COMMUNITY ESSAY

Sustainability: science or fiction?

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Author's Personal Statement:

It is clear that in making the concept of sustainable development concrete, one has to take into account a number of practical elements and obstacles. There is little doubt that integrated approaches are required to support sustainable development. Therefore, a new research paradigm is needed that is better able to reflect the complexity and the multidimensional character of sustainable development. The new paradigm, referred to as sustainability science, must be able to encompass different magnitudes of scales (of time, space, and function), multiple balances (dynamics), multiple actors (interests) and multiple failures (systemic faults). I also think that sustainability science has to play a major role in the integration of different styles of knowledge creation in order to bridge the gulf between science, practice, and politics—which is central to successfully moving the new paradigm forward.

What is Sustainable Development?

The essence of sustainable development is simply this: to provide for the fundamental needs of humankind without doing violence to the natural system of life on earth. This idea arose in the early 1980s and came out of a scientific look at the relationship between nature and society. The concept of sustainable development reflected the struggle of the world population for peace, freedom, better living conditions, and a healthy environment (NRC, 1999). During the latter half of the 20th century, these four goals recurred regularly as worldwide, basic ideals.

With the end of World War II in 1945, it was widely believed that the first goal of peace had actually been achieved. But then came the arms race and, although a kind of global peace was maintained, the Cold War led to a range of conflicts fought out at the local level. When one looks today at many parts of the world—the Middle East and Central Africa for example—it is all too evident that peace is still a long way off.

Under the banner of freedom, people fought for the extension of human rights and for national independence. Today, the poorest two thirds of the world population see "development" as the most important goal, by means of which they hope to achieve the same material well-being as the wealthy one third.

But this ideal, upon which so much emphasis has been laid recently, has to reckon with the earth itself. This reckoning began with concern about the exhaustion of our natural resources and only later did it dawn on us that a disturbance of the complex systems upon which our lives depend can have enormous consequences.

The last 25 years have been characterized by an attempt to link together the four ideals cited above—peace, freedom, improved living conditions, and a healthy environment (NRC, 1999), an ambition that stems from the realization that striving for one of these principles often means that we must strive for the others as well. This struggle for "sustainable development" is one of the great challenges for today's society.

Sustainable development is a complex idea that can neither be unequivocally described nor simply applied. There are scores of different definitions, but we shall restrict ourselves to the most frequently quoted, that of the Brundtland Commission (WCED, 1987): "Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs."

If we look at the lowest common denominator of the different definitions and interpretations of sustainable development, it is possible to identify four common characteristics (Grosskurth & Rotmans, 2005). The first indicates that sustainable development is an *intergenerational* phenomenon: It is a process of transference from one to another generation. In other words, if we wish to say anything meaningful about sustainable development, we have to take into account a time span of at least two generations. The time period appropriate to sustainable development is thus around 25 to 50 years.

The second common characteristic is the *level of scale*. Sustainable development is a process played out on several levels, ranging from the global to the regional and the local. What may be seen as sustainable at the national level, however, is not necessarily sustainable at an international level. This geographic incompatibility is due to shunting mechanisms, as a result of which negative consequences for a particular country or region are moved to other countries or regions.

The third common characteristic is that of *multiple domains*. Sustainable development consists of at least three: the economic, the ecological, and the socio-cultural domains. Although sustainable development can be defined in terms of each of these domains alone, the significance of the concept lies precisely in the interrelation among them.

The aim of sustainable social development is to influence the development of people and societies in such a way that justice, living conditions, and health play an important role. In sustainable ecological development the controlled use and protection of natural systems is the main focus of concern and the maintenance of our natural resources is of primary importance. In sustainable economic development, the focus is on the development of the economic infrastructure and on an efficient management of natural and social resources.

At issue here are three aspects of sustainable development that in theory need not conflict, but that often do in practice. The underlying principles are also essentially different: with sustainable economic development efficiency has a primary role, whereas with sustainable social development the same may be said of justice, and with sustainable ecological development resilience or capacity for recovery is primary.

The fourth common characteristic concerns the *multiple interpretations* of sustainable development. Each definition demands a projection of current and future social needs and how these can be provided for. However, no such estimate can be really objective and, furthermore, any such estimate is inevitably surrounded by uncertainties. As a consequence, the idea of sustainable development can be interpreted and applied from a variety of perspectives.

As is apparent from the above discussion, a concept such as sustainable development is difficult to pin down. Because it is by its nature complex, normative, subjective, and ambiguous, it has been criticized both from a social and from a scientific point of view. One way of escaping from the "sustainability dilemma" is to begin from the opposite position: that of *non*-sustainable development. Non-sustainable, or unsustainable, development is only too visible in a number of intractable problems entrenched in our social systems and that cannot be solved through current policies. These obdurate problems are characterized by the involvement of multiple interests, as well as by their great complexity, lack of structure, structural uncertainty, and apparent uncontrollability.

Such problems can be recognized in many national and global economic sectors. One sees them in agriculture, for example, with its many facets of unsustainability becoming manifest in the form of protein-related diseases such as BSE (mad cow disease) and in foot-and-mouth disease. The water sector has to deal with such symptoms as flooding, droughts, and water quality problems, while the energy sector performs in a one-sided manner and—as a direct result—harms the environment. One sees the same symptoms in traffic and transport systems where atmospheric pollution and congestion are symptoms of unsustainability. As far as our health is concerned, the spread of severe acute respiratory syndrome (SARS) and the global increase in malaria, as well as malnutrition and its counterpart obesity, are all far from sustainable.

These unsustainable developments reflect systemic faults embedded in our society. In contrast to market faults, systemic faults derive from deep-seated deficiencies or imbalances in society. They cannot be corrected through the "market" and form a serious impediment to the optimal functioning of our social system. Systemic faults operate at various levels and can be of economic, social, or institutional in nature. If such intractable problems are a sign of an unsustainable development, they can only be solved through fundamental changes in our society. Only thus can non-sustainable conditions be transformed and put on a more sustainable basis.

Sustainability Science: A New Paradigm

It is clear that in making the concept of sustainable development concrete, one has to take into account a number of practical elements and obstacles. Thus there is little doubt that integrated approaches are needed to support sustainable development. Questions as to exactly how such integration—underpinned by the right research—should be conceived and put into effect have so far been the preserve of a select group.

On a global scale, great progress has been achieved, within the framework of the international "global change" research program, in the integration of previously separated disciplines. Fifteen years ago, atmospheric chemists and biologists were not sharing the knowledge emerging from their studies of atmospheric change—despite the fact that biological processes are an important factor in regulating the composition of the atmosphere. Nor was either discipline well integrated with atmospheric physics, oceanography, or climatology. Today these disciplines are much more closely linked and together, on the basis of integrated research and risk analysis, they form the core of our knowledge about global climate change.

The international research community that is concerned with global change has thus made huge progress in coupling the various relevant natural sciences. Unfortunately, however, despite great national and international commitment, there has been far less progress in understanding the interactions between humankind and environment.

To realize the high level of expectations, a new research paradigm is needed that is better able to reflect the complexity and the multidimensional character of sustainable development. The new paradigm must be able to encompass different magnitudes of scales (of time, space, and function), multiple balances (dynamics), multiple actors (interests) and multiple failures (systemic faults).

This new paradigm emerges from a scientific sub-current that characterizes the evolution of science in general—a shift from mode-1 to mode-2 science (see Table 1) (Gibbons, 1994). Mode-1 science is completely academic in nature, monodisciplinary and the scientists themselves are mainly responsible for their own professional performance. In mode-2 science, which is at core both inter- and intra-disciplinary, the scientists are part of a heterogeneous network. Their scientific tasks are components of an extensive process of knowledge production and they are also responsible for more than merely scientific production.

Another paradigm that is gaining increasing influence is what is known as post-normal science (Funtowicz & Ravetz, 1993). It is impossible to eradicate uncertainty from decision-making processes, and therefore it must be adequately managed through organized participatory processes in which different kinds of knowledge—not only scientific knowledge—come into play. As a result, those making policy need to be as well informed as possible about complex social problems of major importance.

Table 1 Properties of mode-1 and mode-2 science

Mode-1 science	Mode-2 science
Academic	Academic and social
Mono-disciplinary	Trans- and interdisciplinary
Technocratic	Participative
Certain	Uncertain
Predictive	Exploratory

The research program that is beginning to emerge from this movement is known as "Sustainability Science" (Kates et al. 2001). The virtual Forum on Science and Technology for Sustainability (http://sust.harvard.edu) is at the moment one of the motors behind this initiative. Sustainability science, however, is not an independent profession, let alone a discipline. It is rather a vital area in which science, practice, and visions of North and South meet one another, with contributions from the whole spectrum of the natural sciences, economics, and social sciences. Sustainability is characterized by a number of shared research principles. "Shared" here implies a broad recognition by a growing group of people who—in a steadily extending network—are active in the area of sustainability science. The central elements of sustainability science are:

- inter- and intra-disciplinary research
- co-production of knowledge
- co-evolution of a complex system and its environment
- learning through doing and doing through learning
- system innovation instead of system optimization

Simply stated, this new model can be represented as *co-evolution*, *co-production*, and *co-learning*. The theory of complex systems can be employed as an umbrella mechanism to bring together the various parts of the sustainability puzzle.

Integrated Analysis of Sustainability

This new paradigm has far-reaching consequences for the methods and techniques that need to be developed before an integrated analysis of sustainability can be carried out. These novel methods and techniques can be characterized as follows:

- from supply-driven to demand-driven
- from technocratic to participant
- from objective to subjective
- from predictive to exploratory
- from certain to uncertain

In short, the character of our instruments of integrated analysis is changing. While previous generations of these instruments were construed as "truth machines," the current and future generations will be seen more as heuristic instruments, as aids in the acquisition of better insight into complex problems of sustainability. At each stage in the research of sustainability science, new methods and techniques will need to be used, extended, or invented. The methodologies that are used and developed in the integrated assessment community are highly suitable for this purpose (Rotmans, 1998; Van Asselt & Rijkens-Klomp, 2002).

Generally speaking, there are a number of different approaches for the integrated assessment of sustainability: analytic methods, participative methods, and more managerial methods. Analytic methods mainly look at the nature of sustainable development, employing among other approaches, the theory of complexity. In participative research approaches, non-scientists such as policy-makers, representatives from the business world, social organizations, and citizens also play an active role. The more managerial methods are used to investigate the policy aspects and the controllability of sustainable transitions.

An example of an analytic instrument for the assessment of sustainability is the integrated assessment model that allows one to describe and explain changes between periods of dynamic balance. This model consists of a system-dynamic representation of the driving forces, system changes, consequences, feedbacks, and potential lock-ins and lock-outs of a particular development in a specific area. Another analytic instrument is the scenario that describes sustainable and unsustainable developments, including unexpected events, changes, and lines of fracture.

Participatory methods differ according to the aim of the study and its participants. Thus negotiation processes are mimicked in so-called policy exercises, whether or not these are supported by simulations. In the method of mutual learning, the analysis is enriched by the integration of the knowledge possessed by participants from diverse areas of expertise.

An example of a new kind of policy instrument is provided by transition management (Rotmans et al. 2001; Kemp & Rotmans, 2004). Transition management is a visionary, evolutionary learning process that is progressively constructed by undertaking following the steps:

1. Develop a long-term vision of sustainable development and a common agenda (macro-scale)
2. Formulate and execute a local experiment in renewal that could perhaps contribute to the transition to sustainability (micro-scale)
3. Evaluate and learn from these experiments
4. Assemble the vision and the strategy for sustainability based on what has been learned (this boils down to a cyclical "search and learn" process that one might call evolutionary steering). This approach constitutes a new kind of planning with understanding that is predicated upon learning through doing and doing through learning.

Now that the first steps toward an integrated sustainability science have been taken, there is a prospect of making some major leaps forward.

Toward a Strategy for Sustainable Development

Breaking Down the Barriers

A research framework for sustainability science will need to be further built on existing sciences and scientific programs. I have also shown that the principal opportunities and policies for transitions to sustainability are multiple, cumulative, and interactive. We need more breadth and depth, however, before we can study the sustainability of the interaction between the planet and its ecosystems and peoples.

It should be clear that sustainability science will have to be above all an integrative science, a science that sets out to break down the barriers that divide the traditional sciences. It will have to promote the integration among such different scientific disciplines as economics, earth sciences, biology, social sciences, and technology.

The same can be said for sectoral approaches in which such closely linked aspects of human activity as energy, agriculture, health, and transport are still addressed as separate subjects.

The most significant threats to sustainability appear in certain regions, with their specific social and ecological characteristics. In fact, a sustainable transition will often have to occur within the local surroundings. However, sustainability science will need to promote integration on a larger geographical scale to get beyond the often common, but ultimately artificial, division between global and local perspectives. Regardless of what spatial scale is found most suitable for the investigation of any particular sustainability issues, gaining insight into the linkages between events on both the macro and the micro scale is one of the major challenges facing sustainability science.

Finally, sustainability science must ensure the integration of different styles of knowledge creation to bridge the gulf across science, practice, and politics.

Sustainable Policy

If we look at the consequences of this new vision of sustainability for policy, we can note the following. It is important for policy-makers—both in politics and in the business community—that specific policy aims, along with their associated time limits, are clearly determined. Several possibilities are shown in Figure 1. One of the options the policy-maker has—and this is not so far from the current situation—is to go for short-term goals and simple or cheap means of achieving them. In contrast to such an approach, a more pro-active, innovative standpoint can be adopted that pursues longer-term goals, taking into account developments on different levels of scale and in different sectors. Unquestionably, sustainable development demands the latter approach.

To facilitate decision making, sustainability scientists must assist in the task of making concrete both problems and solutions on all relevant temporal and spatial scales. This means that sustainability at the systemic level must be assessed, bringing to bear the following procedural elements: *analysis* of deeper-lying structures of the system, *projection into the future*, and *assessment* of sustainable and unsustainable trends. *Evaluation* of the effects of sustainable policy and the *design* of possible solutions through sustainable strategies also belong here.

Fortunately, integrated approaches to sustainability issues in such areas as environment and development are not entirely new. For example, research has already been carried out into the interactions between urban, rural, industrial, and natural ecosystems to gain more insight into policy implications for the management of water. The search for integrated theories that combine different disciplinary strengths is an excellent way of creating a better basis for decision making on sustainability.

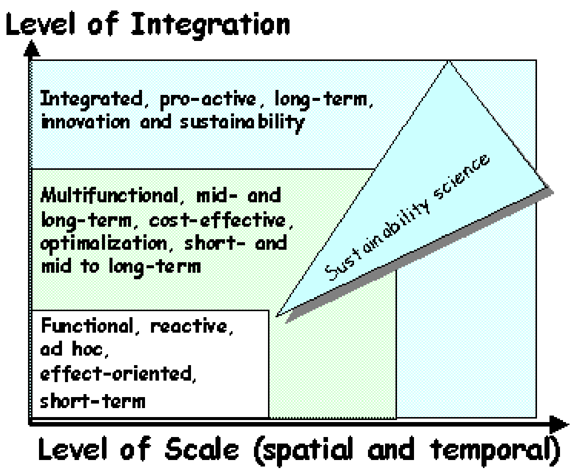

Figure 1. The role of sustainability science in the policy process

Sustainable Education

It will hardly come as a surprise to hear that the development of a healthy, just, and sustainable society demands a major shift in our thinking, our values, and our actions.

Today's students will be the business leaders, scientific researchers, politicians, artists, and citizens of tomorrow. The extent to which they will be prepared to make decisions in favor of a sustainable future depends on the awareness, knowledge, expertise, and values they have acquired during their studies and in the subsequent years. For this reason, the concepts and themes of sustainability should be integrated into all levels of education. Curricula must be revised so that sustainable development forms a guiding principle throughout the entire period of their studies—and afterwards too (see Orr, 1992). With an increasingly widespread awareness of this need, the United Nations has now proclaimed the coming decade as the "Decade of Education for Sustainable Development."

The basic qualities that future sustainability scientists will need are: analytical insight, problem-solving competence, and good skills in both verbal and written presentation. No less important is knowledge of the diversity of instruments provided by the various disciplines involved, ranging from mathematics to history, from health sciences to economics. The range of skills needed is so wide that it can only be acquired through interdisciplinary study.

Another essential quality is the capacity to break down the barriers referred to earlier among the various scientific disciplines involved, policy-makers, and citizens. And, last but by no means least, there is a need to devote great attention to the philosophy and the ethics that underpin sustainability science. At the present moment, however, there is a manifest lack in sustainability science of both fundamental and applied "research capacity." In addition, there is a need for a greater diversity of approaches. It is essential, therefore, that in the coming decades we put everything into the effort to build up this extra capacity in both the northern and the southern hemispheres.

Conclusion

Richard Feynman, one of the greatest physicists of the last century, once remarked: "Whoever says that he understands quantum theory, in all probability does not." The same is true of sustainable development. Whoever says he knows what "sustainability" is, in all probability does not. In a certain sense, a sustainable world is a fiction.

Thus, the concept of sustainable development does not contemplate any statistical state of affairs or finite stocks, but rather emphasizes a positive evolution and positive lines of development. Sustainable development can, in fact, be described as "the capacity of a society to move itself, in a certain time period, between satisfactory, adaptable and viable conditions" (Giampietro, 2003).

As I have tried to explain above, however, it is actually possible to lay a scientific foundation under this concept of sustainable development. And further, this can be given a practical content that can vary from sustainable health to the sustainable use of our oceans and rivers, from sustainable tourism to sustainable enterprise and sustainable regional development.

Those in other sections of society such as the business community must also be encouraged to take responsibility for a sustainable future. They must be mobilized so that they will actively participate in giving shape to sustainable development. Such a broad social front will be a necessary condition for making the abstract term "sustainable development" both concrete and achievable.

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