Seeking sustainability in a complex world

- managing for resilience -

www.resalliance.org

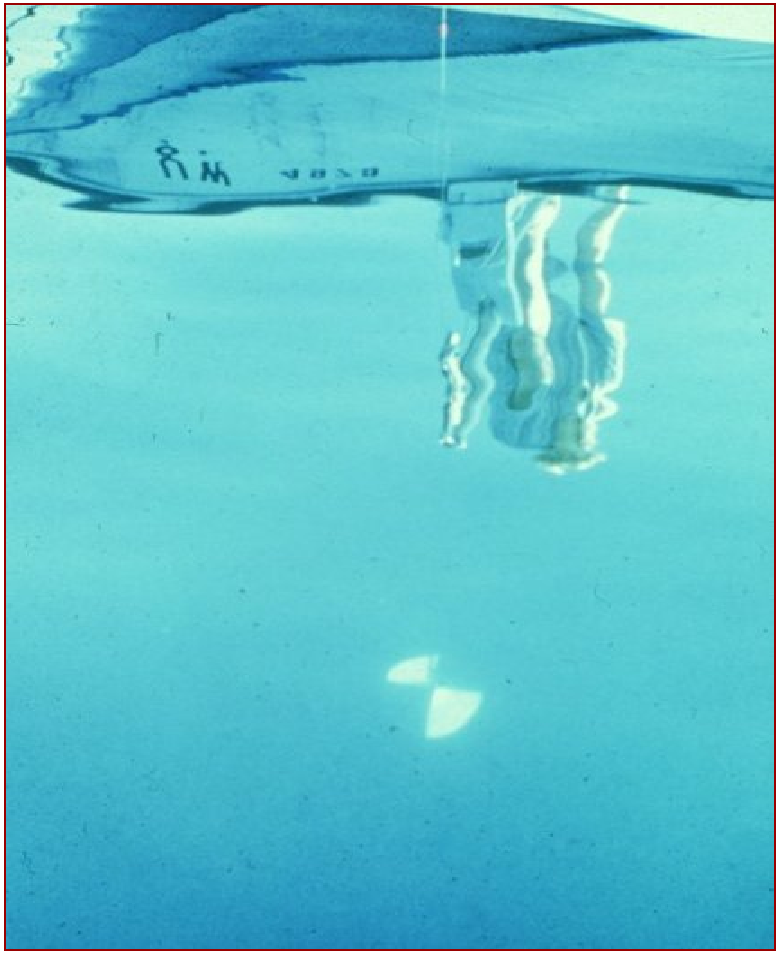
www.cse.csiro.au

Why is it,

that with the best intentions ……

Western Australian wheatbelt

North American lakes



rangelands in Australia

Caribbean coral reefs

These are all social-ecological systems
– interlinked systems of humans and nature

Unwelcome surprises in such systems are a result of loss of **resilience**

Loss of resilience occurs through changes in slow variables leading to changed feedbacks

How does this happen? - - - -

--- top-down, command-and-control development

(hold the system in some “optimal” state that will deliver maximum sustainable yield)

works well to begin with

- but then changed feedbacks cause problems

Two key features of social-ecological systems:

1) Effects of interventions depend on the phase of dynamics (stage of development) a system is in
   - **adaptive cycles and cross-scale effects**

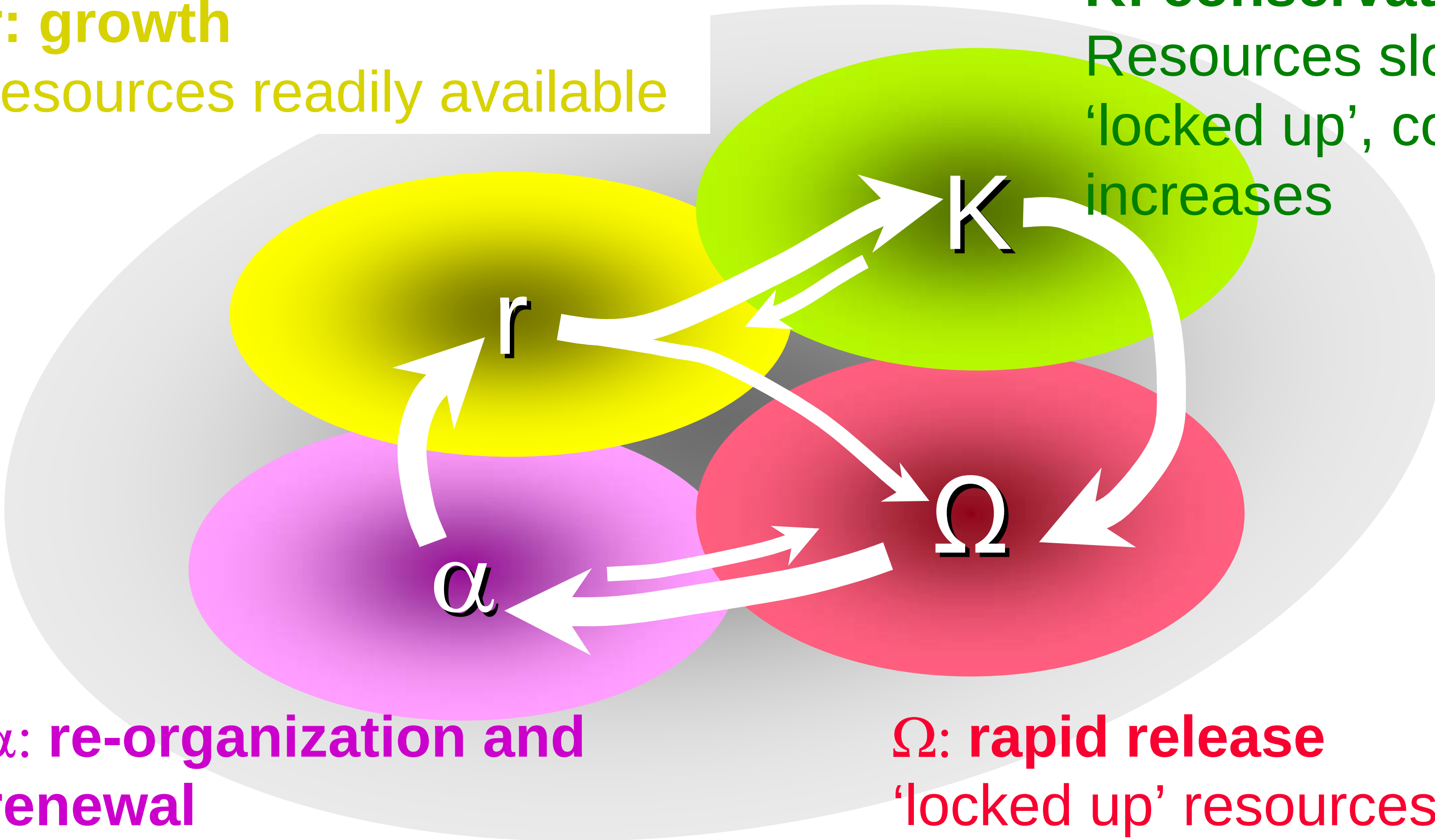
2) The amount of change (through stress or external shocks) a system can undergo, without changing in function, decreases with decreasing resilience
   - **systems have multiple (alternate) regimes**

Adaptive cycles and scales

All systems - ecosystems, societies, social-ecological systems – tend to move through 4 characteristic phases

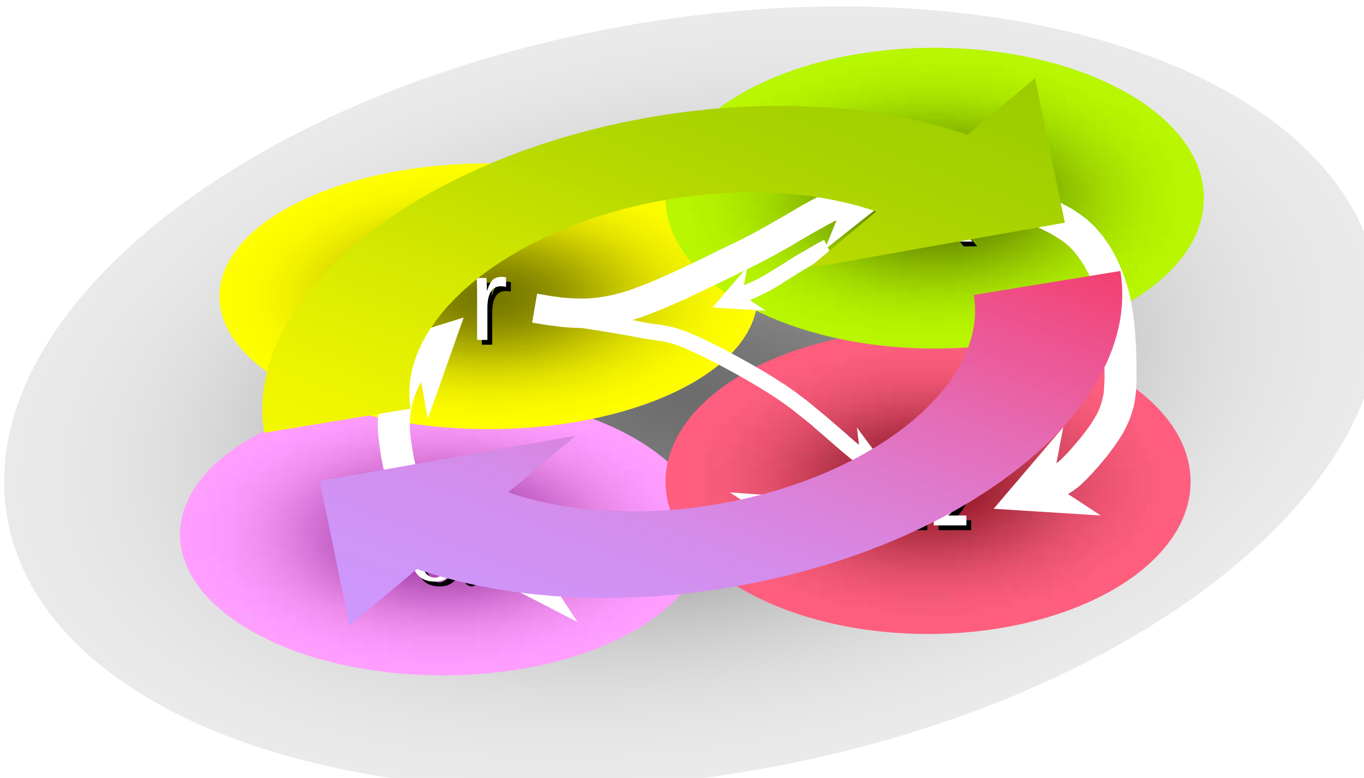
r: growth
resources readily available

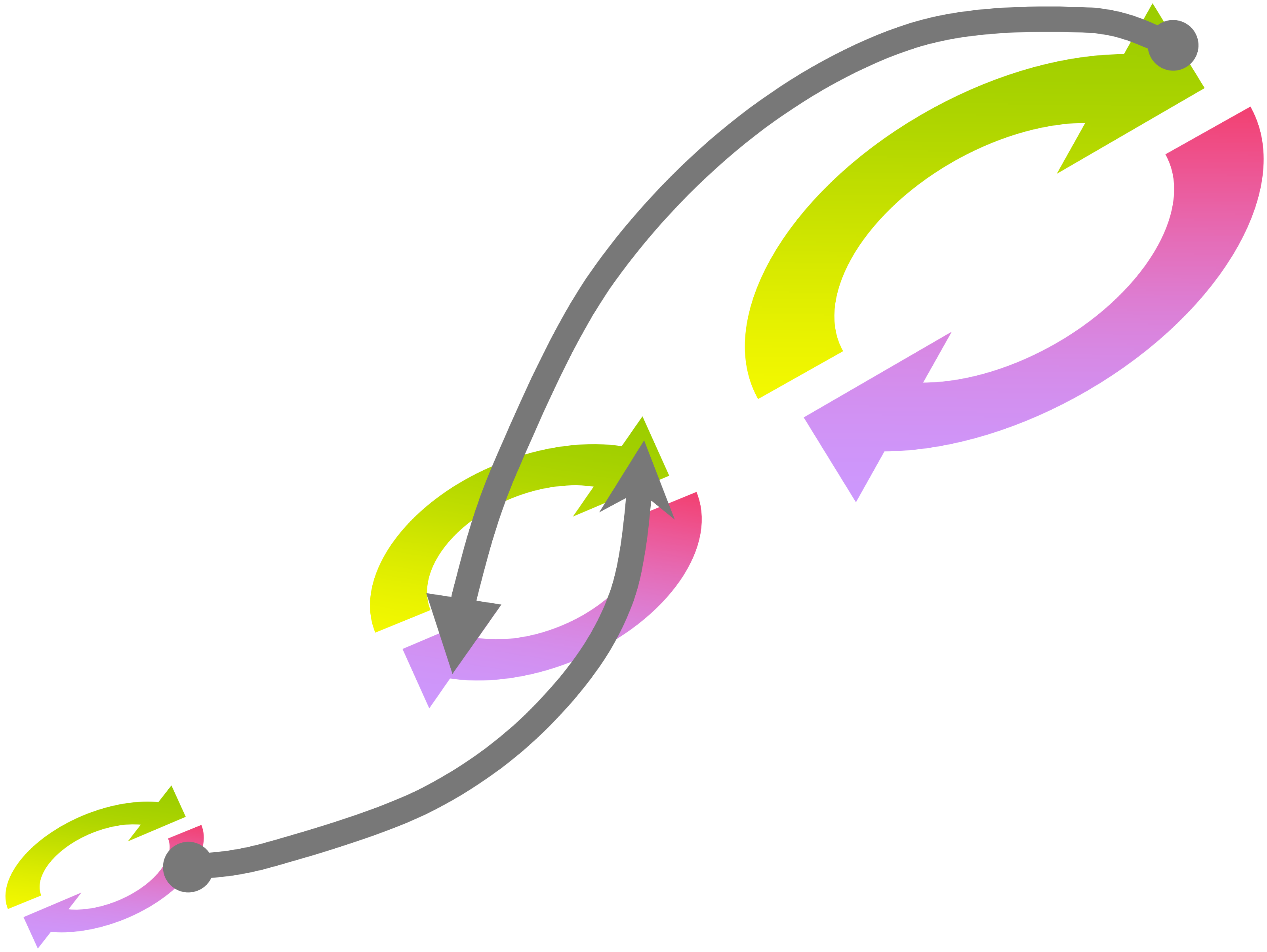
K: conservation
Resources slowly
‘locked up’, complexity
increases



α: **re-organization and renewal**
a time for innovation

Ω: **rapid release**
‘locked up’ resources suddenly
released; chaotic dynamics


r



“Panarchy” - adaptive cycles linked across scales

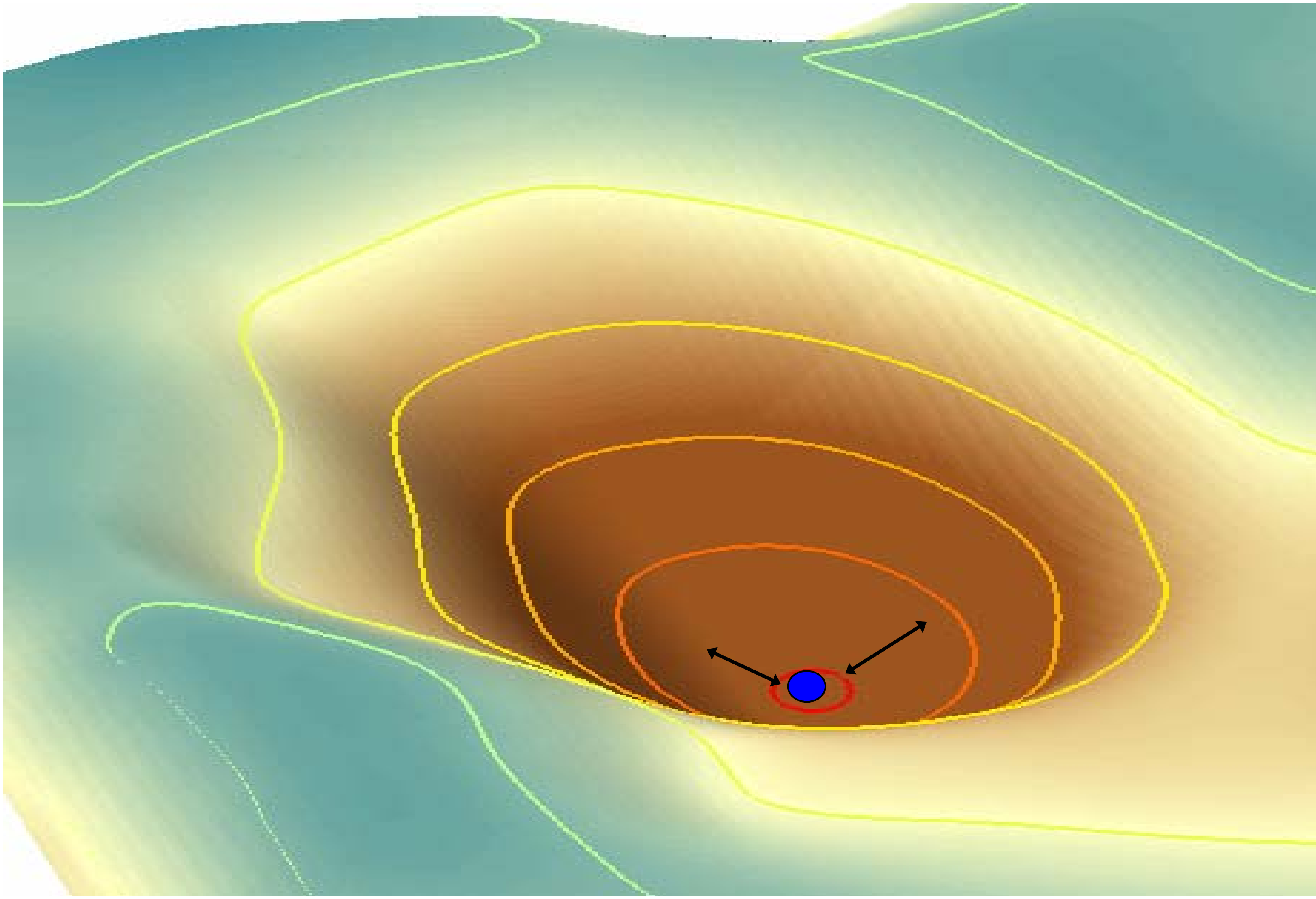
Sustainable development (= staying on desirable trajectories) requires systems that are:

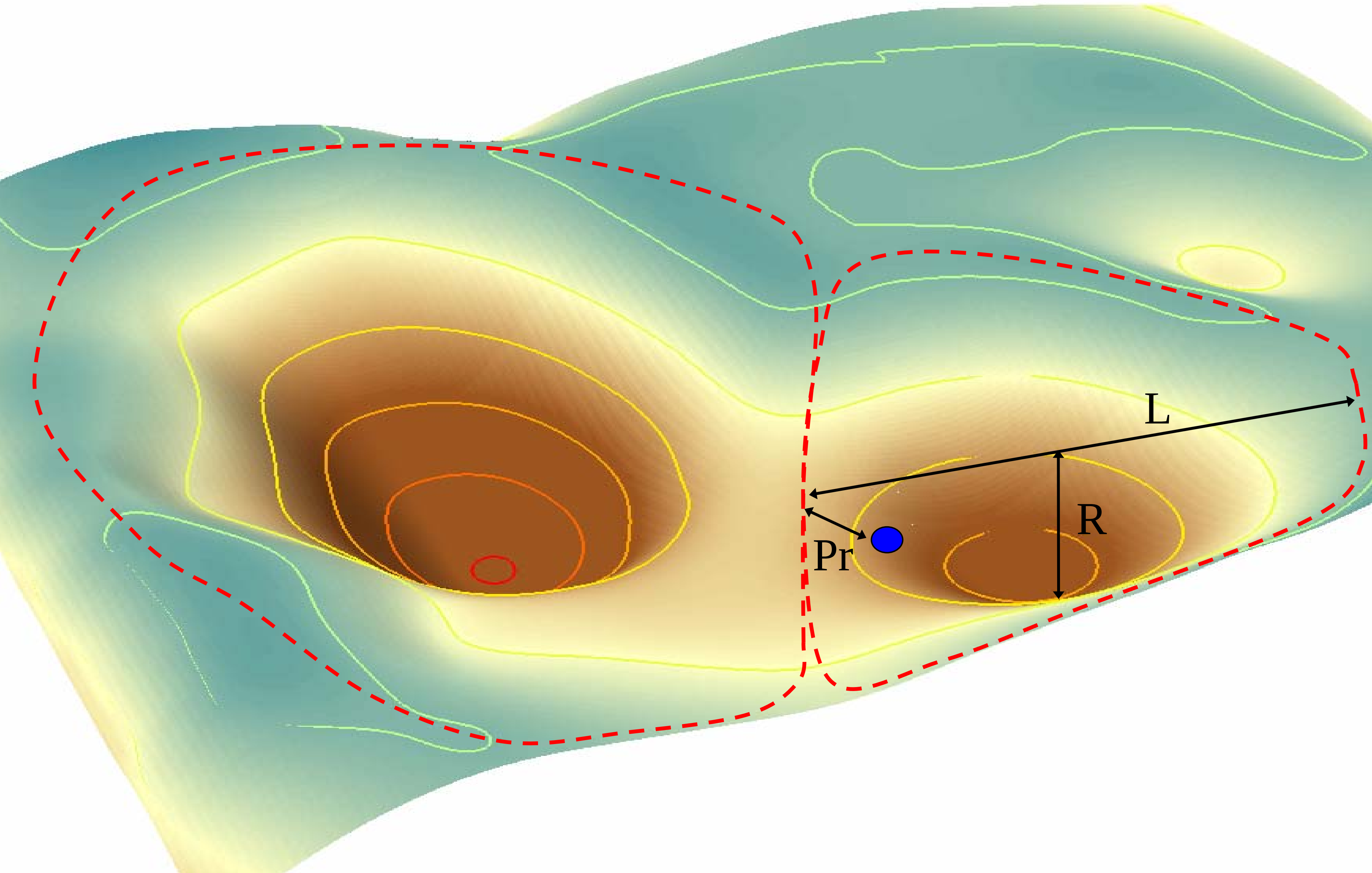
resilient, adaptable & transformable

Resilience

Formal definition:

The capacity of a system to absorb disturbance and re-organise while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks

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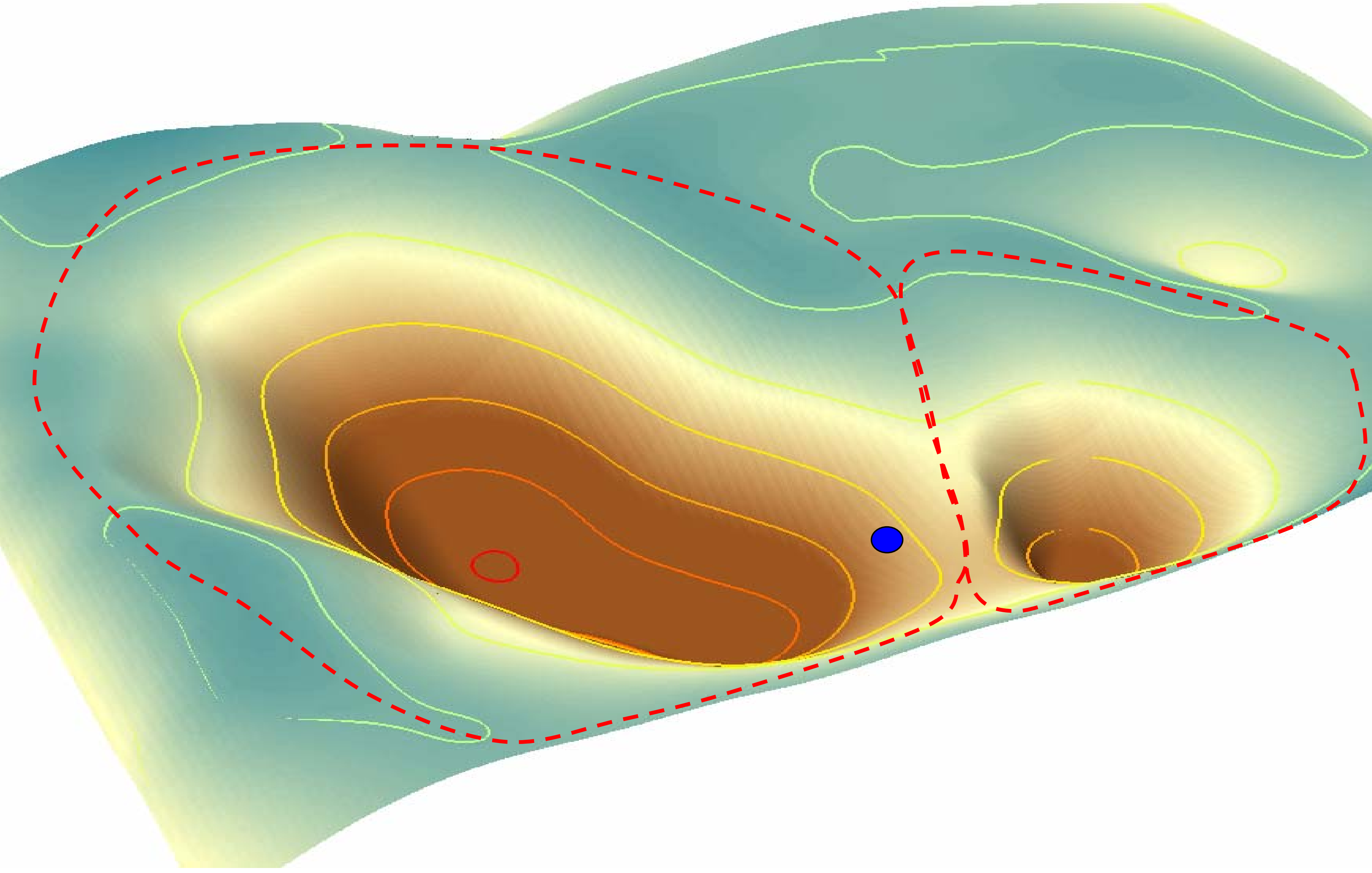
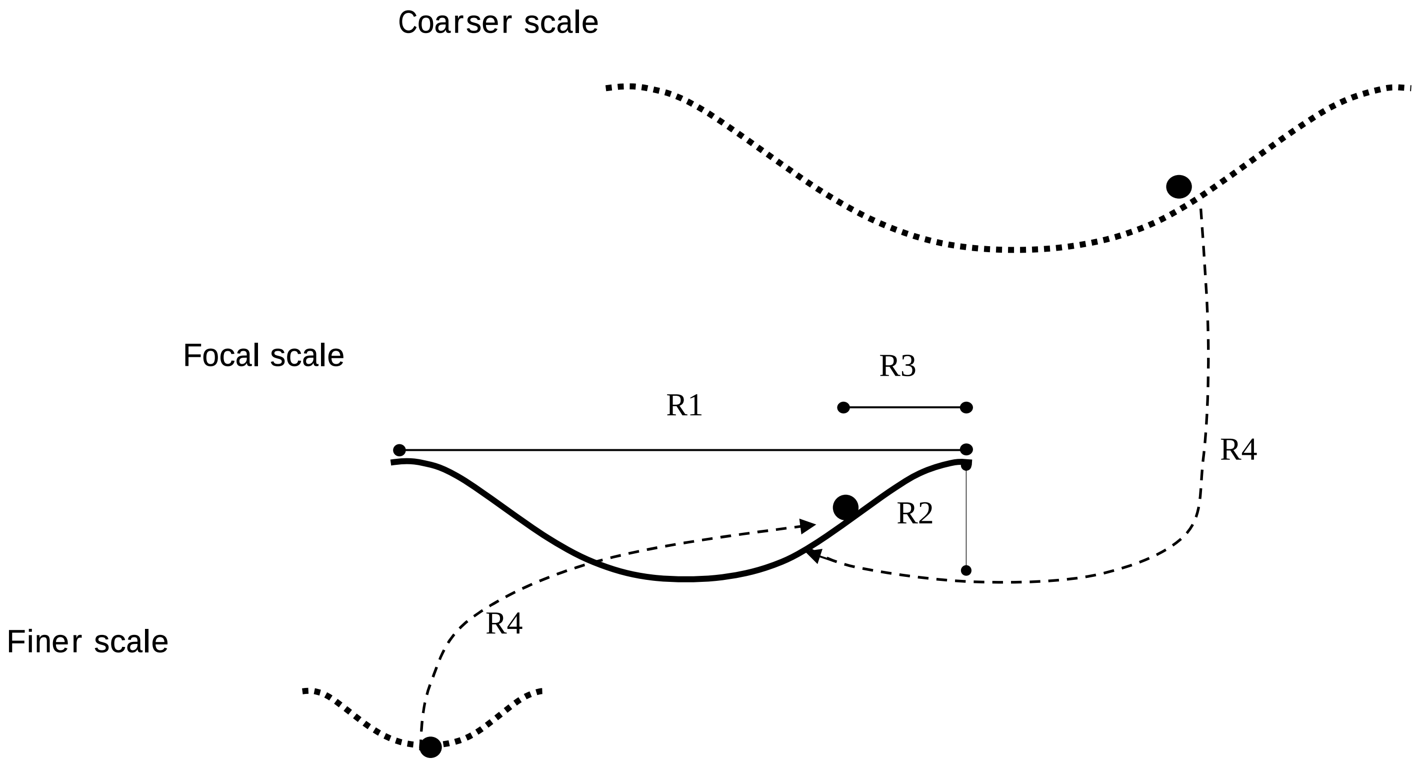




Panarchy (Pa) - influence of the states of the system (including where they are in their adaptive cycles) at scales above and below the focal scale, by impacting the system directly (from the finer scale) or by changing the stability landscape (from the coarser scale).

Four key aspects of resilience

Latitude (L): the maximum amount a system can be changed before losing its ability to recover (before crossing a threshold which, if breached, makes recovery difficult or impossible)

Resistance (R): ease or difficulty of changing the system

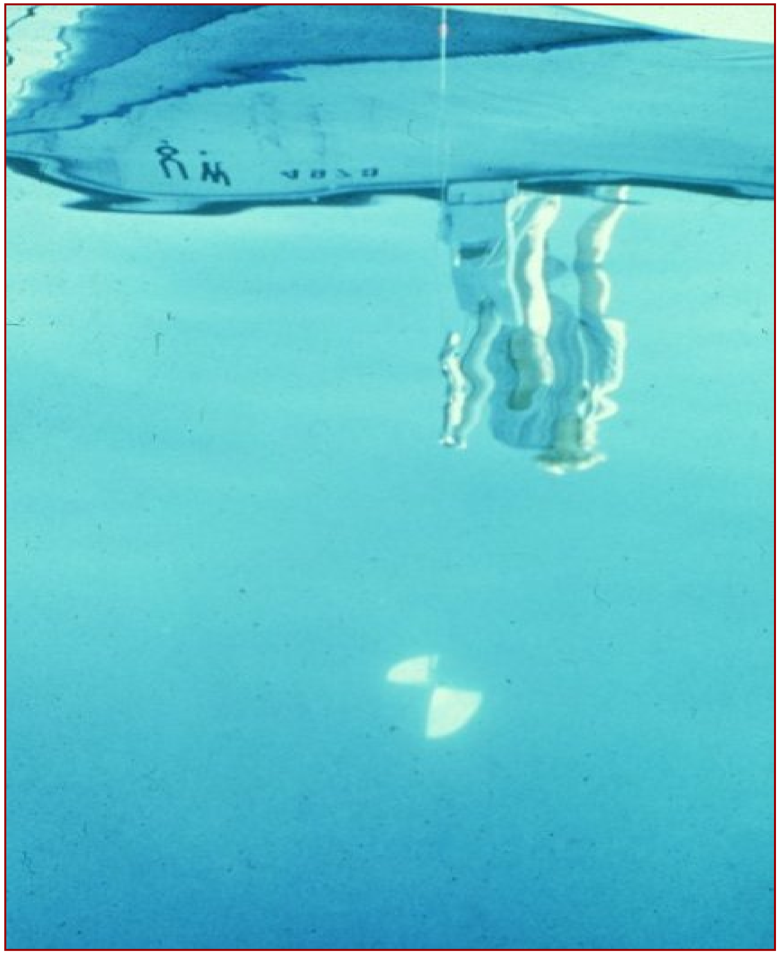
Precariousness (Pr): current trajectory - how close the system is to a 'threshold'

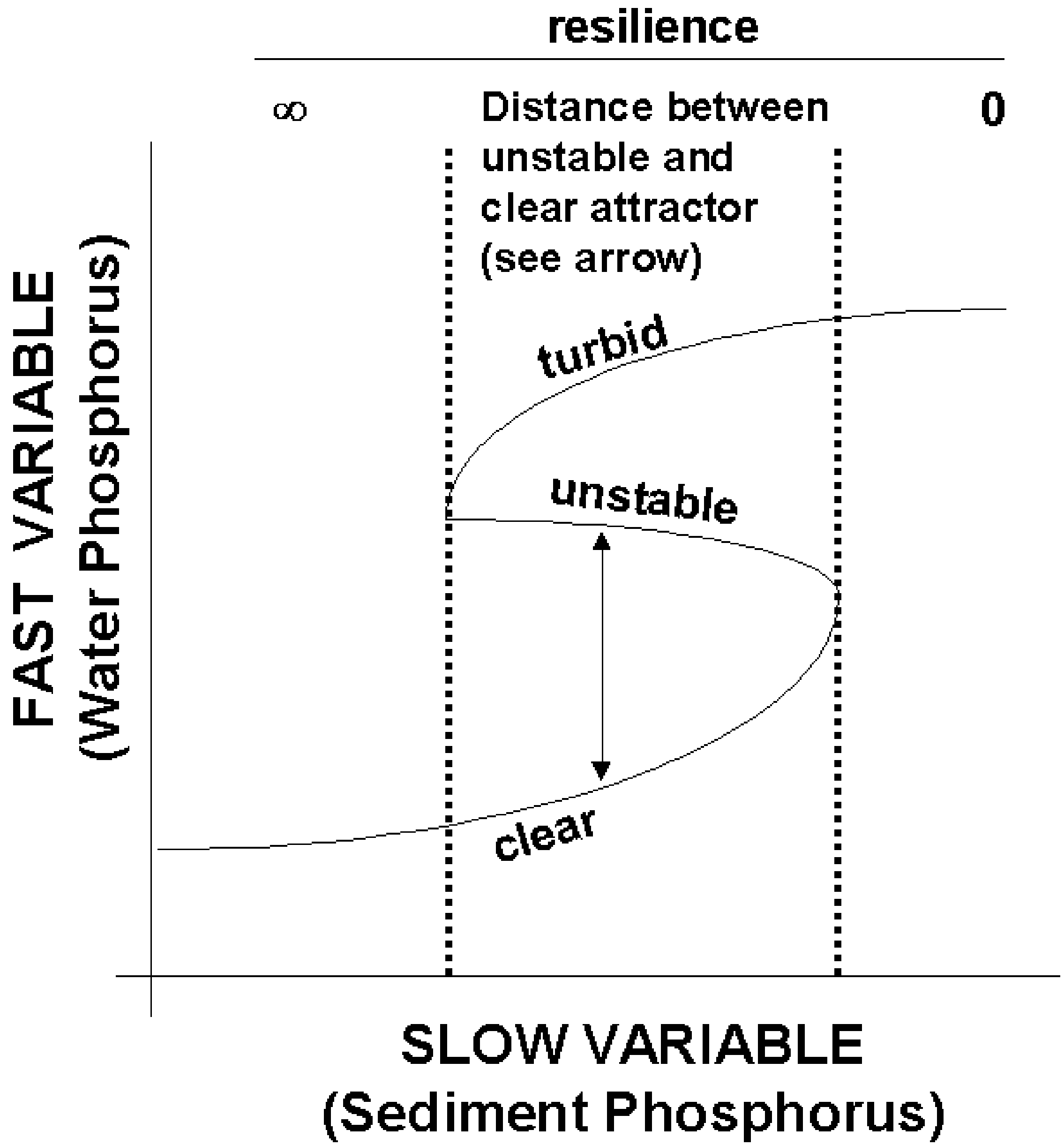
Panarchy (Pa): influence on the focal scale from scales above and below
(external politics, invasions, market shifts, climate change can trigger local surprises and flips)

Multiple regimes and thresholds

Resilience concepts place a strong emphasis on thresholds between alternate system regimes

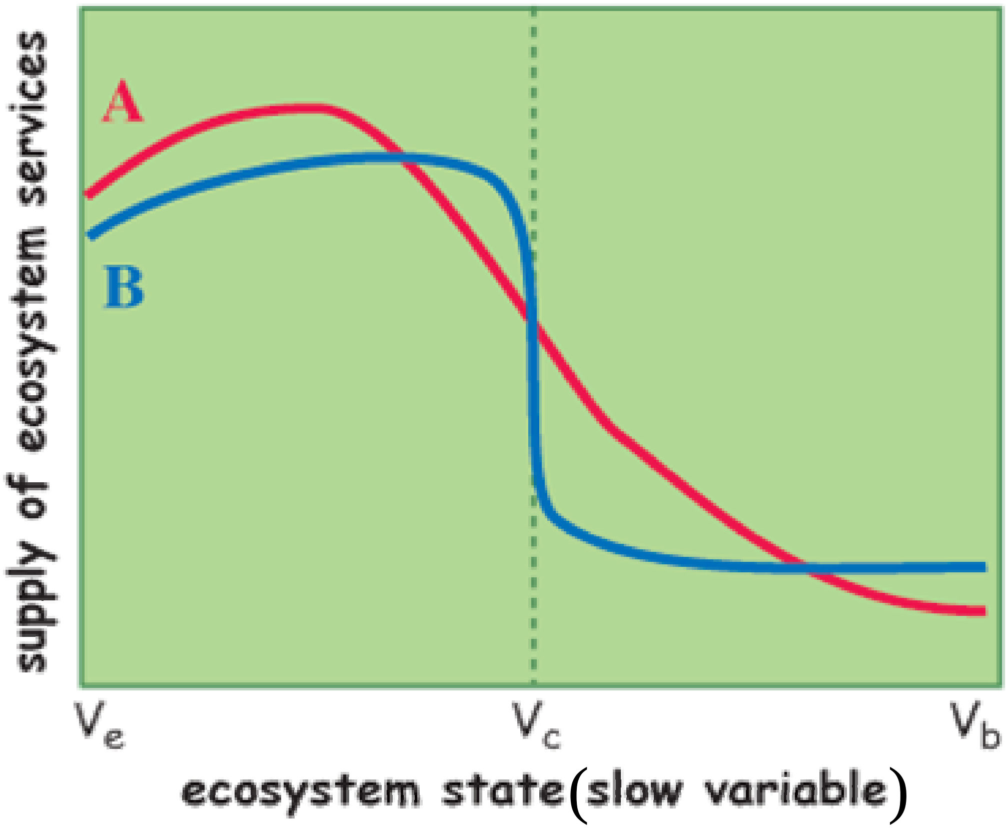
Alternate states in lakes





Alternate regimes in lake ecosystems

rangelands in Australia



Supply of ecosystem services as a function of ecosystem state

‘B’ - lake services (fish, recreation) as a function of phosphate in mud
‘A’ - rangeland services (wool production from grazing) as a function of shrubs
Vc - critical, threshold levels

www.resalliance.org - thresholds database

(“limits” or thresholds and regime shifts?)

Resilience, Adaptability, Transformability

The capacity of the system (people in it) to manage resilience :

(i) change the basin - move thresholds, or make it easier/harder to change the state of the system

(ii) Change the state of the system – ie, control the trajectory of the system (avoid crossing a threshold, or engineer such a crossing)

resilience *per se* is not necessarily desirable

the Hindu caste system

desertified and impoverished parts of the Sahel

transformability - the only way out

Resilience, Adaptability, **Transformability**

The capacity to become (or create) a fundamentally different system when ecological, social and/or economic conditions make the existing system untenable

KEY QUESTION

What attributes of social-ecological systems determine their resilience, adaptability and transformability?

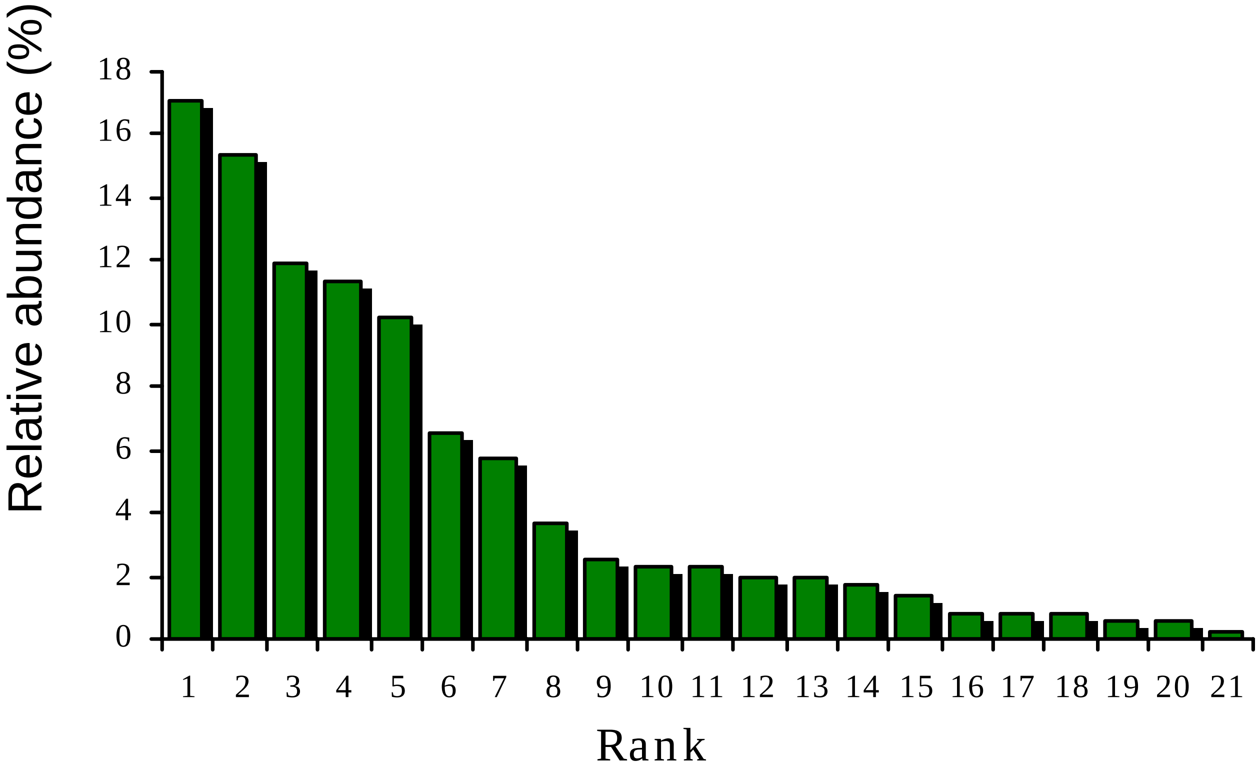
What determines resilience?

- Diversity *
- Modularity (connectedness)
- Tightness of feedbacks
- Openness – immigration, inflows, outflows
- Reserves and other reservoirs (seedbanks, nutrient pools, memory)

Lightly Grazed Site

photo by Jill Landsberg

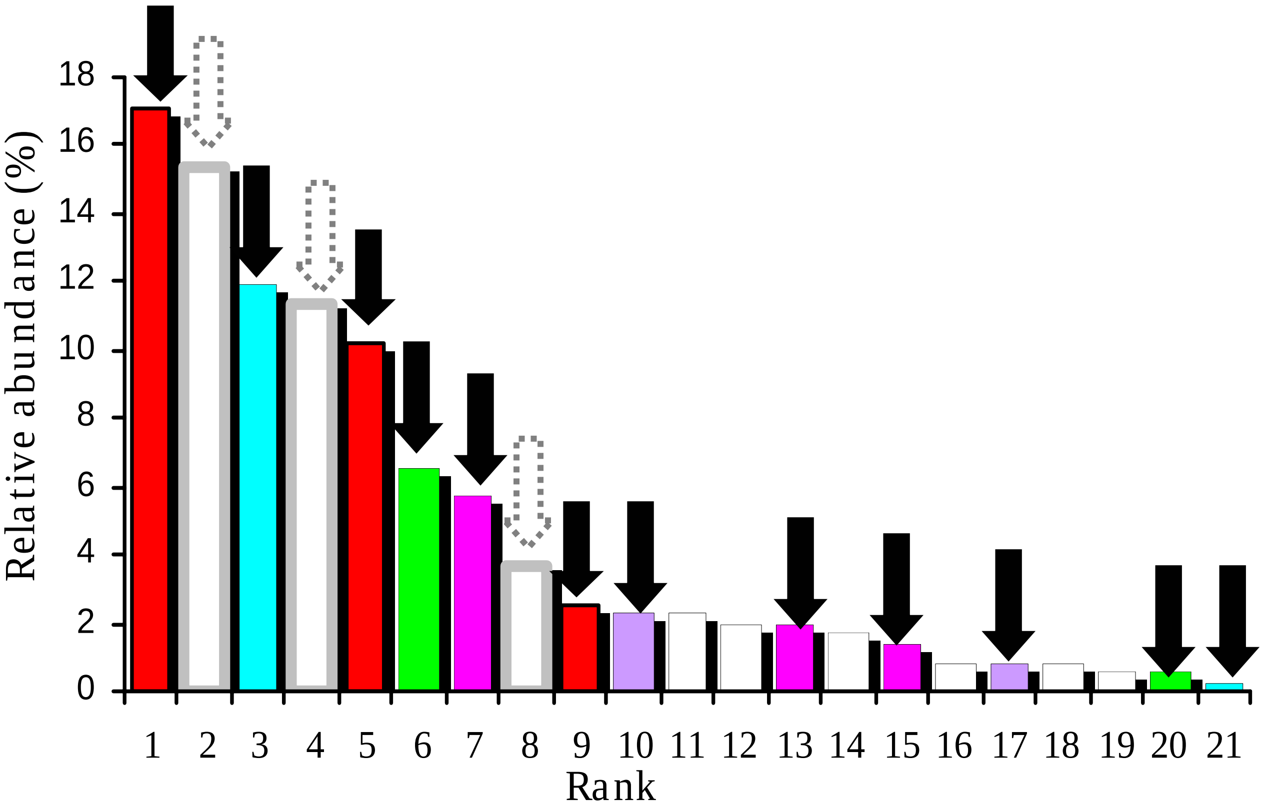
abundance of grass species in lightly grazed rangeland in Australia



Plant attributes determining ecosystem production (available data)

- height
- mature plant biomass
- specific leaf area
- longevity
- leaf litter quality

Functional similarities between dominant and minor species



Heavily Grazed Site

photo by Jill Landsberg

- Ecosystem performance is promoted by high ***functional diversity*** (complementarity)

- Resilience is promoted by high ***response diversity***

shown in rainforests, coral reefs, lakes, rangelands

(Elmqvist etal; Response diversity, ecosystem change and resilience. Frontiers in Ecology and Environment. 2003. Vol1 448 – 494) “general” resilience

(modularity, etc.)

“specified” resilience

(resilience of what, to what?)

What determines Adaptability?

– social “capital” (social capacity)

leadership

trust

networks and information flow

- human capital (skills, education, health)
- financial resources
- natural capital

-ongoing learning

-overlapping institutions (governance)

What determines Transformability?

(we don't yet know, but…)

-cross-scale awareness (knowing when to change)

- propensity for experimentation (rewarded, not penalised)

- external support that provides options for change (vs. incentives and subsidies not to change)

- trust
-?

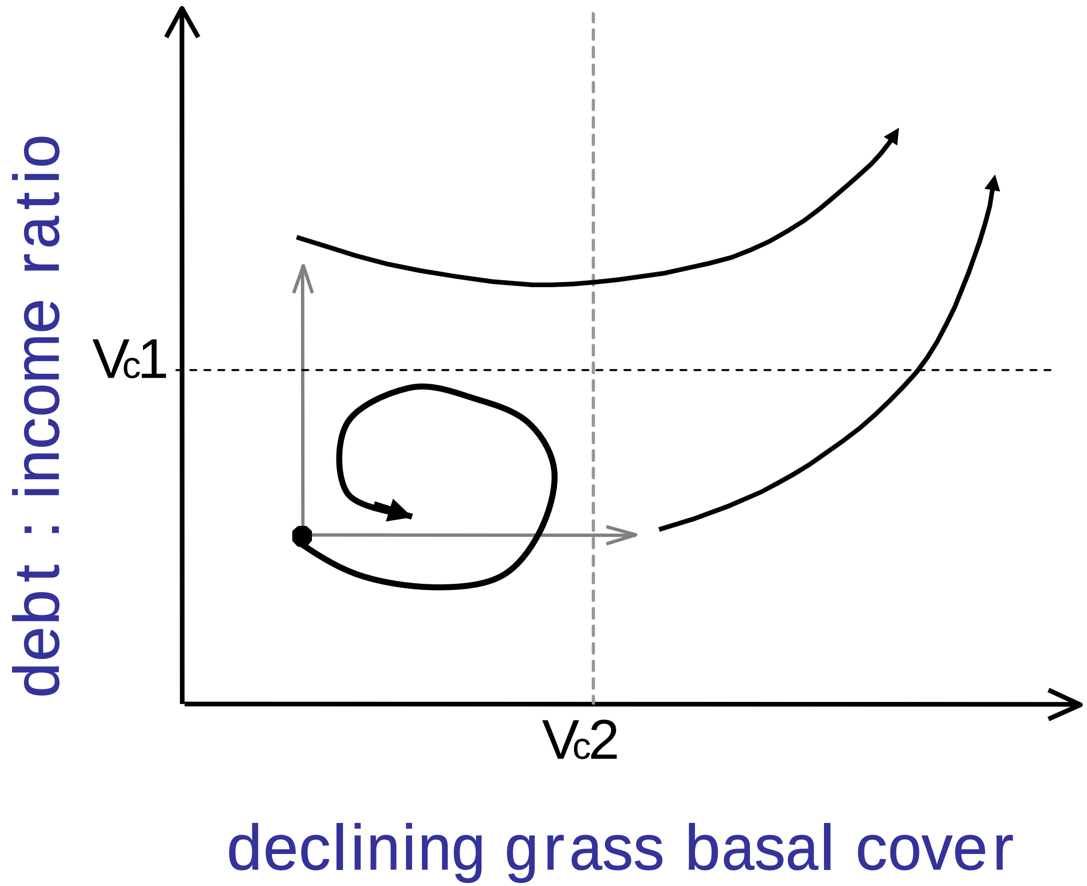
Resilience in complex social-ecological systems:

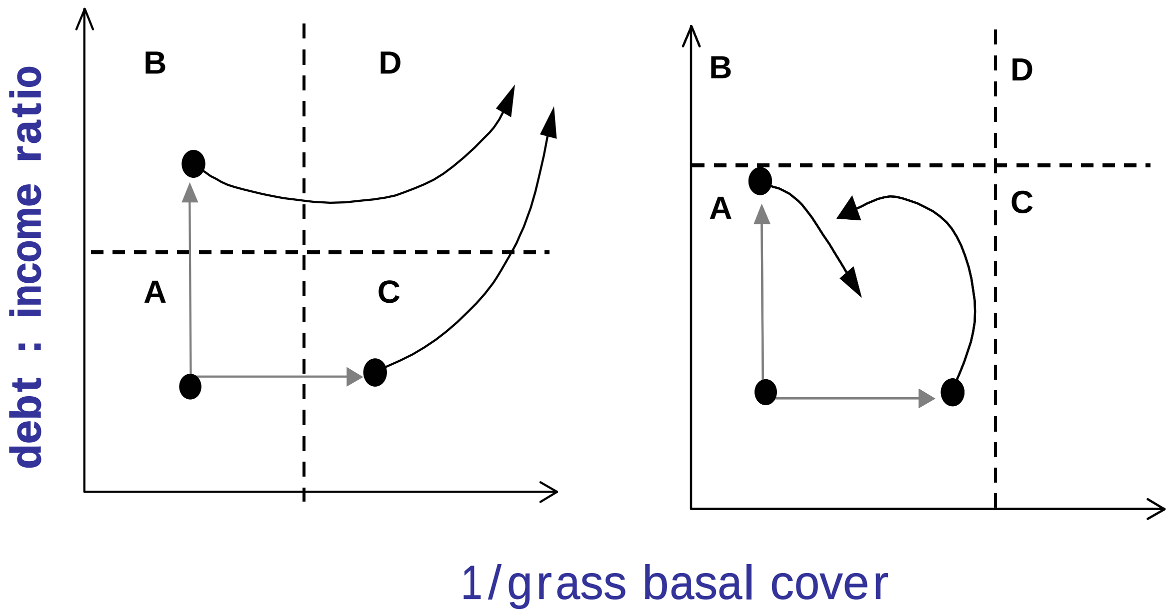
- is multi-dimensional

- involves multiple scales

Multi-dimensional resilience

Resilience and adaptability in desertified regions (Fernandez et al 2003)





debt : income ratio
B
D
A
C
B
D
A
C
1/grass basal cover

Multi-dimensional, multi-scale resilience

The Causse Mejan, France (sheep cheese production)

Western Australian (wheat farming)

SE Australia (irrigated farming)

Southern Madagascar (crop production)

three kinds of thresholds at three different scales:

- patch scale ecological threshold

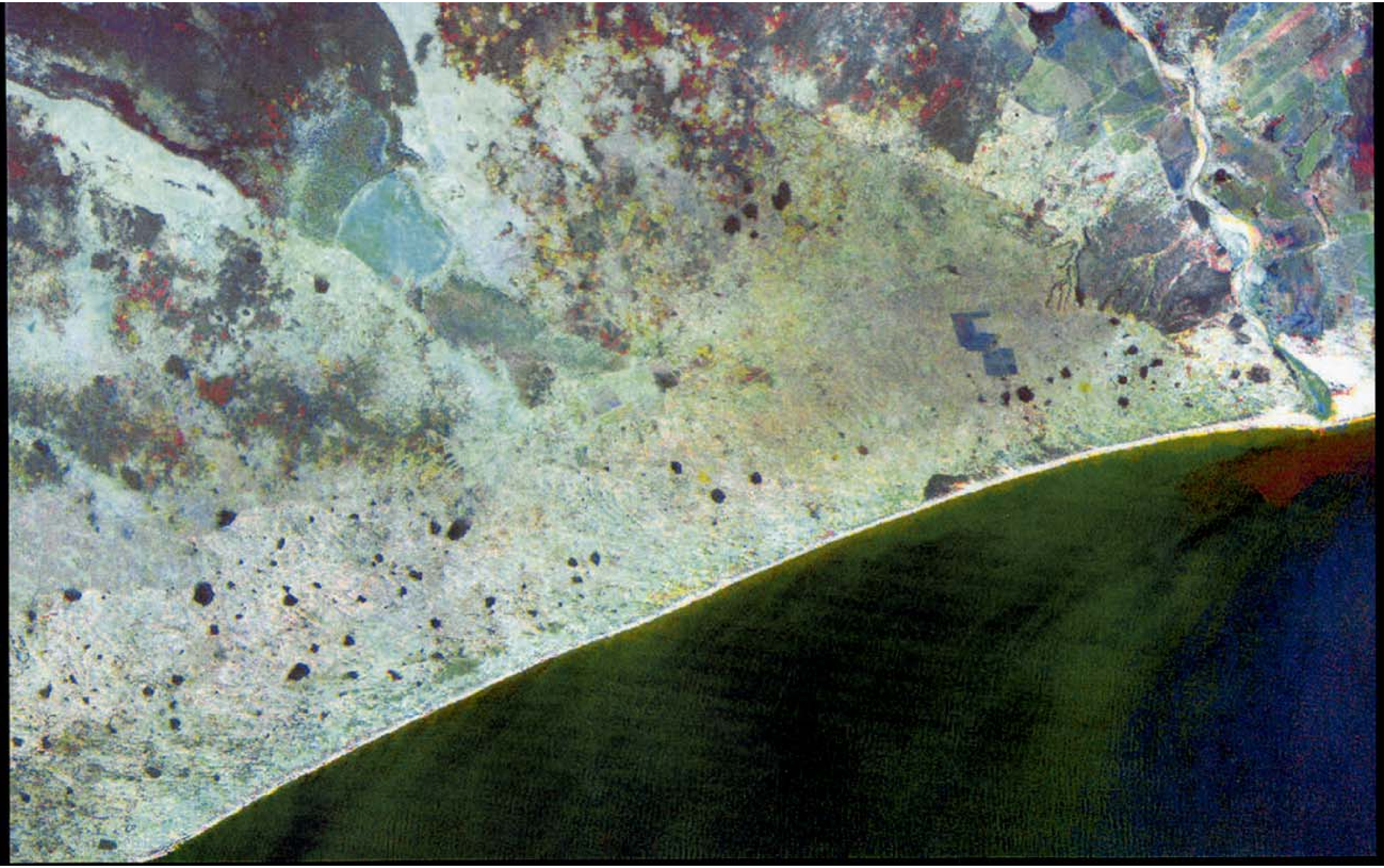
- farm scale economic threshold

- regional (community) scale social threshold.

Southern Madagascar dry thorn forests

Sacred forest (150ha) surrounded by agriculture (insect pollinated)

Sacred Forests - alafaly



Patch: self-maintenance of remnant forests

- connectedness, disturbance

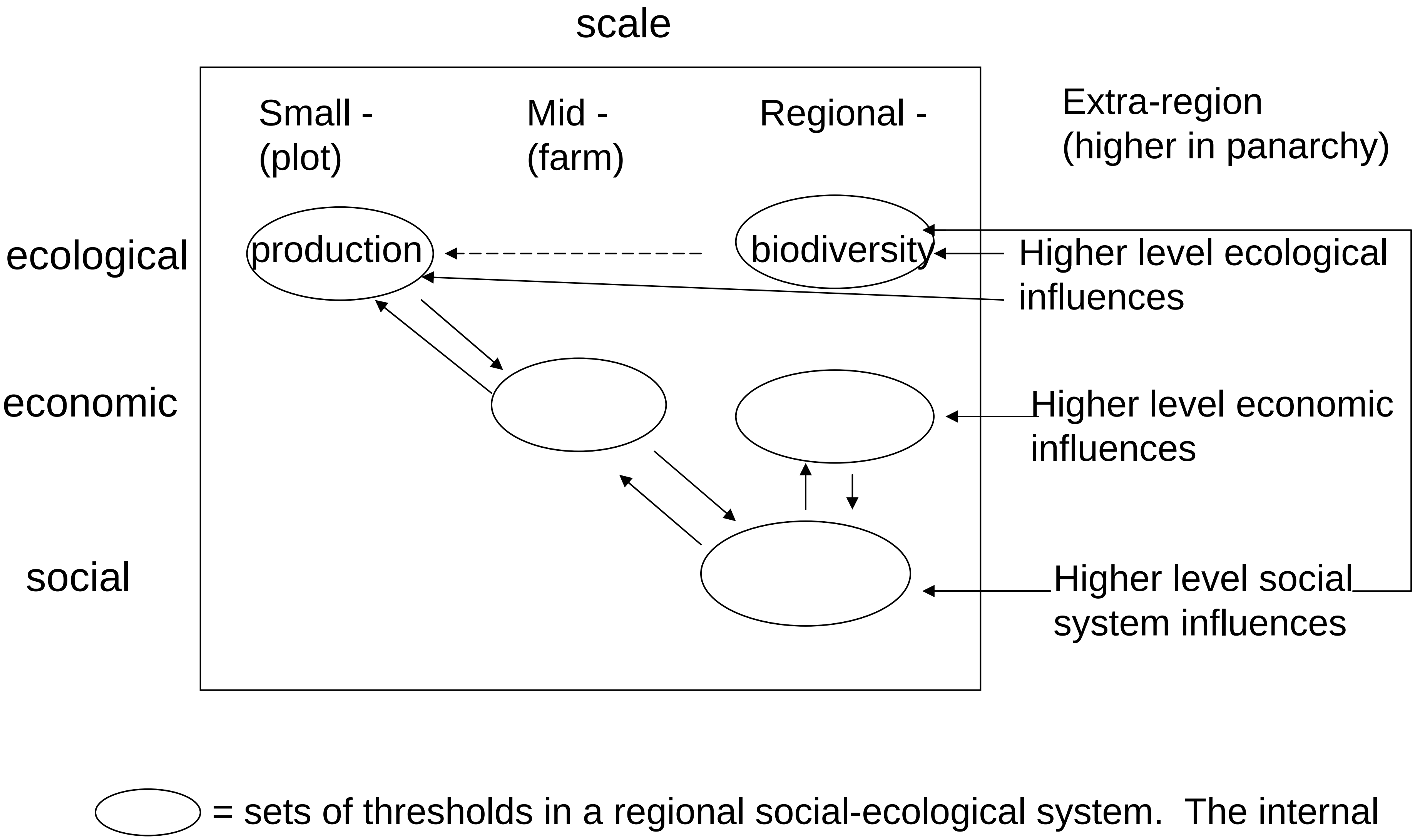
Farm economics: crop production levels (insect pollinated)

- pollinator abundance (in forests)

Region (community): persistence of sacred forests

- proportion of ‘newcomers’ (who do not observe sacred forest rules)

Interactions among thresholds across scales

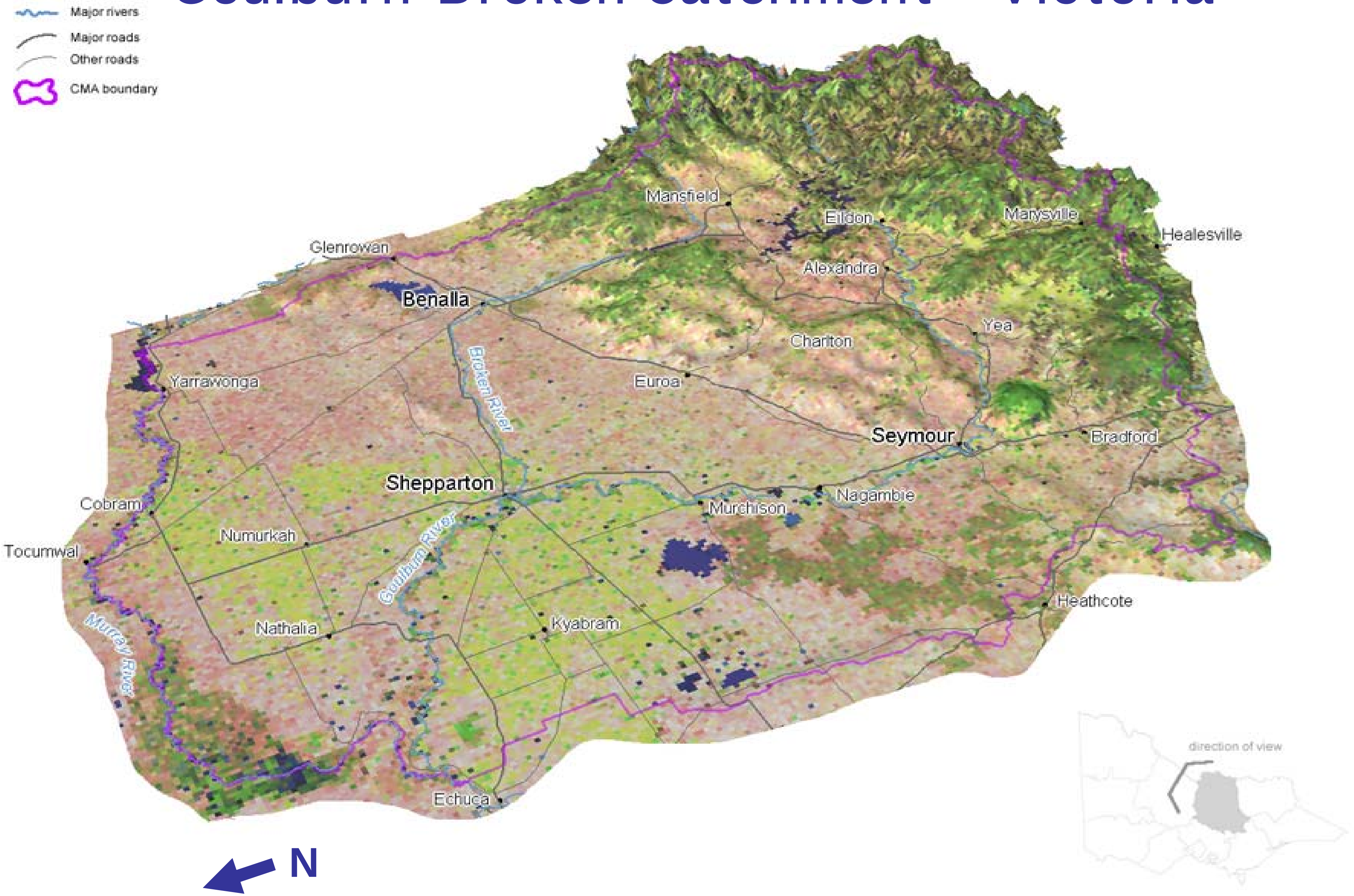


= sets of thresholds in a regional social-ecological system. The internal arrows indicate interactions between thresholds (not just the variables themselves)

Feasible trajectories

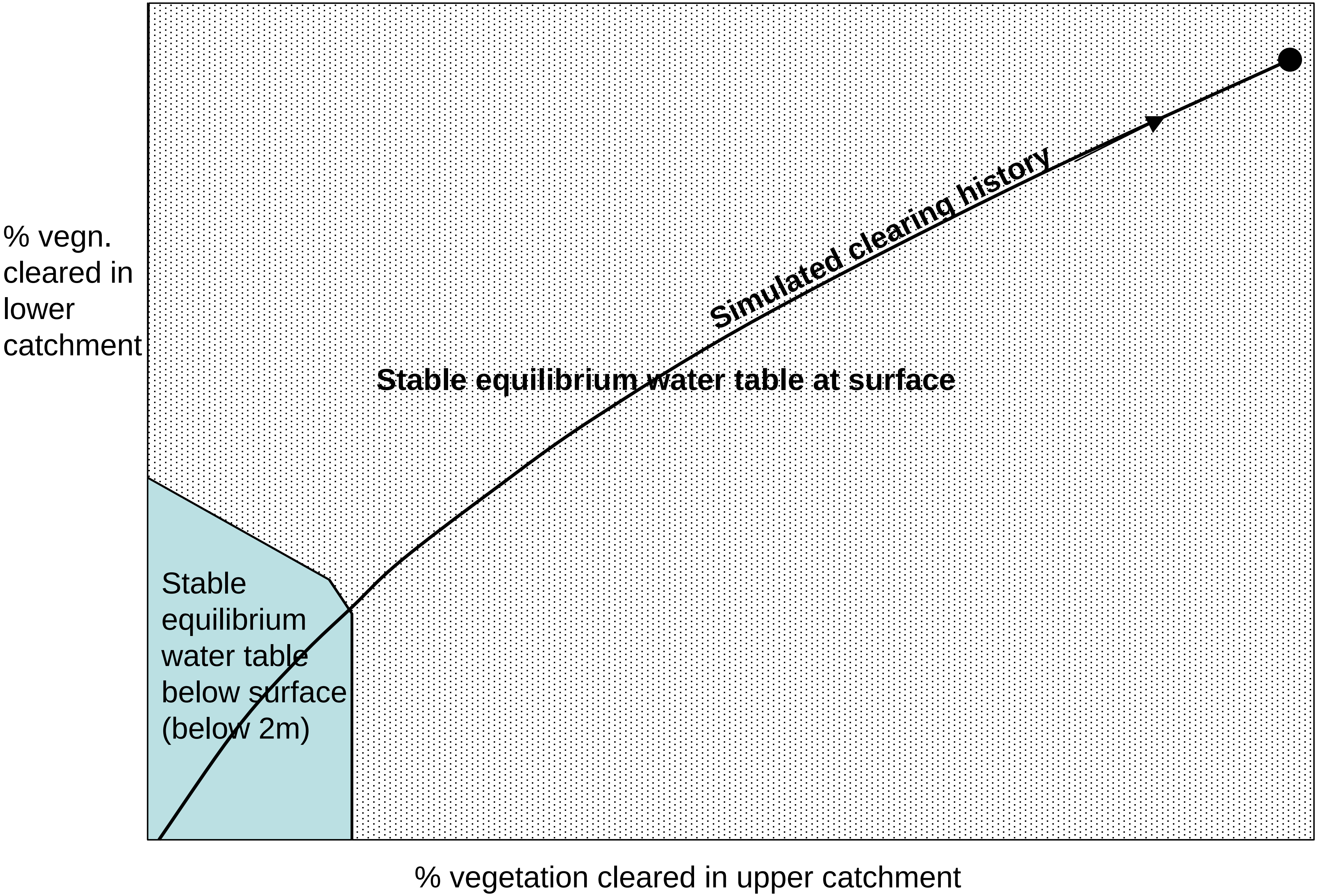
Path dependency and hysteresis in the Goulburn- Broken Catchment

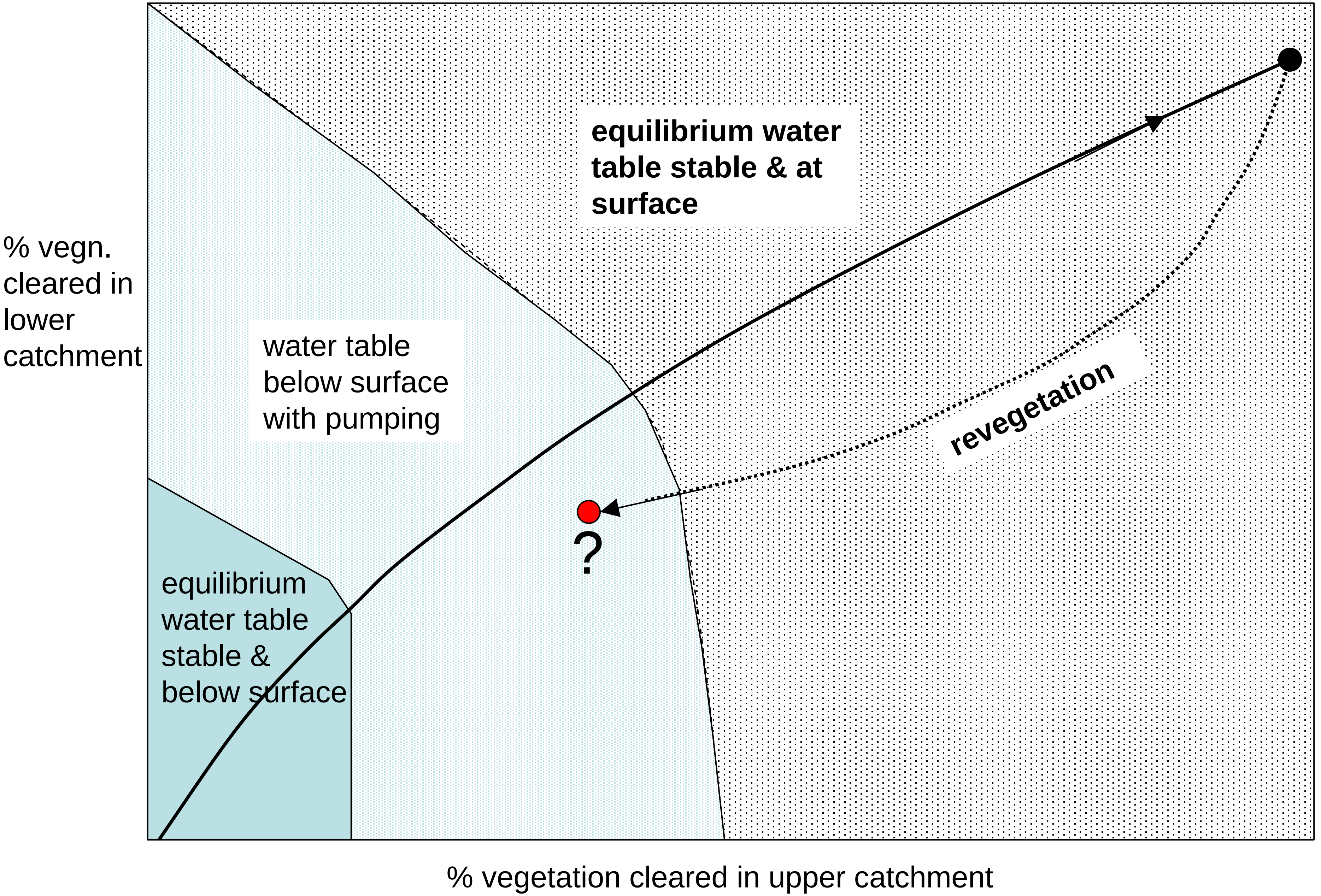
Goulburn-Broken Catchment - Victoria



Slow variable - water table depth

Critical threshold - 2m


% vegn. cleared in lower catchment
Simulated clearing history
Stable equilibrium water table at surface
Stable equilibrium water table below surface (below 2m)
% vegetation cleared in upper catchment


% vegn. cleared in lower catchment
equilibrium water table stable & at surface
water table below surface with pumping
revegetation
?
equilibrium water table stable & below surface
% vegetation cleared in upper catchment

Sustainable development amounts to:

-identifying critical thresholds that lead to unacceptable trajectories

-developing the adaptive capacity to avoid crossing these thresholds

-allowing the system to self-organise within the range of acceptable trajectories

(It does NOT consist of trying to pick *the* "optimal" trajectory)

In developing intervention strategies:

- Thresholds and slow variables are the key
- The effectiveness of an intervention depends on where a system is in the adaptive cycle
- Beware of:
  - pursuing some perceived "optimal" state
  - increasing "efficiency" that removes (apparent) redundancy

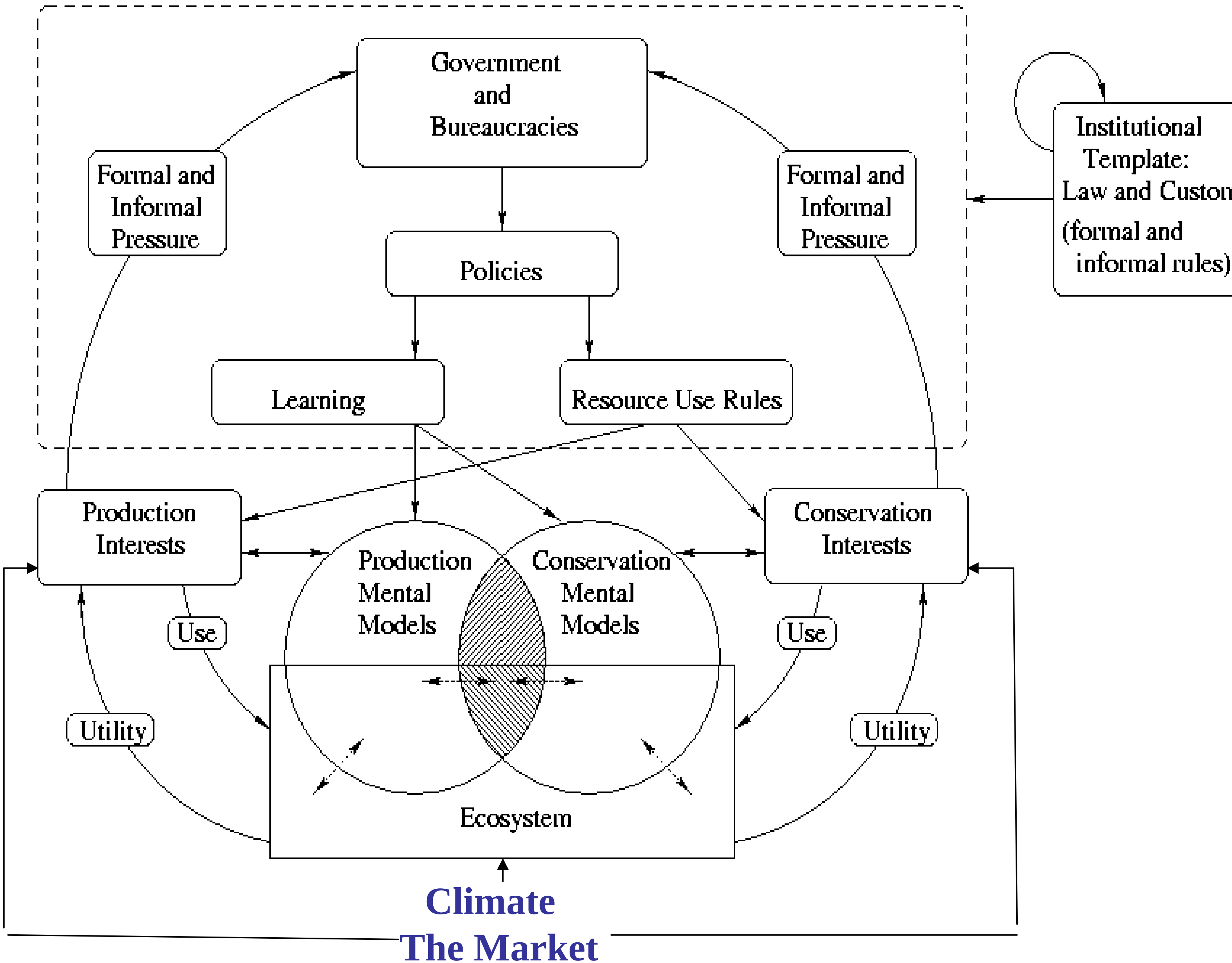
What would a sustainably developing SES look like?

It would:

- promote and sustain diversity - biological, landscape, economic (multiple use of resources), social
- restrict human control of ecological variability
- be modular (overly connected systems are susceptible to shocks)
- emphasize learning, social networks, and locally developed rules

And it would have:

- tight feedbacks
- a policy focus on “slow” variables associated with thresholds
- a mix of common and private property, and overlapping access rights
- strong penalties (including ‘public shaming’) for cheaters
- overlapping institutions (hierarchically)
- unpriced ecosystem services included in development proposals
- low resistance to change; innovation and experiments encouraged
- strong awareness and response to cross-scale influences



Government and Bureaucracies
Formal and Informal Pressure
Formal and Informal Pressure
Institutional Template: Law and Custom (formal and informal rules)
Policies
Learning
Resource Use Rules
Production Interests
Conservation Interests
Production Mental Models
Conservation Mental Models
Use
Use
Utility
Utility
Ecosystem
Climate
The Market

Finite and Infinite Games*

Feature	Finite Game	Infinite Game
Purpose	Winning	Continuing the play
Rules	Fixed	Evolving; rules change when players agree that play is imperiled
Boundaries	Play <u>within</u> boundaries	Play <u>with</u> boundaries
Transparency	Deception is a tool for winning	Openness and vulnerability are tools for continuing the game

*Carse, J.P. 1984. Finite and Infinite Games. Ballantyne.

Targeted resilience and adaptability

General resilience, adaptability and transformability

Define the social-ecological system

Local (individual) scale dynamics and resilience
-"production" systems for desired flows of G&S
- the social model (user choices)
- ecosystem model
- resilience: thresholds and regime shifts

User-group scale dynamics and resilience
- alternate regimes
- feasible regime shift trajectories

Identify system attributes that determine resilience and adaptability

Identify system attributes that determine resilience, adaptability and transformability

Potential points of intervention

Potential points of intervention

Implications for resilience management and governance: Share insights

Resilience management and governance consists of:

1. Maintaining or increasing the resilience of desirable regimes (or, conversely, decreasing it for undesirable regimes)

2. Keeping the system on desirable trajectories - within a desirable regime (or trying to get the system from an undesirable onto a desirable trajectory)

3. Enhancing transformability

The Goulburn-Broken Catchment in SE Australia

Desired flows of goods and services

Agricultural production				*Community*		*Amenity and nature conservation*		
Dairy & processing	Horticulture & processing	Grazing/ cropping	Forestry	Housing, utilities and infrastructure	Recreation	Areas of cultural significance	Nature Conservation	Future options

Capital stocks in Dairy Production

Natural capital :
fodder
cows
water (quality and quantity)

Manufactured capital :
farm equipment and machinery
milking infrastructure
utility infrastructure
irrigation infrastructure

Human capital :
farm labour (including skills)
farm management (including farming expertise and skills)
business management skills

Resilience and alternate regimes of critical capital stocks

Dairy production

(1) Fodder

(1.1) Fodder production in relation to rising water tables and salinity.
Pasture growth reduced as water tables rise to within 2 m of the surface

Alternate regimes : salinised / non salinised
Non-salinised - <X% of the farm <2m ; viable dairy farm
Salinised - >X% <2m; Dairy farming not possible

slow variable - water table depth
fast variable - fodder production

(1.2) Fodder production in relation to climate and water

Desiccation threshold – time that soil moisture is below a certain percentage. Beyond this, the pasture dies.

Soil moisture = f(rainfall + irrigation)

In a drought, if irrigation storage drops below a level where the amount available to farmers leads to soil moisture dropping below the desiccation threshold, the pasture dies.

Alternate regimes: live pasture / dead (re-planting required before fodder is produced)

Slow variable - water storage for irrigation
Fast variable - soil moisture (and pasture growth)

Examples of attributes influencing adaptability in the G-B Catchment

Irrigation region

- Dairy industry; changes in the amount of salt that can be pumped out of the system.
- Agreement on water allocation and sharing; an increase in social capital will limit ‘cheating’.
- Increasing the ratio of horticulture : dairy (ie, reducing the area of irrigated pastures).
- Reduced reliance on feral honey bee populations will reduce bee disease threat and vulnerability to a sudden decline in pollination services

Dryland cropping/grazing region

- Proportion of “lifestyle farmers” (Provide grazing agistment for cattle in droughts). Above some minimum proportion the region can maintain economic viability without degrading grazing lands

Possible thresholds (✓) along “slow” variables (capital stocks) in three production systems in the Goulburn-Broken Catchment)

Capital stocks

Production systems

	Natural Capital						Manufactured Capital				Human Capital		
	Fodder		Livestock (cows & sheep)	Water	Soil	Native Vegn.	Equiment Machinery	Infrastructure			Labour	Skills	
	soil, water table & salinity	water storage	disease	water quality	acidity	area & condn.		t’sport	irrigation	utility		mgmt.	business
Dairy	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓
Dryland Crops	✓		✓	✓	✓		✓	✓		✓	✓	✓	✓
Nature Conservn.						✓	✓				✓	✓	

General Resilience

Natural system

Structure

- Modularity
- Tightness of feedbacks (between components of the natural system)
- Spatial heterogeneity - (including land-use pattern diversity)
- Diversity
  - functional (complementarity)
  - response diversity (apparent redundancy)
- Openness - immigration, inflows, outflows

Function

- Reserves and reservoirs (seedbanks, nutrient pools, etc.)
- other

Social system

Structure

- Diversity - Governance - overlapping hierarchy structure (apparent redundancy)
  - occupations and expertise
  - markets and supplies
  - mental models
  - values
  - ?
- Property and access rights
- Network structures for information, regulations, power, etc,, and the tightness of feedbacks between them. (Are feedbacks loosening or strengthening?)
- Openness
- Panarchy effects - influence and feedbacks from higher and lower scales (including effects of hypercoherence - all sub-systems in the same, or different, phases of the adaptive cycle)
- Reserves and reservoirs - (financial, memory, ?)

Function

- Leadership
- Social capital / trust
- Learning
- Subsidization - of industries, sectors, ?
- Flexibility and preparedness to change (how to measure?)

Total system

- Absolute and relative amounts of the 5 “capitals”: natural, manufactured, financial, human, and social.
- Tightness of feedbacks between the social and natural systems

Finite and Infinite Games*

Feature	Finite Game	Infinite Game
Leadership	A powerful person brings the past to an outcome, settling all its unresolved issues	Strong people carry the past into the future, showing that none of its issues is capable of resolution
Crisis leads to . . .	Contradiction: players desire to bring play to an end.	Paradox: players desire to continue the play in others.
Surprise ...	ends the game. Finite players aim to anticipate every possibility, to control the future to prevent it from altering the past.	is the reason for play to continue. Because the future is always surprising, the past is always changing.

*Carse, J.P. 1984. Finite and Infinite Games. Ballantyne.

Reference

- J.M. Anderies, 2004. Minimal models and agro-ecological policy at the regional scale: an application to salinity problems in south east Australia. Regional Environmental Change. In Press.