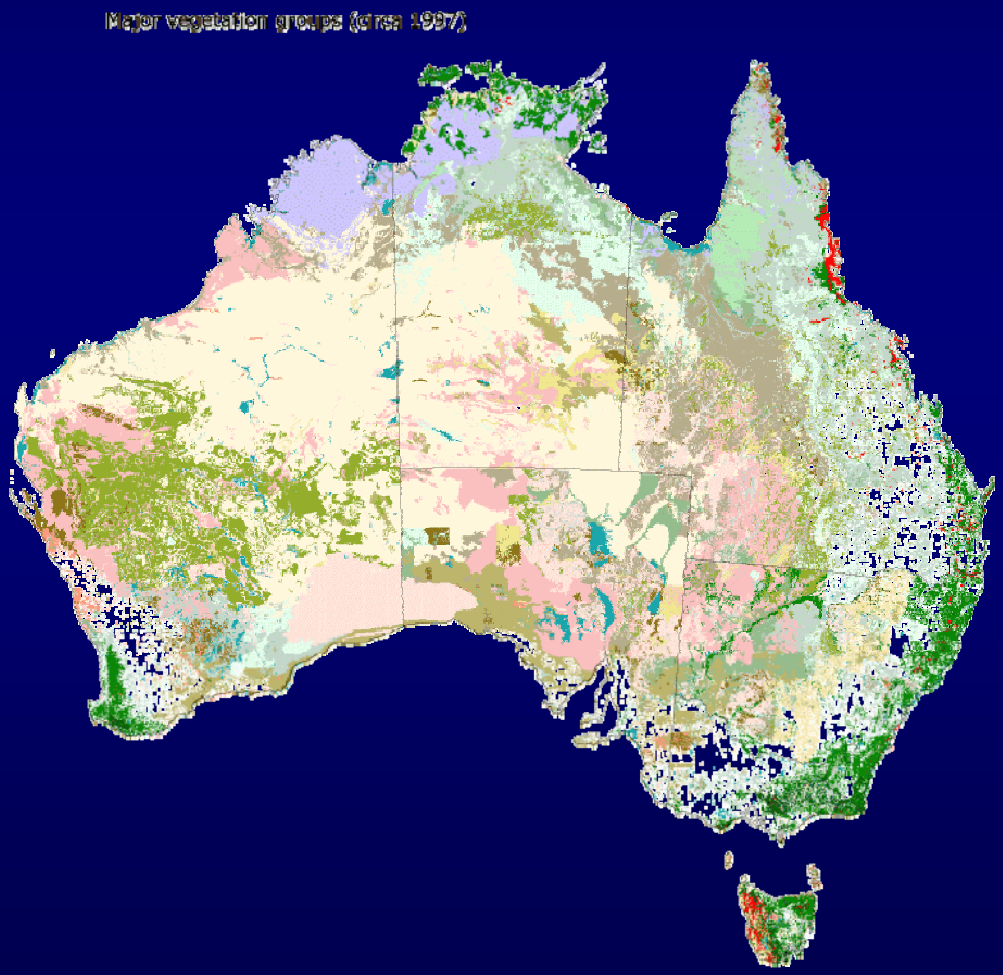
4 fundamental plant functions influenced by rainfall and climate change:

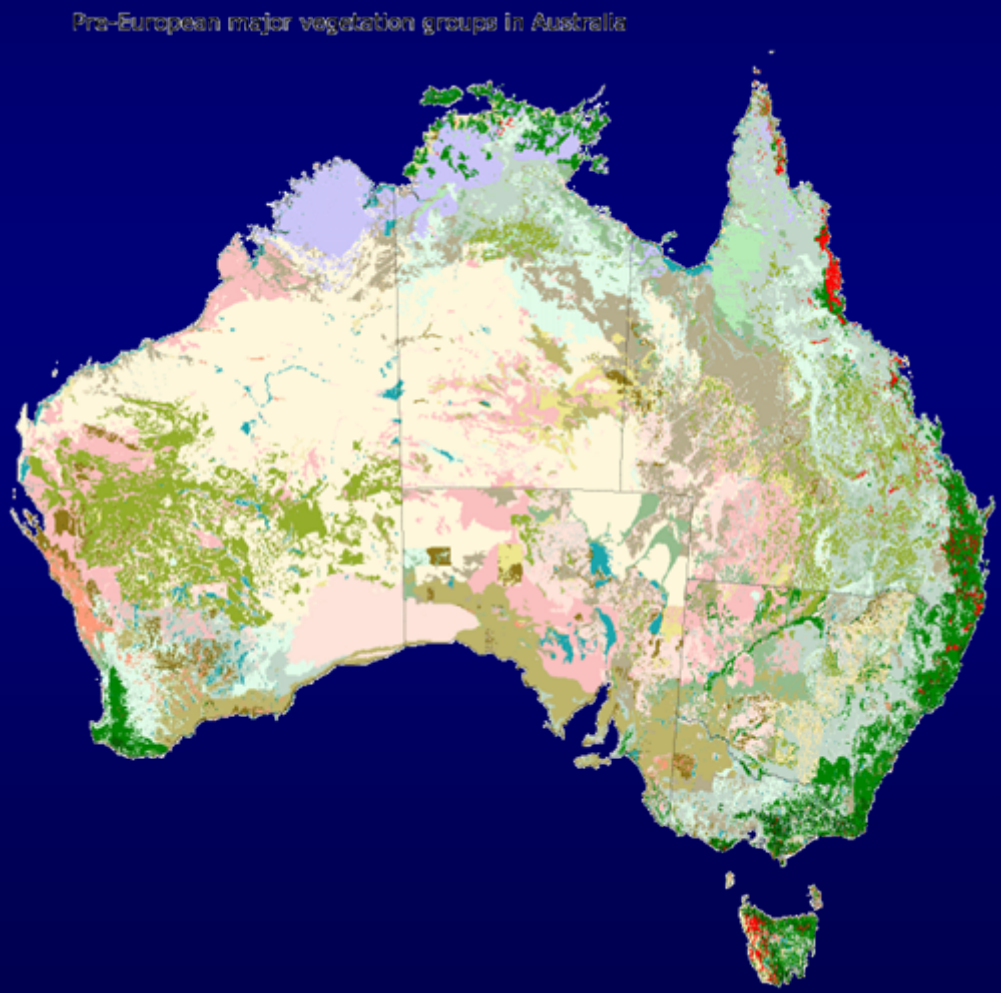
- Photosynthesis
- Respiration
- Nutrient uptake and nutrient cycling
- ***Water use and hence site water balance*** √

How I have interpreted the topic of the talk today

There is a current distribution of species and ecosystems that looks something like this



Of course veg distribution could look like this (spot the difference) ….



But in reality it isn't the distribution of ecosystems *per se* that is important – it is the functioning of those ecosystems that is important to us – and the function I think I am being asked to talk about is:

water use, water yield

and hence

water balance

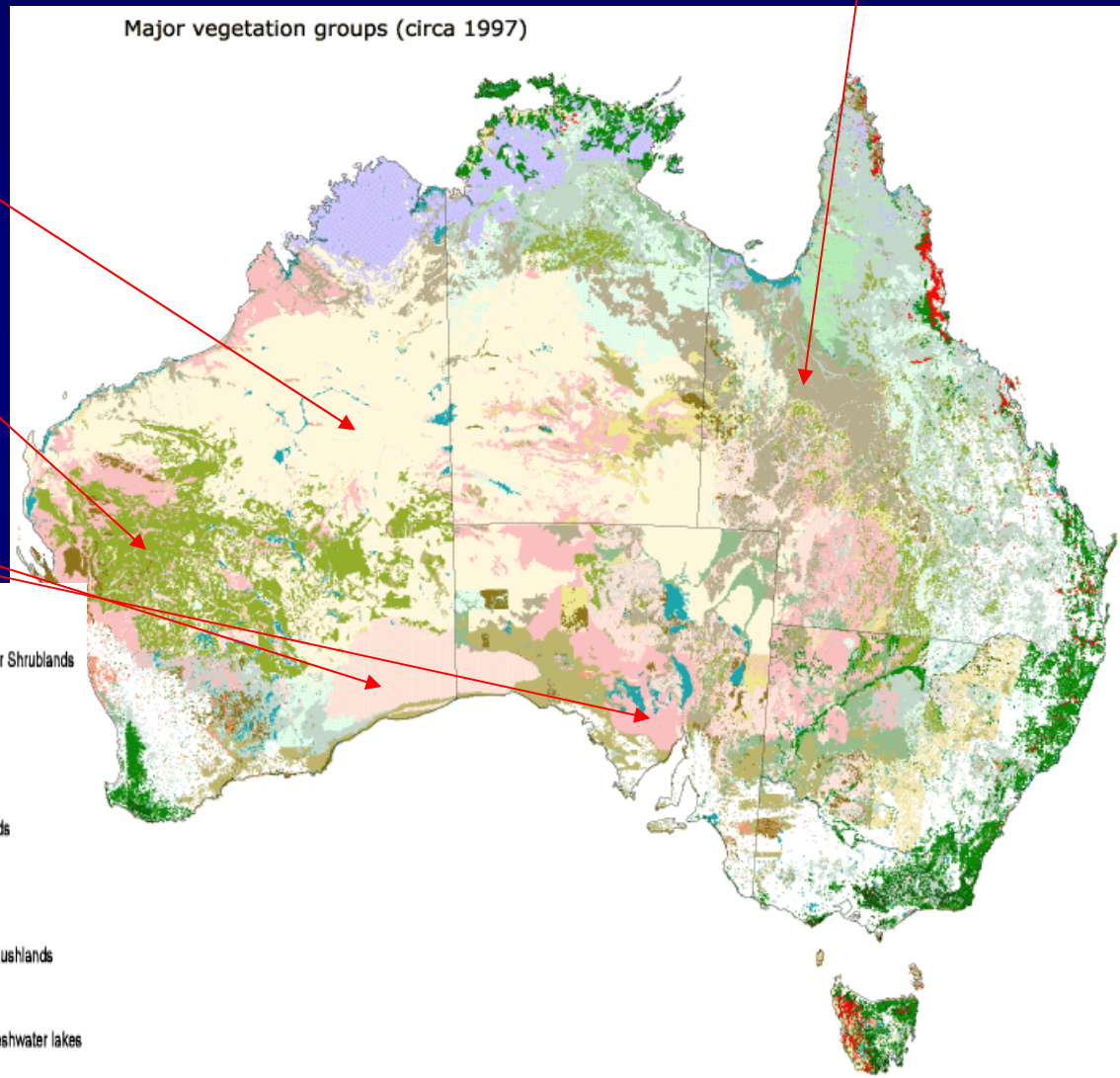
There are lots of arid and semi-arid systems out there!

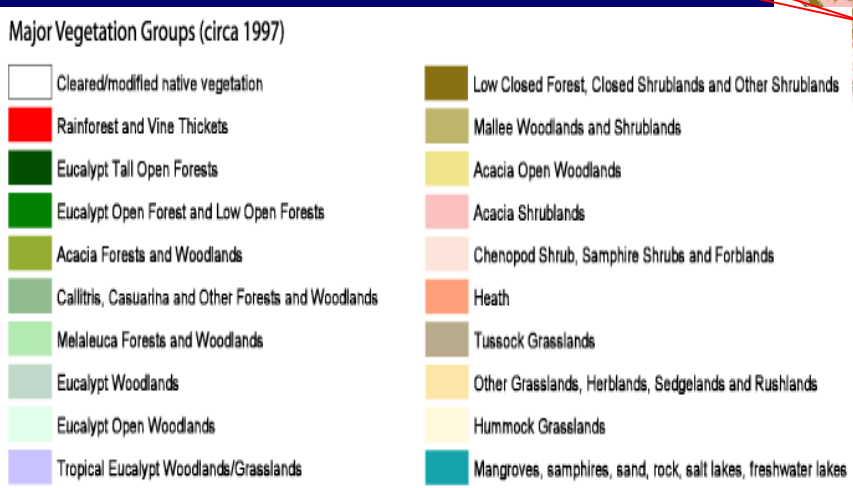
Tussock grassland

Hummock grassland

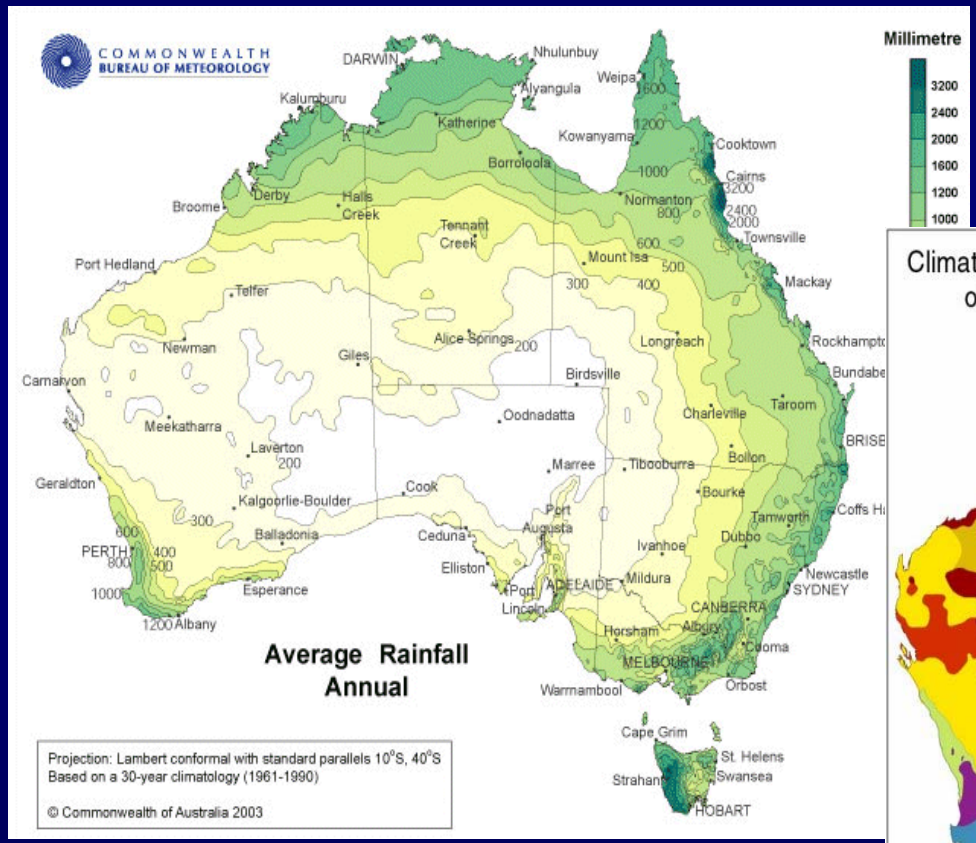
Acacia woodland / forest

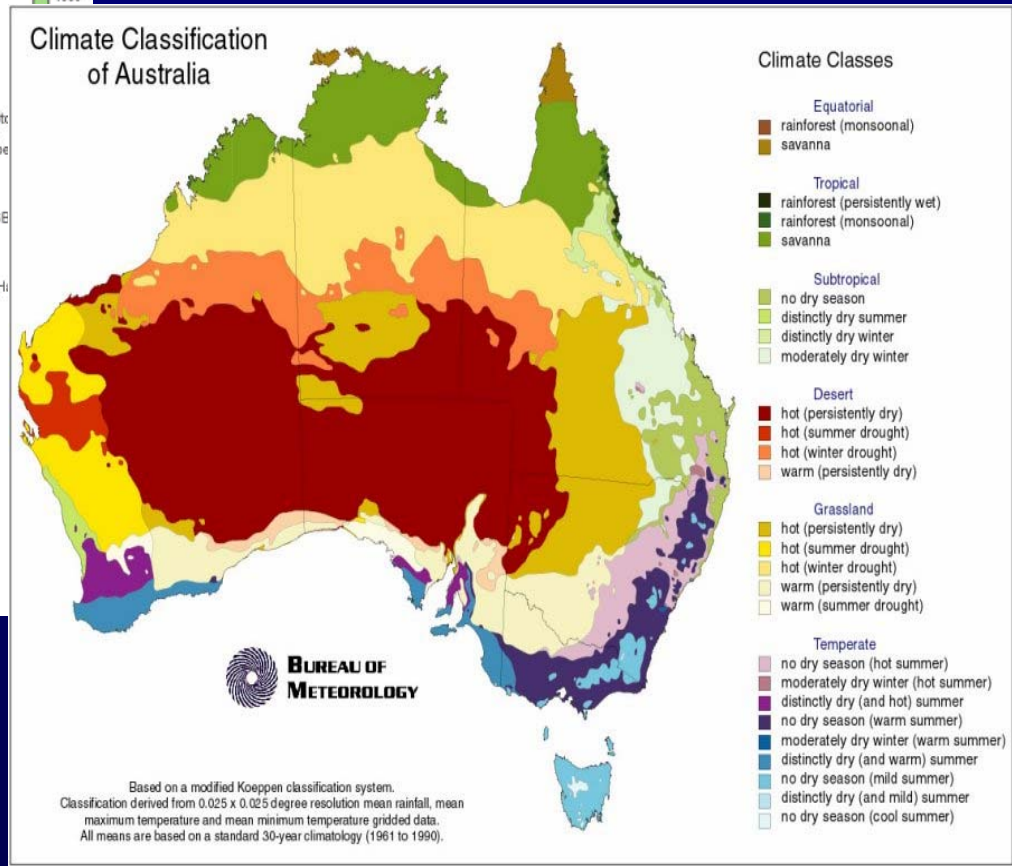
Shrublands



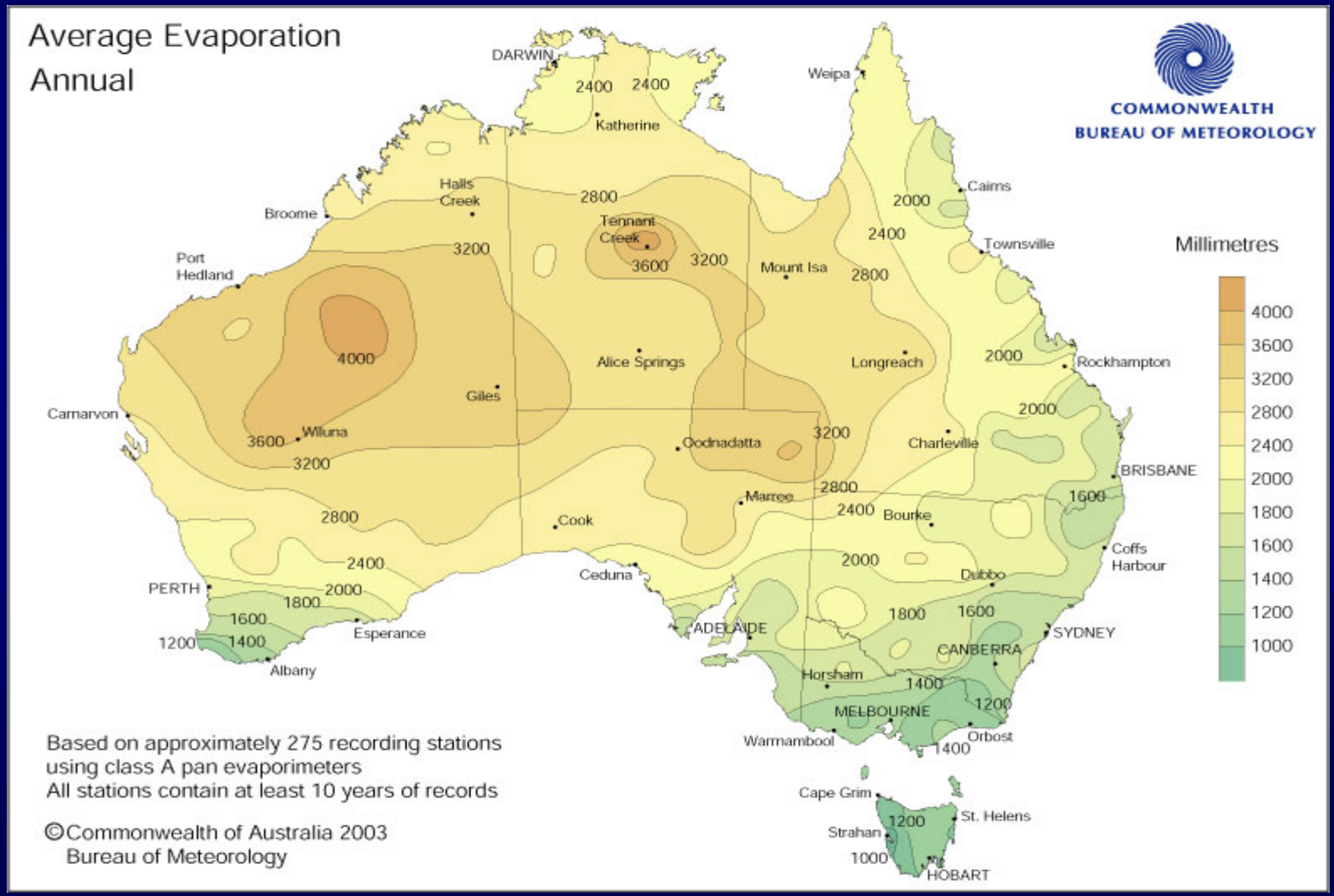


Annual rainfall patterns and ecosystem distribution and function are linked





Shouldn't forget evaporative demand as a determinant of water balance



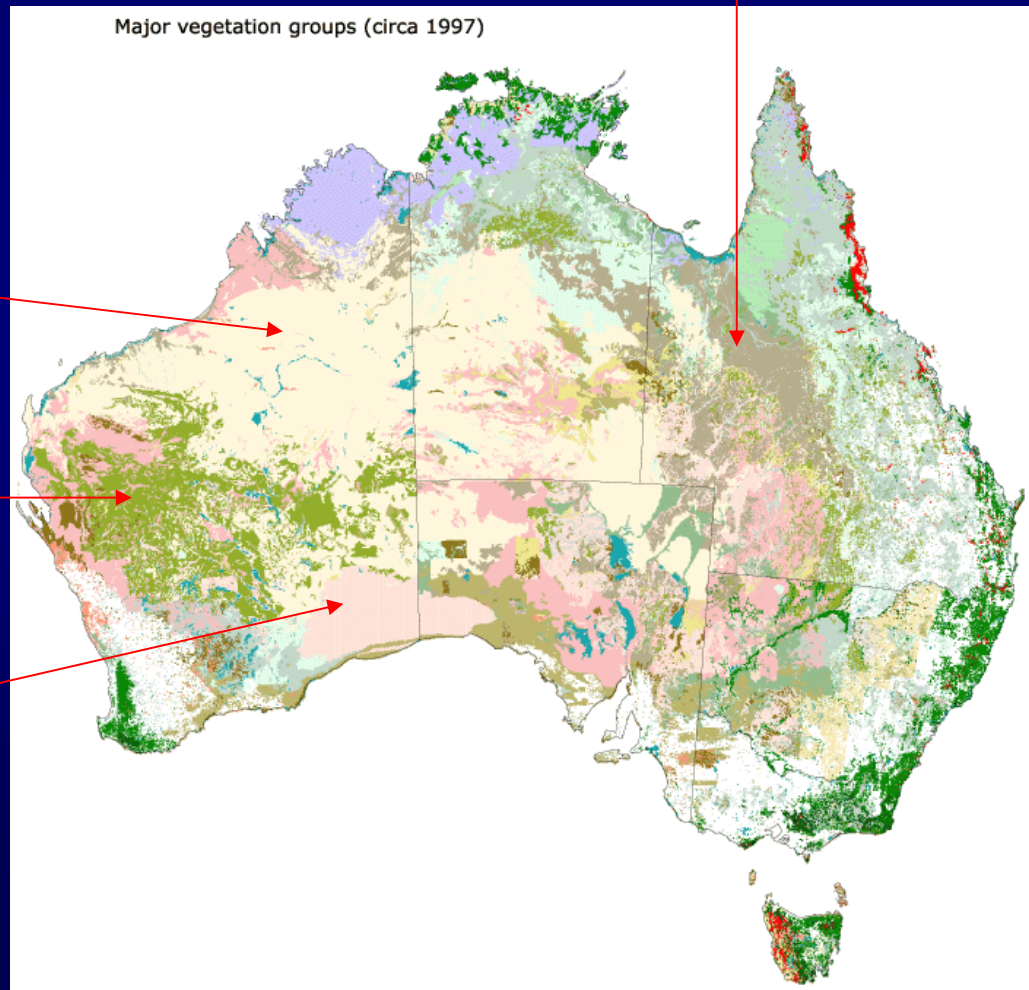
Veg distribution mapped onto rainfall and evaporative demand… question is: *How will changes to rainfall, evaporative demand and CO_2 concentration influence site water balance and hence vegetation distribution?*

Tussock grassland

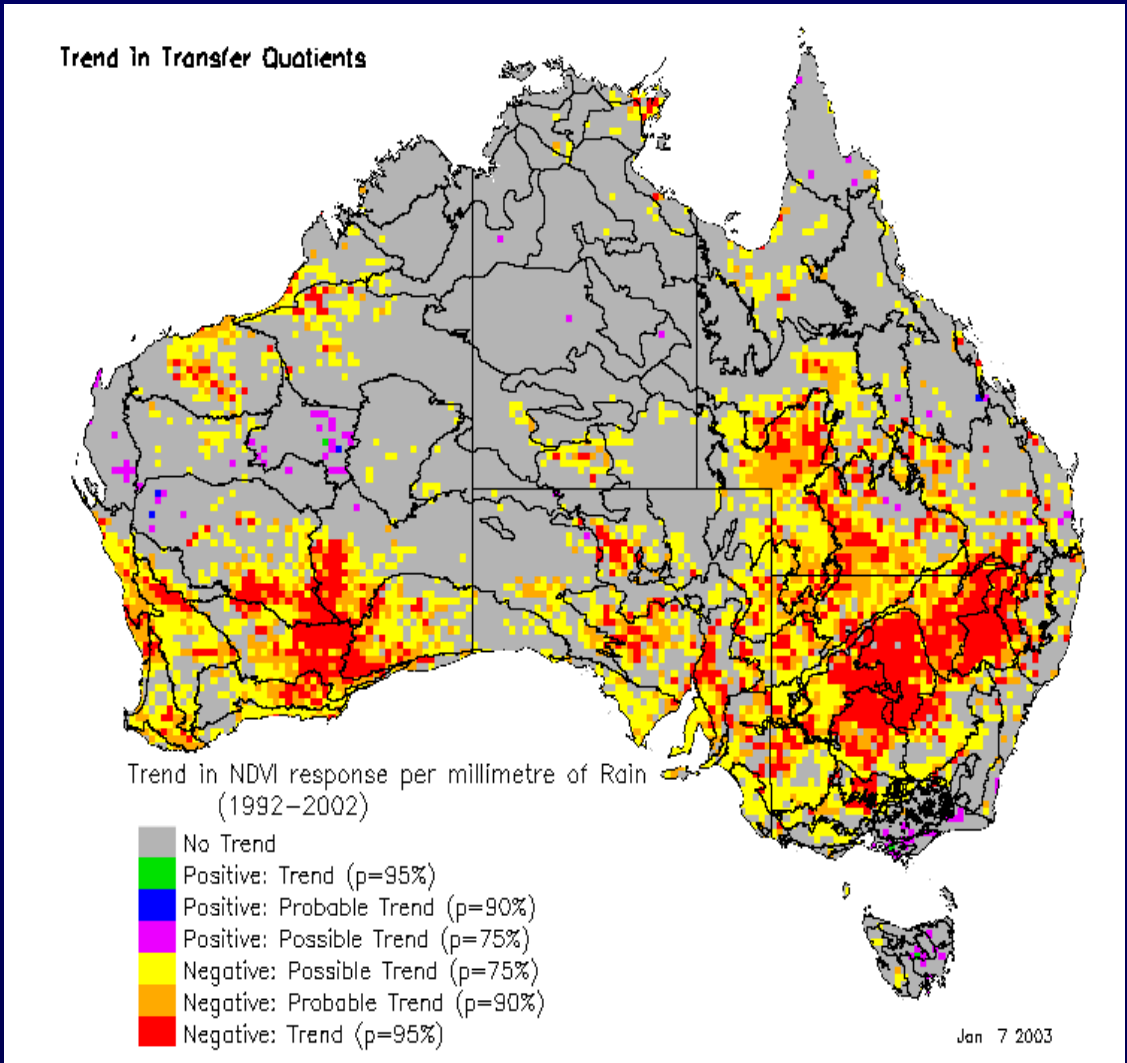
Hummock grassland

Acacia woodland / forest

Shrublands



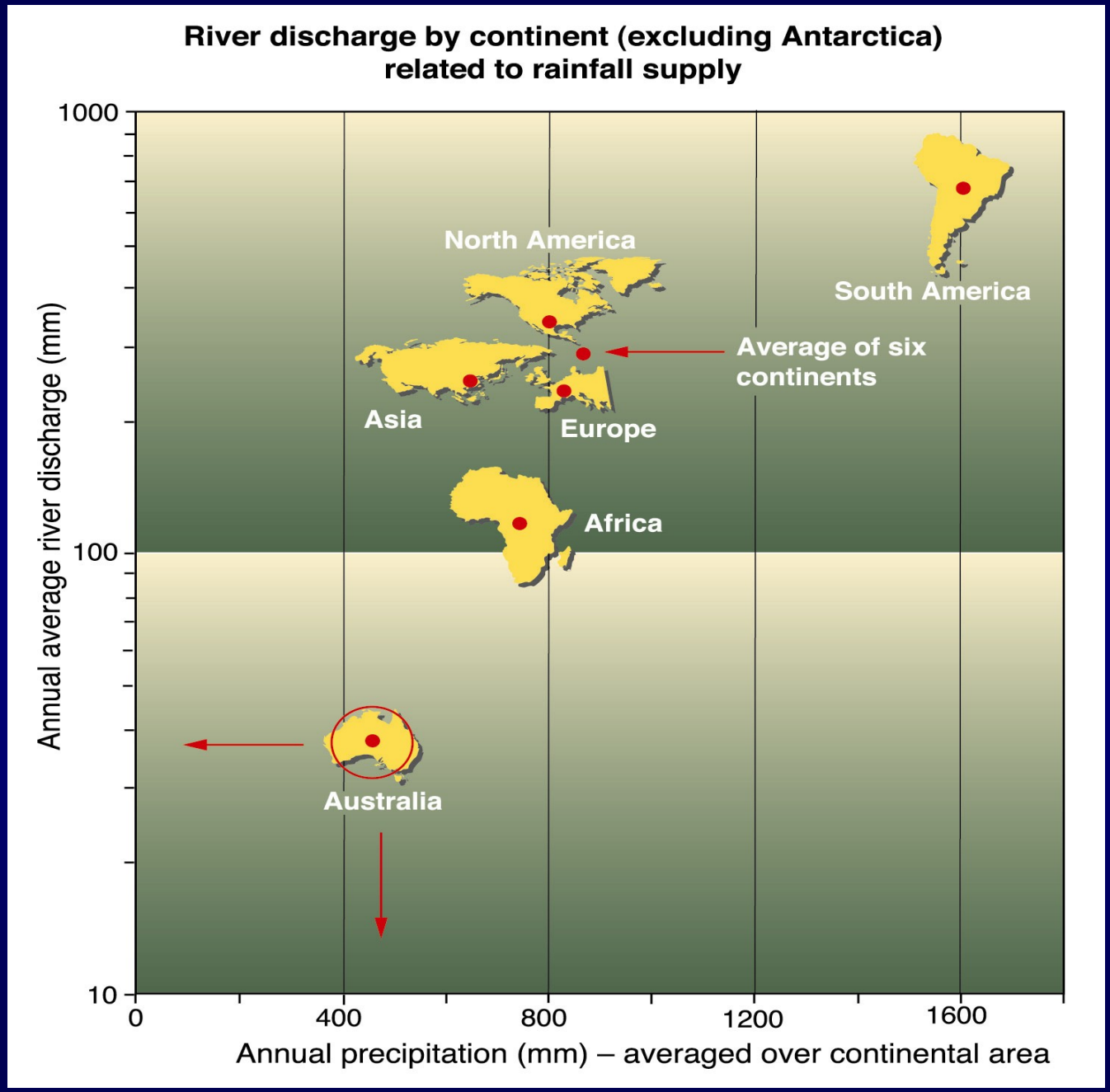
Are we seeing it already? …. trends in rain use efficiency



Is there an increase in permanent perennial vegetation in parts of northern Australia?

Has there been a reduction in water use in southern Australia?

Is woody thickening occurring across much of Australia?



Australia receives the least rain and discharges the least water as river flow

Australia's continental water balance: nearly all evapotranspired

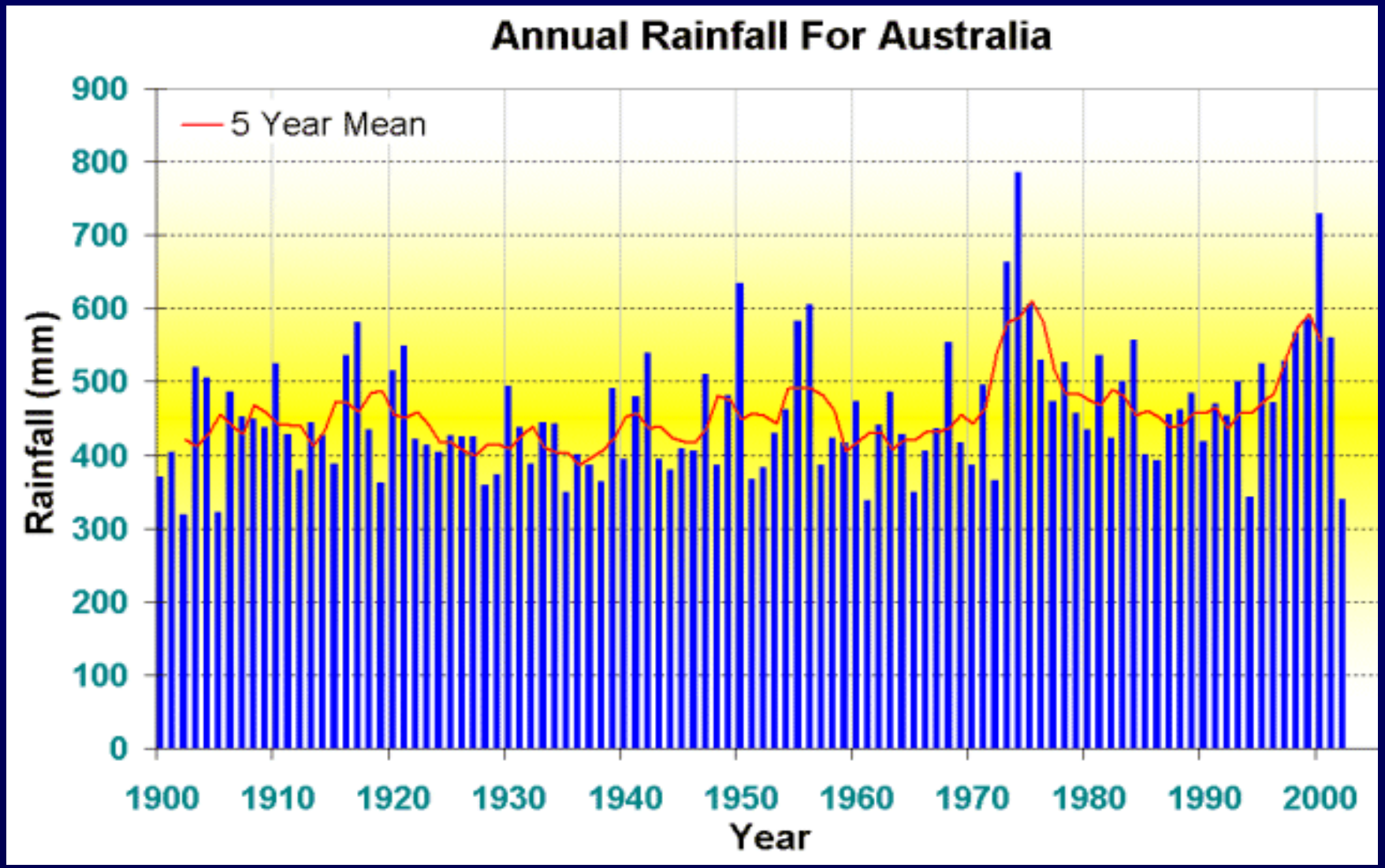
IN: 3.3 million GL rain per year (100%)

OUT: 3 million GL (90%) lost as evapotranspiration

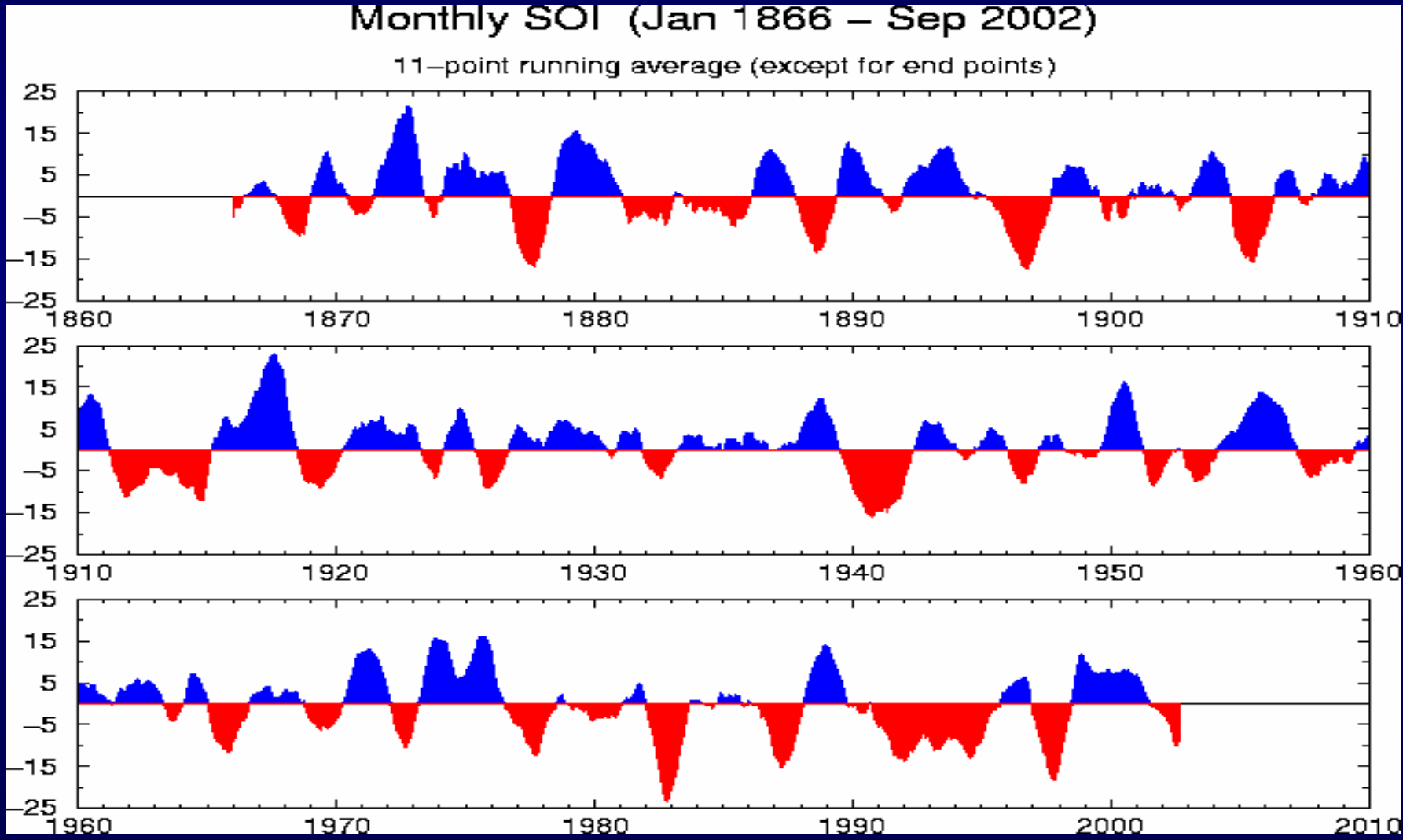
0.3 GL (10%) remaining in the landscape for our use?

The remaining 10% maintains river flow and river health….

Australia's rainfall is highly variable



The frequency and duration of El Nino is highly variable



Land use effects on streamflow

Globally, we observe generally :

- Where rain-fed agriculture replaces woodland, evapotranspiration declines; recharge and stream flow increase
- Where irrigation replaces woodland; evaporation increases and streamflow declines

Are we seeing this in Australia?

Rangeland degradation: a commentary (Wilcox 2007)

- Rangelands: include savannas, grasslands, shrublands, “deserts”
- Cover the majority of Australia
- Globally rangelands are being degraded, as is true in Australia, through 3 processes:
  - Desertification
  - Woody Plant Encroachment
  - Invasion by Weeds

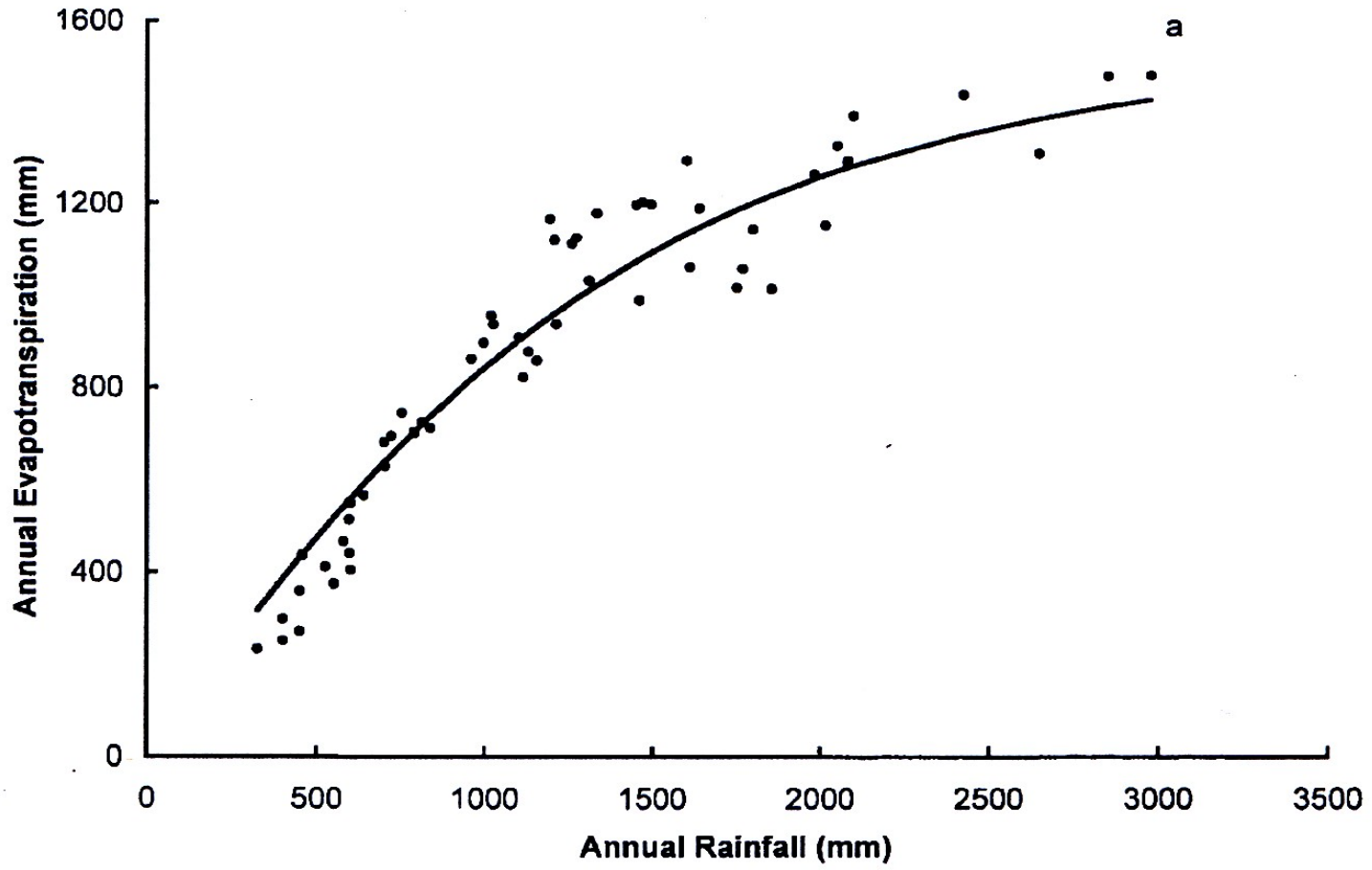
Weed invasion

What are the ecohydological implications of replacing annual by exotic perrenial grasses? …..

more specifically, how does the amount and timing of water use change?

(Wilcox and Thurow 2006)

Australian forested catchments



Australian grasslands

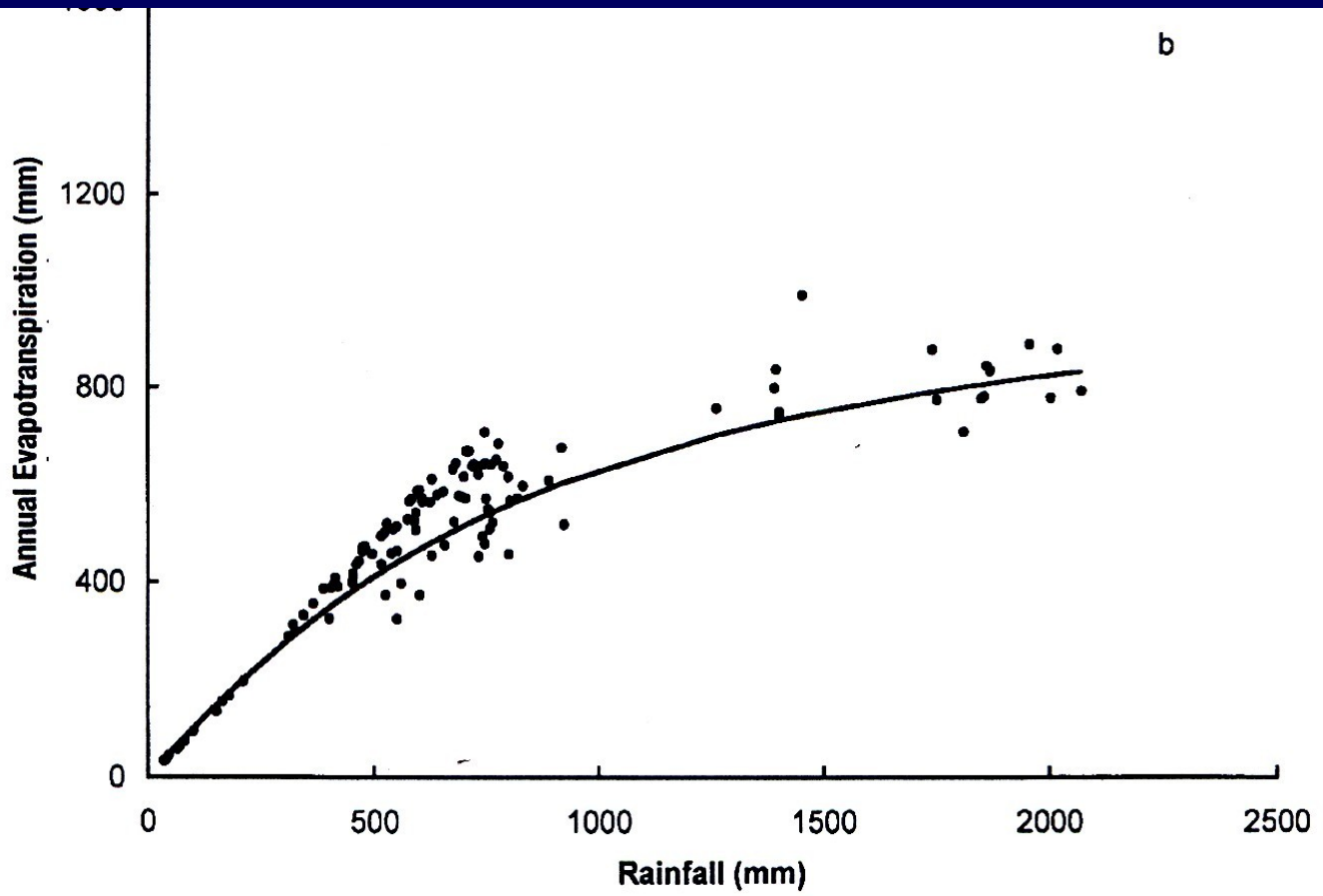


Figure. 8: Scatter plots of the least-squares fit for (a) forested and (b) grassed catchments.

Issue 6: Modelling and field work

- Need to be linked
- Truly integrate modelling with experimental work

  Bayesian models can:

  (i) predict impact of climate change, and

  (ii) direct research in climate change by identifying factors/parameters that need more/less experimental input

Woody Encroachment and Ecohydrology (Huxman et al (2005)

- Two separate possible impacts of woody encroachment
  - = change in recharge
  - = change in stream flow
- Even if transpiration not substantially affected … surface flow, interception losses and infiltration can be

Issue 13: Desertification and degradation

- What are the links between degradation, vegetation cover, run-off, nutrient loss and water budgets?
- What is the nature and timing and extent of feedbacks ? (Wilcox and Thurow 2006)