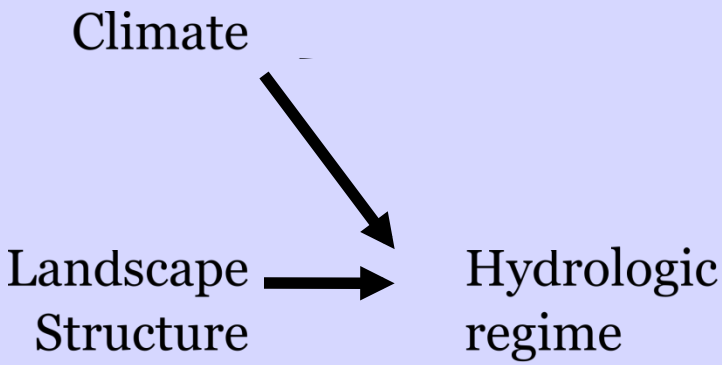
Water, Earth and Biota in the Anthropocene

A Research Agenda for Systems in Transition

Murugesu Sivapalan
University of Illinois at Urbana-Champaign

Predictions under Change

View so far:



Climate and the landscape combine to determine the hydrologic regime

Ciaran Harman

Coupling processes across scales

Fast dynamics: e.g. soil moisture

$$\frac{d}{dt}\Theta = f(\Theta, Vegetation, Soils, \ldots)$$

Slow dynamics: e.g. vegetation

$$\frac{d}{dt} Vegetation = f(\Theta, Vegetation, Soils, \ldots)$$

Very slow dynamics: e.g. soil properties

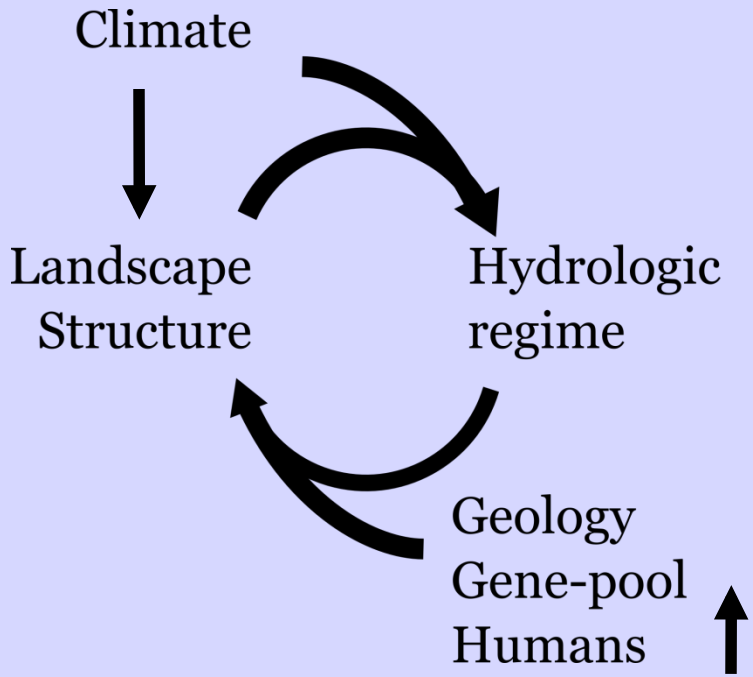
$$\frac{d}{dt} Soils = f(\Theta, Vegetation, Soils, \ldots)$$

Ciaran Harman

Predictions Under Change

Predictions under Change

Richer view:



Landscape structures have a history

Structures that control hydrology have co-evolved within the context of the landscape

Ciaran Harman

Newtonian and Darwinian approaches: need a synthesis

"Newtonian"	"Darwinian"
Study the individual mechanisms	Study the behavior that emerge from interactions
Search for universal laws	Search for weak trends across populations
Goal is prediction	Goal is insight/explanation
Initial and boundary conditions determine solution	System arises from historical contingent factors
Focus on ideal systems	Focus on real systems

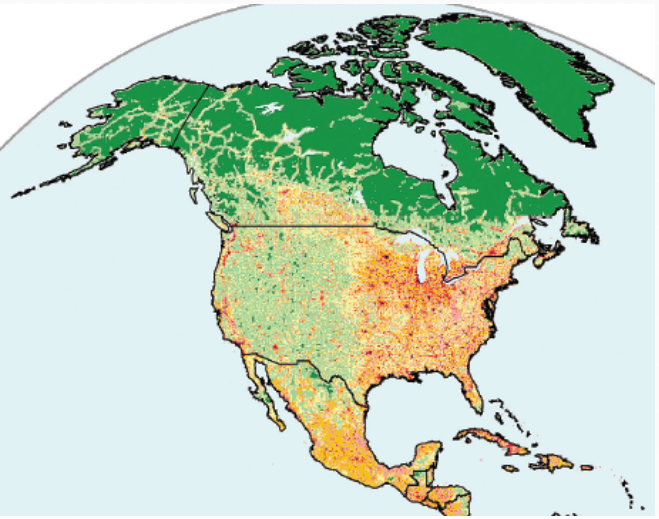
John Harte

Predictions Under Change

The Economist

Welcome to the Anthropocene

Humans have changed the way the world works. Now they have to change the way they think about it, too



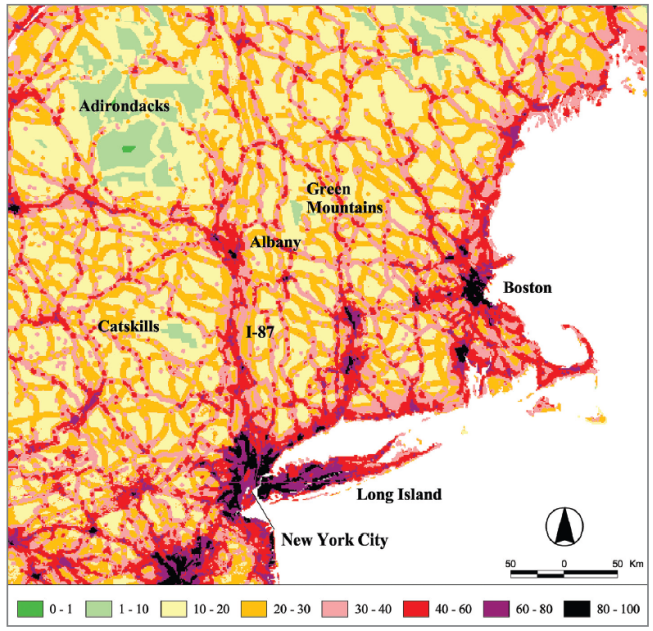
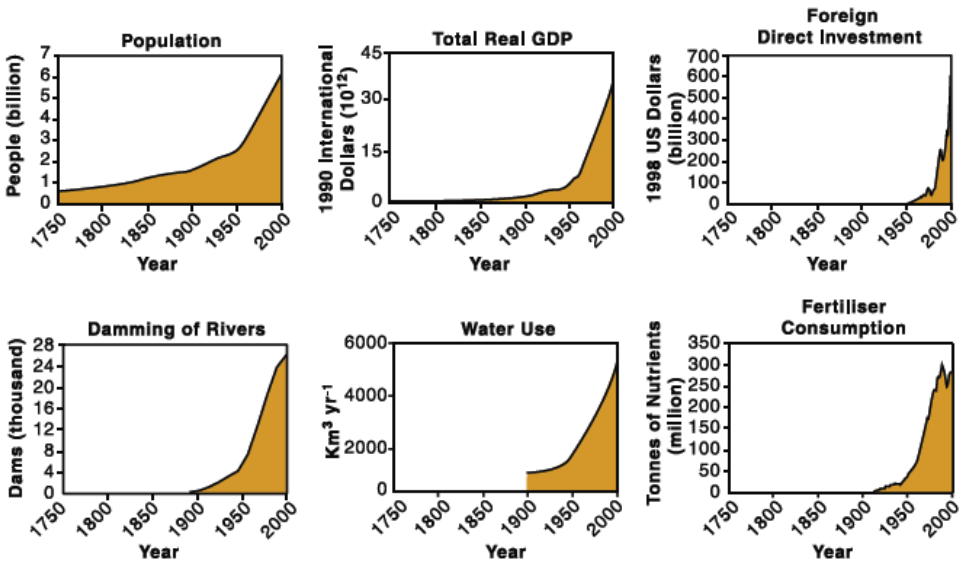
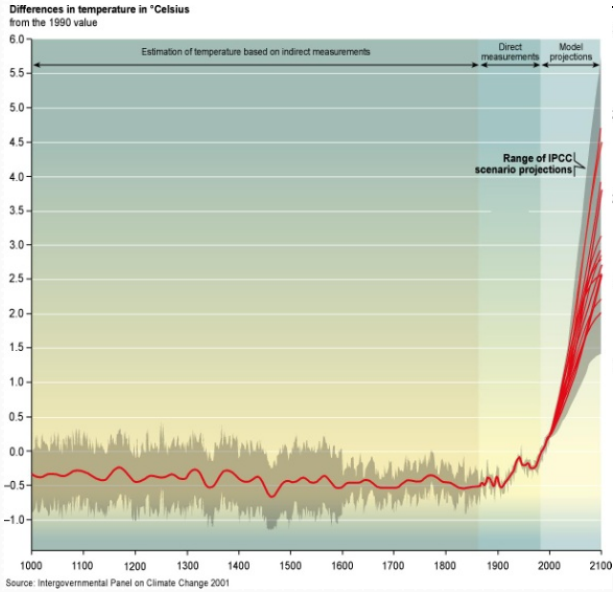
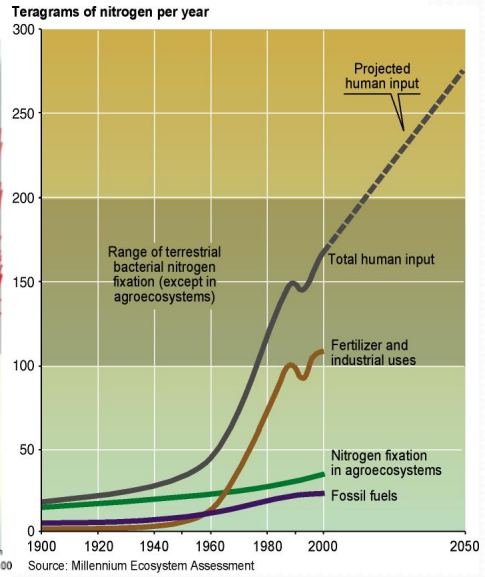


Figure 4. The "human footprint" in the northeastern United States.

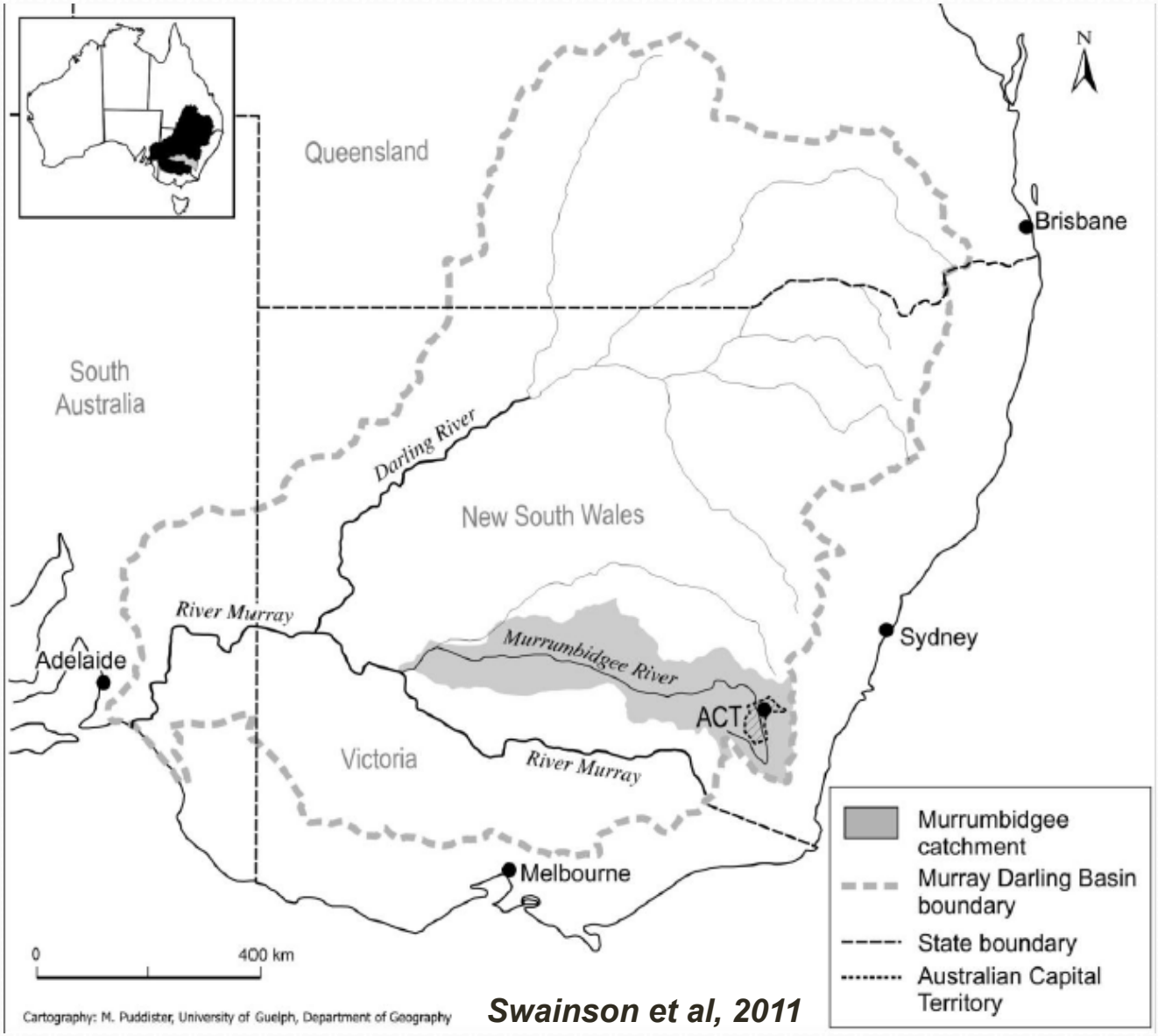






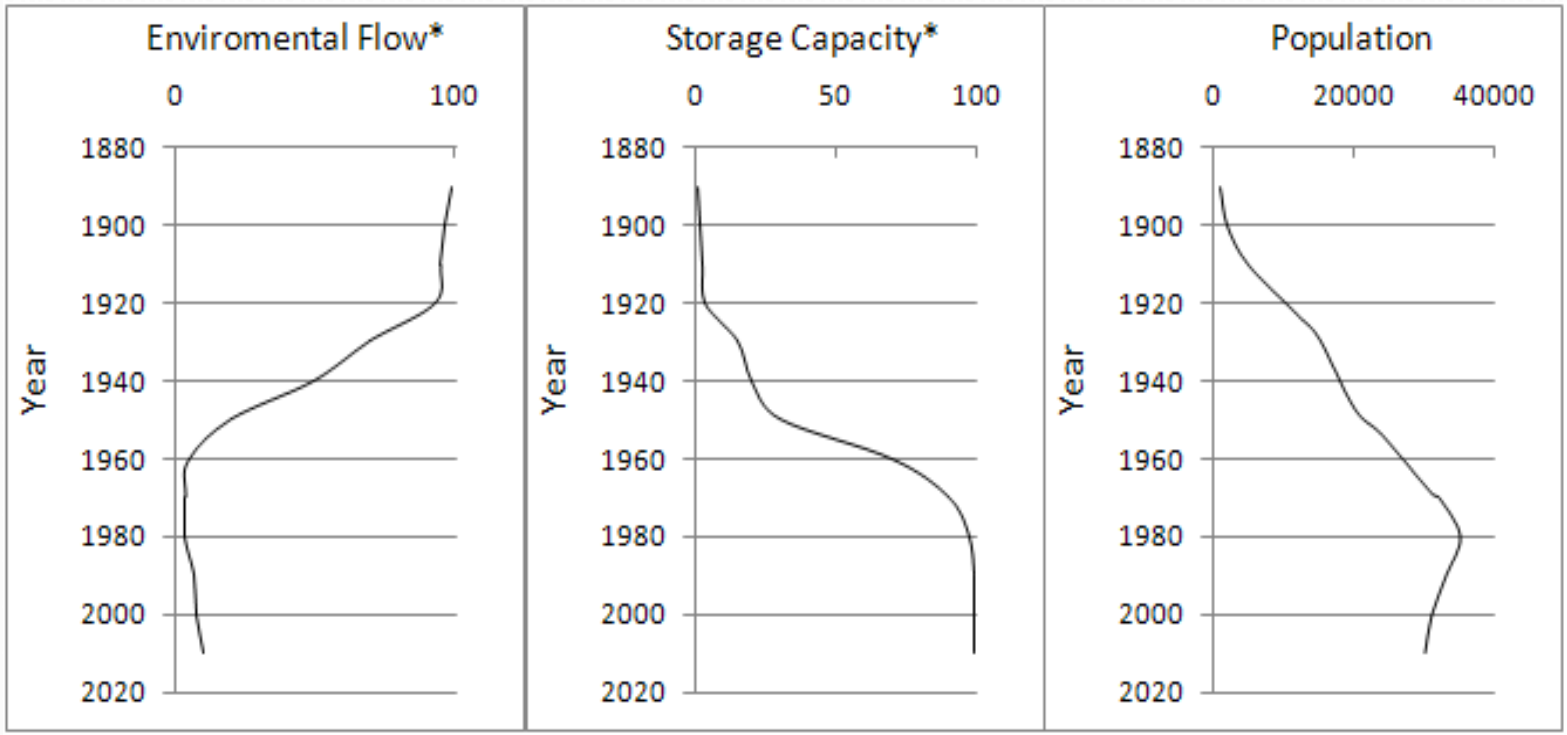
Predictions Under Change

Murrumbidgee within the Murray – Darling Basin



- 7.5% of the Murray Darling Basin, draining an area of 84,000Km^2.
- Murrumbidgee catchment is home to about 545,000 people.
- River supplies water to Riverina agricultural region, considered as South East Australia's 'food-bowl'.
  - Agricultural production in the catchment is worth over AUD $1.9 billion per annum.

CONCEPTUAL REPRESENTATION OF ENVIRONMENTAL FLOWS AND RELATED INDICATORS



- * Environment flow as % of river flow
- ** man made Storage Capacity (as a %) comprising dams and weirs
- Population in Murrumbidgee Irrigation Area

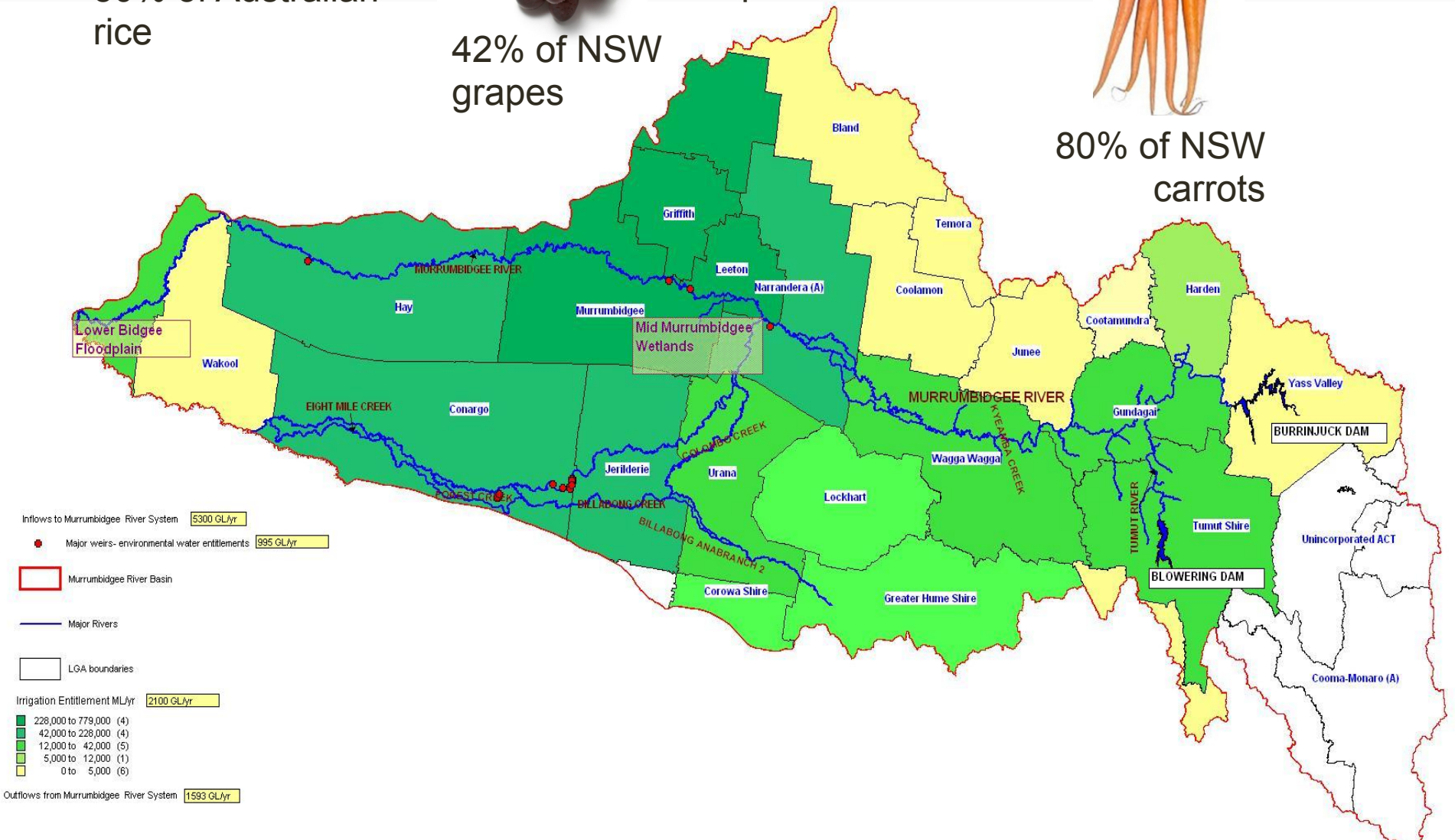
Predictions Under Change

50% of Australian rice

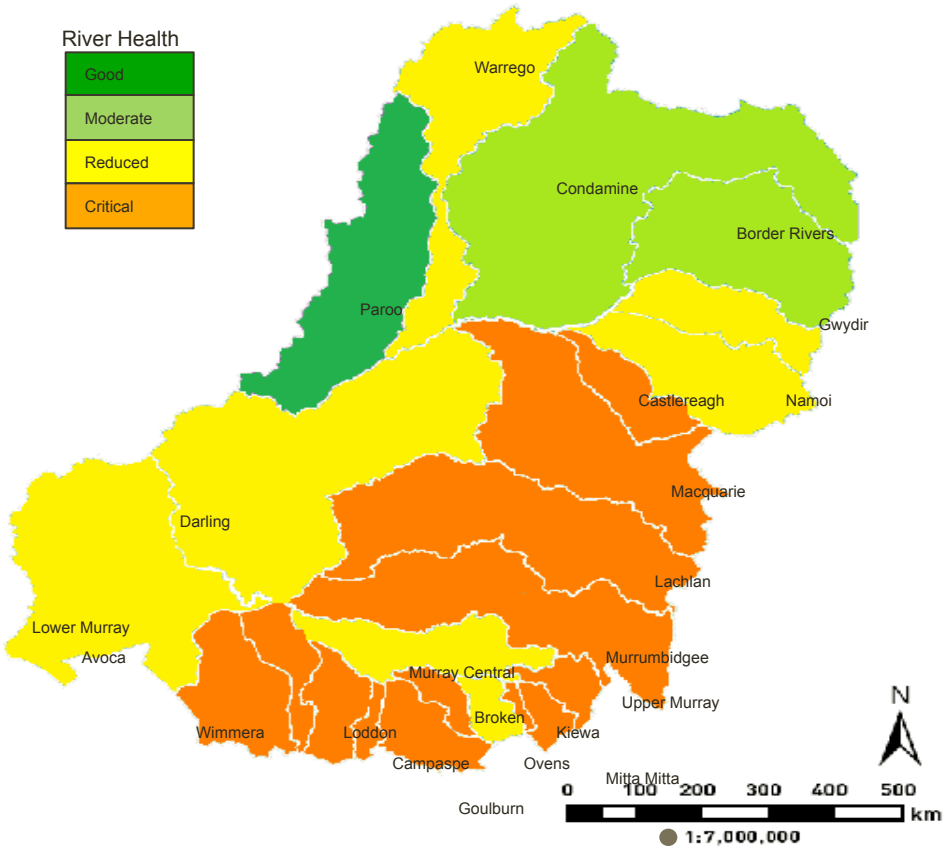
42% of NSW grapes

90% of NSW potatoes

80% of NSW carrots



River Health



A crystal ball

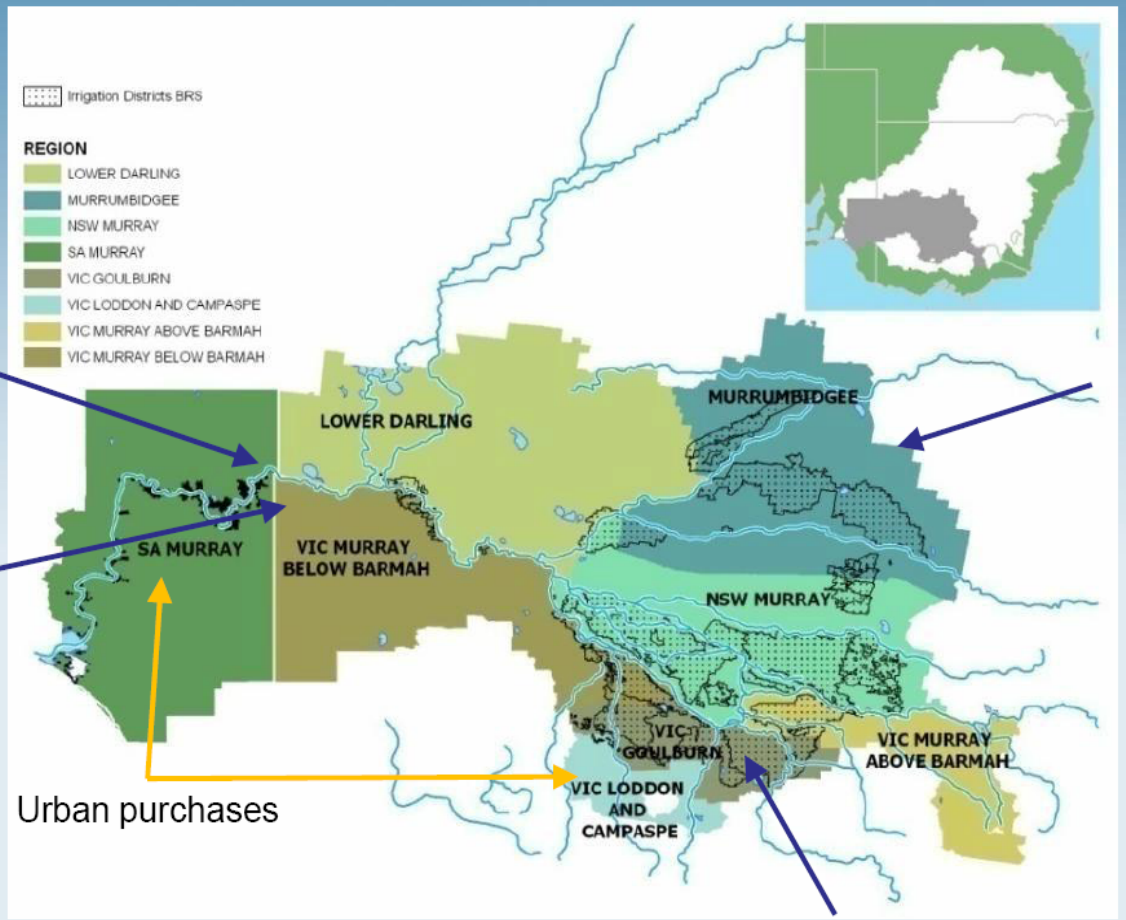
- Increased productivity is a given with more produced per drop ($ farm output /ML).
- New assets in the valley with primary purpose of efficiently supplying to environmental customer
- Water trading becoming more efficient and sensitive to climate trends, better than stock traders in Wall Street
- Less number of farmers, only most water efficient surviving with the rest selling out their water rights
- Some communities/townships disappearing from the map.

Predictions Under Change

Water Trading

Horticulturalists purchased allocations in low allocation seasons

New private horticultural developments purchased entitlements, but public districts sold entitlement



Urban purchases

Rice growers sold annual allocations

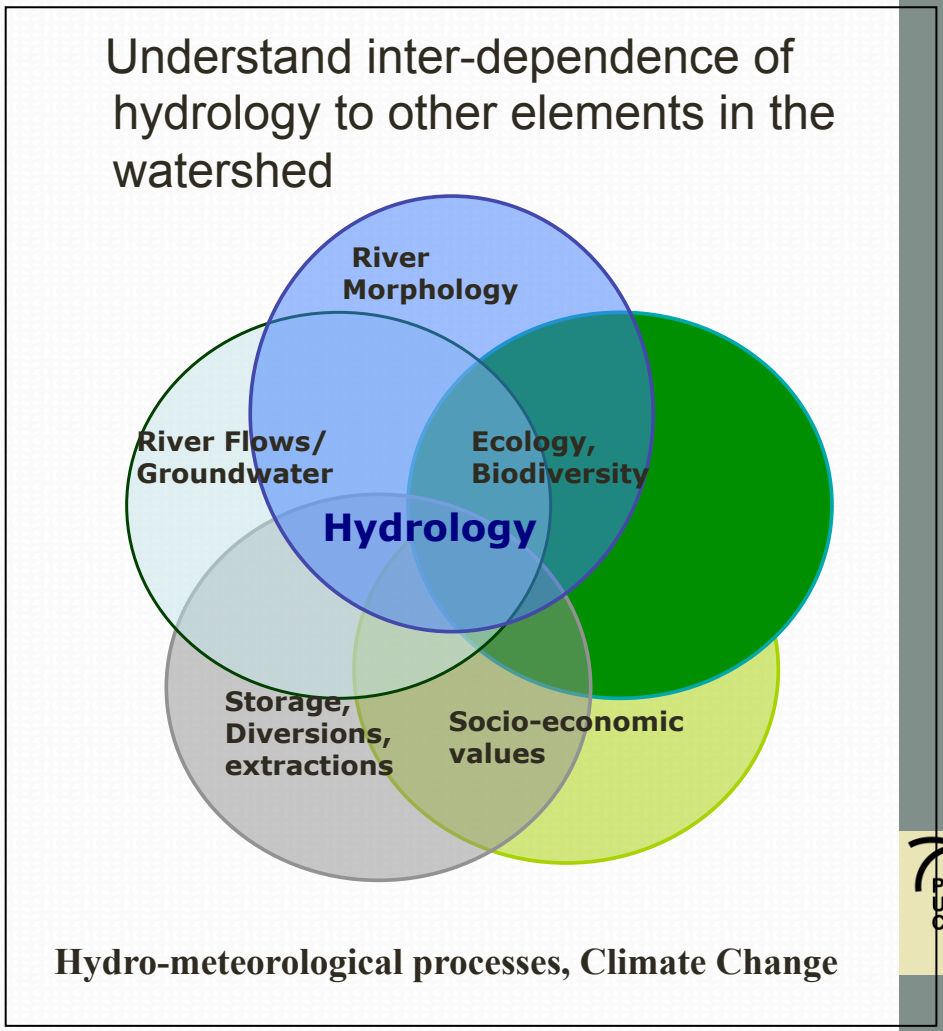
Dairy and mixed farming bought and sold water, with. net entitlement sales to downstream users

Source: National Water Commission

Predictions Under Change

Socio-Hydrology Research Alliance to Investigate Future Assets Strategy for Murrumbidgee Basin

- Increase the understanding of where the water may move to in the catchment – identify location for new and redundant assets
- Understand the cost of delivery of water within the Basin
- Improved understanding of the value of water within the local communities
- Investigate the development of new assets to deliver water to the environmental customers
    - water efficiency measures
    - New water storages



Predictions Under Change

PRAVEEN KUMAR

Predictions under Change

Natural systems don't exist, they evolve

HUMANS AS DRIVERS OF GLOBAL WATER CYCLE CHANGE

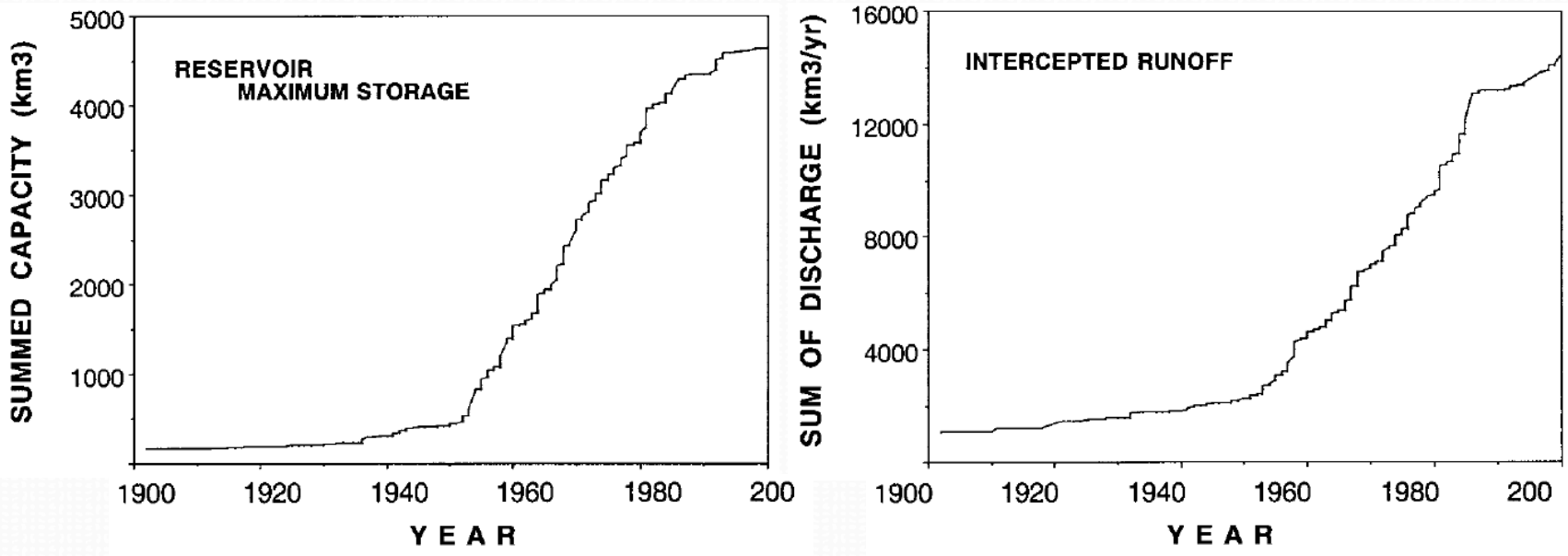
END OF STATIONARITY
END OF LINEARITY
START OF COMPLEXITY

HYDROLOGY OF AN EVOLVING LANDSCAPE

Focus on understanding, predictability, sustainability

What must we do to face the new prediction challenges?

- Non-stationarity: Embrace the time arrow



Vörösmarty and Sahagian 2000 BioScience

Predictions Under Change

What must we do to face the new prediction challenges?

- Non-stationarity: Embrace the time arrow
- Inter-connectedness: Hydrology is not just about water!

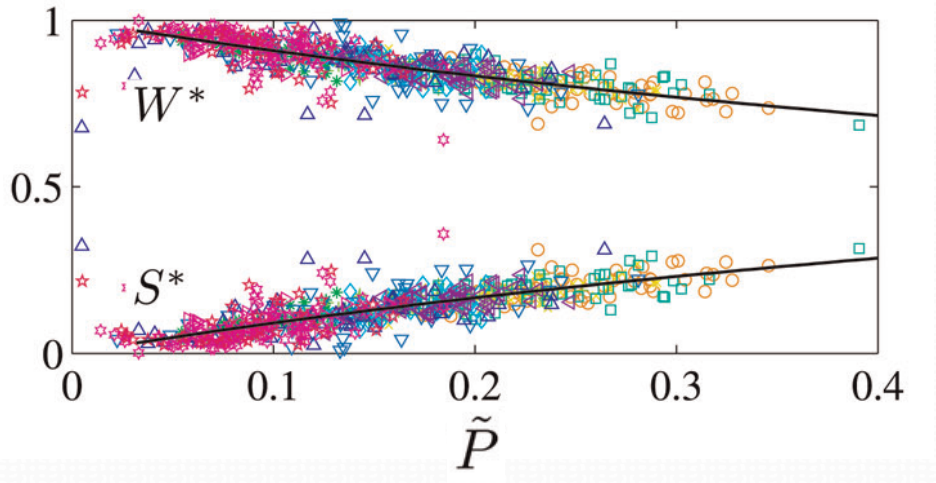
Dying black box, Gol Gol Swamp Photo: Paul Lloyd

Many serious problems with a hydrologic component are also ecologic, geomorphic, economic, (etc, etc...), problems

Predictions Under Change

What must we do to face the new prediction challenges?

- Non-stationarity: Embrace the time arrow
- Inter-connectedness: Hydrology is not just about water!
- Newtonian-Darwinian synthesis: Connect the individual to the population



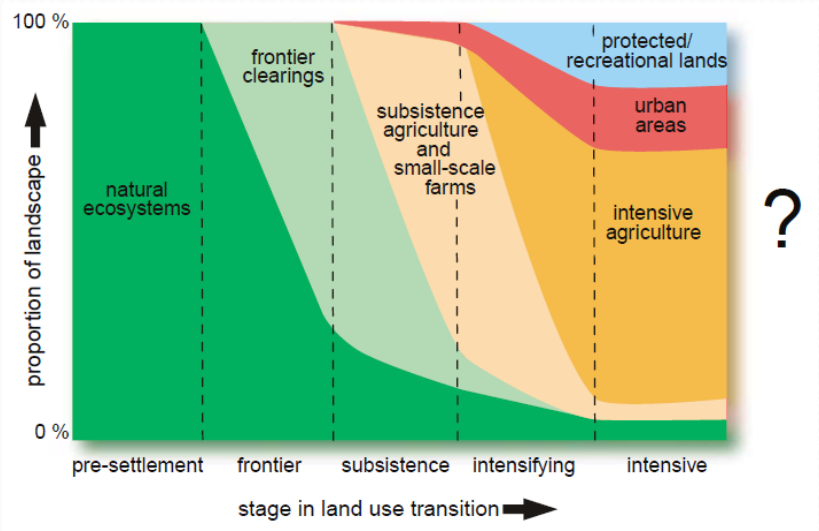
Sivapalan et al 2011 WRR

Relate behavior of particular systems to other systems with similar history or conditions

Predictions Under Change

What must we do to face the new prediction challenges?

- Non-stationarity: Embrace the time arrow
- Inter-connectedness: Hydrology is not just about water!
- Newtonian-Darwinian synthesis: Connect the individual to the population
- Socio-hydrology: a new science of people and water

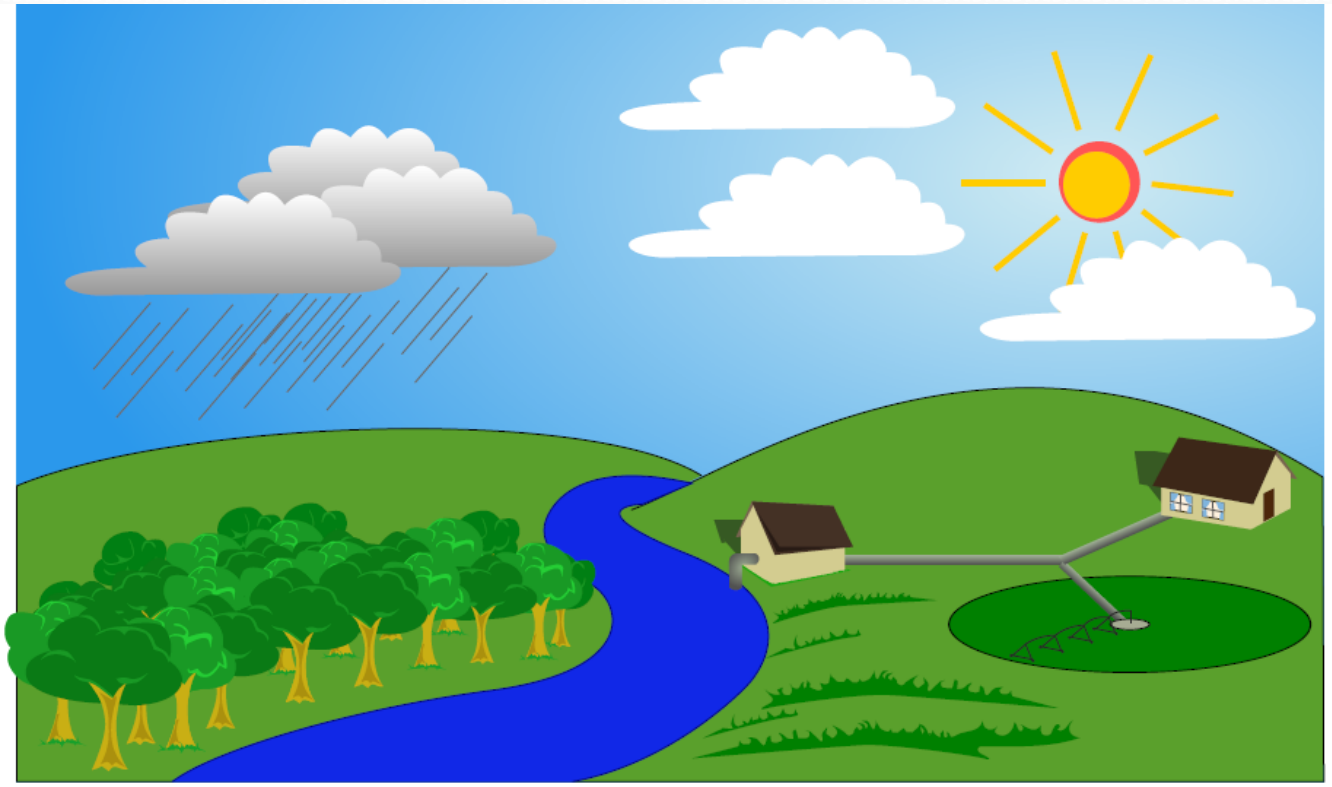


Human activities are part of the landscape, and human choices are conditioned on environmental change

Foley et al 2005 Science

Predictions Under Change

- Growth of understanding
- about the hydrology of landscapes

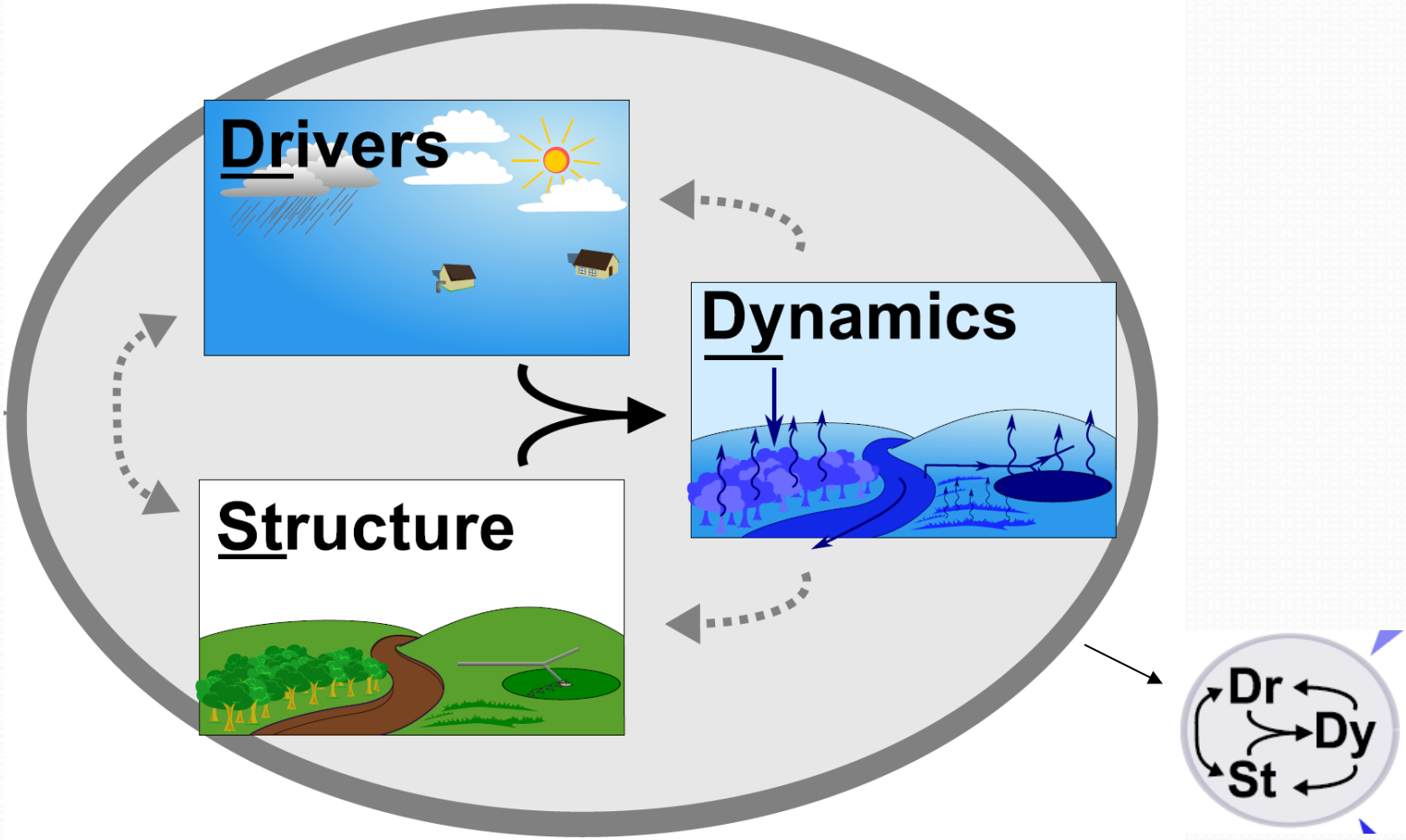


It is a conceptual model of the *science,* NOT of the *system*

Ciaran Harman

Predictions Under Change

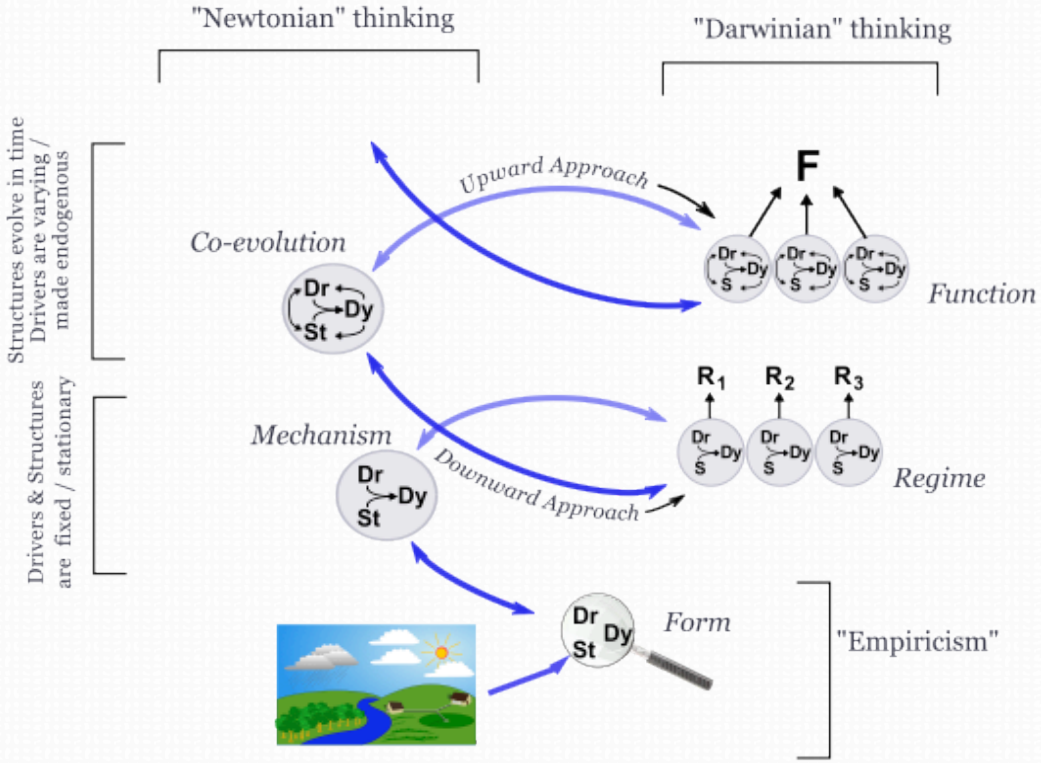
Drivers + Structure + Dynamics

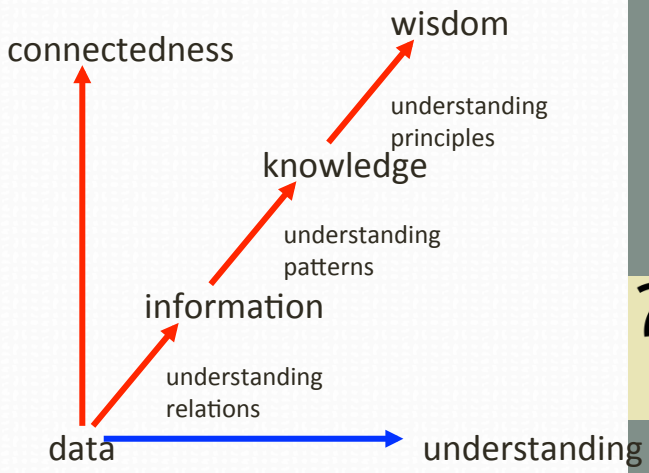


Predictions Under Change

Ciaran Harman

Five types of science questions:
PI Science along Hydrocomplexity Spiral





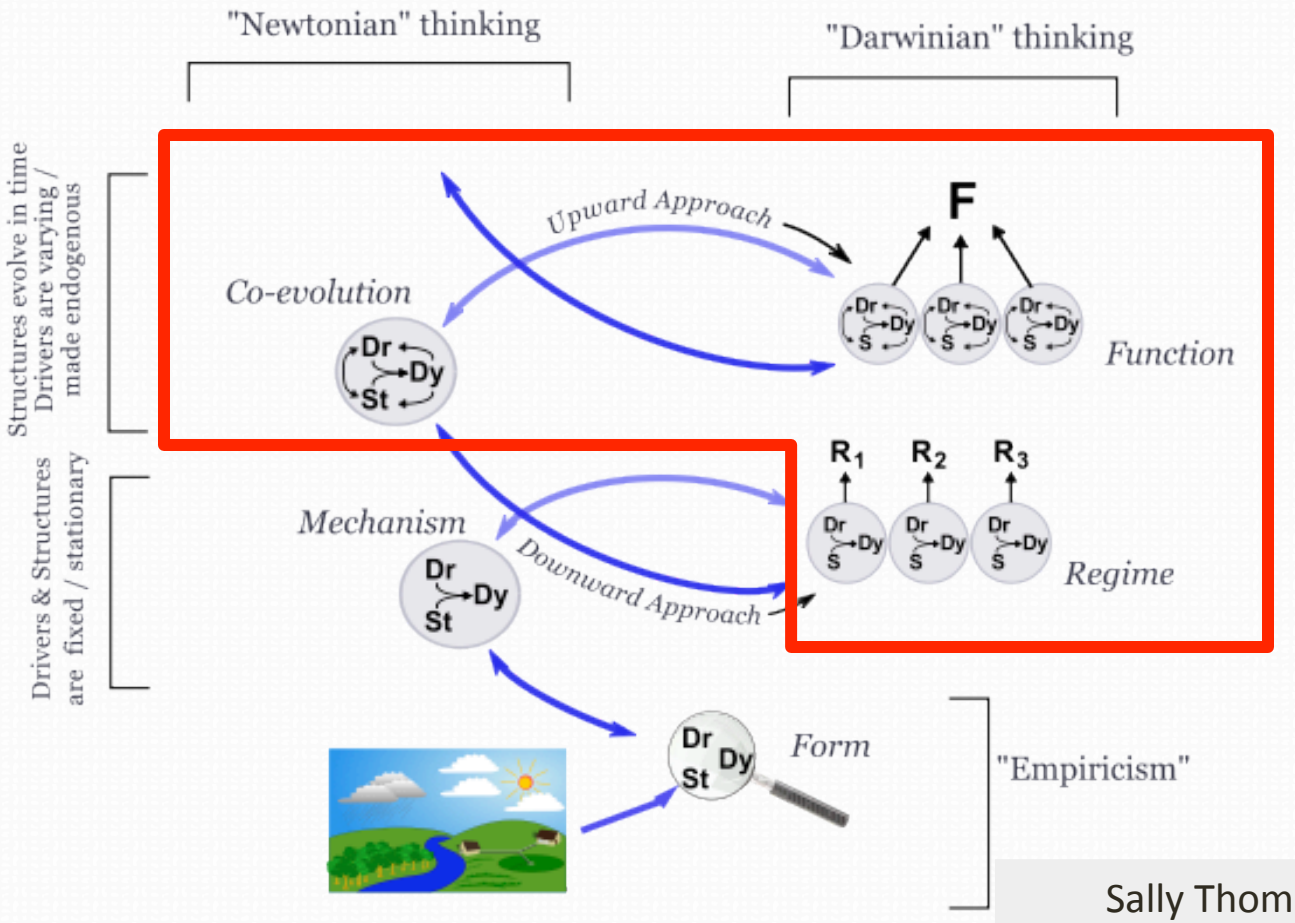
from systems-thinking.org, Gene Bellinger

Predictions Under Change

Ciaran Harman

Water Cycle Projections over Decades to Centuries at River Basin to Regional Scales

Need for "Big/Team Science"

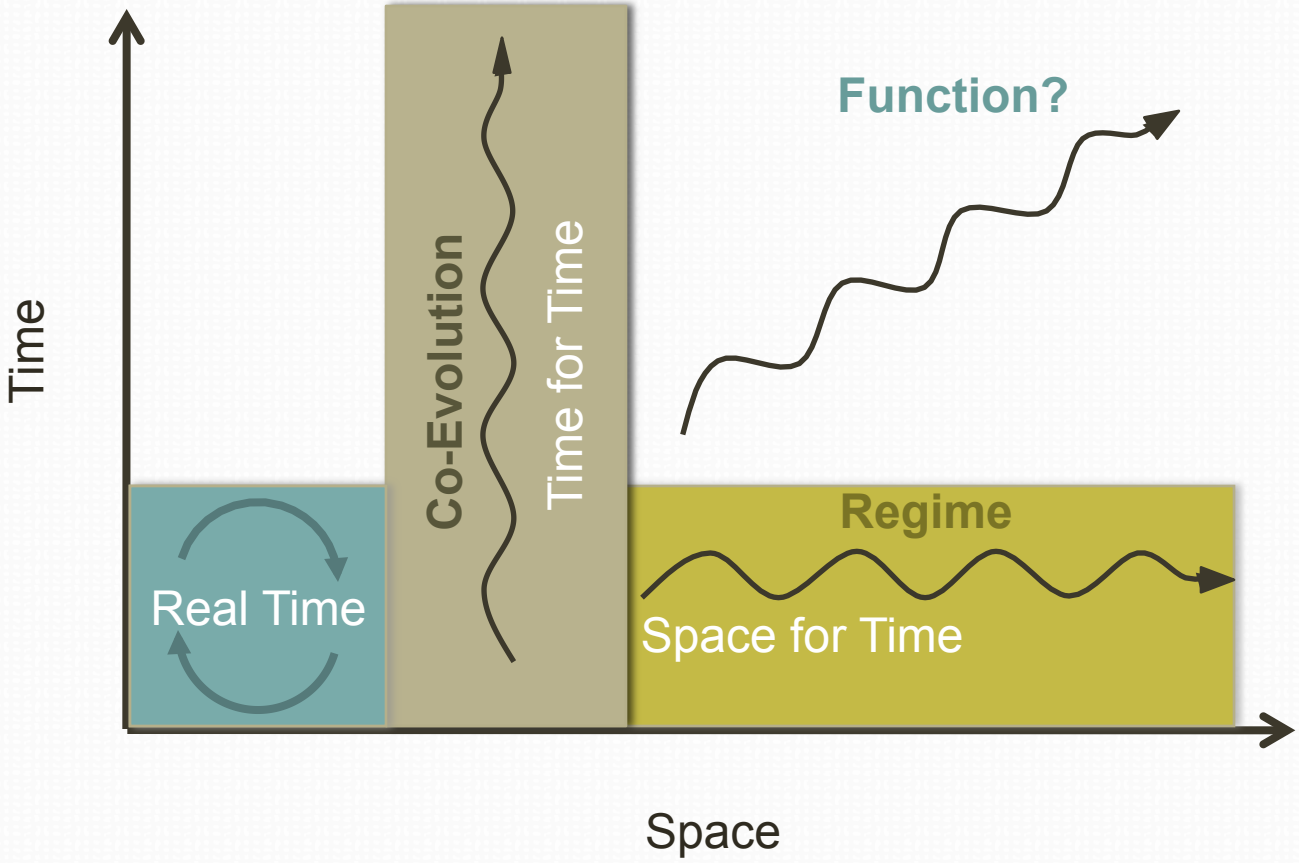


Sally Thompson,
Ciaran Harman

Predictions Under Change

Water Cycle Projections over Decades to Centuries at River Basin to Regional Scales

Investment in "Big/Team Science"



Sally Thompson

Predictions Under Change

Water Cycle Projections over Decades to Centuries at River Basin to Regional Scales

Summary

- **PI Science along the Hydro-complexity Spiral**
  - (co-evolution modeling, socio-hydrology, discovery of organizing principles, predictability/ uncertainty)

- **Big/Team Science**
  - **Space for time**: comparative hydrology, analysis across a climatic or human impact gradient
  - **Time for time**: historical reconstruction
  - **Real-Time learning**: interactive modeling and observation in real places where real people live

Predictions Under Change