Sustainability science

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Sustainability science is an emergent field of science whose origins are found both in elite institutional efforts to bring environment and development together and in an outpouring of published studies related to sustainability or sustainable development. Sustainability science is characterized by use-inspired research and as such similar to the agricultural or health sciences. It is defined by the practical problems of sustainability which it addresses and by theories and models of interactions between natural and social systems. It is clearly transdisciplinary in structure integrating research from the natural, biological, social, and engineering sciences. Above all, sustainability science seeks to link knowledge with action on the identified problems of sustainability.

Origins of sustainability science

A series of major reports and international meetings document the first efforts to bring together environment and development beginning with the 1980 International Union for Conservation of Nature (IUCN) World Conservation Strategy, followed by the emergence of sustainable development in the 1987 Bruntland report, *Our Common Future*, and acted upon at the 1992 first Rio Earth Summit. Sustainable development, while politically successful, had little science content until the preparation of the US National Academy of Sciences 1999 report, *Our Common Journey*, that called for the development of a sustainability science and followed in 2003 by its journal, *Proceedings of the National Academy of Sciences USA* (*PNAS*), creating a sustainability science section now containing hundreds of research articles.

Figure 1 also graphs the individual authors of articles and conference proceedings written in English between 1974 and 2010 with "sustainability" or "sustainable development" in the title, abstract, or keywords. There were over 20 000 papers, published mostly in biology, engineering, and social science journals, with 37 000 distinct authors based in such diverse institutions as corporations, governments, NGOs, and universities (large and small) in 174 countries and 2200 cities. From the 1990s on, the number of authors of articles grew rapidly, doubling about every 8 years, with its worldwide authorship, including many developing countries. By analyzing the author's interconnections, the field seems to unify around 2000, when the size of interconnected clusters of authors began to grow and the number of disconnected clusters of authors and reflecting disciplines rapidly declined.

Sustainability science as use-inspired research is often illustrated by Donald Stokes's quadrant model of scientific research contrasting the quest for fundamental understanding with considerations of use by society. The quest for fundamental understanding is called, by some, basic science in contrast with applied science characterized by user needs. But a third option

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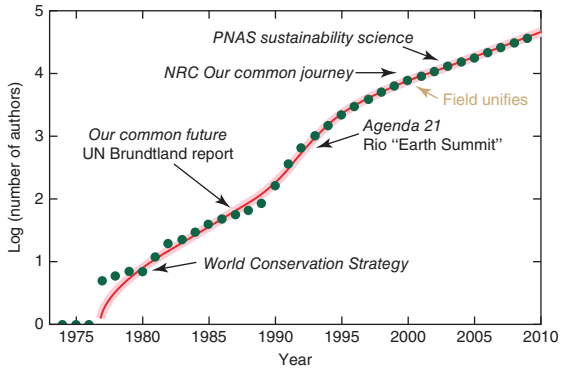

Figure 1 Source: Bettencourt and Kaur 2011.

is use-inspired basic research as exemplified by such researchers as Louis Pasteur and such fields as the agricultural or health sciences. Within this category, sustainability scientists address use-inspired problems of sustainability, perhaps emphasizing interactions between natural and social systems, perhaps emphasizing applied solutions to practical problems, or both.

Sustainability science as interactions between natural and social systems

Basic overviews of interacting natural and social systems have been used for many years labeled variously as nature–society, socio-environment, socio-ecology, or human environment and often presented as box-and-arrow diagrams rather than as operable models. Geographers have played major roles in developing this view of nature–society relationships and related research. This research, which is a study of how interactions between natural and social systems emerged in global change, notes the key roles of eight geographers whose discipline "by training, bridged social and natural sciences and had a strong spatial focus; furthermore, they had a cadre of scientists with strong leadership attributes" (Mooney, Duraiappah, and Larigauderie 2013, 3).

These box-and-arrow diagrams of nature–society interactions usually contain a societal or human subsystem, a natural or environmental subsystem, and other external systems that impact or modify these subsystems. Analysts differ on the important elements of each. Judging from the literature, much of nature–society systems study focuses on the environmental subsystem, especially its production of ecosystem or environmental services (provisioning, cultural, supporting, or regulating). Important elements of social subsystems are population, technology, governance, and economy, but these are seldom interacting and studied primarily as separate elements. If present, they are introduced into models usually as external inputs or scenarios.

As a research field with a theoretical perspective on coupled nature–society systems, sustainability science has evolved a set of seven core questions and research themes. These are as follows.

- What shapes the long term trends and transitions that provide the major directions for this century?
- What determines the adaptability, vulnerability, and resilience of nature–society systems?
- How can theory and models be formulated that better account for the variation in nature–society interactions?
- What are the principal tradeoffs between human well-being and the natural environment?
- Can scientifically meaningful "limits" be defined that would provide effective warning for nature–society systems?
- How can society most effectively guide or manage nature–society systems toward a sustainability transition?
- How can the sustainability of alternative pathways of environment and development be evaluated?

Sustainability science as applied problems of sustainability

The core questions and research themes can also be asked of specific places or sectors of human activity where applied problems of sustainability occur. Six initial sectors were first identified in 1987 by the World Commission on Environment and Development as global challenges for sustainable development: population and human resources, food security, species and ecosystems, energy, industry, and urban. With the addition of water, these have appeared in various guises, the latest being water, energy, health, agriculture, biodiversity, and urban.

Scientists and technologists who wish to help provide knowledge useful in addressing such sustainability problems do so best when these problems are determined collaboratively with potential users and policymakers, who often have their own traditional or practitioner knowledge to contribute. Such coproduction of knowledge enhances the search for solutions and the likelihood that use-directed knowledge will actually be used.

Transdisciplinary sustainability science

There are three kinds of major interactions between traditional disciplines when trying to understand or address a scientific or practical problem. In its simplest form, *multidisciplinarity*, which is when various disciplines present their separate perspective of the problem and the research on it found within their discipline. A more interactive form is *interdisciplinarity*, where relevant disciplines are brought together, usually in teams, to conduct joint research on the problem. Much of sustainability science functions in this way. But, increasingly, many sustainability scientists aspire to *transdisciplinarity*, moving beyond the approaches, training, and skill sets of their disciplines to become problem oriented rather than discipline oriented. In so doing, they seek to master and use the skills and approaches needed to address the problem, from whatever sources these may be derived.

Sustainability science in 2015

Since its unification as a scientific field in early 2000, sustainability science has become rooted in the scientific enterprise with new research, publications, institutions, and educational opportunities. As noted, its research increasingly seeks solutions to problems along with deepening theoretical perspectives in coupled nature–society systems. It has a very large published library of work, much appearing in new dedicated journals. Centers and institutes and a growing number of degree programs dedicated to sustainable development, sustainability, or sustainability science are found in many parts of the world and in their variety reflect the regional differences in how the science is pursued and that no common sets of needed competencies for students have yet emerged.

But sustainability science is a young science and there is much more work to be done. Most important is moving knowledge into action. The practical problems of sustainability are increasingly studied in joint undertakings with practitioners from local communities, industry, government, and civil society, but there is a lag between research and implementable solutions offered or problems solved. (A set of videos of such problem-solving in the state of Maine in the United States is available at www.mpbn.net/Television/LocalTelevisionPrograms/SustainableMaine.aspx.) The next major metric

for sustainability scientists should be in practical problems solved.

SEE ALSO: Environment and development; Environmental science and society; Socio-nature; Sustainable development

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Further reading

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