Science and Technology Needs for a Sustainability Transition

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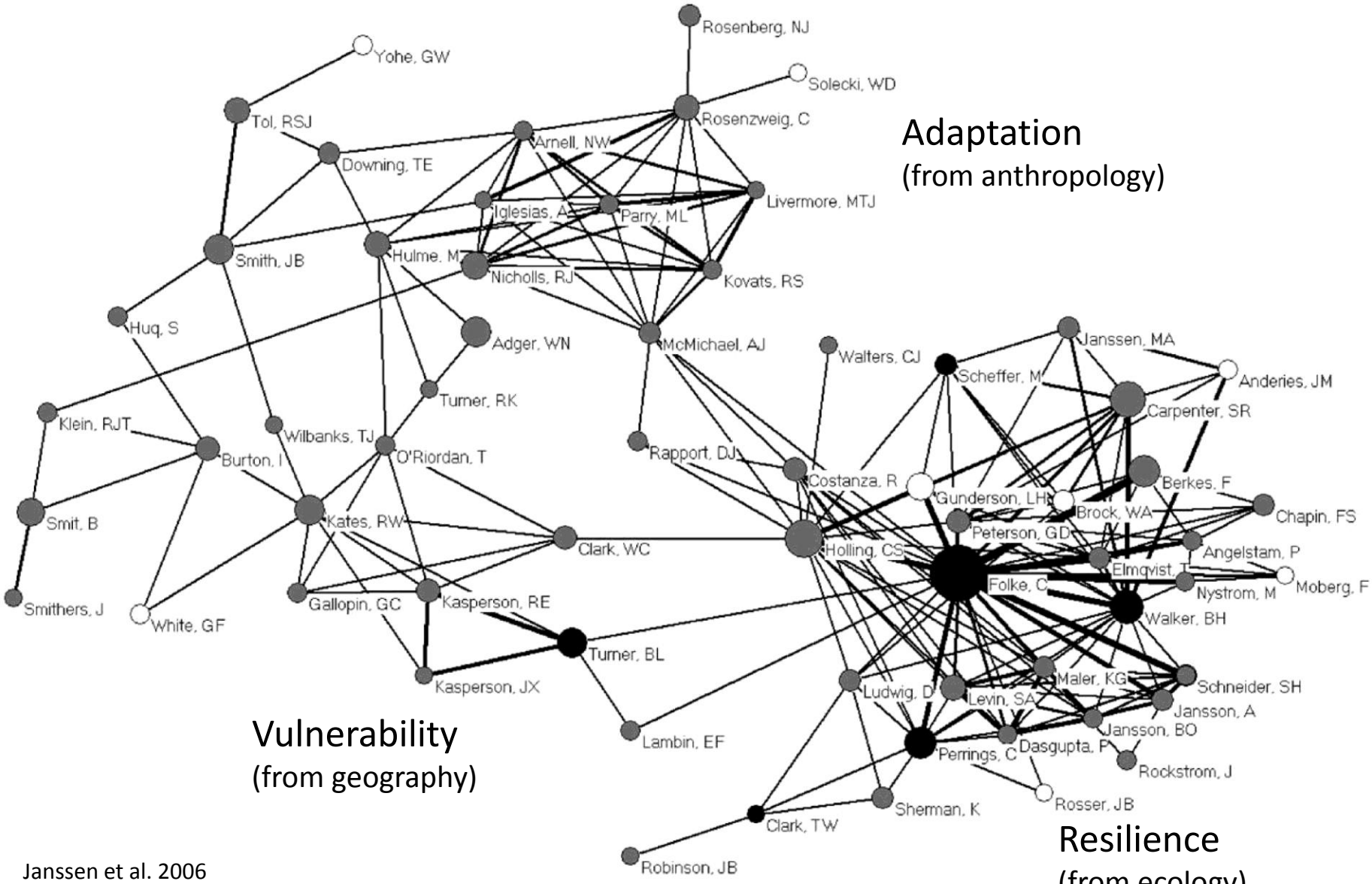
Some milestones in sustainability science

- Roots in ancient philosophies and religions
- 1987: Brundtland Report: Our Common Future
- 1992: Rio Earth Summit
- 2000: Coalescence as a cohesive co-authorship network of sustainability scientists
- 2003 Sustainability Science Section of PNAS
- 2010 NSF-supported report on research priorities in sustainability science

Bettencourt and Kaur 2011, Kates 2011

Co-authorship Network: The roots of sustainability



Janssen et al. 2006

The nature of sustainability science

- Highly interdisciplinary and collaborative
  - Integrates social science, ecology, engineering, and other disciplines
- Connects theory with practice
  - Focused primarily on solutions
- Well represented in developing nations and political capitals
- Explosion of interest (doubling time of 8 years)
  - 20,000 papers, 37,000 authors, 174 countries (2010)

Kates et al. 2001, Bettencourt and Kaur 2011

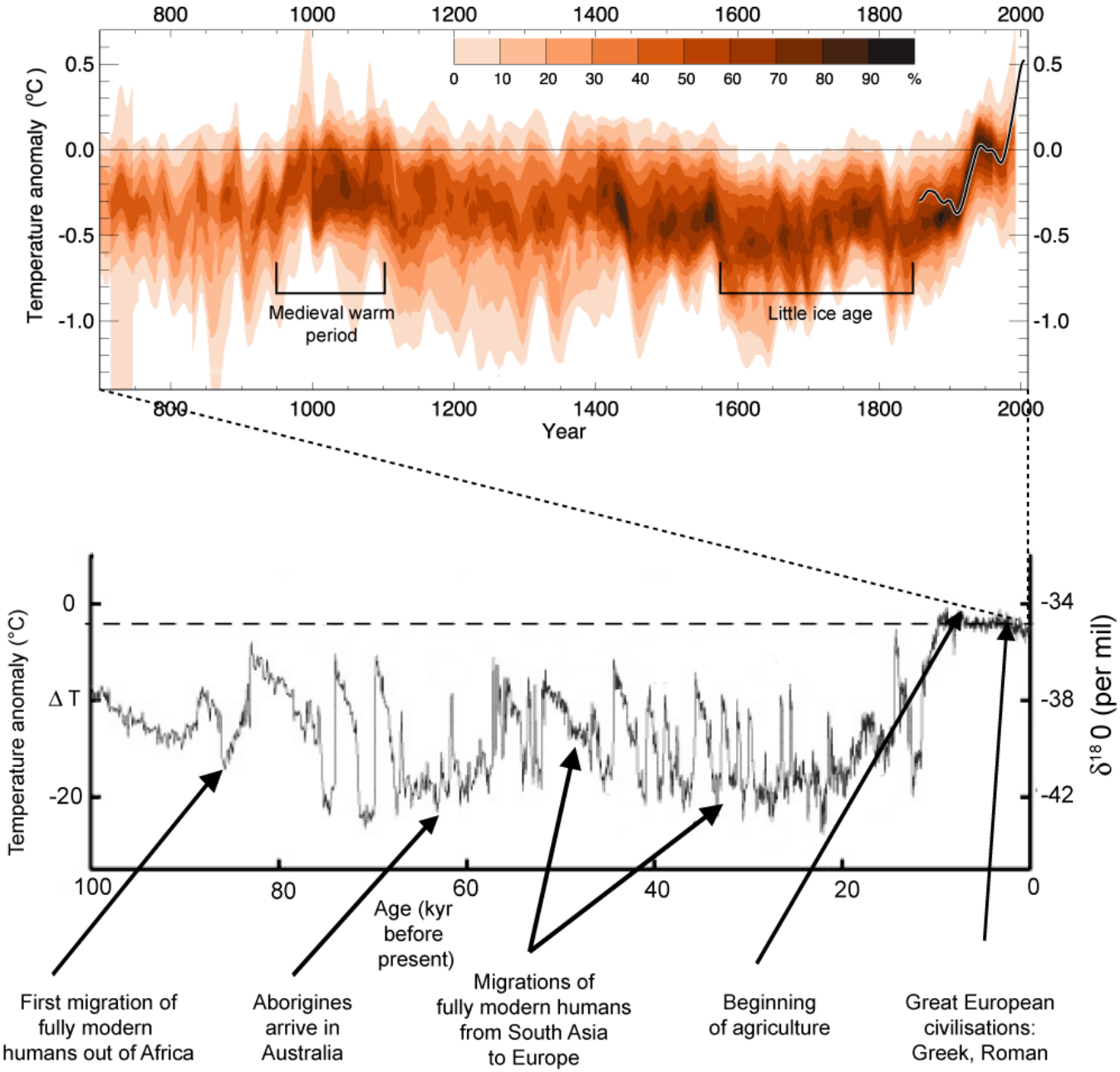
Examples of research networks for sustainability science

- International
  - Millennium Ecosystem Assessment
  - ICSU Grand Challenges for Sustainability
  - Future Earth: Platform for global sustainability
- National
  - Natural Capital Project (Universities and NGOs)
  - National Climate Assessment (Federal)
- Local
  - ICLEI (local governments for sustainability)

Sustainability

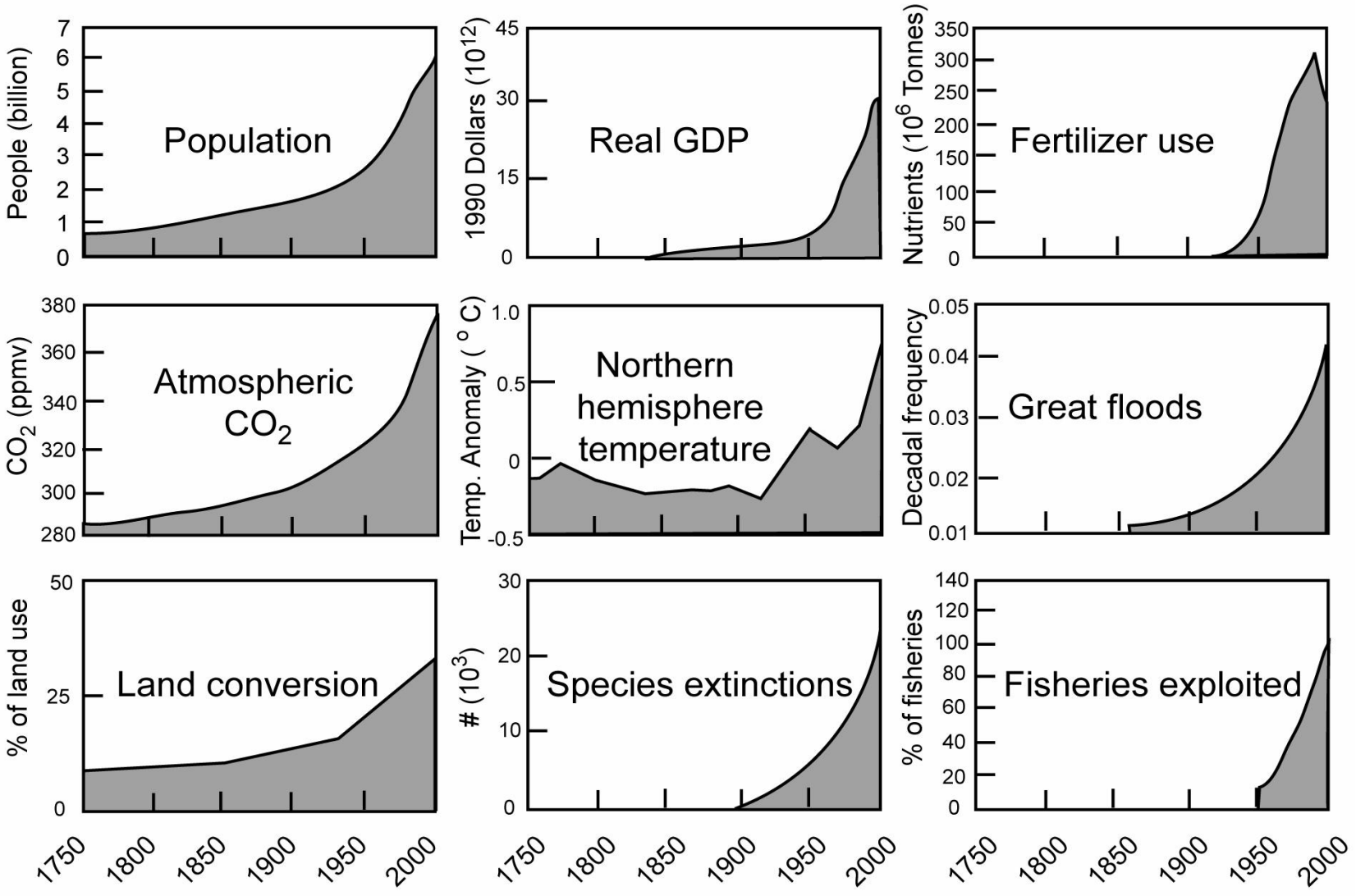
- Use of the environment and resources to meet the needs of the present without compromising the ability of future generations to meet their needs

WCED 1987 (Brundtland Report)



Young and Steffen 2009

Earth is experiencing directional changes in many drivers of social-ecological processes



Steffen et al. 2004

Major challenges

- We are not on a sustainable trajectory.
- How do we foster a transition to sustainability?

Key sustainability issues

- Managing synergies and tradeoffs between human well-being and the environment
- Maximizing resilience and reducing vulnerability of coupled human-environment systems
- Monitoring progress toward sustainability
- Managing human-environment systems for sustainability

Clark and Levin 2010

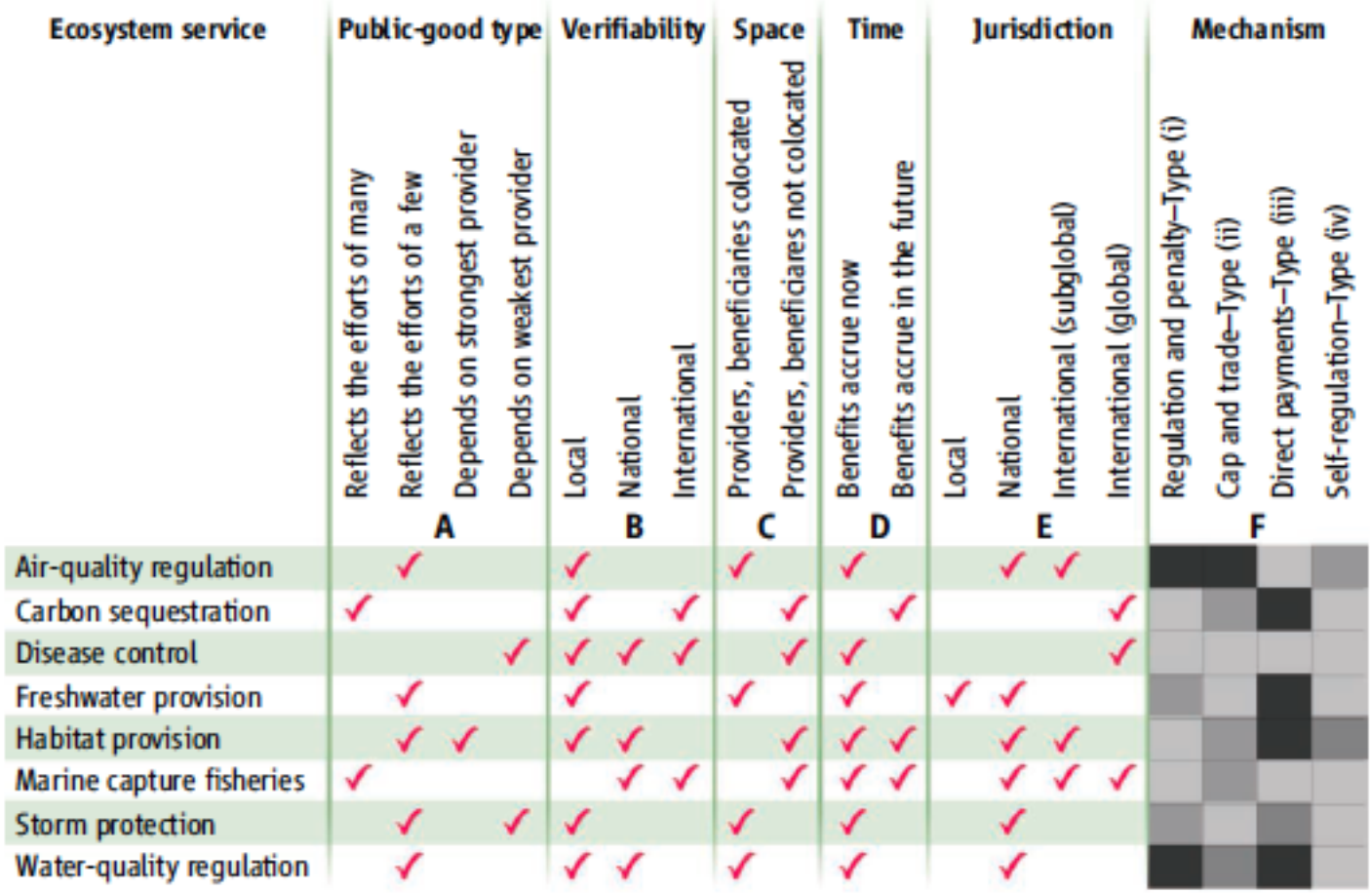
Managing synergies and tradeoffs

- Goals:
  - Maintain or enhance sum of natural, human, social, and built capital
  - Sustain ecosystem services over the long term
- Research opportunities
  - Analysis of decision-making for sustainable development
  - Inducing and harnessing technology
  - Understanding consumption patterns (what motivates it?)
  - Analysis of social phenomena that underlie sustainable development

Clark and Levin 2010

Harnessing science and technology (e.g., agriculture)

- Engagement of credit unions to motivate wise fertilizer use
- Fine-scale GIS and lasers to match nutrient addition to crop demand at the field scale
- Wood chips and riparian buffers to immobilize nutrients draining from fields
- Web tools and social networks for knowledge sharing



Ecosystem service	Public-good type				Verifiability			Space		Time		Jurisdiction				Mechanism			
	Reflects the efforts of many	Reflects the efforts of a few	Depends on strongest provider	Depends on weakest provider	Local	National	International	Providers, beneficiaries colocated	Providers, beneficiaries not colocated	Benefits accrue now	Benefits accrue in the future	Local	National	International (subglobal)	International (global)	Regulation and penalty—Type (i)	Cap and trade—Type (ii)	Direct payments—Type (iii)	Self-regulation—Type (iv)
	A				B			C		D		E				F			
Air-quality regulation		✓			✓			✓		✓			✓	✓					
Carbon sequestration	✓				✓		✓		✓		✓				✓				
Disease control				✓	✓	✓	✓		✓	✓					✓				
Freshwater provision		✓			✓			✓		✓		✓	✓						
Habitat provision		✓	✓		✓	✓			✓	✓	✓		✓	✓					
Marine capture fisheries	✓					✓	✓		✓	✓	✓		✓	✓	✓				
Storm protection		✓		✓	✓			✓		✓			✓						
Water-quality regulation		✓			✓	✓		✓		✓			✓						

Characteristics of ecosystem services and payment mechanisms. The table schematizes authors' impressions of the effectiveness of incentive mechanisms (column F) in providing environmental public goods. Column A classifies a sample of ES as public goods (*35*). Column B indicates the scale(s) at which delivery of a service can be verified (*20*). Column C denotes the geographic location of providers relative to beneficiaries (*27*). Column D and E indicate timing (*20*) and the governance level(s) needed to achieve effective outcomes (*36*). Darker shading in column F indicates mechanisms considered more effective for achieving the socially optimal level of provision, although effectiveness is context-dependent.

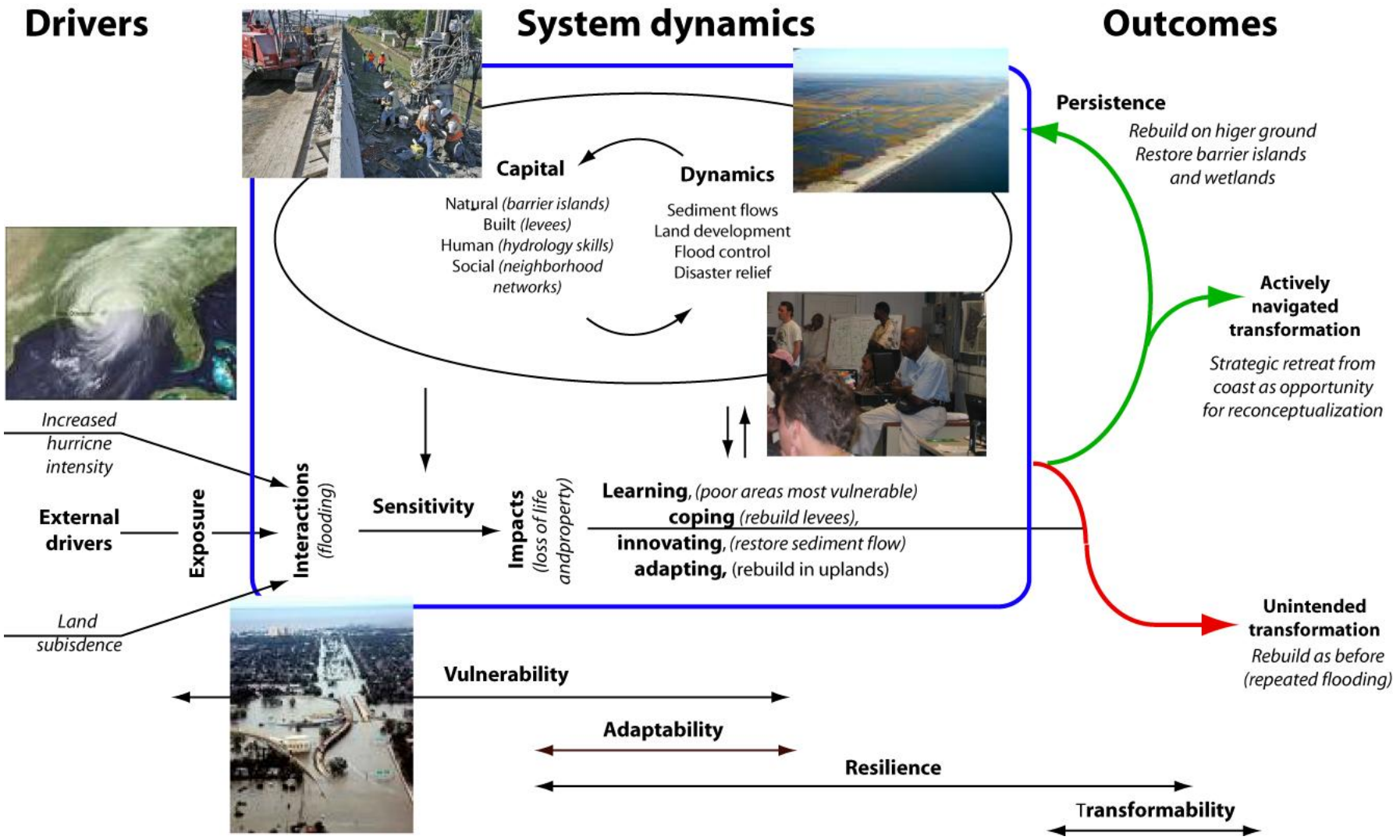
Kinzig et al. 2011

Reducing vulnerability and maximizing resilience

- Goals
  - Reduce exposure and sensitivity to stresses
  - Enhance capacity to adapt and transform
- Research opportunities
  - Characterize and understand emergent properties
  - Global consequences of local adaptation (cross-scale interactions)
  - Characterize tradeoffs to inform choices

Clark and Levin 2010

Systems approach to Hurricane Katrina: Choosing whether to transform



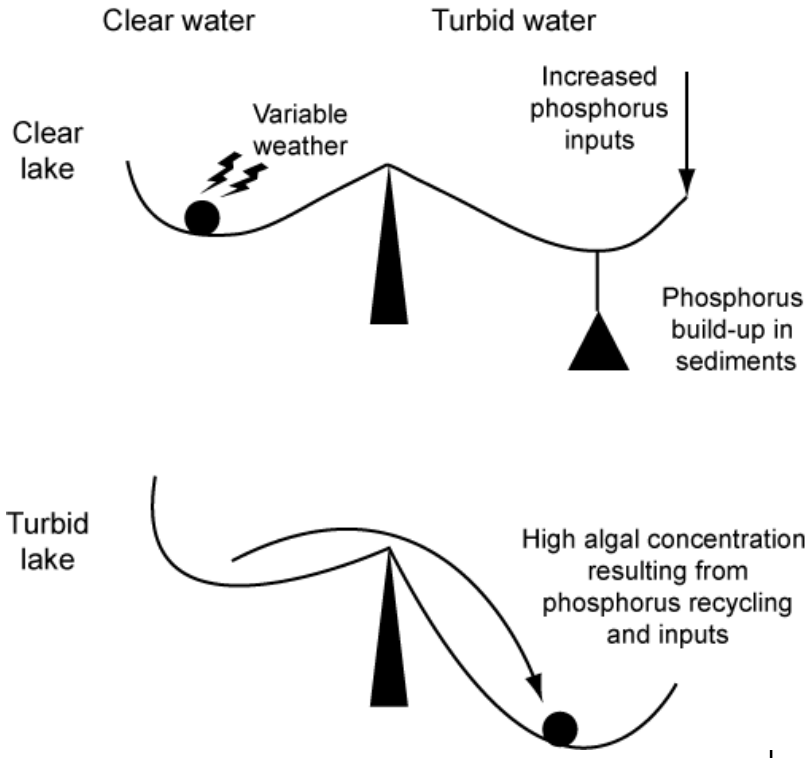
Chapin et al. 2010

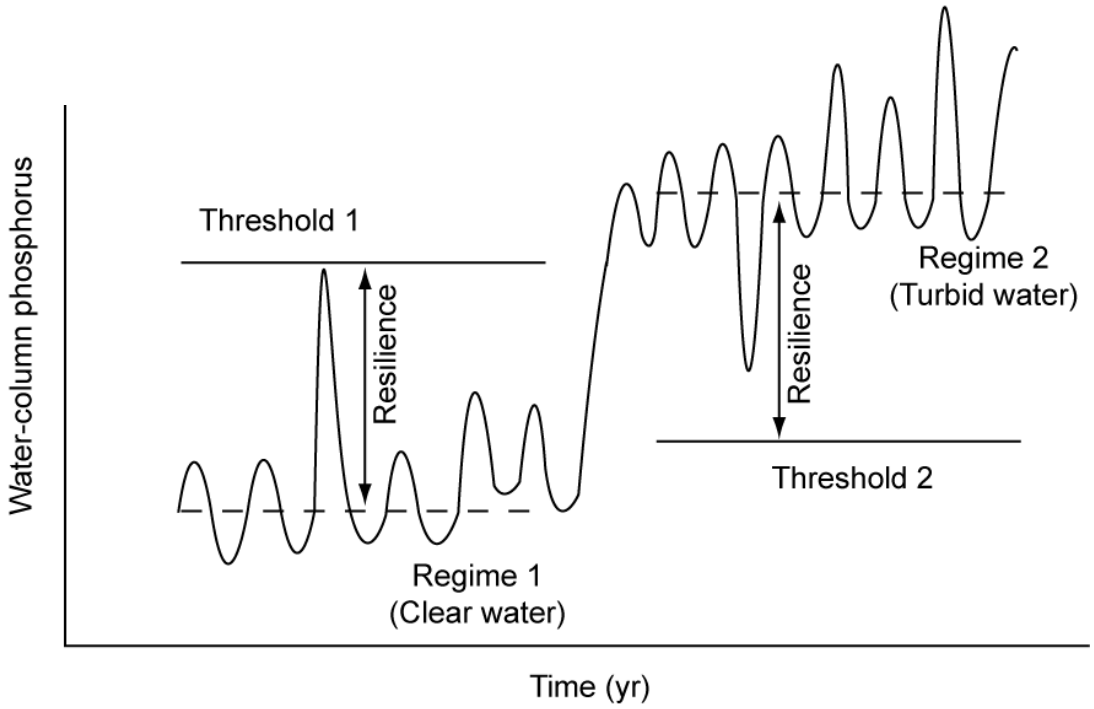
Monitoring progress toward sustainability

- Goals
  - Identify underlying determinants and feedbacks
  - Assess progress so as to respond adaptively
- Research opportunities
  - New generation of social-ecological models
  - Developing a pragmatic monitoring strategy and funded measurement programs
  - Research to identify, understand, and manage critical transitions

Clark and Levin 2010

Identifying and managing critical transitions



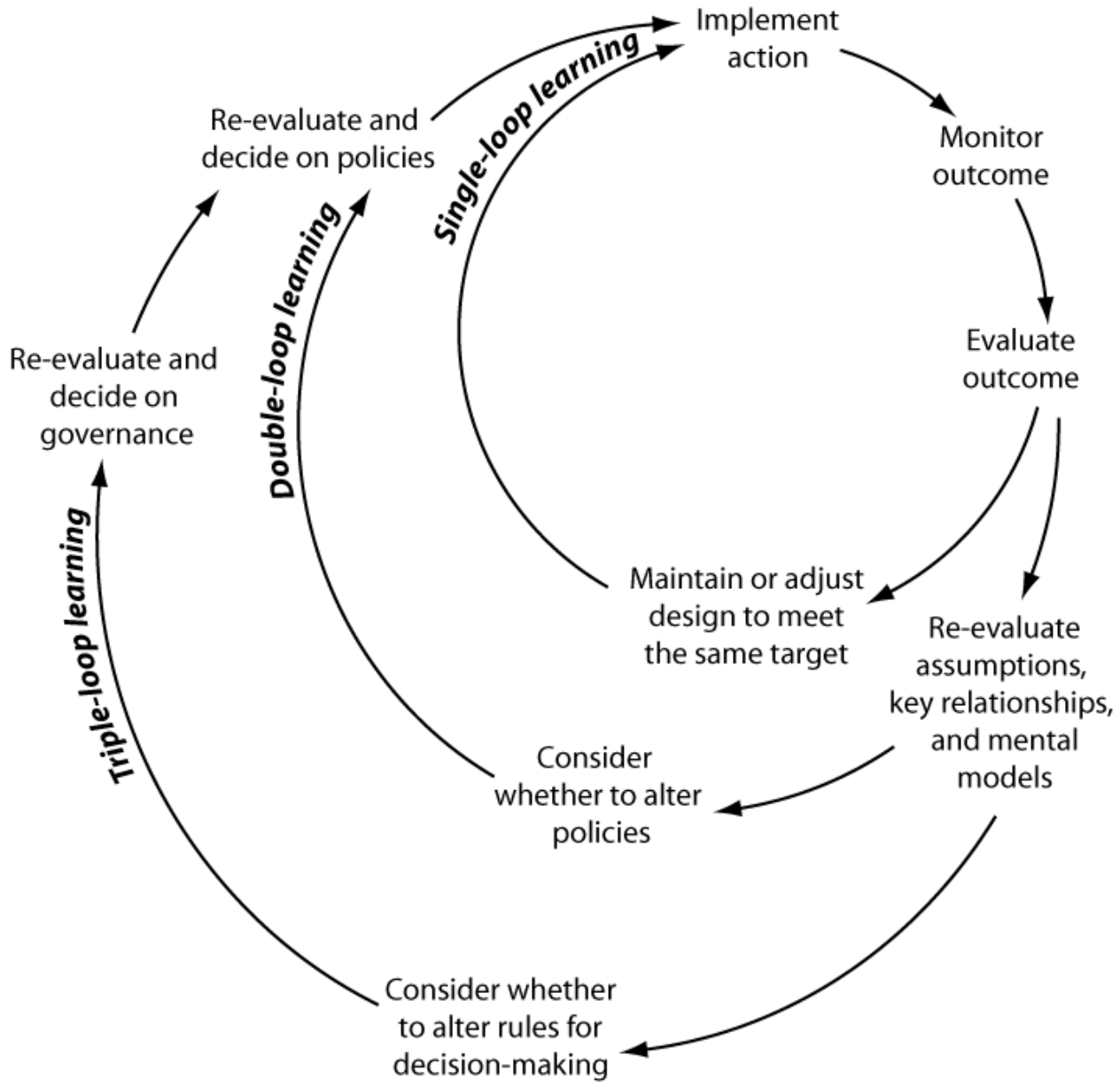


Carpenter 2003

Managing for sustainability

- Goals
  - Develop a pragmatic approach to managing for sustainability
- Research opportunities
  - Integrating knowledge frameworks for sustainability
  - Managing under uncertainty
  - Adaptive governance as a component of management

Clark and Levin 2010



Folke et al. 2009

ICSU Grand Challenges for Sustainability

- Improve usefulness of forecasts
- Develop observation systems to manage change
- Learn to anticipate, recognize, avoid and adapt to abrupt change
- Understand institutional, economic, and behavioral responses that shape sustainability
- Encourage innovation in technological, policy, and social responses for sustainability

How does sustainability science fit with responsibilities of federal agencies?

- Good potential fit (managing stocks)
  - Sustain natural capital and ecosystem services
  - Foster human well-being
- Remaining challenges (managing dynamics)
  - Managing integrated human-environment feedbacks
  - Adaptive governance for learning and flexible responses
  - Design and funding for interdisciplinary monitoring
  - Managing for transformative change

Application of sustainability science as a pathway to learning

- Build the science (sustainability science)
  - Engage multiple disciplines and practitioners
  - Define the science need
    - science of people and nature
  - Identify scenarios of change and intervention points
- Apply the science (stewardship)
  - Engage key stakeholders
  - Communicate the science needed to support societal engagement

Conclusions

- Sustainability science provides the foundation for a transition to a more sustainable trajectory
- We know enough to implement it now!
- Managing sustainability *dynamics* requires greater collaboration among agencies and across scales
- Implementation of sustainability science (stewardship) is a key research need
  - Active learning
  - Adaptive governance
  - New partnerships