# Scientific Research & Sustainable Development

## Nghiên cứu khoa học và Phát triển bền vững

Journées Franco-Vietnamiennes de l'Innovation
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cirad

# HUMAN ACTIVITIES OVER THE PAST FIFTY YEARS HAVE ALTERED ECOSYSTEMS AROUND THE WORLD FASTER AND MORE EXTENSIVELY THAN AT ANY OTHER TIME IN HISTORY.

60% of wildlife lost

World population x 2 (3.5B  to 7.7B)

Global crop production x 3

Urbanised areas x 3

Energy consumption x 6

CO2 emissions x 7

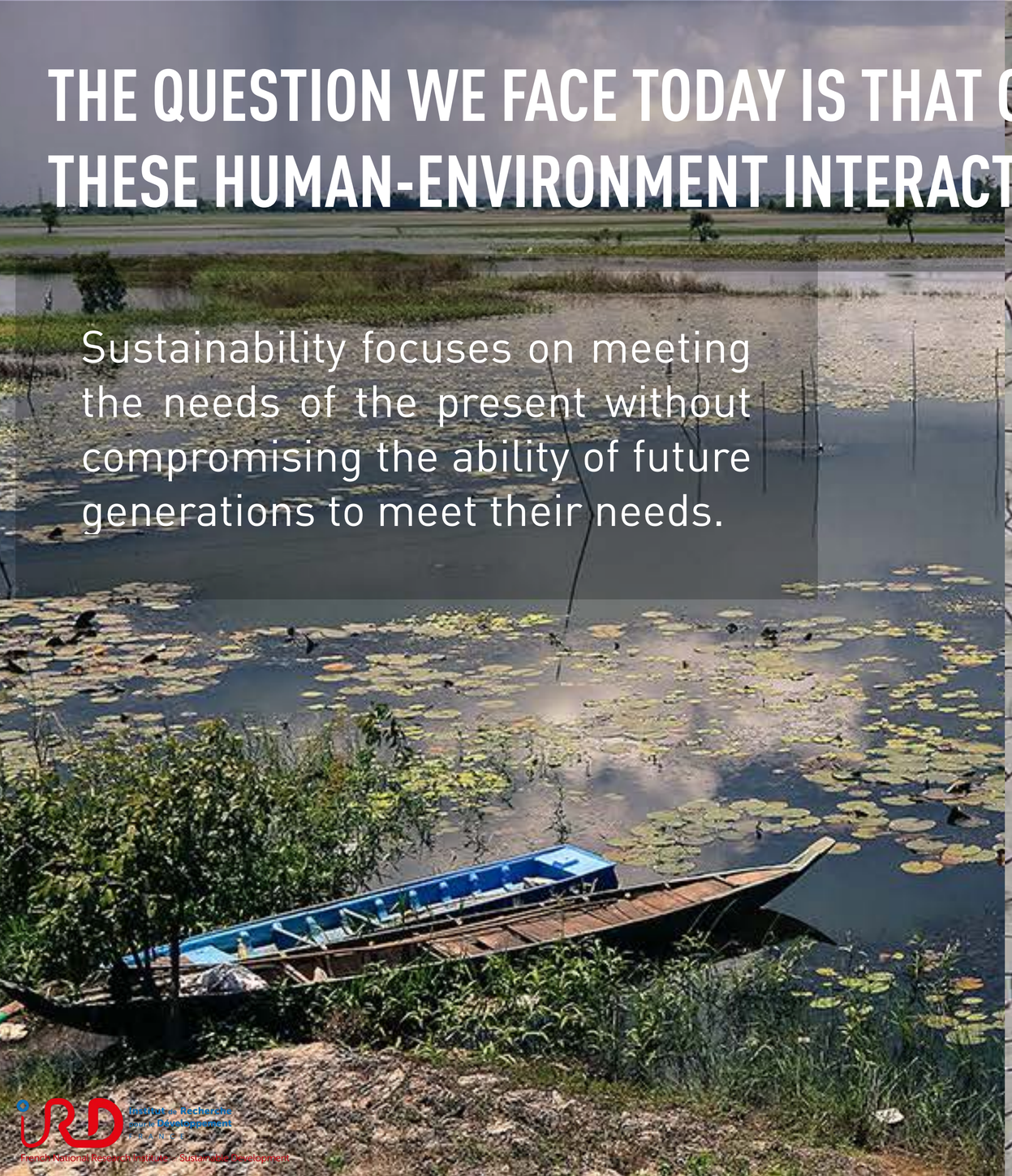
International tourists x 48

Freshwater use x 3

**https://ourworldindata.org/**

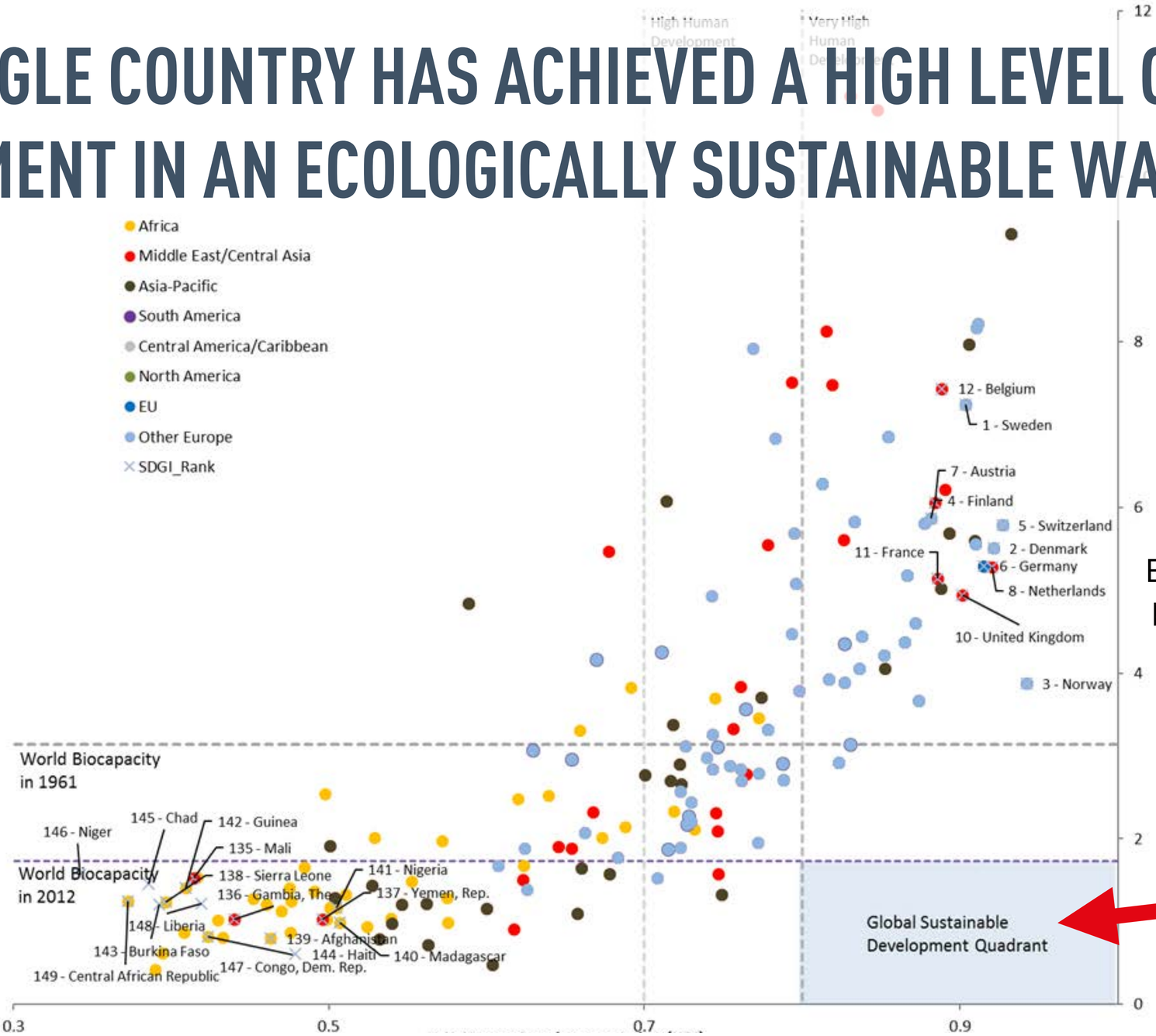
# THE QUESTION WE FACE TODAY IS THAT OF THE LONG-TERM SUSTAINABILITY OF THESE HUMAN-ENVIRONMENT INTERACTIONS

Sustainability focuses on meeting the needs of the present without compromising the ability of future generations to meet their needs.



This question requires a **deeper understanding** of how humans and ecosystems adapt to changes, how to approach their interactions, but also how to manage the ecosystems upon which human well-being depends

# NOT A SINGLE COUNTRY HAS ACHIEVED A HIGH LEVEL OF HUMAN DEVELOPMENT IN AN ECOLOGICALLY SUSTAINABLE WAY

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# IN 2015, THE 17 SUSTAINABLE DEVELOPMENT GOALS WERE ADOPTED, LINKING SOCIAL AND ENVIRONMENTAL PRIORITIES

**Eradicate poverty**

**Foster prosperity**

**Protect the planet**


**https://sdg-tracker.org**

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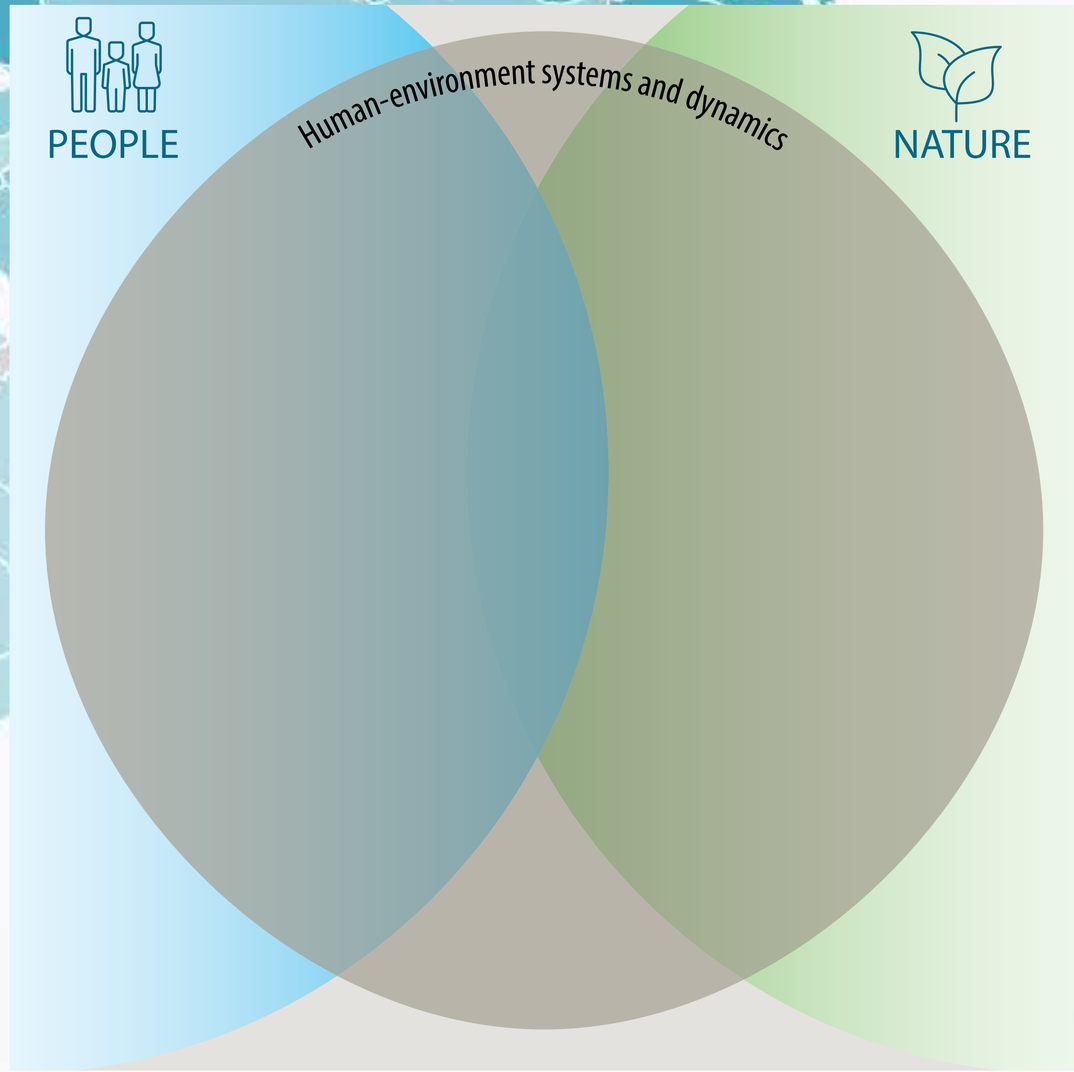

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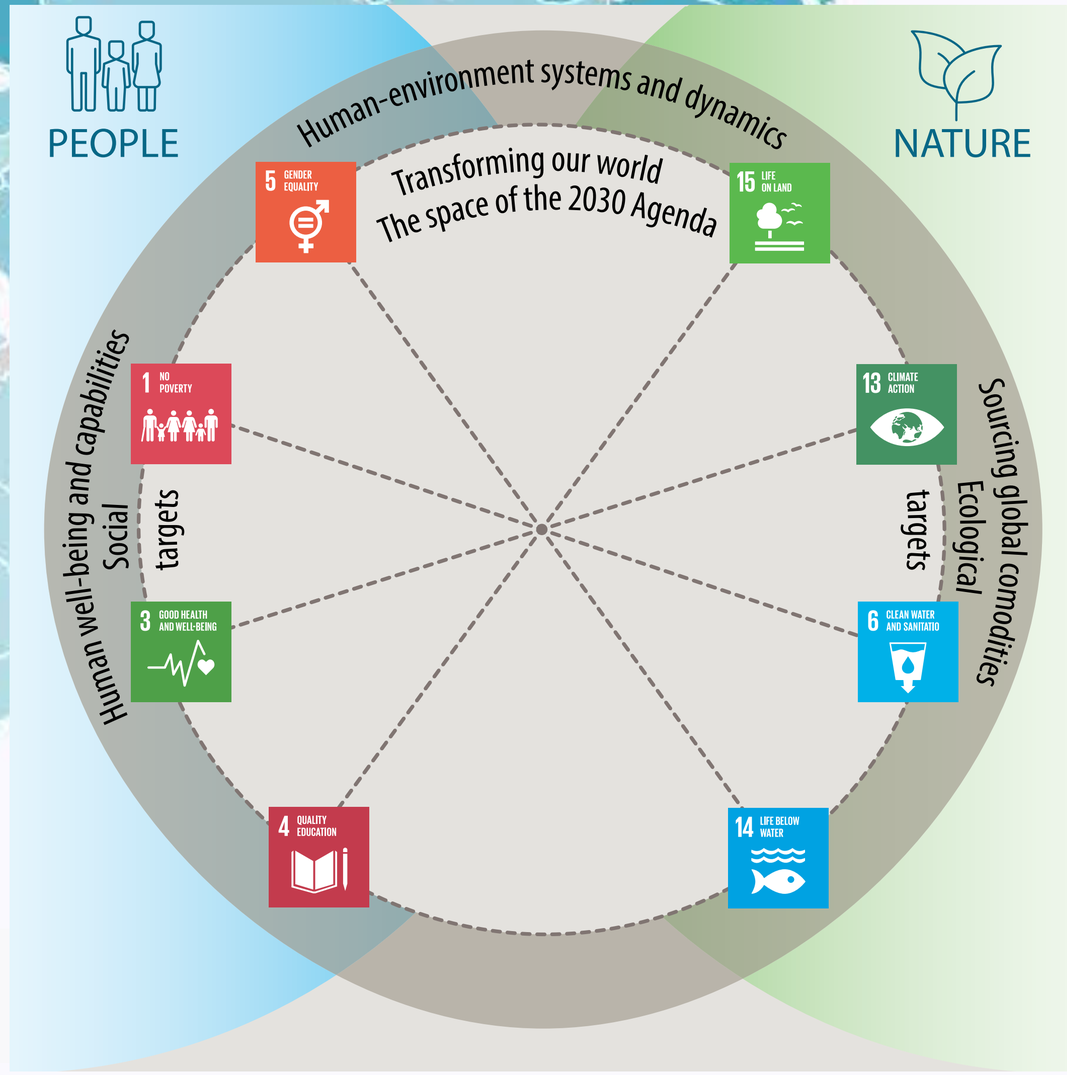

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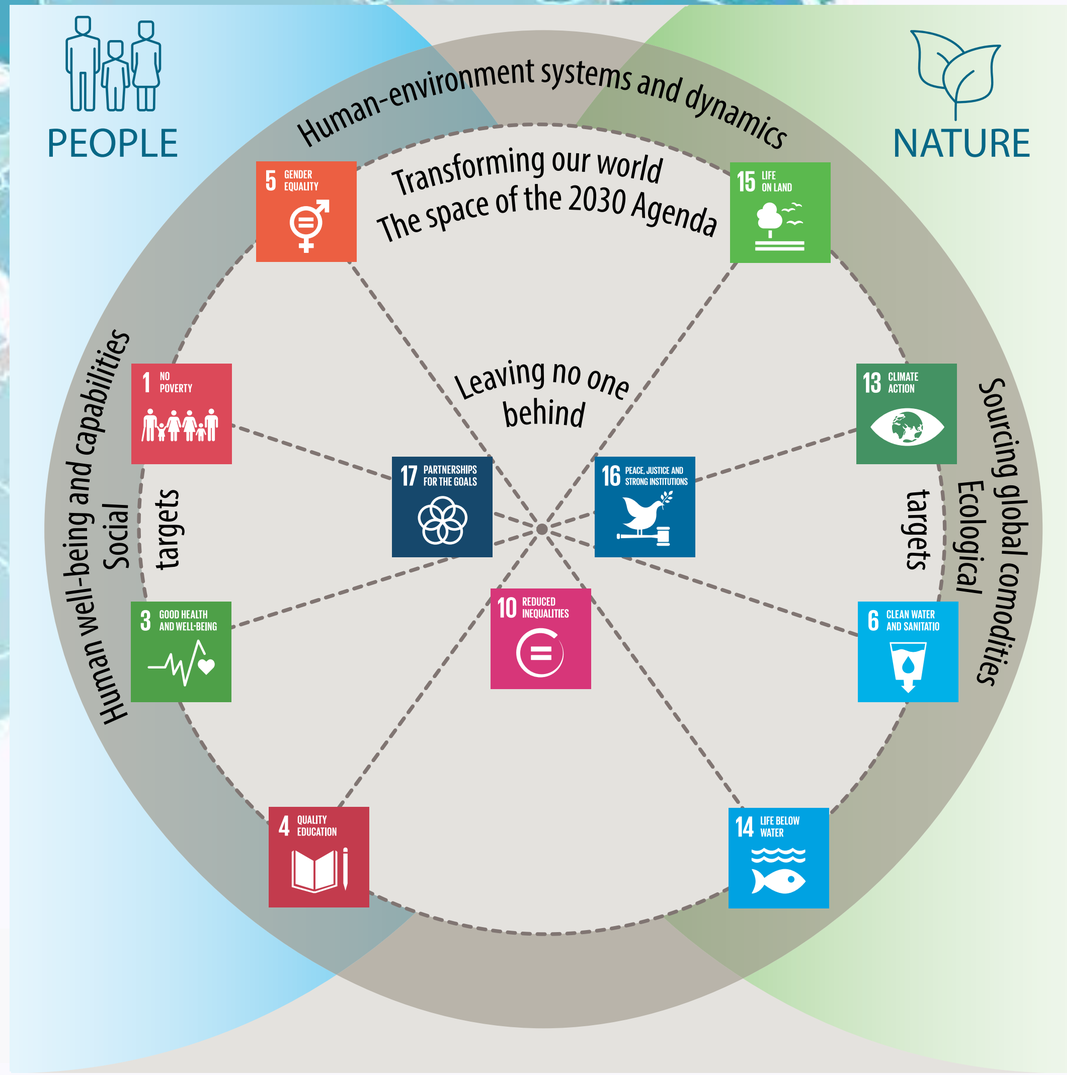

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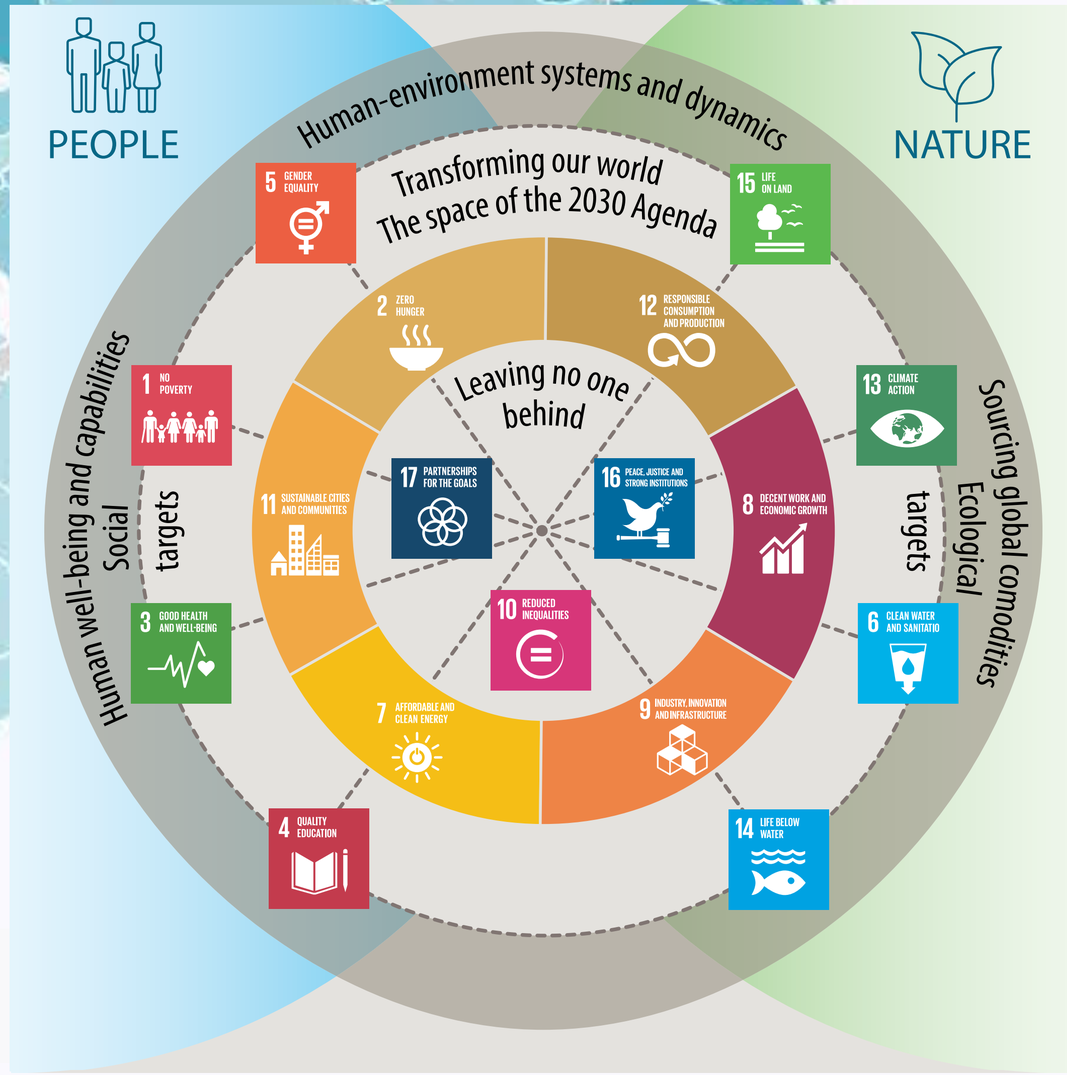

# 4 YEARS LATER, IN SEPT. 2019, PUBLICATION OF A 1ST REPORT BY A GROUP OF INDEPENDENT SCIENTISTS

Despite considerable efforts these past four years, **we are not on track to achieve the Sustainable Development Goals by 2030.**

*Antonio Gutteres - UN Secretary-General*

(...) we are at **risk of irreversibly degrading the natural systems that sustain us** and (...) **off track in "leaving no one behind"**.

*Liu Zhenmin - UN Under-Secretary-General*

- (...) in order to secure the future of humanity and the planet **we cannot wait for crises** – with potentially irreversible consequences – to trigger change. Rather, we need to **act now based on our current knowledge and understanding**.
- (...) we need to overcome the gap between what we know and what is being done. We believe that **scientific evidence must contribute to formulating effective policies** for the necessary transformations.


**http://is.gd/gsdr2019**

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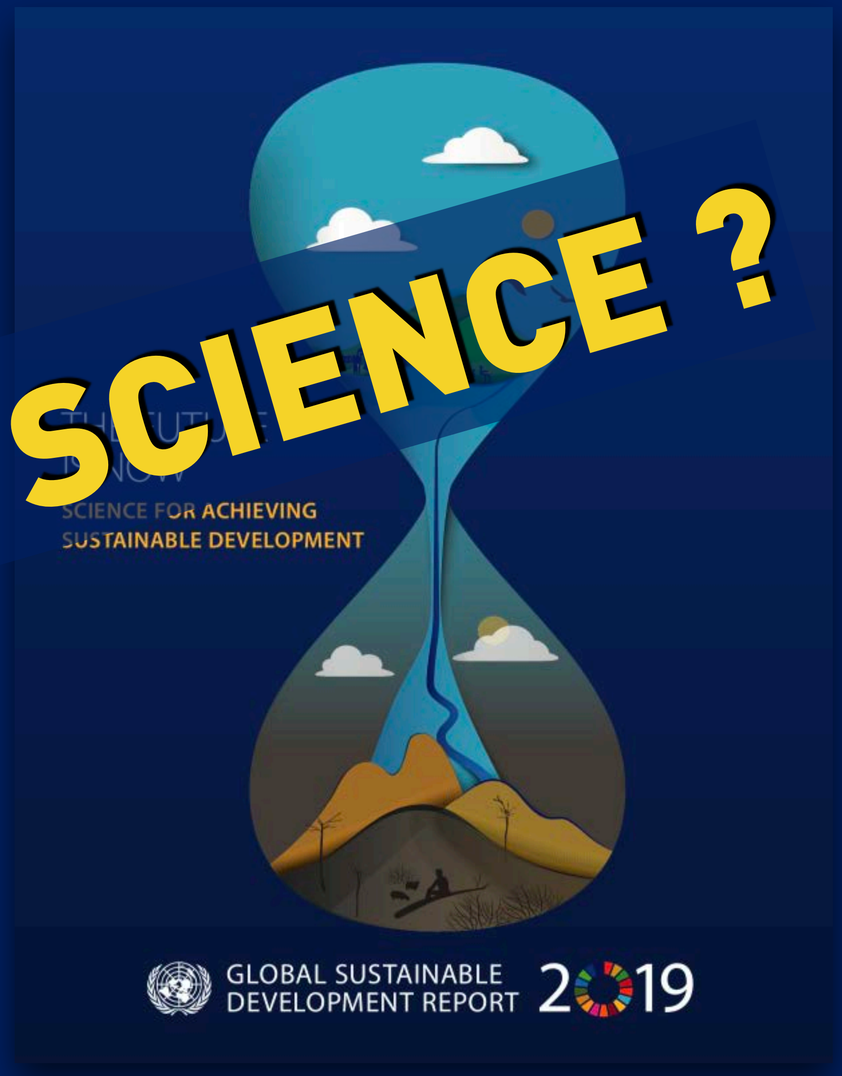
**BUT WHAT KIND OF SCIENCE ?**

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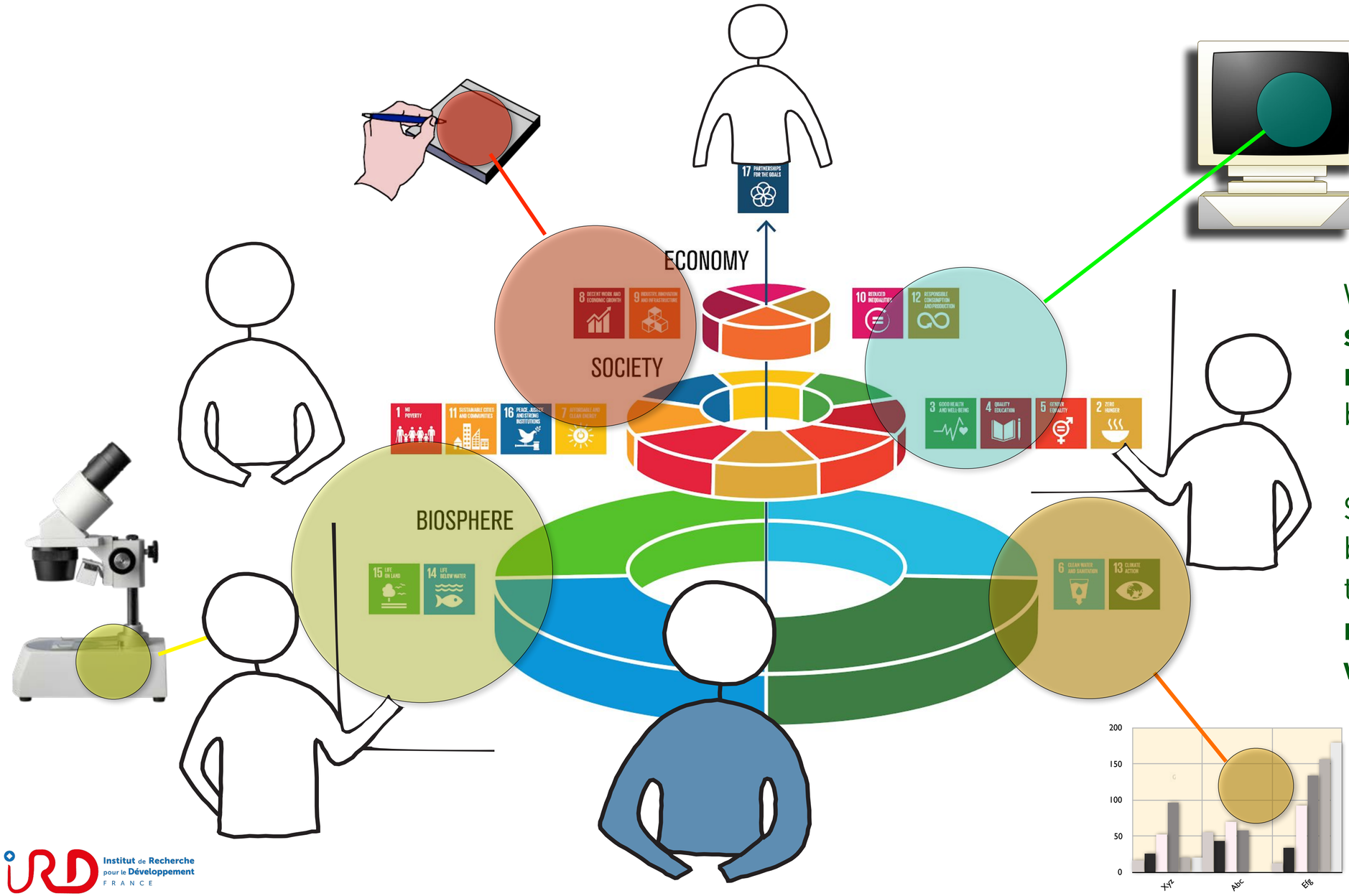
# SUSTAINABLE DEVELOPMENT ISSUES ARE INTERDISCIPLINARY BY NATURE

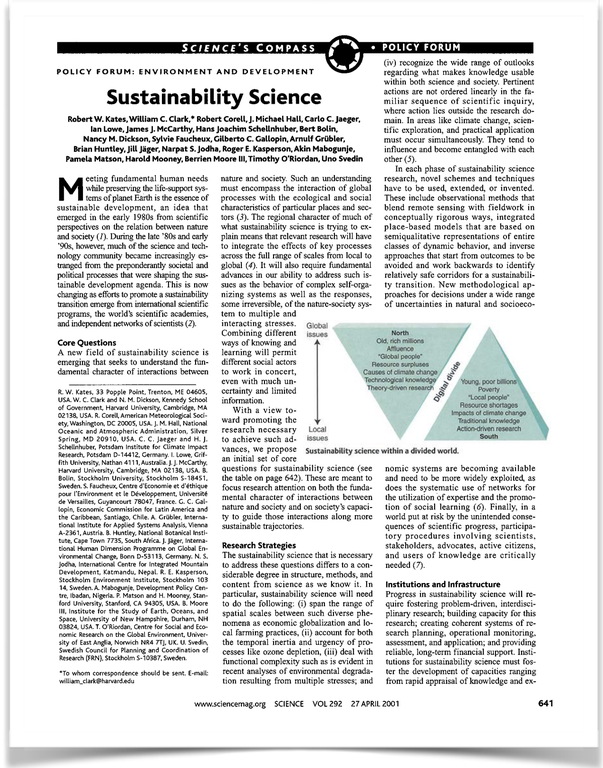



What needs to be studied are **social transformations in relation to material limits** in the biosphere.

Sustainability is a complex field – best understood and explained through **interdisciplinary research in close collaboration with society.**

# PROPOSAL OF *SUSTAINABILITY SCIENCE* IN 2001

- The idea of 'a' sustainability science was broadly introduced with the seminal Science article by Kates and colleagues in which they defined core questions for this emerging research field.

SCIENCE'S COMPASS • POLICY FORUM

POLICY FORUM: ENVIRONMENT AND DEVELOPMENT

## Sustainability Science


Robert W. Kates, William C. Clark,* Robert Corell, J. Michael Hall, Carlo C. Jaeger, Ian Lowe, James J. McCarthy, Hans Joachim Schellnhuber, Bert Bolin, Nancy M. Dickson, Sylvie Faucheux, Gilberto C. Gallopin, Arnulf Grübler, Brian Huntley, Jill Jäger, Narpat S. Jodha, Roger E. Kasperson, Akin Mabogunje, Pamela Matson, Harold Mooney, Berrien Moore III, Timothy O'Riordan, Uno Svedin


Meeting fundamental human needs while preserving the life-support systems of planet Earth is the essence of sustainable development, an idea that emerged in the early 1980s from scientific perspectives on the relation between nature and society (*1*). During the late '80s and early '90s, however, much of the science and technology community became increasingly estranged from the preponderantly societal and political processes that were shaping the sustainable development agenda. This is now changing as efforts to promote a sustainability transition emerge from international scientific programs, the world's scientific academies, and independent networks of scientists (*2*).

### Core Questions

A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. Such an understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors (*3*). The regional character of much of what sustainability science is trying to explain means that relevant research will have to integrate the effects of key processes across the full range of scales from local to global (*4*). It will also require fundamental advances in our ability to address such issues as the behavior of complex self-organizing systems as well as the responses, some irreversible, of the nature-society system to multiple and interacting stresses. Combining different ways of knowing and learning will permit different social actors to work in concert, even with much uncertainty and limited information.

With a view toward promoting the research necessary to achieve such advances, we propose an initial set of core questions for sustainability science (see the table on page 642). These are meant to focus research attention on both the fundamental character of interactions between nature and society and on society's capacity to guide those interactions along more sustainable trajectories.

### Research Strategies

The sustainability science that is necessary to address these questions differs to a considerable degree in structure, methods, and content from science as we know it. In particular, sustainability science will need to do the following: (i) span the range of spatial scales between such diverse phenomena as economic globalization and local farming practices, (ii) account for both the temporal inertia and urgency of processes like ozone depletion, (iii) deal with functional complexity such as is evident in recent analyses of environmental degradation resulting from multiple stresses; and (iv) recognize the wide range of outlooks regarding what makes knowledge usable within both science and society. Pertinent actions are not ordered linearly in the familiar sequence of scientific inquiry, where action lies outside the research domain. In areas like climate change, scientific exploration, and practical application must occur simultaneously. They tend to influence and become entangled with each other (*5*).

In each phase of sustainability science research, novel schemes and techniques have to be used, extended, or invented. These include observational methods that blend remote sensing with fieldwork in conceptually rigorous ways, integrated place-based models that are based on semiqualitative representations of entire classes of dynamic behavior, and inverse approaches that start from outcomes to be avoided and work backwards to identify relatively safe corridors for a sustainability transition. New methodological approaches for decisions under a wide range of uncertainties in natural and socioeconomic systems are becoming available and need to be more widely exploited, as does the systematic use of networks for the utilization of expertise and the promotion of social learning (*6*). Finally, in a world put at risk by the unintended consequences of scientific progress, participatory procedures involving scientists, stakeholders, advocates, active citizens, and users of knowledge are critically needed (*7*).




Sustainability science within a divided world.

### Institutions and Infrastructure

Progress in sustainability science will require fostering problem-driven, interdisciplinary research; building capacity for this research; creating coherent systems of research planning, operational monitoring, assessment, and application; and providing reliable, long-term financial support. Institutions for sustainability science must foster the development of capacities ranging from rapid appraisal of knowledge and ex-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Kates, R.; Clark, W.; Corell, R.; Hall, J.; Jaeger, C.; et al. (2001). "Sustainability science". *Science*. **292** (5517): 641–642.

# SUSTAINABILITY SCIENCE

… is a **problem-driven, interdisciplinary research domain** that seeks to **facilitate the design, implementation, and evaluation of effective interventions** that **foster shared prosperity and reduced poverty while protecting the environment**. It (…) draws from multiple disciplines of the **natural, social, medical and engineering sciences**, from the professions, and from the knowledge of practice. (Harvard Univ.)

# THE MAIN QUESTIONS OF SUSTAINABILITY SCIENCE WERE (RE)FORMULATED IN 2011

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

COMMENTARY

**What kind of a science is sustainability science?**

Robert W. Kates[1]
*Independent Scholar, Trenton, ME 04605*

Sustainability science, as described by the PNAS website, is "…an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems." Over the past 7 y, PNAS has published over 300 papers in its unique section on sustainability science and has received and reviewed submissions for many hundreds more. What kind of a science is sustainability science?

The article by Bettencourt and Kaur (1) on the evolution and structure of sustainability science provides one answer. It confirms this characterization of an emerging field of research, plots its extraordinary growth over time, identifies its geographical locations and contributing disciplines, and measures its cohesion as a unified science. As such, it places the PNAS effort in long-term perspective, discovers for sustainability science a very different field structure than for most sciences, and argues for its unification in an exceptional collaborative network.

The authors begin with assembling a huge database of scientific publications in English written between 1974 and 2010 that contain the words "sustainability" and/or "sustainable development" in their title, abstract, or key words. The base contains about 20,000 papers, authored by about 37,000 authors found in 174 countries and in 2,200 cities. The ability to create and analyze very large datasets has opened new possibilities in many fields, as explored in a recent special feature of *Science* (2).

The publications themselves are quite varied, as shown in the word cloud of bigrams (figure S3 in ref. 1 reproduced below as Fig. 1). The database, although surely a major achievement, is probably not equivalent to sustainability science, given the nature of the word search. Researchers in the field might argue that all sustainability science publications should contain integrated research and not include papers that only offer perspectives, frame issues, or advocate policies, and some research articles do not contain the word "sustainability" or "sustainable development."

Plotted against time (figure 1 in ref. 1), sustainability articles grow rapidly beginning in the 1990s and are doubling about every 8 y. However, perhaps the most impressive thing about the very large number of papers and authors is where they were written and the disciplines from which they were drawn. Sustainability science, as represented by the authors' addresses and institutions, is widely distributed and includes many authors beyond the normal concentration in such centers of traditional science as Japan, the United States, and Western Europe. These include almost all the emerging BRICS (Brazil, Russia, India, China, South Africa) economies but also such developing countries as Kenya and Nigeria. Home cities and institutions for papers also differ from traditional centers, with many originating in political centers (e.g., Beijing, Canberra, London, Tokyo, Washington) and in much more varied institutions, including corporate laboratories, government, and non-governmental organizations, as well as universities large and small.

Sustainability science, as reflected in the disciplinary classification of the journals in which the papers were published, is also extraordinarily multidisciplinary, spanning the natural, social, and technological sciences, with a third of the papers appearing in social science journals, a quarter in biological journals, and a fifth in engineering journals. Finally, in the judgment of Bettencourt and Kaur (1), using network analysis of coauthorship, sustainability science unifies around the year 2000, with most scholars and places connected with links of authorship.

Bettencourt (with affiliations in applied mathematics) and Kaur (with affiliations in informatics) are outsiders to sustainability science. Their study of the evolution and structure of sustainability science began as a complement to their other studies of the evolution of new research fields in physics and biology (e.g., cosmic strings, H5N1 influenza, prions, quantum computing) (3). I am a sustainability science insider, having cochaired with William Clark the National Research Council study (4) that was among the early promoters of sustainability science; taken part in a series of international meetings that elicited views on the nature of and needs for sustainability science around the world (5); and, most recently, completed an electronic *Readings in Sustainability Science and Technology* (6). As an insider, I found myself highly stimulated by the study by Bettencourt and Kaur (1), but I can also add some significant dimensions of sustainability science not captured by their bibliometric analysis.

One such dimension is the balance in sustainable development papers between those that emphasize research on environment and those that emphasize research on development. Most insiders I know have backgrounds originally in the environmental sciences, and their research topics often reflect this despite their commitment to a science of both environment and development. In an analysis of titles of 232 research papers in the sustainability section of PNAS, 62% had a major focus on sustaining environmental life support systems, as contrasted with 38% that primarily addressed human well-being and a few that addressed poverty alleviation (7).

Another major dimension in sustainability science is the emergence of academic fields of study in a number of countries with concentrations, majors, and graduate degrees in sustainability science. It is possible to get a doctorate or master's degree in sustainability science, sustainable development, interdisciplinary environmental science/studies with a focus on sustainability, or specific disciplines with programs in sustainability. The Association for the Advancement of Sustainability in Higher Education Web site lists eight doctorate programs and 41 master's degree programs.

The evolution and structure paper also leads me to question one of our insider assumptions as to the relative importance of the international initiatives and publications in launching the field. In our insider story, sustainable development emerged in the early 1980s from scientific perspectives on the interdependence of society and environment (8). It entered the high political agenda through the publication by the Brundtland-led World Commission on Environment and Development (1983–1987) report, *Our Common Future* (9) and the subsequent United Nations Conference on Environment and Development held in Rio de Janeiro in 1992. Although a great political success, many scientists found it difficult both to conceptualize and to measure sustainable development and make it a subject of scientific inquiry. To assist, the US National Academy of

Author contributions: R.W.K. wrote the paper.
The author declares no conflict of interest.
See companion article on page 19560.
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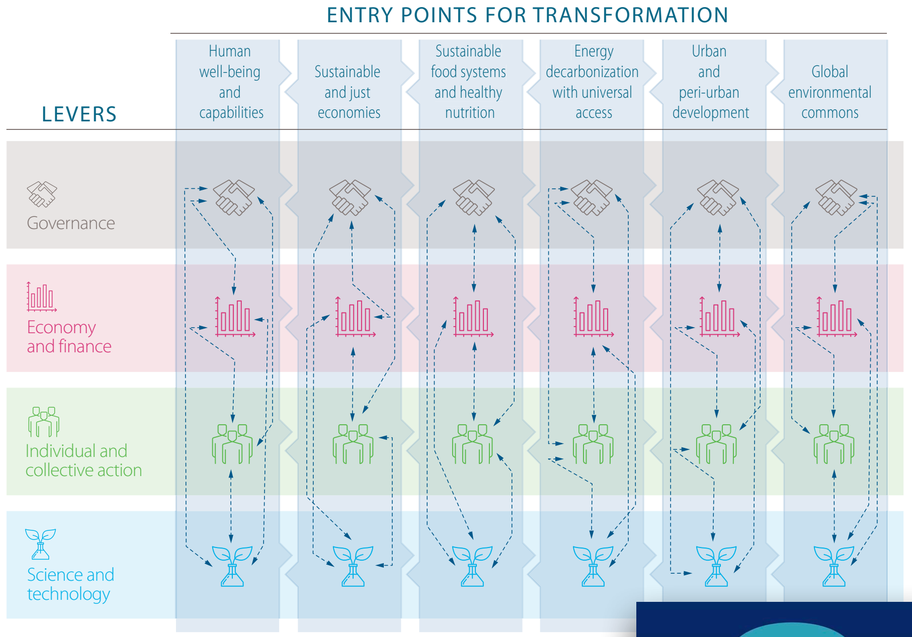
Kates, R. (2011) "What kind of a science is sustainability science?" *PNAS*, **108** (49)

# AND ITS MOST URGENT TARGETS (OR ENTRY POINTS) WERE (RE)LISTED IN 2019

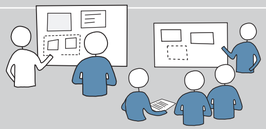
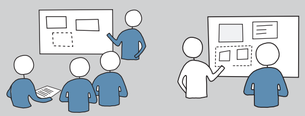
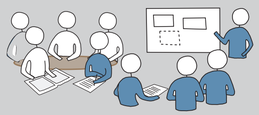
Sustainability science should cooperate with other levers (governance, economy, social action) to support **6 targets:**

1. **Strengthening** human well-being and capabilities
2. **Shifting** towards sustainable and fair economies
3. **Building** sustainable food systems and nutrition patterns
4. **Achieving** energy decarbonisation with universal access
5. **Promoting** sustainable urban and peri-urban development
6. **Sustaining** global environmental commons.




Messerli, P., Kim, E.M., Lutz, W. *et al.* ”Expansion of sustainability science needed for the SDGs”. *Nat Sustain* **2,** 892–894 (2019)

# THE MATRIX OF QUESTIONS X TARGETS PROVIDES THE FRAMEWORK OF SUSTAINABILITY SCIENCE TODAY

| HES = human-environment systems | Strengthening human well-being and capabilities | Shifting towards sustainable and fair economies | Building sustainable food systems and nutrition patterns | Achieving energy decarbonisation with universal access | Promoting sustainable urban and peri-urban development | Sustaining global environmental commons |
|---|---|---|---|---|---|---|
| What shapes long-term trends and transitions of HES ? |  |  |  |  |  | |
| What determines adaptability, vulnerability, resilience of HES? |  |  |  |  |  |  |
| How can models account for variations in interactions within HES ? |  |  |  |  |  |  |
| What are the tradeoffs between human well-being and the natural environment? |  |  |  |  |  |  |
| Can “limits” be defined that would provide warning for HES? |  |  |  |  |  |  |
| How can society manage HES toward a sustainability transition? |  |  |  |  |  |  |
| How can the “sustainability” of alternative pathways of development be evaluated? |  |  |  |  |  |  |

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Each cell represents a set of complex issues, to which sustainability science contributes, using a variety of scientific tools and methods, by allowing stakeholders (incl. researchers):

**1. to develop a common view about the scope of the problem,**

**2. to elaborate a shared long-term vision for the future**

**3. to explore the possible pathways to achieve that vision**

Sustainability science can contribute both an approach to dealing with these challenges and support for decisions and implementation.

1. What does it mean to take sustainable development into account in our research activities ?
2. What does it change in our ways to **conduct** scientific research ?
3. What does it change in our ways to **organise** research ?
4. How do French and Vietnamese institutions handle this new research domain ?