Sustainability Science:
An Emerging Interdisciplinary Frontier

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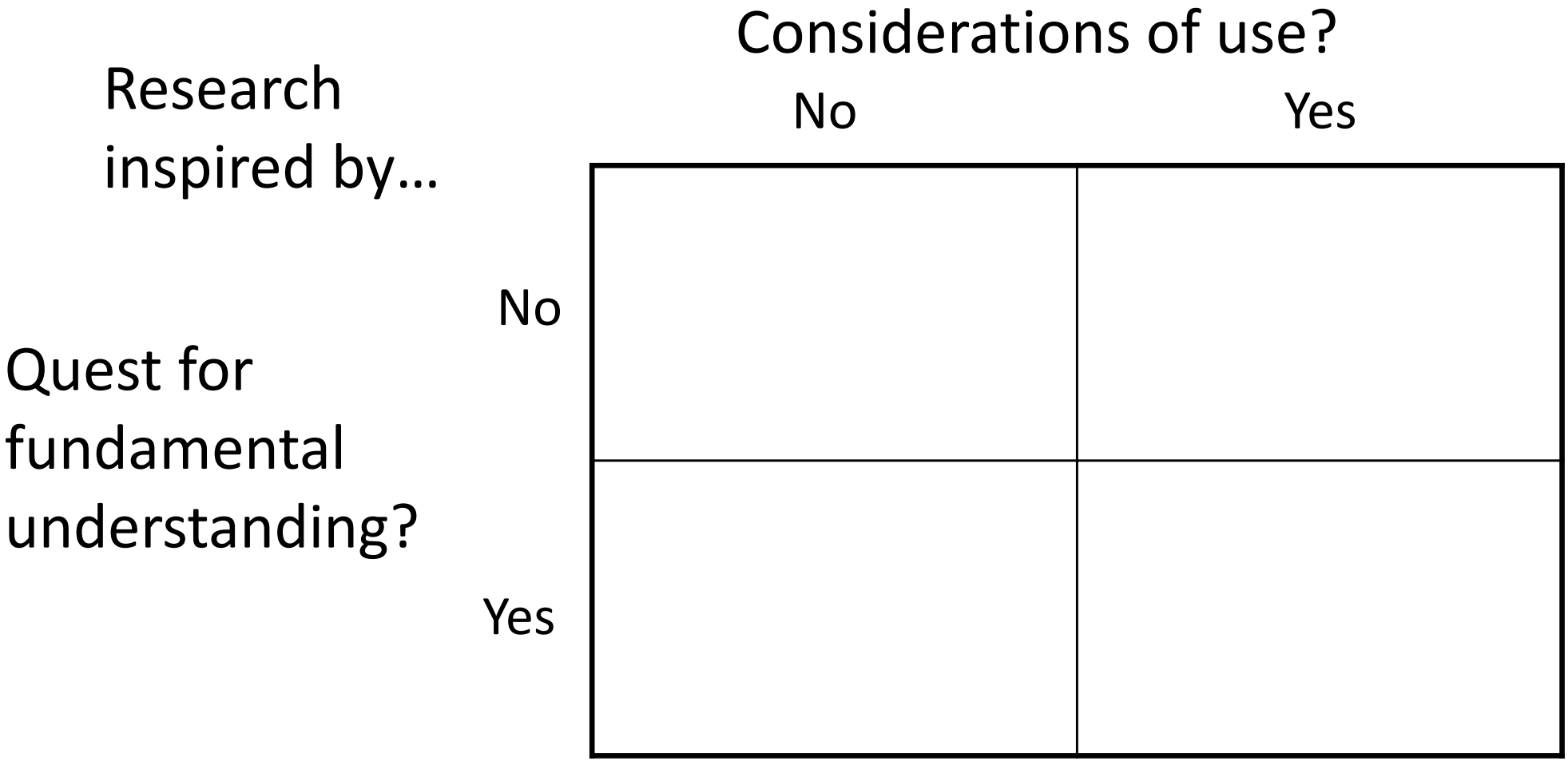
Sustainability Science in Overview

- An *emerging field* of ‘use-inspired’ research and innovation that, like ‘health science’ or ‘agricultural science’ before it …
- Is *defined* by the practical problems it addresses, specifically the problems of sustainable development;
- Is *focused* on scientific understanding of (strongly) interacting human and environmental systems;
- *Is conducted* by drawing from and integrating research from natural, social, medical and engineering sciences, and by engaging the resulting knowledge with the world of action.

A Field of *Use-Inspired Research?*



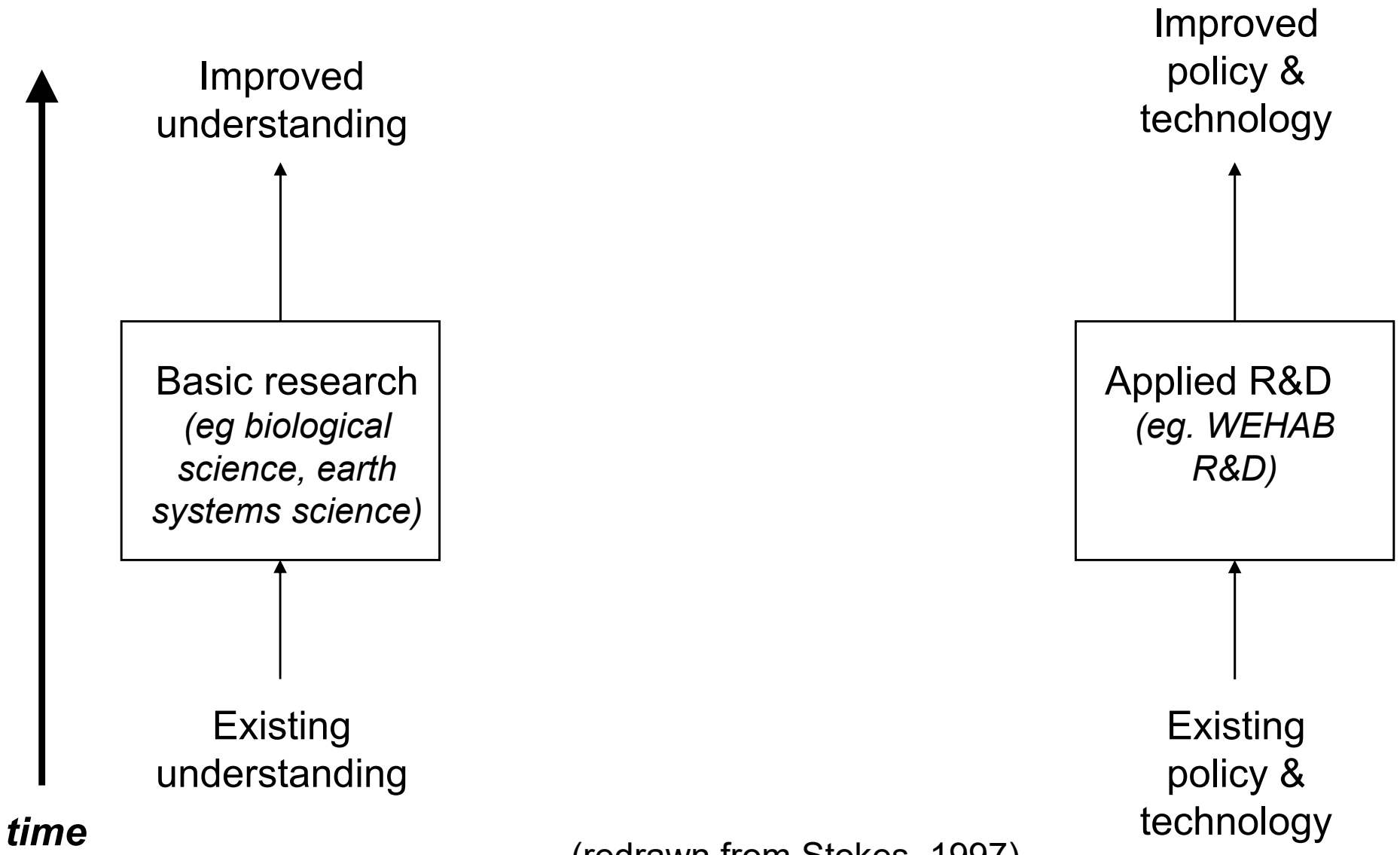
(redrawn from Stokes, 1997)

A Field of *Use-Inspired Research?*

Research inspired by… / Quest for fundamental understanding?	Considerations of use? No	Considerations of use? Yes
No	"Soaking and poking"	Applied research (Edison)
Yes	Basic research (Bohr)	*Use-inspired research (Pasteur)*

(redrawn from Stokes, 1997)

Dynamically linking knowledge & action



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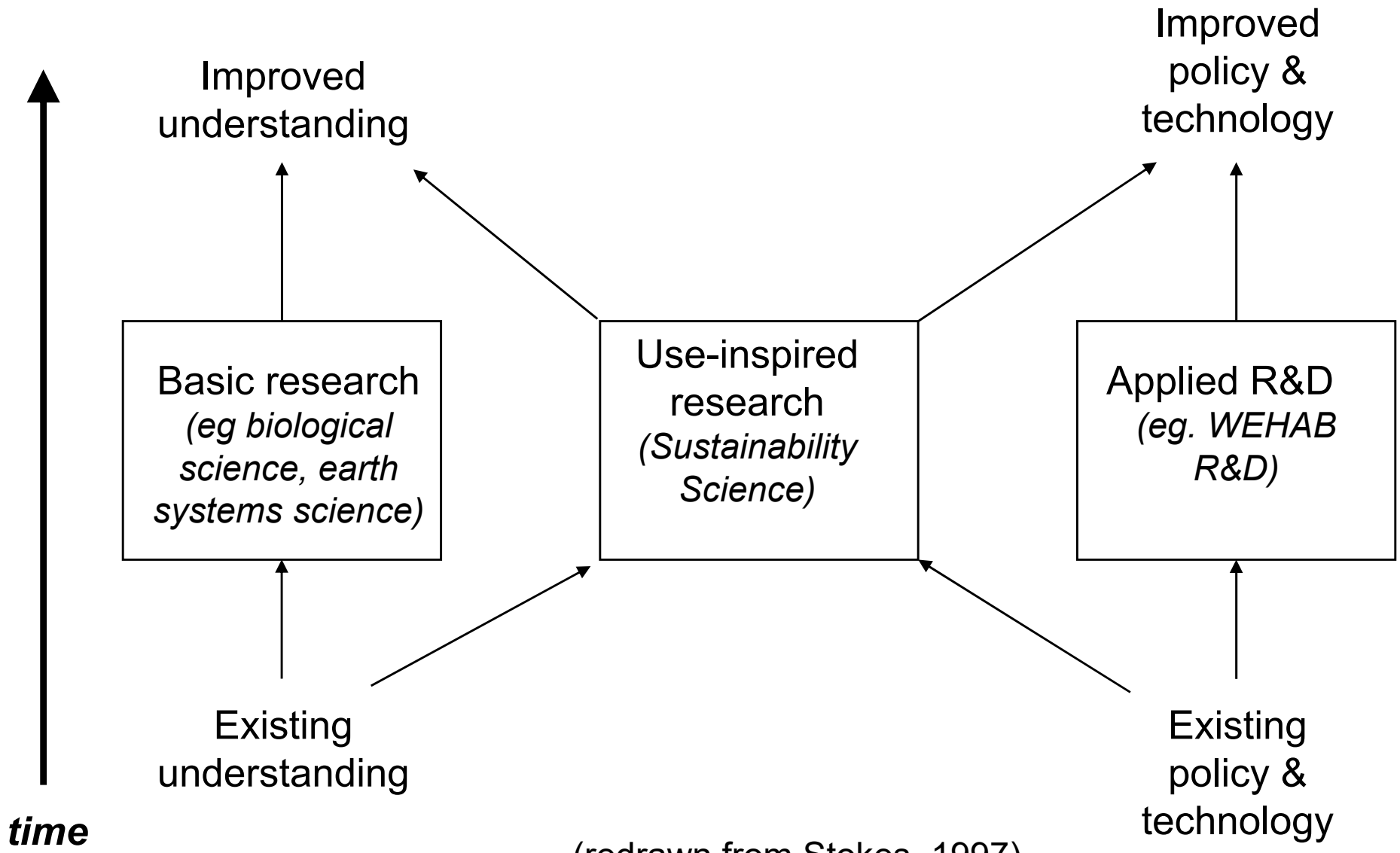

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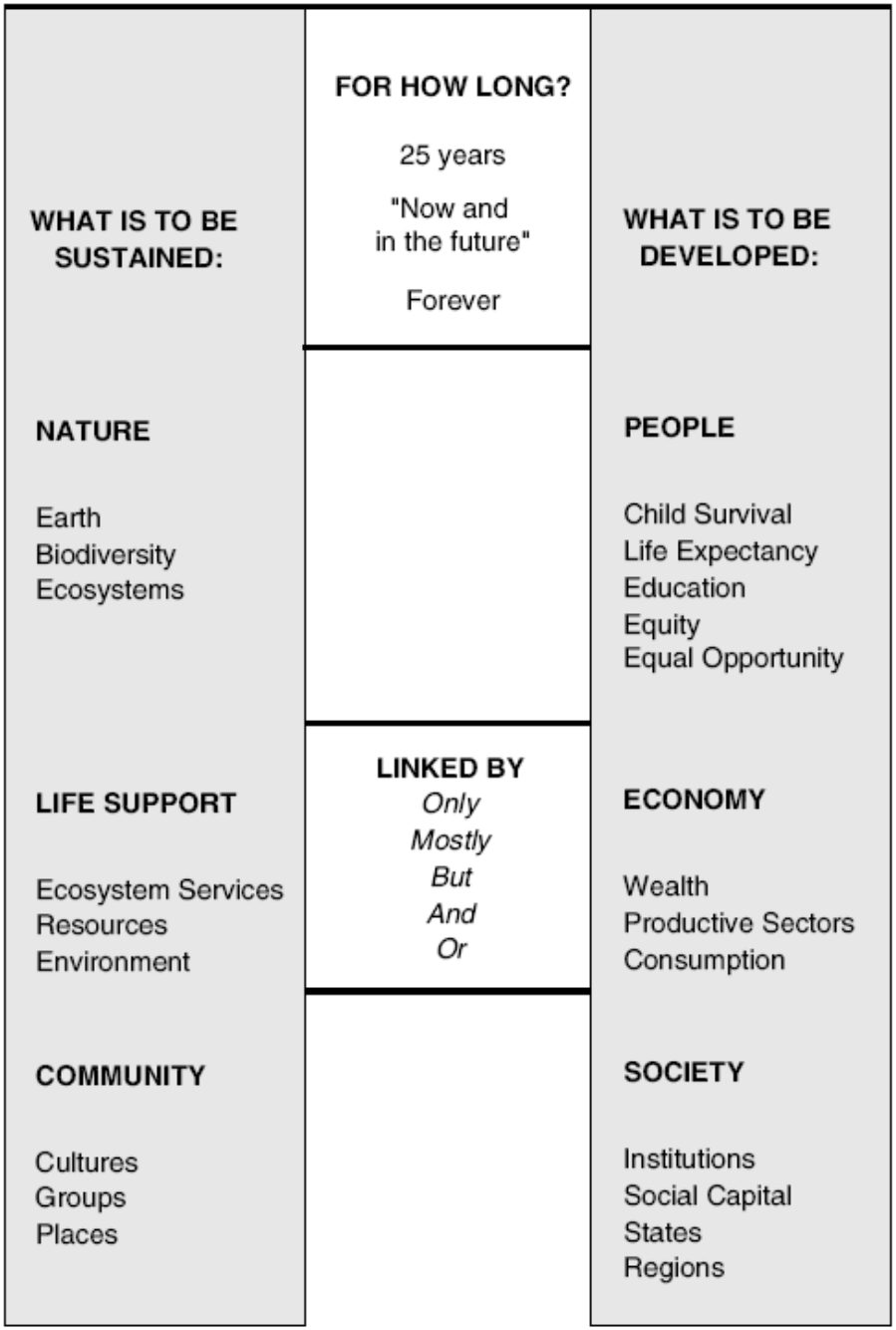
Which problems?
Origins of "Sustainability" thinking

- Conservationist thinking
  - Sustainable yields, "exotic" wildlife (1800s) →
  - IUCN "World Conservation Strategy" (1980)
- Environmental science thinking
  - Vernadsky's "biosphere and noosphere" (1940s) →
  - NASA's "Mission to Planet Earth" (1980s)
- Political ("radical") thinking
  - Ghandi's "too much wealth, too much poverty" (1972)
  - Latin America Commission "Our Own Agenda" (1990)
    - not "how to manage", but "who decides"…



Conceptualizing Sustainable Development

(National Research Council, 1999)

Goals for Sustainable Development

- Global consensus on international norms...
  - Meeting human needs
    - feed, house, nurture, educate, employ...
  - Preserving life support systems
    - water, air, oceans, ecosystems...
  - Reducing hunger and poverty
    - with special attention to the most vulnerable.
- Recognized need for local reinvention
  - WSSD on the limits of intl. action, the need for place-based, solution-oriented partnerships...
- Emergence onto high table of international affairs
  - Kofi Annan's 3 grand challenges: "freedom from want, freedom from fear, freedom of future generations to sustain their lives on this planet."

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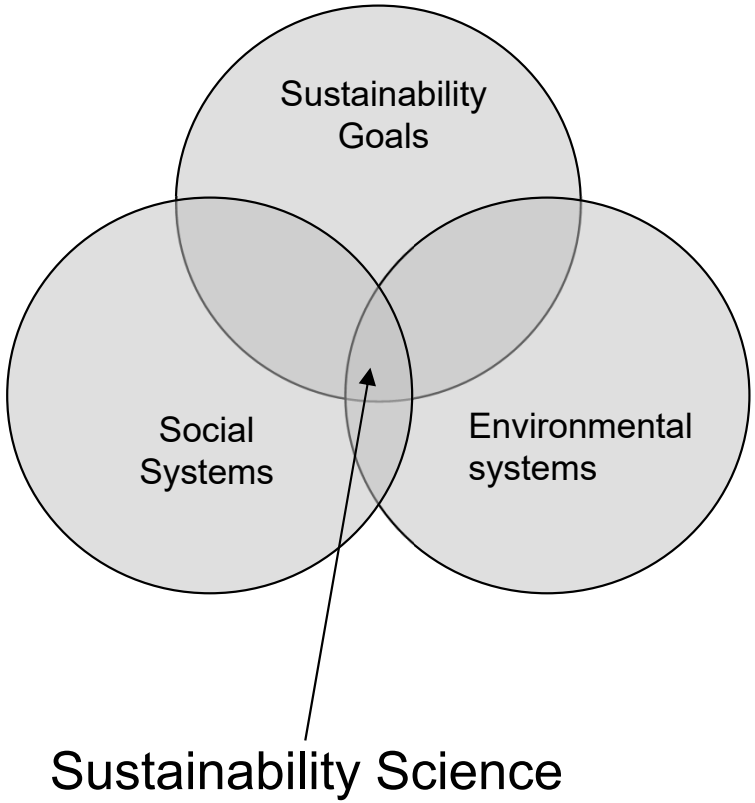
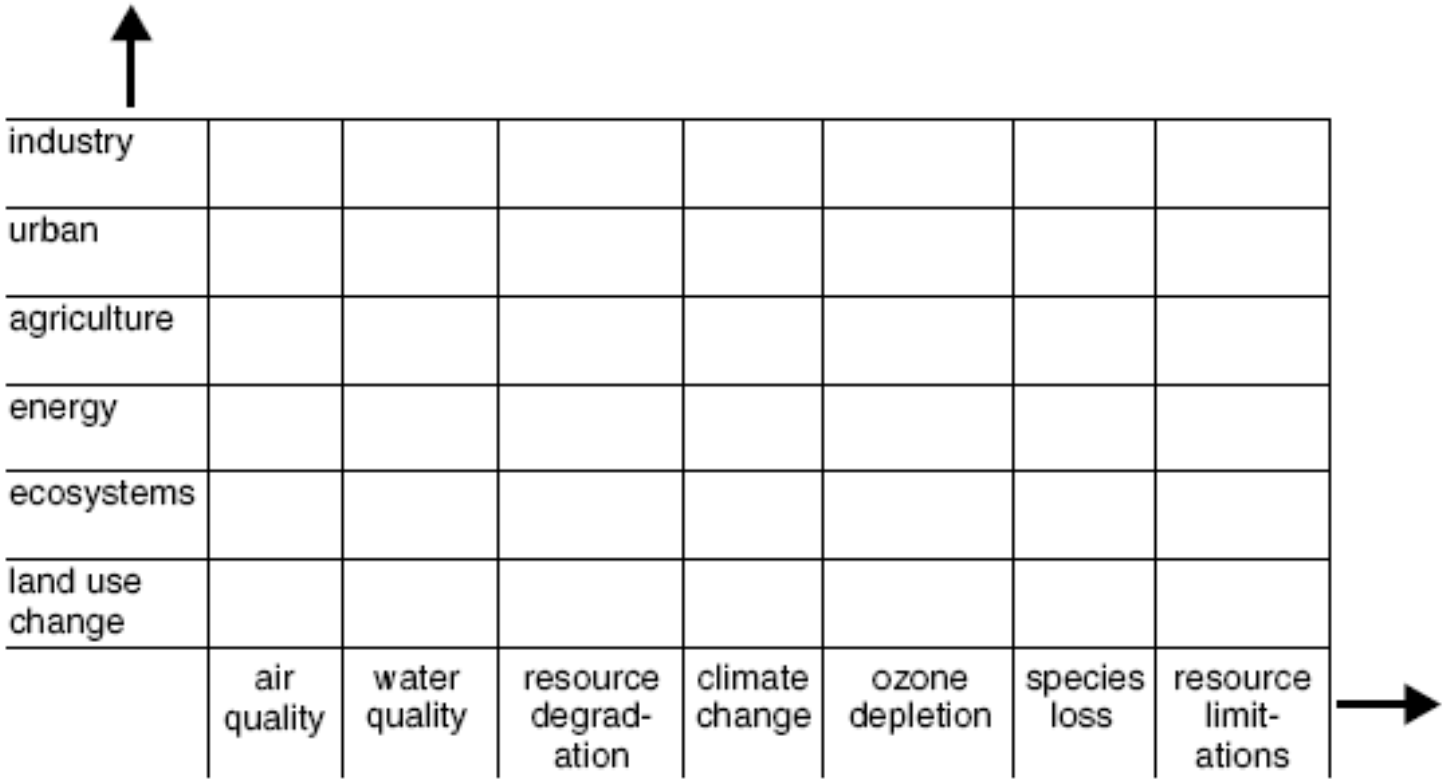
The domain of Sustainability Science



The Science Focus: Understanding the complex interdependence among efforts to achieve the goals of sustainable development

Meeting Human Needs for…



while Preserving Life Support Systems of…

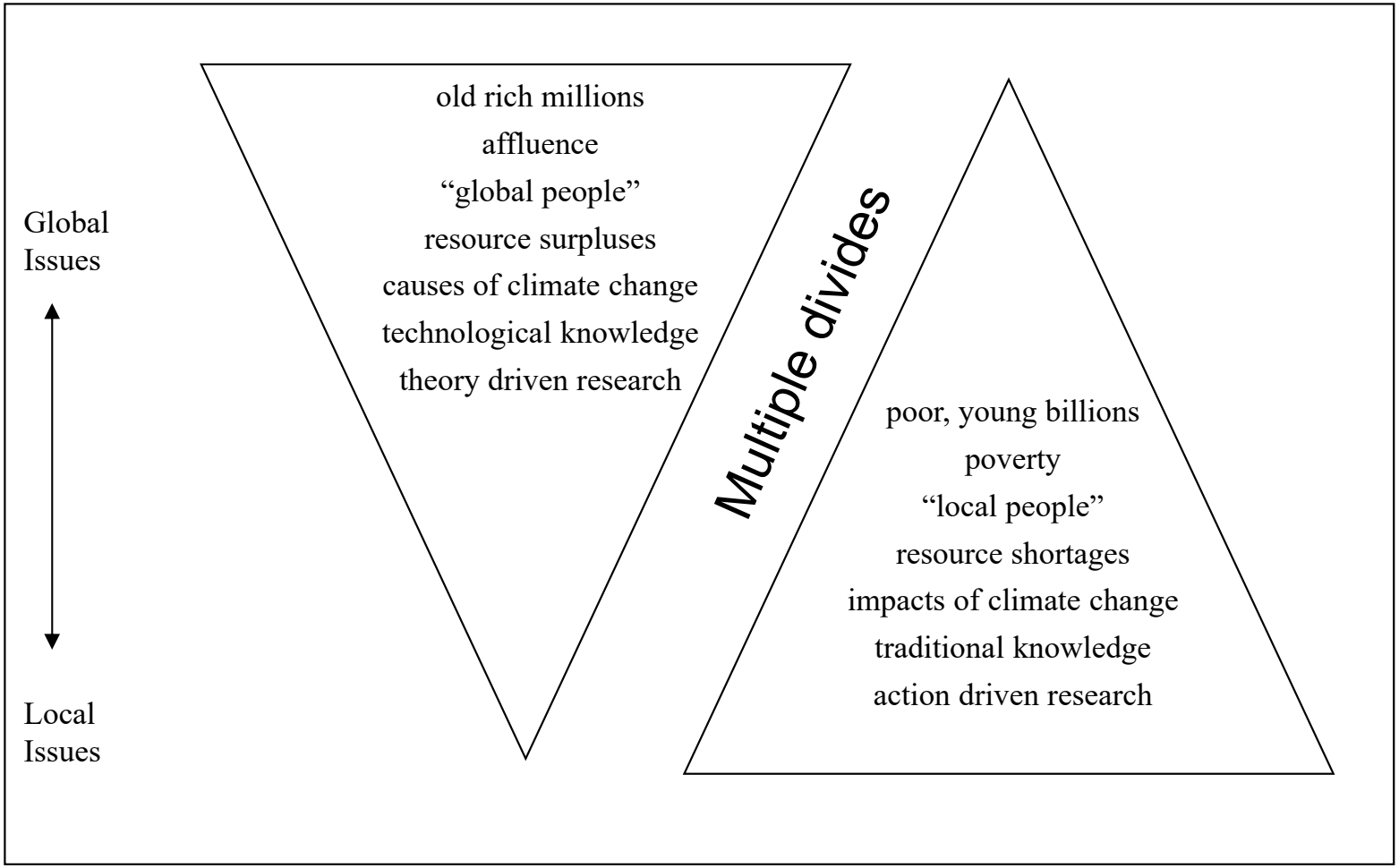
An intensifying effort to mobilize S&T for sustainability

- Building on foundation work of early…
  - Agricultural, natural resource, land use scientists…
- Featured at UNCED and Agenda 21 (early 1990s)
  - Managing Societal and Natural Resources (MSNR)
- S&T initiatives from South (from mid-90s)
  - TWNSO, COMSATS, South Center, …
- *Earth System Analysis : Integrating Science for Sustainability (*Schellnhuber & Wenzel, 1998)
- Special Issue on "Sustainability Science" (1999) *International Journal of Sustainable Development*
- *Our common journey: a transition toward sustainability* (National Research Council 1999)

Continuing into new Millennium…

- World Academies of Science Conf. (Tokyo 2000)
  - *Transition Toward Sustainability in the 21st Century*
- Global Assessments embrace sustainability…
  - IPCC, Millennium Ecosystem, Agriculture, ...
- ICSU initiatives on S&T for Sustainability
  - SCOPE, START, Earth System Science Consortium
  - Focal role for representing science at WSSD (2002)
- Workshops on regional priorities for sustainability science
  - Bangkok, Abuja, Santiago, Bonn, Chiang Mai, Ottawa, Cairo,…
- Synthesis sessions in Friiberg (2000), Mexico City (2002), Dahlem (2003), Venice (2006) …

Reveal profound differences in problems and perspectives…



(Kates et al., 2001. *Science*)

… but also wide-spread agreement that the science and technology needed to promote a transition toward sustainability should be…

Integrative…
thus committed to bridging:

- the communities engaged in promoting environmental conservation, human health, and economic development;
- the natural, social and engineering sciences, plus insights from the humanities;
- multiple sectors of human activity;
- the worlds of knowledge and action.

Multi-scale...

But generally place-based, regionally focused at scales where…

- multiple stresses intersect to degrade human-environment systems (Aral Sea);
- complexity is comprehensible, integration is possible
- innovation and management happen
- significant transitions toward sustainability have already begun.

Simultaneously fundamental and applied…

But grounded in Pasteur's Quadrant…

- Addressing cutting-edge questions regarding the interactive nature-society system and its evolving dynamics…
- While recognizing the concurrent need to address sustainability concerns in problem-solving mode, applying what we already know in science-based action programs.

Core Questions of Sustainability Science

- Driving forces
  - The origins of "transitions" beyond the demographic
  - Production-consumption relationships
- Impacts / consequences
  - Nature of "limits," carrying capacities, tipping points
  - Vulnerability and resilience of couple H-E systems to multiple stresses
- Guidance
  - Incentives for environment-conserving innovation / development;
    - PES-like ventures
  - Institutions for governing H-E systems ("Beyond panaceas")
  - Valuing outcomes in H-E systems
  - Designing effective knowledge-action systems

Core Questions of Sustainability Science: An emerging consensus

- Normative questions
  - valuing, evaluating, measuring
- Analytic questions
  - causes, consequences, control
- Operational questions
  - models, methods and data
- Strategic questions
  - engaging real world problems

(Framework after IGBP / GAIM)

Normative questions

- What are the values shaping interactions between human development and the natural environment?
- How, and with what consequences for sustainability, do these vary across space, time, and social groups?
- How should we evaluate progress toward sustainability in ways that fully account for the dependence of human well-being on the natural environment? (eg. ‘Green GDP’)
- What should be the human use of the earth?

Analytic Questions (1)

- Driving forces (long term, large scale)
  - What are the principal shapers of the "longue duree" relations between humans and the environment?
  - What are the origins of fundamental "transitions" in those long term trends (beyond the demographic)?
  - How, and with what implications for sustainability, are spatial relationships of production and consumption changing under the impetus of globalization?

- Impacts / consequences
  - How can we build a rigorous understanding of "limits," carrying capacities, tipping points in H-E systems?
  - What determines the vulnerability and resilience of couple H-E systems to multiple stresses?
  - How do humans adapt to environmental change?

Analytic Questions (2)

- Guidance and governance
  - Which sorts of incentives, under what conditions, are most effective for fostering environment-conserving development
    - Eg. payments for ecosystem services?
  - What kind of institutional arrangements are most effective for governing H-E systems in ways that promote sustainability?
    - Eg. scaling up common property successes, learning what to decentralize
  - How can we designing more effective systems for linking knowledge with action?
    - Eg. harnessing private incentives for innovation to the provision of public (knowledge) goods / biofuels?
  - For all of the above, how can global lessons and guidance be adapted to (rather than imposed on) local contexts?

Operational questions

- Modeling complex H-E systems
  - Field vs agent-based approaches; modeling adaptation
  - Handling space, its heterogeneity and multi-scale systems
  - Integrating the ecological, social, and economic
- Observations and data
  - Importance of history in illuminating H-E dynamics
  - Disciplined learning from small-n case comparisons
  - Design of early warning indicators for tipping points
- Linking knowledge with action
  - What participatory approaches are most effective, when
  - Integrating systems of R&D, assessment, observations
  - Importance of boundary work, co-production

Strategic questions
(Grand Challenges for Sustainability Science)

- Of the most important problems of sustainable development, those for which…
- S&T have the potential for making important contributions to practical solutions, but…
- That potential is not being realized due to barriers of one sort or another
  - e.g. inadequate theory, methods, data; insufficient training or other capacity; shortfalls in funding or other motivations for scientists.

Grand challenges?

- Great variety of possibilities differing by place, scales, sectors…
- National Academies' global list includes…
  - accelerate trends in fertility reduction
  - reverse declining trends in ag productivity in Africa
  - accelerate improvement in efficiency of energy, material use
  - accommodate 2-3x increase in urban population
  - restore degraded ecosystem services….
- MSU's list for its regional, global work?

Quadrant Model of Sustainability Science

Research inspired by…

Quest for fundamental understanding?

	Considerations of use? No	Considerations of use? Yes
Quest for fundamental understanding? No		Grand Challenges *(Strategic Qs)*
Quest for fundamental understanding? Yes	Foundations *(Earth Systems Science, Environmental economics, H-E systems of geog, etc.)*	*Core Questions* *(Normative, analytic, operational)*

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Present systems of priority-setting, funding and publication encourage (good) research …

- anchored in single (or neighboring) *disciplines*
- *either* problem-driven *or* fundamental;
- focused at single *scales;*
- not directly connected to *assessment*; *operations*, or *decision-support;*
- And therefore necessary but insufficient to advance goals of a sustainability transition.

Needed is additional capacity to:

- *Target* S&T on "most pressing problems" as prioritized by stakeholders in development…
  - avoiding pitfall of scientists guessing user needs
- *Integrate* appropriate mixes of disciplines, expertise and public/private sector in support of such problem-driven R&D…
  - avoiding pitfalls of disciplinary "hammers," of undervaluing informal, practical expertise

Needed is additional capacity to...

- *Link* expertise and application across scales, from local to global
  - avoiding bias for universal over place-specific knowledge
- *Integrate* research planning, observations, assessment & operational decision support
  - avoiding pitfall of “island empires”.

Examples of international research systems that have been (relatively) effective in meeting such needs

- *Development*: CGIAR system in agriculture
- *Envir*: ENSO research/applications progs
- *Health*: WHO smallpox campaigns
- *Commons*: Stratospheric ozone protection

Lessons for designing university-based knowledge systems for sustainability

1. Maintain *and engage* strength in the foundation disciplines
2. Support focused programs of "use-inspired basic research" on core questions of sustainability science
   -eg. vulnerability of nature/society systems
3. Build collaborative problem-solving programs engagine users and stakeholders where we know enough to begin…
   -eg. sustainable biofuels
4. Create recognition and reward systems for those who develop and participate in such programs
   - tie degrees, faculty promotion to engagement as well as research;
   - develop high impact publication venues for sustainability science

National Academies establish in PNAS new publication venue for interdisciplinary research in sustainability science

*qualified peer review
*high impact (>10)
*fast publication
*available free on line in developing world

The bottleneck: Regional Centers Integrating Science for Sustainability

- Providing useful integration of sectoral expertise, disciplinary science, technical know-how, and informal knowledge in response to priorities of development stakeholders is a complex process…
- …often left to local decision makers and managers who "make do"… but with limited skill.
- Needed are Regional Centers to catalyze, facilitate and support such integration, by building experienced problem-driven teams in trusted institutions, networked to global system
- MSU lead in a network of "world grant" universities?

Additional Information

- Forum on Science and Innovation for Sustainability (and associated network)
  - http://sustainabilityscience.org
- PNAS Sustainability Science
  - http://www.pnas.org/misc/sustainability.shtml
- Sustainability Science Program at Harvard
  - http://www.cid.harvard.edu/sustsci/index.html
- Me…
  - william_clark@harvard.edu