

## **Institutional Needs for Sustainability Science**

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### **Abstract**

In this paper, I summarize 3 years of intensive consultation among members of the world's scientific community on the question of how science and technology could be more effectively harnessed to meet the goals of sustainable development. I begin with a review of the historical roots of the sustainability science movement and characterize the R&D agenda that has begun to emerge from that movement. I then turn to the question of how the institutions governing the S&T enterprise would need to change in order to support sustainability science at a scale commensurate with the challenges before us. I place particular emphasis on questions of mobilizing solution-driven R&D, facilitating integration across disciplines, capacity building, and financing.

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## **Institutional Needs for Sustainability Science<sup>1</sup>**

“How can science and technology contribute more effectively to achieving society’s goals of sustainable development?” Over the last three years, organizations representing the world’s science and technology communities conducted more than a dozen fact-finding studies, discussions, conferences, and workshops that addressed this question from a wide range of perspectives. One common theme of those deliberations was how the institutions that govern science and technology would need to be reformed as part of a larger process for realizing the potential of S&T to promote sustainable development around the world. The present paper attempts to draw together some of the more widely shared findings and conclusions of those efforts, and to connect them with a longer tradition of debate on the role of international science in sustainability going back to at least the Stockholm Conference on the Human Environment. Its goal is to provide background for the Workshop on "Governance and Science for Sustainability," hosted by the University of East Anglia in the context of the Third International "Sustainability Days" in September 2003.

### **Science, technology and sustainable development**

Sustainability concerns have occupied a place on the global agenda since at least the 1980s, with publication of the International Union for the Conservation of Nature’s (IUCN) *World Conservation Strategy* and the Brundtland Commission’s report *Our Common Future*.<sup>2</sup> The prominence of that place has been rising, however. UN Secretary-General Kofi Annan reflected a growing consensus when he wrote in his Millennium Report to the General Assembly that “Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet” are the three grand challenges facing the international community at the dawn of the 21<sup>st</sup> century.<sup>3</sup> Sustainability has become a “high table” issue in international affairs, and on many regional, national, and local agendas.

Science and technology are increasingly recognized to be central to both the origins of Secretary-General Annan’s three challenges, and to the prospects for successfully dealing with them.<sup>4</sup> Science and technology brought us the CFCs that preserved our foods, cooled our homes... and depleted the ozone layer. But they also brought us the research and monitoring programs that raised the ozone alarm, and the substitute technologies that have allowed us to continue meeting the needs that CFCs have fulfilled in a manner less damaging to the environment. Science and technology have also played a central role in bringing about the increases in agricultural yields and distribution systems that have helped to keep most of the world from famine... but only at the cost of significant environmental degradation. Promoting transitions toward sustainability in the 21<sup>st</sup> century will require much more than improvements in the production and effective use of science and technology. But no serious analysis has suggested that it will be possible to meet the sustainable development challenge without intelligent and effective use of science and technology to do the job.

Despite the importance of achieving sustainability, and the centrality of science and technology to strategies for doing so, a great imbalance exists in the resources and attention devoted to harnessing science and technology in the service of Secretary-General Annan's three transcendent goals.<sup>5</sup> Efforts to achieve "freedom from fear" are supported by a mature, well-funded, problem-driven R&D system based in the world's military establishments. Efforts to achieve "freedom from want" have created and been supported by several effective R&D systems, for example those engaged in international agricultural research and in certain global disease campaigns. In contrast, efforts to achieve sustainability are relatively new because, in the words of the Secretary-General, the "founders of the UN could not imagine that we would be capable of threatening the very foundations for our existence."<sup>6</sup> As a result, efforts to harness science and technology for sustainability have largely had to draw on R&D systems built for other purposes – begging monitoring data from the world's military establishment, piggy-backing on the already over-extended international agricultural research system, and borrowing insights gained from basic research programs on global environmental change. With a few important but relatively small and under-funded exceptions, efforts to "sustain the lives of future generations on this planet" still lack dedicated, problem-driven R&D systems of anything like the scale or maturity of those devoted to security and development per se.

Calls for strengthening the institutional foundations of S&T programs targeted on sustainable development built slowly during the 1990s following the UN Conference on Environment and Development (UNCED) in Rio. Many of the earliest and most thoughtful contributions to this discourse came from the developing world through the work of individual scholars and of institutions such as the Third World Network of Scientific Organizations (TWNISO), the Commission on Science and Technology for Sustainable Development in the South (COMSATS), the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), and the South Center.<sup>7</sup> A further regional perspective was provided by the African Academy's *Millennial Perspective on Science, Technology and Development*.<sup>8</sup> European thinking of the late 1990s was exemplified in Schellnhuber and Wenzel's *Earth Systems Analysis: Integrating Science for Sustainability*, the European Union's *Fifth Framework Programme*, and a special issue on "Sustainability Science" published by the *International Journal of Sustainable Development*.<sup>9</sup> A number of national academies of science or other advisory bodies – including those of Brazil, Germany, Japan, the United Kingdom, and the United States also addressed the links between sustainability and global change.<sup>10</sup> Many of these perspectives were brought together in UNESCO's *World Conference on Science for the 21st Century*, held in Budapest in 1999.<sup>11</sup>

With the turn of the Millennium, discussions on science, technology and sustainability intensified significantly. On the political side, impetus was provided by the World Summit on Sustainable Development (WSSD) in August 2002. In the policy arena, international environmental assessments were increasingly called on to address sustainability issues.<sup>12</sup> And on the scientific side, national and international stock-taking on the first decade of global environmental change research and planning for the decade ahead provided additional opportunities for rethinking the relationships among science,

technology and sustainability.<sup>13</sup> As part of this increased attention, during the last three years organizations representing the international scientific and technology communities conducted more than a dozen fact-finding studies, discussions, conferences, and workshops that addressed, inter alia, the question of how institutions governing science and technology can be reformed to contribute more effectively to achieving society's goals of sustainable development.

These “consultations” reflected a wide range of perspectives (see Table 1). The InterAcademy Panel (IAP) of the World's Scientific Academies led the way with a May 2000 symposium on the contributions that science and technology could make to a transition toward sustainability.<sup>14</sup> The Global Change Research Programmes – IGBP, IHDP, WCRP, and Diversitas – made sustainability a focus of their forward-planning efforts at a major Open Science Conference in Amsterdam (July 2001) and a smaller follow-up meeting in Paris (February 2002).<sup>15</sup> The International Council for Science (ICSU) was invited, along with the World Federation of Engineering Organizations (WFEO), by the UN Commission on Sustainable Development (CSD) to serve as the official representative of the scientific and technological community during the preparation for the World Summit. In this capacity ICSU brought together the IAP, the Third World Academy of Sciences (TWAS), and a number of other international scientific organizations in a survey of progress made and lessons learned in efforts to apply science and technology to sustainability since the 1992 Rio Conference.<sup>16</sup> The Initiative on Science and Technology for Sustainability (ISTS) – an ad-hoc, international group of scholars working on problems of environment and development – organized with the Third World Academy a series of global and regional workshops to assess what on-the-ground efforts to promote human well-being while protecting the earth's life support systems most need from science and technology in different parts of the world.<sup>17</sup> Finally, ISTS, TWAS, and ICSU jointly organized a pair of workshops on institutions to harness science to sustainable development (Trieste, February 2002; Cambridge, April 2002)<sup>18</sup> and a synthesis workshop in Mexico City (May 2002) that brought leaders of these various efforts together to produce a consensus statement on science, technology and sustainable development that ICSU carried forth into the World Summit preparatory process.<sup>19</sup>

The present paper attempts to draw together in one place some of the more widely shared findings and conclusions of the last three years' international consultations listed in Table 1, and to connect them with a longer tradition of discussion on the role of international science in sustainability noted above.

## **A Research and Action Agenda for Sustainability Science<sup>20</sup>**

The research and action agenda for sustainability science predates the term itself. Its elements range from the “mundane technologies” that have improved delivery of basic needs for sanitation and cooking,<sup>21</sup> through the yield-enhancing, land-saving accomplishments of the international agricultural research system,<sup>22</sup> to the fundamental scholarship of geographers and anthropologists on nature-society interactions.<sup>23</sup> In more

recent times, a host of R&D efforts explicitly aimed at promoting sustainability have been launched. These extend from a rich tradition of work on energy systems<sup>24</sup> and ecosystem resilience<sup>25</sup> to new initiatives in industrial ecology<sup>26</sup> and earth system complexity.<sup>27</sup> A feel for the breadth and scope of relevant R&D now underway around the world is suggested by the rapidly growing list of entries on the virtual “Forum on Science and Technology for Sustainability,”<sup>28</sup> and a recent Special Issue of the *Proceedings of the National Academy of Sciences of the US*.<sup>29</sup>

Much, however, remains to be done. Perhaps the strongest message to emerge from dialogues induced by the Johannesburg Summit was that the research community needs to complement its historical role in identifying problems of sustainability with a greater willingness to join with the development and other communities to work on practical solutions to those problems. This means bringing our science and technology to bear on the highest priority goals of a sustainability transition, with those goals defined not by scientists alone but rather through a dialogue between scientists and the people engaged in the practice of “meeting human needs while conserving the earth’s life support systems and reducing hunger and poverty.”<sup>30</sup> At the international level, the Johannesburg Summit – building on the UN Millennium Declaration – has defined these priorities in terms of the so-called “WEHAB” targets for water, energy, health, agriculture, and biodiversity.<sup>31,32</sup> As important as this international consensus on goals and targets may be for targeting problem-driven research in support of a sustainability transition, however, it is not sufficient. A joint workshop held by the International Council for Science, the Third World Academy of Science, and the Initiative on Science and Technology for Sustainability concluded that “agenda setting at the global, continental, and even national scale will miss a lot of the most important needs... The transcendent challenge is to help promote the relatively ‘local’ (place- or enterprise-based) dialogues from which meaningful priorities can emerge, and to put in place the local support systems that will allow those priorities to be implemented.”<sup>33</sup> Where such systems exist, the production of usable, place-based knowledge for promoting sustainability has been impressive indeed.

The commitment of sustainability science to problem-driven agenda setting does not mean that it has been confined to “applied” research. Indeed, pursuit of practical solutions to the pressing challenges of sustainability has driven the field to tackle an array of fundamental questions. The Friibergh Workshop on Sustainability Science<sup>34</sup> identified a half dozen such core conceptual questions that have been further developed through the virtual Forum on Science and Technology for Sustainability<sup>35</sup> and are beginning to appear in the context of emerging agendas in other more established fields such as global environmental change.<sup>36</sup> Examples of the new sorts of research now beginning to emerge on several of those core questions is reported in a recent Special Feature of the *Proceedings of National Academy of Sciences of the United States*.<sup>37</sup> The sustainability science program is also beginning to address a range of fundamental observational and methodological challenges.<sup>38,39</sup> And a number of groups are calling for re-examination of national and international social account measures to include sustainability considerations.

In short, activities to advance a program of sustainability science are moving forward on a number of fronts and at scales from the global to the local. Nowhere, however, are these activities taking place at a scale remotely consistent with the magnitude and urgency of the sustainability challenges that face us. To rectify this shortcoming, and bring support for sustainability science to a level commensurate with that already provided for defense and health science will require not merely changes in the agendas of science, but changes in the institutions that govern research and development. It is to the nature of those needed institutional changes that I now turn.

## **Institutions for Sustainability Science**

The institutional initiatives needed to support agendas of S&T for sustainable development follow closely from the reorientations in the practice of science itself suggested earlier. In the previous section the focus was on what S&T professionals would need to *do* in their work to better support social goals of sustainable development. In this section my focus shifts to the institutions that would be necessary to support individual scientists and engineers seeking to carry out such R&D agendas. (Note that “institutions,” as the term has been used in the consultations summarized here, is not synonymous with “organizations.” We follow Young in treating “institutions” as “systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles to the participants in these practices, and guide interactions among occupants of the relevant roles.”<sup>40</sup> “Institutions” thus include organizations, but also norms and expectations within which individual organizations are embedded.)

The last three years of global consultations I am drawing on here made it clear that institutions supportive of the mobilization of science and technology for sustainable development are not impossible to design and implement. At the international level, some relatively successful international programs linking S&T to sustainable development goals have already been developed to address problems ranging from increasing agricultural productivity, to combating human disease, to protecting the earth's ozone layer.<sup>41</sup> Likewise, at the regional level, there already exist efforts such as START's South East Asia Regional Center and IIASA's RAINS assessment for acid rain in Europe that have made a good beginning in implementing integrated, problem-driven, place-based research and applications programs in support of sustainable development.<sup>42</sup> Finally, the workshop on “Harnessing Institutional Synergies for Sustainable Development” organized by the Third World Academy of Sciences highlighted dozens of effective local-level institutions for mobilizing S&T to contribute to the solution of pressing sustainable development problems.<sup>43</sup>

To date, however, these successes reflect idiosyncratic, if invaluable, exceptions rather than general rules. This observation emphasizes the previously noted research need for a systematic and critical effort to learn from both successes and failures of the past lessons that have the most to offer the design of effective institutions for promoting transitions toward sustainability.<sup>44</sup> Such learning will in turn require a determination to move beyond advocacy of existing programs that have been built for other (often excellent)

reasons, toward a critical dialogue about the science and technology strategies most needed to support sustainable development per se. Above all, it will demand a unified campaign by the scientific, engineering, and development communities to build the political support needed to implement – at a scale worthy of the challenges before us – an R&D system for sustainable development.<sup>45</sup>

In the meantime, however, the consultations summarized here – together with the findings of other groups – have highlighted a number of challenges that institutions for harnessing S&T to sustainable development will need to address, and some specific reforms and initiatives that can be justified on the basis of evidence already in hand.

### **Mobilizing the appropriate S&T for sustainable development<sup>46</sup>**

There is a dual challenge here. The first is to assure that the S&T conducted in the name of sustainable development will be focused on the most pressing problems of sustainable development as defined by stakeholders in those problems. Meeting this challenge requires institutions that avoid the pitfalls of R&D agendas set to reflect topics of most concern to donors, or to people selling particular technologies, or to scientists pursuing the latest theoretical developments in their fields. (All of these may be fine things to do, but they are unlikely to address priority needs of sustainable development.)

The second challenge is to assure that the most appropriate S&T is indeed mobilized in the service of particular problems. Meeting this challenge requires institutions that select the most appropriate expertise for the task at hand rather than allowing particularly “favored” disciplines or technologies to monopolize the input of S&T to problem-solving efforts.

Institutions meeting these challenges need to have one foot in the politics of problem definition, responsive to issues of appropriate participation and representation, and the other foot in the world of science and technology, responsive to issues of expertise and quality control. The consultations summarized here suggested that this stressful situation is not generally well dealt with by institutions that spend most of their time doing either pure politics, or pure science. Instead, more success has been had by a variety of “boundary-spanning institutions.” Such institutions set themselves between science and politics, partially responsible to both – but not expected to operate fully by the norms of either. At their best, they facilitate two-way communication, and provide neutral “sites” for the “co-production” of useful knowledge by scientists and problem-solvers.<sup>47</sup>

Examples of institutions that have played this “boundary-spanning” role in the arena of science, technology and sustainable development include several of the best international scientific assessments (e.g., IASA’s RAINS effort on European acidification), regional decision support operations such as those involved in facilitating the use of El Niño climate forecasts, and local organizations such as India’s Honey Bee network.<sup>48</sup>

## **Integrate science and technology in problem-solving efforts**

The consultations reported here also revealed general agreement that more effective use of S&T in problem-solving for sustainable development will require much more integrative R&D institutions.

The needed integration will often encompass the communities engaged in promoting not only environmental conservation, but also human health, social services, and economic development.

We will need to entrain formal expertise not only from university-based natural and social sciences, but also from engineering. Better ways must be developed to tap relevant formal expertise (from all these sources) that resides in the private sector.

Even more challenging, we will need to find ways of identifying, utilizing and honoring the vast resources of informal expertise derived from practical experience in grappling with particular sustainable development problems in particular social and ecological settings.

More generally, promoting sustainable development requires institutions that can integrate what have too often been the "island empires" of research, monitoring, assessment, and operational decision support.

Examples of institutions that have successfully performed all of these integration functions are rare to non-existent, though a number of efforts reviewed in the consultations summarized here have made a start. The community might usefully devote some attention to identifying effective models.<sup>49</sup>

## **Facilitate a balance of flexibility and stability**

It will be important to do a better job of facilitating a balance of flexibility and stability in efforts to harness S&T to sustainable development. The challenges of sustainable development are rapidly changing, requiring that S&T efforts to respond to those challenges be flexible enough not to be stuck fighting the last war. On the other hand, experience reviewed in the consultations summarized here argues that it takes time and patience to build up trusting relationships between the S&T and decision-making community, to learn from experience, and to evaluate serious efforts to promote stability. These countervailing pressures driven by the need to learn and adapt in a complex and rapidly changing world, coupled with glaring capacity deficiencies in particular regions of the world, generate conflicting demands on the next generation of S&T institutions: adapt but remain stable. In light of the highly differentiated needs and capabilities in different places around the world, no single institutional model is likely to be optimal. Needed is probably a portfolio of institutions for managing S&T for sustainable development that can handle these tensions.

One response has been to reform existing long-term research organizations to make them more responsive to changing needs (e.g., CGIAR). Another is the use of task forces or



ad-hoc teams of experts commissioned to address particular problems (e.g., the World Commission on Dams, the Millennium Ecosystem Assessment). A third model – one felt to be particularly promising by participants in the consultations summarized here – combines the previous two approaches by means of permanent secretariats that accumulate experience, trust and learning, but which convene ad-hoc teams to provide flexible strength on particular topics (e.g., the InterAcademy Panel, the Canadian Policy Research Institute).<sup>50</sup>

### **Strategic approach to infrastructure and capacity building<sup>51</sup>**

Priority needs for investment in infrastructure and capacity were shown by the consultations summarized here to vary dramatically around the world. There exists general agreement, however, on a number of points. First, any strategy for enhancing the infrastructure and capacity needed to connect S&T to sustainable development must balance investment in individuals, organizations, and networks.<sup>52</sup> Second, in those regions where basic education – the most fundamental source of R&D capacity – is underdeveloped, priority must be given to building the educational base and enhancing an appreciation for the methods and potential contributions of science.<sup>53</sup> More generally, one of the greatest needs is for institutions that support cross-scale linkages among experts and problem-solvers.<sup>54</sup> These will need to be structured to facilitate "vertical" connections between the best research anywhere in the world and practical experience in particular field situations. At the same time they will need to foster "horizontal" connections among regional research and application centers to promote learning from one another. Finally, it will be essential everywhere to identify existing strengths and to build on them rather than seeking to create capacity from scratch.

### **Financing science and technology for sustainability<sup>55</sup>**

It is clear that a restructuring of the funding for S&T at all levels from the local to the global will be essential if it is to substantially increase its contribution to sustainability.<sup>56</sup>

The strategies for funding the science aspects of S&T for sustainable development differ markedly from those appropriate to the technology aspects, e.g., science funding often involves granting and contracting mechanisms while technology funding could involve venture capital or direct industrial investments. The financial issues addressed herein are primarily focused on the science aspect of the S&T agenda. It is clear that more detailed analyses of the whole range of issues regarding the technology aspects of sustainable development, including financial strategies, are essential and must be addressed.

There are two modalities for funding the S&T aspect of a sustainable development effort: Mode A - where the approach is a "partnership" where the science and technology aspects are an integral part of and funded within a overall sustainable development effort,<sup>57</sup> and Mode B - where the research in support of sustainable development seeks to develop fundamental concepts and knowledge, models and methods, and application strategies. The funding mechanisms for these two modalities are likely to differ.

Existing and novel funding mechanisms involving philanthropic foundations, businesses, and governmental and intergovernmental bodies should be explored to support these endeavors. Efforts to address sustainable development issues or to increase scientific capacity will take place within a context of very different funding patterns, environmental concerns, and research orientations.

A view was advanced by some participants in the consultations summarized here that moving forward in supporting S&T for sustainable development might require a multinational funding mechanism that is designed specifically to meet the unique needs of harnessing S&T for sustainable development.<sup>58</sup> Such a funding capability would have a broad mandate for building social, human, and technical capacity, enhancing education, supporting research institutions, and improving scientific capacity and technology innovation, development and dissemination, particularly in emerging economies and other developing countries. Such a funding mechanism would be founded on – but would likely need to extend – the remarkably effective financial leveraging strategies of existing multinational development banks, and emerge as part of a new generation of financing facilities. Such an international funding facility could include:

- A diverse portfolio of products (e.g., innovation and venture capital funds, education funds, loans, grants, start-up funds, etc.) that could meet heterogeneous needs in different types of countries;
- The ability to leverage resources to build countries' own research capacity and appropriate technology;
- The capacity to tap resources from private capital markets, which have grown enormously during the last two decades, and which are increasingly paying attention to sustainability issues – for example, through the emergence of “green” investment funds and institutions;
- Engagement of multiple shareholders, including foundations, NGOs, countries, private banks, citizen groups, and the development banks;
- An evolving and flexible structure; and
- Responsibility for and authority in the management of the facility by the potential beneficiaries of S&T funding.

The community should give the highest priority options to moving forward the creation of this or other funding mechanisms. Without them, all of the talk and consultations and high hopes of the last three years will be unable to amount to much more than a business-as-usual approach that we can no longer afford.

**Table 1: Chronological Listing of Activities Synthesized in this Paper**  
(Copies of the reports available through the *Forum on Science and Technology for Sustainability*)<sup>59</sup>

- Tokyo Symposium organized under the auspices of the World's Scientific Academies; Tokyo, Japan, 15-18 May 2000. [Interacademy Panel. 2000. *Transition to Sustainability in the 21<sup>st</sup> Century: The Contribution of Science and Technology*. Tokyo: IAP, <http://www4.nationalacademies.org/intracad/tokyo2000.nsf/all/home>.]
- Friibergh Workshop organized under the auspices of the ISTS; Friibergh, Sweden, 11-14 October 2000. [ISTS/Friibergh. 2000. *Sustainability Science*. Friibergh: ISTS. Summarized in R. W. Kates et al. 2001. "Sustainability science." *Science* 292: 641-642.]
- Amsterdam Global Change Open Science Conference organized under the auspices of the International Geosphere-Biosphere Programme (IGBP), the International Human Dimensions Programme (IHDP), and the World Climate Research Programme (WCRP); Amsterdam, Netherlands, 10-13 July 2001. [IGBP. 2001. *Global Change and the Earth System: A Planet Under Pressure*. IGBP Science Series No. 4. Stockholm: IGBP; and IGBP. 2002. *The Amsterdam Declaration on Global Change – Challenges of a Changing Earth*. Both at <http://www.igbp.kva.se/>.]
- Abuja Regional Workshop organized under the auspices of the ISTS; Abuja, Nigeria, 13-15 November 2001. [ISTS/Abuja. (A. Mabogunje, ed.) 2001. *African Perspectives on Sustainability Science*. Abuja: ISTS.]
- Report produced under the auspices of ICSU and the WFEO in collaboration with the IAP, ISSC, and TWAS as Dialogue paper to the 2<sup>nd</sup> Preparatory Committee of the WSSD. 28 January 2002. [ICSU. 2002a. *Report of the Scientific and Technological Community to the World Summit on Sustainable Development (WSSD)*. ICSU Series on Science for Sustainable Development No. 1. Paris: ICSU, <http://www.icsu.org/Library/WSSD-Rep/index.html>.]
- Chiang Mai Regional Workshop organized under the auspices of the ISTS; Chiang Mai, Thailand, 4-6 February 2002. [ISTS/Chiang Mai. (L. Lebel, ed.) 2002. *Sustainability Science: Knowledge, Technology and Institutions for Sustainability Transitions in Asia*. Chiang Mai: ISTS.]
- Paris Workshop organized under the auspices of the Global Change Science Programmes; Paris, France, 4-6 Feb. 2002. [Global Change. 2002. *Science as a Foundation for Sustainable Development*. Bonn: IHDP].
- Trieste Workshop organized by TWAS under the auspices of the ISTS; Trieste, Italy, 6-9 February 2002. [TWAS. 2002. *Lessons Learned from the Workshop on Science, Technology and Sustainability: Harnessing Institutional Synergies*. Trieste: TWAS/ISTS.]
- Bonn Regional Workshop organized under the auspices of the ISTS; Bonn, Germany, 27 February - 1 March 2002. [ISTS/Bonn. 2002. *European Science for Sustainability: Achievements and Challenges*. Bonn: ISTS.]
- Santiago Regional Workshop organized under the auspices of the ISTS; Santiago, Chile, 5-7 March 2002. [ISTS/Santiago. (G. Gallopín, ed.) 2002. *Report on the Latin American and Caribbean Regional Workshop on Science and Technology for Sustainable Development*. Santiago: ISTS.]
- Ottawa Regional Workshop organized under the auspices of the ISTS; Ottawa, Canada, 25-26 March 2002. [ISTS/Ottawa. 2002. *Science and Technology for Sustainability: North American Challenges and Lessons*. Ottawa: ISTS.]
- Cambridge Workshop organized under the auspices of the ISTS, ICSU, and TWAS; Cambridge, Massachusetts, USA, 10-12 April 2002. [ISTS/Cambridge. 2002. *Mobilizing Science and Technology for Sustainable Development*. Cambridge: ISTS.]
- Report produced under the auspices of the ICSU and the WFEO in collaboration with the IAP, ISSC, and TWAS as Summary by the Scientific and Technological Community for the Multi-Stakeholder Dialogue Segment of the WSSD PrepCom IV Meeting, draft of 23 April 2002. [ICSU. 2002b. *Science and Technology as a Foundation for Sustainable Development*. Paris: ICSU.]
- World Summit on Sustainable Development, organized by the United Nations, 24 August - 6 September 2002, <http://www.johannesburgsummit.org/index.html>.
- Arab States Regional Workshop organized under the auspices of the ISTS, Trieste, Italy 12-13 June 2003. [ISTS/Trieste 2003. *Arab States Roundtable Planning Meeting*. Trieste, TWAS and ISTS.]

## End Notes

<sup>1</sup> An earlier version of some of the material covered in this paper was prepared by the author as background for the Mexico City Synthesis Conference on Science and Technology for Sustainable Development. It draws heavily on a number of regional consultations conducted under the auspices of the international Initiative on Science and Technology for Sustainability and summarized in Table 1 of this paper. Particularly valuable were the findings reported at greater length in the following: Trieste Workshop organized locally by the Third World Academy of Sciences under the auspices of the ISTS on *Science, Technology and Sustainability: Harnessing Institutional Synergies* (Trieste, Italy, 6-9 February 2002), co-chaired by Mohamed Hassan, Calestous Juma, and William Clark (report at [http://sustainabilityscience.org/ists/docs/twas\\_rpt\\_v1\\_020222.pdf](http://sustainabilityscience.org/ists/docs/twas_rpt_v1_020222.pdf); cited below as ISTS/Trieste, 2002; Cambridge Workshop organized locally by Harvard University's Weatherhead Center for International Affairs under the auspices of the ISTS, ICSU, and TWAS on *Mobilizing Science and Technology for Sustainable Development* (Cambridge, Massachusetts, USA, 10-12 April 2002), co-chaired by William Clark, Mohamed Hassan, Gisbert Glaser, and Calestous Juma (report at [http://sustainabilityscience.org/ists/docs/ists\\_cfia\\_rpt\\_final.pdf](http://sustainabilityscience.org/ists/docs/ists_cfia_rpt_final.pdf); cited below as ISTS/Cambridge, 2002).

<sup>2</sup> International Union for the Conservation of Nature. 1980. *World Conservation Strategy: Living resource conservation for sustainable development*. Gland: IUCN; World Commission on Environment and Development. 1987. *Our Common Future*. Oxford: Oxford University Press; W. C. Clark. 1986.

"Sustainable development of the biosphere: Themes for a research program." pp. 5-48 in William C. Clark and R.E. Munn, eds. *Sustainable development of the biosphere*. Cambridge: Cambridge Univ. Press.

<sup>3</sup> K. Annan. 2000. *We, the Peoples: The Role of the United Nations in the 21st Century*. New York: United Nations, <http://www.un.org/millennium/sg/report/full.htm>.

<sup>4</sup> United Nations Development Program. 2001. "Making new technologies work for human development: The Human Development Report 2001." Oxford: Oxford Univ. Press; World Bank. 1998. "Knowledge for development: The World Development Report for 1998/9." Oxford: Oxford Univ. Press; J. D. Sachs. 2000. "A new map of the world." *The Economist* 355: 81-83 (24 Jun 2000).

<sup>5</sup> See the report on the Global Change Open Science Conference: W. Steffen, J. Jäger, D. Carson, and C. Bradshaw, eds. 2003. *Challenges of a Changing Earth. Proceedings of the Global Change Open Science Conference, 10-13 July 2001, Amsterdam, NL*. Berlin: Springer-Verlag (cited here as Global Change Programmes, 2003), especially the plenary address by William Clark on "Research systems for a transition toward sustainability," (cited here as Clark, 2003, and available at [http://sustainabilityscience.org/keydocs/fulltext/BC\\_ResSys\\_Amsterdam02.pdf](http://sustainabilityscience.org/keydocs/fulltext/BC_ResSys_Amsterdam02.pdf)).

<sup>6</sup> Annan, 2000, op. cit.

<sup>7</sup> Third World Network of Scientific Organizations (TWNSO), <http://www.ictp.trieste.it/~twas/TWNSO.html>; Commission on Science and Technology for Sustainable Development in the South (COMSATS), <http://www.comsats.org.pk>; Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), <http://www.sristi.org/>; South Centre at <http://www.southcentre.org/> (see particularly the *Elements for an Agenda of the South: Report of the NAM Ad Hoc Panel of Economists*, section 4 on "science and technology" at [http://www.southcentre.org/papers/nam/namfinal-02.htm#P287\\_47302](http://www.southcentre.org/papers/nam/namfinal-02.htm#P287_47302)). See also policy statements by the International Foundation for Science (IFS), <http://www.ifs.se/index.htm>; the International Science Programme (ISP), <http://www.isp.uu.se/Home.htm> and the Millennium Science Initiative (MSI), [http://www.msi-sig.org/MSI-SIG\\_summary.htm](http://www.msi-sig.org/MSI-SIG_summary.htm).

<sup>8</sup> African Academy of Sciences' *Tunis Declaration: Millennial Perspective on Science, Technology and Development in Africa and its Possible Directions for the Twenty-first Century* (Fifth General Conference of the African Academy of Sciences, Hammamet, Tunisia, 23-27 April 1999), [http://www.unesco.org/general/eng/programmes/science/wcs/meetings/afr\\_hammamet\\_99.htm](http://www.unesco.org/general/eng/programmes/science/wcs/meetings/afr_hammamet_99.htm).

<sup>9</sup> H. J. Schellnhuber and V. Wenzel, eds. 1998. "Earth System Analysis: Integrating Science for Sustainability." Berlin: Springer-Verlag; European Commission. 1998. "Fifth Framework Programme: Putting Research at the Service of the Citizen," <http://www.cordis.lu/fp5/src/over.htm>; S. Funtowicz and M. O'Connor, eds. 1999. "Science for sustainable development." Special issue of *International Journal of Sustainable Development* 2: 3.

<sup>10</sup> C. E. Rocha-Miranda, ed. 2000. "Transition to Global Sustainability: The Contributions of Brazilian Science." Rio de Janeiro: Academia Brasileira de Ciências,

<http://sustainabilityscience.org/keydocs/brazilsci.htm>; Series of Annual Reports by the German Advisory Council on Global Change (WGBU), particularly its *World in Transition: The Research Challenge, Annual Report 1996*. Berlin: Springer-Verlag, 1997, [http://www.wbgu.de/wbgu\\_publications.html](http://www.wbgu.de/wbgu_publications.html); United States National Research Council, Board on Sustainable Development. 1999. *Our Common Journey: A Transition Toward Sustainability*. Washington, D.C.: National Academy Press, <http://www.nap.edu/catalog/9690.html>; Science Council of Japan. 2000. *Towards a comprehensive solution to problems in education and the environment based on a recognition of human dignity and self-worth*. Science Council of Japan; Royal Society. 2000. *Towards sustainable consumption: A European perspective*. London.

<sup>11</sup> UNESCO. 1999. *World Conference on Science for the 21<sup>st</sup> Century: A new commitment*.

<http://www.unesco.org/bpi/science/content/press/anglo/4.htm>.

<sup>12</sup> Robert Watson, John A. Dixon, Steven P. Hamburg, Anthony C. Janetos, and Richard H. Moss. 1998. *Protecting Our Planet, Securing Our Future*. Nairobi: UN Environment Programme, <http://www-esd.worldbank.org/planet/>; Intergovernmental Panel on Climate Change. 2001. *Special Report on Climate Change and Sustainable Development, IPCC Plenary Seventeenth Session*. Nairobi, 4-6 April 2001, <http://www.ipcc.ch/meet/p17.pdf>; Millennium Ecosystem Assessment, <http://www.millenniumassessment.org/en/index.htm>

<sup>13</sup> See Note [5] above.

<sup>14</sup> World's Scientific Academies' *Transition to Sustainability in the 21st Century* (Tokyo Summit of May 2000), <http://www4.nationalacademies.org/intracad/tokyo2000.nsf/all/home>.

<sup>15</sup> The Global Environmental Change Programmes have made "global sustainability" a center point of their research planning for the coming years (see IGBP. 2001. *Global change and the earth system: A planet under pressure*. IGBP Science Series No. 4. Paris: ICSU, <http://www.igbp.kva.se/>; and IGBP. 2001. *The Amsterdam Declaration on Global Change – Challenges of a Changing Earth*. Global Change Open Science Conference, Amsterdam, 13 July 2001, <http://www.sciconf.igbp.kva.se/fr.html>; Paris Workshop organized under the auspices of the Global Change Science Programmes on *Sustainable Development: The Role of International Science*. Paris, 4-6 February, 2002, [http://sustainabilityscience.org/ists/synthesis02/icsu\\_paris\\_2pager\\_final.pdf](http://sustainabilityscience.org/ists/synthesis02/icsu_paris_2pager_final.pdf) (cited here as Global Change, 2002).

<sup>16</sup> World Summit on Sustainable Development. 2002. *Role and Contributions of the Scientific and Technological Community (S&TC) to Sustainable Development*. Secretary-General's Note for the Multi-Stake Holder Dialogue Segment of the Second Preparatory Committee. Addendum No. 8: Dialogue Paper by Scientific and Technological Communities. United Nations Economic and Social Council E/CN.17/2002/PC.2/6.Add.8. Advance Copy, 28 January 2002. Prepared by the International Council for Science (ICSU) and the World Federation of Engineering Organizations (WFEO), [http://sustainabilityscience.org/keydocs/fulltext/wssd\\_stc\\_020128.pdf](http://sustainabilityscience.org/keydocs/fulltext/wssd_stc_020128.pdf). Cited here as ICSU et al., 2002a; subsequently issued in final form as International Council for Science. 2002. *Report of the Scientific and Technological Community to the World Summit on Sustainable Development*. ICSU Series on Science for Sustainable Development No. 1. 20pp. ICSU and WFEO also prepared the follow-up document "Science and technology as a foundation for sustainable development: Summary by the scientific and technological community for the multis takeholder dialogue segment of the WSSD PrepCom IV meeting. (Report available at [http://sustainabilityscience.org/ists/synthesis02/icsu\\_s+t\\_2pager\\_wssd-prepcom4.pdf](http://sustainabilityscience.org/ists/synthesis02/icsu_s+t_2pager_wssd-prepcom4.pdf); cited here as ICSU et al., 2002b).

<sup>17</sup> The Initiative is an open, ad-hoc group of environment and development scholars devoted to linking science, technology and sustainable development. Its co-conveners are Akin Mabogunje and Robert Kates. It was founded through a call from participants at the Friibergh Workshop on Sustainability Science in October 2000 (see Robert Kates et al. 2001. "Sustainability Science." *Science* 292:641-2, <http://sustainabilityscience.org/keydocs.htm#sustsci>). Further information on the Initiative is available on its web site at <http://sustainabilityscience.org/ists>. The Initiative conducted the following regional workshops under a steering committee consisting of the individual leaders named below and chaired by Robert Corell: **Abuja, Nigeria:** 13-15 November 2001, organized locally by the Nigerian National Committee on Sustainability Science, chaired by Professor Akin L. Mabogunje, Development Policy Centre, Ibadan, Nigeria (report at <http://sustainabilityscience.org/events/africa-sustsci0111.htm>, cited here as ISTS/Abuja, 2001); **Chiang Mai, Thailand:** 4-6 February 2002, organized locally by Chiang Mai University and University Kebangsaan Malaysia, co-chaired by Dr. Louis Lebel, Faculty of Social



Sciences, Chiang Mai University and Science Coordinator for the Southeast Asian Regional Committee (SARCS) for START, Bangkok, Thailand, and Dr. Mohammed Nordin Hassan, Institute for Environment and Development (LESTARI), University Kebangsaan Malaysia, Bangi, Malaysia (report at [http://sustainabilityscience.org/ists/docs/ists\\_regws\\_chiangmai\\_synthesis.pdf](http://sustainabilityscience.org/ists/docs/ists_regws_chiangmai_synthesis.pdf); cited here as ISTS/Chiang Mai, 2002); **Bonn, Germany:** 27 February - 1 March 2002, organized locally by the International Human Dimensions Programme on Global Environmental Change (IHDP), chaired by Dr. Jill Jaeger, Executive Director, International Human Dimensions Programme on Global Environmental Change, Bonn, Germany (workshop supported by the German Federal Ministry for Education and Research; report at [http://sustainabilityscience.org/ists/docs/ists\\_regws\\_walberberg.pdf](http://sustainabilityscience.org/ists/docs/ists_regws_walberberg.pdf); cited here as ISTS/Bonn, 2002); **Santiago, Chile:** 5-7 March 2002, organized locally by the Economic Commission for Latin America and the Caribbean (ECLAC), co-chaired by Dr. Gilberto Gallopín, Regional Advisor on Environmental Policies, Division of Environment and Human Settlements, Economic Commission for Latin America and the Caribbean, UNESCO, Santiago, Chile, and Armando Rabuffetti, Director, Inter-American Institute for Global Change Research, São Paulo, Brazil (report at [http://sustainabilityscience.org/ists/docs/ists\\_regws\\_santiago\\_summary.pdf](http://sustainabilityscience.org/ists/docs/ists_regws_santiago_summary.pdf); cited here as ISTS/Santiago, 2002); **Ottawa, Canada:** 25-26 March 2002, organized locally by Environment Canada, the Policy Research Institute, and the North American Free Trade Agreement Commission for Environmental Cooperation (this workshop focused on regional-scale issues of science and technology for sustainability in Canada, Mexico, and the United States; report at [http://sustainabilityscience.org/ists/docs/ists\\_regws\\_ottawa\\_rpt.pdf](http://sustainabilityscience.org/ists/docs/ists_regws_ottawa_rpt.pdf); cited here as ISTS/Ottawa, 2002); **Trieste, Italy:** 12-13 June, 2003, organized locally by the Third World Academy of Sciences (this workshop focused on regional scale issues of S&T for sustainability in the Arab States; report forthcoming on <http://sustainabilityscience.org>). Results of the individual workshops are also available on the Forum on Science and Technology for Sustainability, <http://sustainabilityscience.org>. A summary of the workshop findings is provided in ISTS. 2002. "Summary Insights and Perspectives from the Regional Workshops of the Initiative on Science and Technology for Sustainability." Prepared by the Regional Workshop Chairs. Edited by Robert W. Corell and Noelle Eckley, [http://sustainabilityscience.org/ists/synthesis02/ists\\_regws\\_synthesis\\_020503.pdf](http://sustainabilityscience.org/ists/synthesis02/ists_regws_synthesis_020503.pdf) (cited here as ISTS/Regional Summary, 2002).

<sup>18</sup> ISTS/Trieste, 2002; ISTS/Cambridge, 2002; op cit. at Note [1].

<sup>19</sup> **Mexico City, Mexico:** 20-23 May 2002; organized locally by the National Autonomous University of Mexico (UNAM) under the joint sponsorship of ISTS, TWAS and ICSU; co-chaired by William Clark, Robert Corell, Gisbert Glaser, Mohamed Hassan, Calestous Juma, Robert Kates, Akin Mabogunje, Thomas Rosswall, and Jose Sarukhán; <http://sustainabilityscience.org/ists/synthesis02.htm> (cited here as ISTS/TWAS/ICSU/Mexico City, 2002). Results of the World Summit on Sustainable Development are summarized on the Summit's website <<http://www.johannesburgsummit.org/>> and in the follow-up activities of the UN Commission on Sustainable Development, <http://www.un.org/esa/sustdev/index.html>.

<sup>20</sup> This section draws heavily on text I initially wrote to introduce a Special Issue on Sustainability Science of the Proceedings of the National Academy of Sciences of the US: Clark, William C., and Nancy M. Dickson. 2003. Sustainability Science: The Emerging Research Program *Proceedings of the National Academy of Sciences of the United States of America* 100(14) (8 July): 8059-8061.

<sup>21</sup> Dove, M. R. & Kammen, D. M. (1997) *Environment* **39**, 10-15, 38-41.

<sup>22</sup> Ruttan, V. W. (2001) *Technology, Growth, and Development* (Oxford, New York).

<sup>23</sup> Glacken, C. (1967) *Traces on the Rhodian Shore* (University of California, Berkeley).

<sup>24</sup> Haefele, W. & the Energy Systems Program Group of the International Institute for Applied Systems Analysis (1981) *Energy in a Finite World* (Balinger, Cambridge).

<sup>25</sup> Holling, C. S. (1973) *Annu Rev Ecol Syst* **4**:1-23.

<sup>26</sup> National Academy of Engineering (1997) *The Industrial Green Game* (National Academy Press, Washington, D.C.).

<sup>27</sup> National Science Foundation Advisory Committee on Environmental Research and Education (2003) *Complex Environmental Systems* (National Science Foundation, Washington, D.C.).

<sup>28</sup> Initiative on Science and Technology for Sustainability (2003) *Forum on Science and Technology for Sustainability*, <http://sustainabilityscience.org>.

<sup>29</sup> Research and Assessment Systems for Sustainability Program. 2003. *Proceedings of the National Academy of Sciences of the United States of America*. Special Feature. 100(14) (8 July): 8059-8091.

<http://sust.harvard.edu/pnas>.

<sup>30</sup> National Research Council (1999) *Our Common Journey* (National Academy Press, Washington D.C.).

<sup>31</sup> UN World Summit on Sustainable Development (2002) *WEHAB Framework Papers*,  
[http://www.johannesburgsummit.org/html/documents/wehab\\_papers.html](http://www.johannesburgsummit.org/html/documents/wehab_papers.html).

<sup>32</sup> United Nations General Assembly (2000) *United Nations Millennium Declaration* (United Nations, New York), A/RES/55/2.

<sup>33</sup> International Council for Science (2002) *Science and Technology for Sustainable Development* (ICSU, Paris), <http://www.icsu.org/Library/WSSD-Rep/Vol9.pdf>, pg. 9.

<sup>34</sup> Kates, R.W., et al. (2001) *Science* **292**: 641-2.

<sup>35</sup> Initiative on Science and Technology for Sustainability (2003)

<http://sustainabilityscience.org/questions/intro.htm>.

<sup>36</sup> Sahagian, D. & Schellnhuber H. J. (2002) *Global Change Newsletter* **50**, 7-10,  
[http://www.igbp.kva.se/uploads/3\\_GAIM.pdf](http://www.igbp.kva.se/uploads/3_GAIM.pdf).

<sup>37</sup> PNAS, op. cit.

<sup>38</sup> Schellnhuber, H. J. (2003) in *Challenges of a Changing Earth*, eds. Steffen, W., Jaeger, J., Carson, D., & Bradshaw, C. (Springer, Berlin).

<sup>39</sup> Lucht, W. (2002) *IHDP Update* **2**, 6.

<sup>40</sup> Young, 1999, op. cit.

<sup>41</sup> ISTS/Trieste, 2002, op. cit.; Clark, 2002, op. cit.

<sup>42</sup> See IASA RAINS at <http://www.iiasa.ac.at/~rains/>, and the SE Asia START effort at  
<http://www.start.or.th/>.

<sup>43</sup> ISTS/Trieste, 2002, op. cit.

<sup>44</sup> See also ISTS/Bonn, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.

<sup>45</sup> Clark, 2003, op. cit.

<sup>46</sup> See especially ICSU, 2002a, op. cit.; ISTS/Trieste, 2002, op. cit.; and ISTS/Cambridge, 2002, op. cit.

<sup>47</sup> See especially ISTS/Ottawa, 2002, op. cit.; and ISTS/Trieste, 2002, op. cit.

<sup>48</sup> ISTS/Trieste, 2002, op. cit.

<sup>49</sup> ISTS/Chiang Mai, 2002, op. cit.

<sup>50</sup> ISTS/Ottawa, 2002, op. cit.; ISTS/Trieste, 2002, op. cit.

<sup>51</sup> This is a central topic of ICSU et al., 2002a and 2002b, op. cit., and is developed in Global Change, 2002, op. cit.

<sup>52</sup> ISTS/Trieste, 2002, op. cit.

<sup>53</sup> ICSU et al., 2002b, op. cit.; Global Change, 2002, op. cit.; ISTS/Abuja, 2001, op. cit.; ISTS/Bonn, 2002, op. cit.; ISTS/Chiang Mai, 2002, op. cit.; ISTS/Ottawa, 2002 op. cit.

<sup>54</sup> See especially the discussion of scale in ISTS/Chiang Mai, 2002, op. cit.; and ISTS/Trieste, 2002, op. cit.

<sup>55</sup> These issues were a special focus of ISTS/Cambridge, 2002, op. cit.; many of the conclusions at that workshop drew on the earlier ISTS regional workshops.

<sup>56</sup> See the conclusions of ICSU et al, 2002a; and Clark, 2003, both op. cit.

<sup>57</sup> On this, see especially the arguments in ISTS/Abuja, 2001, op. cit.

<sup>58</sup> See the arguments developed in ISTS/Santiago, 2002, op. cit., and elaborated in ISTS/Cambridge, 2002, op. cit. Both of these draw extensively upon conversations with Francisco Sagasti, and material presented in Francisco Sagasti and Keith Bezanson. 2001. *Financing and providing global public goods: Expectations and prospects*. Stockholm, Sweden: Ministry of Foreign Affairs.

<sup>59</sup> <http://sustainabilityscience.org>.