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Science and Technology for Sustainable Development

A Latin American and Caribbean Perspective

Latin American and Caribbean Regional Workshop on Science and Technology for Sustainable Development

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This publication has been compiled by Gilberto C. Gallopín, Regional Adviser in Environmental Policy for Latin America and the Caribbean and coordinator for this workshop. Section II "Summary of discussions and conclusions" is based on the deliberations of the Working Groups organized during the workshop as well as on the contributions of the Drafting Group convened immediately after the Workshop (J. Carrizosa, R. Dagnino, S. Díaz, R. Díaz, A. Elizalde, G. Gallopín, J. Rabinovich, J. Sarukhan y H. Vessuri). It has been edited and completed by G. C. Gallopín. Hernán Dopazo helped with the preparation of the document.

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Abstract

This document contains the results of the deliberations of the Latin American and Caribbean Regional Workshop on Science and Technology for Sustainable Development.

The purpose of the Workshop was to discuss the practical, theoretical and organizational challenges that the quest for sustainable development poses to science and technology (S&T). The increase in complexity and connectivity characteristic of our times results in that the components of the problems are now much less separable than before, and emphasizes the need to approach the problems of development and the environment not only as complex issues in themselves, but also as inseparable and mutually determined. This represents an exceptional challenge to science and technology, particularly to the analytical approaches compartmentalized into disciplines, which represents the bulk of activities and priorities of current S&T systems in both north and south. The Workshop attempted to articulate a Latin American and Caribbean vision towards the search of more effective ways of generating and applying Science and Technology to the problems and opportunities of the region.

The workshop proceedings were conducted along four main lines:

1. Core scientific questions. What key knowledge is required for science to make an effective contribution to sustainable development? What core scientific questions need to be answered?

2. Methodological and conceptual challenges. What challenges does the problem of sustainable development poses to the criteria and method of science and technology?
3. Research strategies. What research strategies may be employed and on what scale in order to address the core questions defined?
4. Institutional innovations. How can scientific and technological institutions be better organized to develop research strategies, including cooperation between countries and sectors?

The report ends with a set of proposals for future action.

I. Introduction

In the framework of its contribution to the international Initiative on Science and Technology for Sustainability, the Environment and Human Settlements Division of ECLAC, with partial financial support from the David and Lucile Packard Foundation, organized a Latin American and Caribbean Regional Workshop on Science and Technology for Sustainable Development. The workshop was held at ECLAC, Santiago, Chile, on 5-8 March 2002.

The purpose of the Workshop was to discuss the practical, theoretical and organizational challenges that the quest for sustainable development poses to science and technology. The Workshop aimed to obtain a Latin American and Caribbean vision of the quest for more effective forms of generating and applying science and technology to the problems and opportunities of the region.

The workshop was attended by professionals from Argentina, Brazil, Chile, Colombia, Costa Rica, Cuba, Mexico, Peru, Uruguay, Venezuela, the U.S., and the Inter-American Institute for Global Change Research (IAI)[1]. In addition, ECLAC staff from the Division of Production, Productivity and Management and from the Environment and Human Settlements Division participated.

At the opening session of the workshop, Alicia Bárcena, Director of the ECLAC Environment and Human Settlements Division acknowledged the financial support for the workshop by the Packard Foundation and highlighted the importance of learning the opinions of the region's scientists, technological experts and public policy

[1] The list of participants appears in Annex 2.

executors in order to carry forward a programme of science and technology for sustainable development. Then Jorge Katz, Director of the ECLAC Division of Production, Productivity and Management, presented an economic analysis of the system of innovation following the liberalization and deregulation of the economies of Latin America. Both Directors thanked the invited experts for their attendance and expressed confidence that their presence would make for fruitful deliberations during the workshop.

Gerhard Breulmann then took the floor to speak of the programme conducted by the Inter-American Institute of Global Change Research (IAI). Next, Nancy Dickson, of Harvard University, gave an account of the International Initiative on Science and Technology for Sustainable Development. Then Robert Corell, also of Harvard University, presented an overview of similar meetings which had already been held on other continents.

Gilberto Gallopín spoke of the objectives and the methodological and logistical aspects of the meeting.

Subsequently, the participants made their presentations as scheduled in the workshop agenda, their conclusions are presented in the following chapters.

II. Summary of discussions and conclusions[2]

A. Background

In October 2000, two dozen scientists, drawn from the natural and social sciences and from across the world, convened at Sweden's Friibergh Manor, near Stockholm, to explore the intellectual questions underlying a transition to sustainability that will require the emergence and conduct of a new field of scientific and technological inquiry– sustainability science. The Workshop explored this issue from three perspectives:

- **Core Science Questions:** What are the core scientific questions and issues that must be addressed in the decades ahead that will form the foundations for sustainability science and technology,
- **Research Strategies:** What research strategies will be required to enable the scientific inquiry and facilitate the research to address these core questions of sustainability science, and
- **Institutions and Infrastructure:** What innovations and changes will be required to more fully enable the institutions and infrastructure essential to the conduct of sustainability science and technology.

[2] Based on the discussions of the Working Groups held at the Workshop, the contributions of the Drafting Group which convened immediately afterwards (J. Carrizosa, R. Dagnino, S. Díaz, A. Elizalde. G. Gallopín, J. Rabinovich, J. Sarukhan and H. Vessuri) and subsequent editing and completion by G. Gallopín.

Box 1

CORE SCIENTIFIC QUESTIONS IDENTIFIED AT FRIIBERG:

- How can the dynamic interactions between nature and society –including lags and inertia– be better incorporated into emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?
- How are long-term trends in environment and development, including consumption and population, reshaping nature-society interactions in ways relevant to sustainability?
- What determines the vulnerability or resilience of the nature-society system in particular kinds of places and for particular types of ecosystems and human livelihoods?
- Can scientifically meaningful "limits" or "boundaries" be defined that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation?
- What systems of incentive structures –including markets, rules, norms, and scientific information– can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories?
- How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?
- How can today's relatively independent activities of research planning, monitoring, assessment, and decision support be better integrated into systems for adaptive management and societal learning?

Source: Author's elaboration.

The workshop participants concluded that the world's present development path is not sustainable and that efforts to meet the needs of a growing population in an interconnected but unequal and human-dominated world are undermining the Earth's essential life-support systems. The extraordinary complexity of the challenges that lie ahead is suggested by today's emerging interactions among global environmental changes and the profound transformations underway in social and economic life. These include such diverse alterations of the earth as climate warming, land transformation, and loss of biological diversity, together with social transitions including a population that is growing more slowly, while aging and urbanizing; an economy that is globalizing while increasing both wealth and inequality in the face of persisting poverty; and a system of resource utilization that in the energy, manufacturing and agricultural sectors is making more with less even as it increases its overall demands on the earth to unprecedented levels.

One of clearest issues to emerge was the need to initiate a world-level dialogue that would take into account the specific features of the different regions, which have different social, economic, cultural and ecological realities. This led to the recommendation that workshops should be held in different regions of the developed and developing world in order to consider these differing realities and points of view.

As a result of the Friiberg meeting and other activities, an international Initiative on Science and Technology for Sustainability (ISTS)[3] was created. This is coordinated by an international group of scientists and academics that are committed to pursuing sustainable development.

Further to the recommendations of the Friiberg meeting, a number of regional workshops have taken place. The first was the workshop for Africa, which was held in Abuja, Nigeria, from 13 to 15 November 2001; the Asian workshop was held on 4 and 5 February in Chiang Mai, Thailand;

[3] See (http://www.sustsci.harvard.edu/ists) for further information.

and the European workshop from 27 February to 1 March in Bonn, Germany. The Latin American event that is the subject of this report was the fourth regional workshop. The North American workshop was held on 25 and 26 March in Ottawa, Canada.

In May 2002 another workshop was held, this time to integrate and summarize the key messages from the different regional meetings and other issues covered in the framework of ISTS.

Although the ISTS is conceived as a continuing process of dialogue and consolidation, one of the immediate milestones on the horizon was the World Summit on Sustainable Development, which took place in September 2002 in Johannesburg, South Africa. The main conclusions reached by the time, were presented at this world event, including participation in the Type II Partnership "Science and Tecnology for sustainable Development".

B. Objectives: the Challenge Posed to Science and Technology by Sustainable Development

The meeting was convened to initiate a process of reflection and exchange of ideas and experiences concerning the challenges and opportunities posed by the quest for sustainable development, from a Latin American and Caribbean perspective.

The results of this intense and condensed discussion among S&T professionals from different disciplines and orientations, drawn from different countries of the region, are expected to be of particular interest to: (a) institutions that conduct research and development (R&D) activities (universities, public and private research institutes, etc.); and (b) institutions that define and implement science and technology policies, or promote or finance R&D (ministries or departments of science and technology, national scientific and technological research committees, private enterprises, foundations, etc.). In addition to these two specific categories, the deliberations of this workshop may be of interest to the general public, and to politicians and other decision-makers who are concerned about sustainable development in the region.

The initial question requiring to be answered in the framework of this meeting was: in what way, if any, does sustainable development pose S&T challenges that differ from other major challenges of our times, such as globalization, economic competitiveness, and so on?

In many instances, it is becoming clear that the predominant approach in S&T is exhibiting major shortcomings. This in no way relates to attacks to science and technology that have come from certain hostile quarters, but rather reflects constructive criticism and warnings that have arisen within the scientific community itself.

Although recognizing that major advances due to specialization within a number of disciplines have contributed to improving the quality of life of millions of human beings, it is becoming clear that in a significant number of important cases, the very success of compartmentalized scientific approaches has led to the aggravation of the environmental and development problems they set out to resolve.

A number of processes have played a part in this. One of these is the fundamental uncertainty introduced both by our limited understanding of human and ecological processes and the intrinsic indeterminism of complex dynamic systems (including human components, man-made infrastructure and artificial objects, and natural components) that comprise the subject of sustainable development, and by the myriad of human purposes and choices.

In addition, the current historical context exhibits major differences to the relatively recent past. On the one hand, the world is moving through a period of extraordinary turbulence and volatility reflecting the economic, cultural, social and political processes associated with

globalization. In addition the speed and magnitude of global change, the increasing connectedness of the social and natural systems at the planetary level, and the growing complexity of societies and of their impacts upon the biosphere, result in a high level of uncertainty and unpredictability.

On the other hand, current trends are proving to be ecologically and socially unsustainable. In recent years millions of the region's inhabitants have slid into poverty and live in deteriorated environmental conditions.

In this respect, problems and situations have become increasingly complex in recent decades. The main reasons for this include (Gallopín et al. 2001): [*]

***Ontological changes*:** human-induced changes in the nature of the real world are proceeding at unprecedented rates and scales and are resulting in growing connectivity and interdependence at many levels. The molecules of carbon dioxide emitted by fossil fuel consumption (mostly in the North) combine with the molecules of carbon dioxide produced by the burning of forests (mostly in the South) to force global climate change; an economic crisis in Asia reverberates across the global economic system affecting investments in countries far away.

***Epistemological changes*:** changes in our understanding of the world related to the modern scientific awareness of the behavior of complex systems, including indeterminism, self-organization and emergent properties.

***Changes in the nature of decision-making*:** in many parts of the world, a more participatory style of decision-making and government is gaining ground. This, together with the widening acceptance of additional criteria such as the environment, human rights, gender, and others, as well as the emergence of new social and economic actors such as non-governmental organizations and transnational corporations, has increased the number of dimensions used to define issues, goals and solutions and hence augmented the complexity of decisions.

In short, increasing complexity and connectedness mean that the components of problems are not nearly as easy to separate as they once were. Development and environmental problems must therefore be approached not only as complex problems *per se*, but also as inseparable and mutually determined.

This represents an exceptional challenge to science and technology, particularly to the analytical compartmentalization of disciplines, which represents the bulk of activities and priorities of current S&T systems in both north and south.

The proposals of ISTS, and of this regional workshop on science and technology for sustainable development, are motivated primarily by the need for a holistic or systemic approach to sustainable development problems, together with the associated epistemological, methodological, strategic and institutional implications for science and technology. The chief aim of the workshop was to develop a regional perspective on the challenge and to scale the definition of the problem down from a global to a regional level, taking into account the specific features, problems and opportunities of the region.

The focus of this workshop lay in the questions: How can science and technology contribute to sustainable development in Latin America and the Caribbean? What characteristics are required by a Science and technology for Sustainable Development (STSD)? One of the strategically and politically important aspects of the current period in our history is the overlapping of economic, ecological, cultural, political, social and demographic processes generated by the intersection of globalization with growing global ecological interdependence. Unlike other eras, today it is

[*] Gallopín, GC, S Funtowicz, M O'Connor and J Ravetz. 2001. Science for the 21st Century: From Social Contract to the Scientific Core. *International Journal of Social Science* 168.

virtually impossible for any country to delink itself from the world economic system, nor, obviously, from the global ecological system. One of the implications of this is that there can be no segregated solutions for the north and the south. Either a solution is found that encompasses everyone, or there can be no solution worthy of the name. The *agendas* of the north and south, however, can and should be different, given the different conditions that prevail from one region to another.

Sustainable development is the name given to the quest for such a solution, in which *development* is understood to be the genesis and unfolding of qualitative potential –not just the pursuit of quantitative growth– and *sustainability* covers the ecological, economic, and social[4] dimensions.

It is becoming increasingly clear that sustainable development requires the coordination of measures at the local or micro level (at which many of the problems are manifested and solutions are put into practice) and the macro –national and international– level (policies, agreements, economic instruments which help to create an environment that is conducive to and supportive of micro actions). This means that the quest for common sustainable development requires the participation of all peoples in an effort of mutual cooperation, and work at multiple scales ranging from local to global. It was proposed to work along two complementary lines to deliberate the contribution of Latin America and the Caribbean to science and technology for sustainable development: (1) to consider the specific features of the Latin American and Caribbean region in terms of obstacles to and opportunities for STSD; and (2) to contribute to the global dialogue a Latin American and Caribbean perspective, not only on the region's problems, but on global problems and the universal issues of science and technology for sustainable development.

The subject of is this workshop was therefore the *role of science and technology as a contribution to sustainable development, from a Latin American and Caribbean perspective, focusing on the challenges (and opportunities) posed by sustainable development to science and technology*. Clearly, not all sustainable development problems have a technological solution; in fact, the deep-rooted ecological and social unsustainability of world development patterns reflect more the asymmetries of economic, political and military power that characterize our time, rather than technical or demographic factors; however, the deliberations of the workshop concentrated on those sustainable development issues in which science and technology may play an important role.

The workshop did not conceive of science and technology for sustainable development (STSD) as a new science or a new technology, but as a reorientation of scientific and technological research towards the great challenges of sustainable development.

The workshop proceedings were conducted along four main lines:

1. Core scientific questions. What key knowledge is required for science to make an effective contribution to sustainable development? What core scientific questions need to be answered?
2. Methodological and conceptual challenges. What challenges does the problem of sustainable development poses to the criteria and method of science and technology?
3. Research strategies. What research strategies may be employed and on what scale in order to address the core questions defined?
4. Institutional innovations. How can scientific and technological institutions be better organized to develop research strategies, including cooperation between countries and sectors?

[4] Broadly defined, including also the cultural and political dimensions.

There is a clear logic to the choice of these lines of questioning, as the content of the core questions undeniably influences the methodological and conceptual challenges, which in turn affect research strategies; while the requirement for institutional innovations will depend on the response to all of the above.

C. Critical Knowledge Required (Core Scientific Questions)

The participants of the workshop analyzed the core scientific questions presented in Box 1. It was concluded that these were legitimate and sufficiently broad to discount any limitation to their applicability in the Latin American region. Their very generality, however, detracts from their ability as a basis from which to directly derive a working agenda adapted to the specific features of the region. In general they were also perceived to lean markedly towards the natural sciences. In consequence, it was proposed that, for the purposes of application in Latin America, a greater emphasis should be placed on ethical, social, economic, cultural and political aspects and on different visions of the world.

The strategy adopted was to classify priority sustainable development issues (problems/opportunities) as a prior step to identifying key knowledge-needs (or knowledge gaps) for moving towards the solution of the problems or taking advantage of the opportunities.

1. Specific features of Latin America and the Caribbean

Although sustainable development is a global challenge, there is good reason for developing a specific agenda for Latin America and the Caribbean, because of the particular features of the region, which include:

- Increasing levels of extreme poverty and sharp contrasts of inequity and social marginalization.
- Increasing concentration of the population in cities. This trend increases demand for resources and energy and exacerbates the loss of cultural identity, marginalization and social inequity.
- A form of integration into the globalization process that leaves the countries seriously vulnerable in terms of competitive capacity.
- The planet’s greatest biodiversity, but one of its highest loss rates due to the conversion of natural ecosystems.
- Secular problems of land tenure and accreditation of rural properties, which hamper conservation efforts and the sustainable management of natural ecosystems.
- An agricultural frontier that is expanding faster than anywhere else in the world.
- The world’s largest concentration of fresh water.
- Low rates of societal participation in decisions that affect a country’s natural, social and economic capital.
- Severely limited skilled human capital at the tertiary level, which restricts the capacity to deal with social and economic development problems.

2. Critical knowledge needs

What is the key knowledge needed to promote the long-term ecological, economic and social sustainability of development in the region? Although new critical knowledge is needed in all areas, in many cases we already possess enough basic knowledge to approach the path of

sustainability more closely than we are doing at present. The largest difficulty lies, perhaps, in how to put that knowledge into practice.

The knowledge required to solve these problems relate to a range of areas and disciplines. In general, this knowledge concerns the study of society-nature interactions.

The following are some of the areas in which new knowledge is required:

- How to eradicate poverty in the region, and how to do it in a sustainable manner (without replicating the unsustainability of the development patterns that prevail in Latin America and the Caribbean today).
- Identification of the political, economic, cultural and technical obstacles to the application of the already available appropriate scientific and technical knowledge for sustainable development (the political economy of unsustainability).
- The real (market and intangible) value of ecosystemic services (including their differential value for different sectors of society). If we had a clearer picture of what the ecological services that ecosystems provide to society are really worth, many practices that appear to be justifiable from an economic point of view would no longer be perceived as such (the expansion of the agricultural frontier in the Southern Cone, for example).
- What factors represent a threat to biological diversity (genetic, species, functional, landscape, etc.) and what levels of degradation are acceptable in that they allow an adequate response time for adaptive management to steer the situation towards sustainable use or conservation?
- The ecosystemic and ethical values of diversity. In other words, how many and which species can be lost, and what else do we lose when we lose biodiversity? What are the ecosystemic services of biodiversity?
- What are the costs in terms of diversity, ecosystemic services, availability of water and biogeochemical cycles of the carbon-sequestering plantations that have been proposed within the framework of global measures to mitigate the effects of greenhouse gas emissions?
- How can we guarantee the viability of rural agricultural systems on which the maintenance of genetic diversity depends?
- It is necessary to recover and systematize traditional or indigenous practices and technologies for the sustainable use and management of natural resources and environmental services as tools of STSD.
- Most local and global environmental problems derive from the environmental impact of demand for energy and resources by each individual. In consequence, it is vital to learn how to induce positive behavioral changes in order to implement sustainable development models, including also the behavior of public and private decision-makers. Social sciences, philosophy and especially social psychology are key disciplines in the quest for solutions to this problem.
- It is necessary to identify gaps in legislation regarding the protection and the sustained and economically attractive use of natural resources, and to develop mechanisms to ensure compliance with existing legislation.
- It is necessary to generate predictive regional models and scenarios, based on more realistic suppositions than current ones, including the distorted nature of globalization in Latin

America and the Caribbean (for example, the fact that in many countries the destruction of ecosystems is more closely related to the international market than to domestic pressures).

- Study of asymmetries between the rural environment and the large cities, with an emphasis on demands for resources.
- How can the region attain a model of sustainable agriculture that is also competitive at the world level? Consider, for example, the expansion of arable farming at the expense of natural vegetation in Latin America and the Caribbean, leading to the destruction of ecosystemic services, the expulsion of small producers and the concentration of land ownership.
- How can the subsistence agriculture practiced by millions of poor farmers in the region be transformed into sustainable rural agriculture?
- How can existing, technically appropriate solutions be made economically competitive in the conditions that prevail in our countries?
- We need to understand how economic and distributive trends are related to energy, matter and the biological cycles of the environment, at different scales (local areas, water basins, regions, etc).
- Research is needed to improve our understanding of the thresholds, limits and vulnerability of each country's priority ecosystems, in accordance with their resilience and carrying capacity.
- How can scientific and technical knowledge be mobilized to achieve new forms of integration into the global economy, by viewing technological innovation as a contribution to sustainable development? We need to seek opportunities to link dynamic sectors with the practice of sustainability.
- Determinants of ecological, economic and social vulnerability (and resilience) of the region's socioecological systems. This is a key area of interdisciplinary work in Latin America and the Caribbean.
- Means to transform ecological heterogeneity –a feature of many of the region's ecosystems– from an obstacle to production into an opportunity, by designing new systems of marketing and reporting that will guarantee a sufficiently regular delivery of products to the final consumer.
- Management of technological and productive plurality, by combining, when appropriate, cutting-edge, modern and traditional technologies.
- Sustainable and coordinated management of the major biogeochemical cycles in the region that cross political boundaries (such as the water cycle in the Amazon, supranational hydrographic basins, shared ecosystems, etc.).

D. Methodological and Conceptual Challenges

STSD poses substantial methodological and conceptual challenges, which refer not only to specific methodologies for obtaining necessary key knowledge, but also to the very methods and criteria of S&T.

1. Epistemological challenges

Sustainable development calls upon science and technology (science particularly) to re-examine a number of epistemological issues, including the unit or units of analysis to be used, the issue of integration, and the criteria of truth.

The recognition that human (social, economic, etc.) activities and the environment are coupled and therefore mutually determined systems (as well as strongly non-linear, complex and self-organizing) leads to the conclusion that the main unit of analysis of STSD must encompass the total coupled system or "socioecological system" (defined at the scale appropriate for the problem considered) and the associated processes.

An integrated approach to research and to the management of these systems for sustainable development is therefore required. This integration may have several facets (among disciplines, between science and policies, between understanding and action, among spatial-temporal scales, among quantitative and qualitative factors, and among science and other forms of knowledge).

In the research sphere, integration implies the adoption of a systemic approach (the scientific study of wholes) and an inter-disciplinary –or even trans-disciplinary– research style.

Lastly, whether –and how– the criteria of falsification for rejecting hypotheses are applicable to STSD is a question that needs to be re-assessed. Research frequently focuses on narrow and quantifiable aspects of problems, an approach which overlooks potential interactions between the components of complex biological systems of which humans are part.

Ockham's razor, the heuristic scientific principle which states that "one should not increase, beyond what is necessary, the number of entities required to explain anything", is still valid in a complex systemic world, but the definition of "necessary" may require to be drastically expanded in order to encompass the linkages between the object under study and other parts of reality.

2. Interaction with other knowledges

As modern science has evolved, its powerful conceptual structures for understanding the natural world and its historical relation to economic and political intervention have contributed to the exclusion of other sources of knowledge patrimony of marginalized segments of society, be they indigenous, rural, poor or ethnic minorities.

In recent decades, other forms of knowledge have begun to impinge upon different areas of scientific research, particularly when it concerns controversial scientific and technical subjects that have clear public dimensions. Examples from public health research suggest that social movements can participate in distinctive ways in scientific activity, while at the same time the link with science has a significant influence on these movements.

We lack, however, a comprehensive framework regarding the multiplicity of local knowledges that could be used as inputs for scientific research and have thus far remained largely unknown to research systems as potential sources of innovation. The key knowledge generated by the "lay expert" is often contextual, partial and localized, and has not been easy to translate or integrate into a more scientifically manageable conceptual framework.

Although the affirmation of the right to cultural difference has increasingly won legitimacy and is accepted as politically correct, scientific ignorance (and in fact almost always condemnation) of traditional knowledge is still widespread. Science and technology for sustainable development are not exempt from the epistemological debate.

In this respect, it is proposed to seek areas in which scientific research and non-scientific knowledge in relation to specific subjects may overcome their profound differences to exchange

concepts and empirical knowledge. Science for sustainable development creates historic opportunities to use inputs from other forms of knowledge, by exploring the practical, political and epistemological value of traditional/local knowledge as an the under-utilized resource.

Decisions that are taken in the workplace, S&T research laboratories, health care, legislation forums etc, should include all the stakeholders in the subject being researched, particularly when they will be adversely affected by the outputs of science and technology.

The incorporation of lay experts in the processes of public decision-making and the research agenda is not an issue of more democracy. It makes good sense in terms of using the expertise that is available, even when it is found in unexpected places.

3. Methodologies for Conducting Scientific/Technological Activities in Relation to Sustainable Development

Methodologies relating to supradisciplinary[5] approaches

Sustainable development can be approached from many different disciplines, but none of these alone can provide an answer to the main problems of sustainable development. Moreover, a multidisciplinary team can contribute little if the experts from each discipline limit themselves to producing a technically correct vision of their own specialty, and lack the ability or willingness to combine their knowledge with that of other disciplines. The step from the multidisciplinary to the interdisciplinary (or trans-disciplinary) level requires the development of team work and methodologies articulating different sciences (and even different areas of expertise within the same science). In terms of their application to sustainable development-related disciplines, these methodologies are still in their infancy and need to be developed within a Latin American and Caribbean perspective, taking its idiosyncrasies into account.

Methodologies relating to prediction of events and situations

The interdisciplinary approach, especially in relation to sustainable development, tends to involve long term time horizons. There is also a conflict between the time scales of sustainability and political decision-making, which means that methodologies for anticipating problems need to be strengthened. In this respect, scenario-building, mathematical modeling and trend studies are examples of methodological proceedings that should be put to good use. These require large volumes of data and historical information, however, which are rarely available in Latin America and the Caribbean. It is therefore a priority to develop methodologies which can be used to conduct quantitative and predictive evaluations and which are useful and reliable even when data is limited.

Methodologies relating to monitoring and impact indicators

Given that human activity has a cumulative effect on natural resources, studies should be based on the evolution of a range of sustainability indicators. It is therefore necessary to identify the most crucial sustainable development indicators and monitor them over the long term. In Latin America and the Caribbean it is particularly important to monitor biodiversity, the great underground water reserves, and the arable soils in the zone of expansion of the agricultural frontier.

Methodologies for the rigorous processing of qualitative variables

Many of the variables and processes that are important for sustainable development are by nature qualitative (e.g. cultural and political factors). In many cases, although the variables and relations are quantifiable in principle, in practice it is very difficult to arrive at an estimate of the

[5] This term is used as a generic denomination for multidisciplinary, interdisciplinary and trans-disciplinary approaches, without entering into the current debate on the definition and usefulness of each.

corresponding values. It is therefore essential to develop scientific methodologies of qualitative analysis which are logically rigorous, verifiable and reproducible.

Methodologies relating to kinds of knowledge

The Latin American and Caribbean region is home to a wealth of traditional/local knowledge. Scientific knowledge and other kinds of knowledge are potentially complementary. Indigenous and rural knowledge is the result of many centuries –and sometimes millennia– of accumulated wisdom on how to use and live alongside natural resources. For the Latin American and Caribbean region it is important to develop methodologies to integrate this knowledge into conventional scientific/technological systems.

It is worth pausing to consider that first modernization and now globalization, with their push towards cultural homogenization, are rapidly eliminating the region's traditional capital of accumulated empirical knowledge. This amounts to a genuine loss of "socio-diversity", which is dying out in parallel with biodiversity.

Methodologies for establishing priorities, monitoring *and evaluation of S&T*

S&T institutions in the region have a weak capacity to communicate with political decision-makers, which must be reinforced. In order to improve this relationship it is necessary to identify new methods to communicate the opportunities and threats scientists identify. Comprehensible models and simple and realistic indicators are needed for political decision-makers and for non-experts who can participate and help in monitoring. The development of methodologies for "Science-Policy" dialogue is another important strategy. This will make it possible to strengthen public participation in the identification of priorities and the assignment of resources on the science and technology agenda. In this respect, it is also important that research methods should include means to identify priorities and conduct follow-up and evaluation in conjunction with other actors or referents in the problem, including representatives of affected local communities, dissemination experts, other scientists, etc.

E. Research Strategies

- The design of strategies should be based on prospective studies, assessments of regional capacity, research agendas driven by the needs of users and strategies to promote changes in attitudes. In this respect, research strategies must be comprehensive and must provide the opportunity to implement models for the analysis of complex systems and the use of modern tools.
- Strategies should be integrated at the national and regional levels, in order to promote:
  - Frameworks for the discussion and analysis of problems.
  - Reinforcement for existing mechanisms of integration, while promoting new mechanisms when necessary.
  - The development of programs to put these strategies into practice.
- It is also necessary to distinguish levels (different referents and different social actors), geographical zones and thematic areas. Different agendas exist (local, national, regional and global) for different referents. Working on the basis of long-term perspectives and different levels of referents poses operational and financing challenges and affects political implementation in a number of ways. It is essential to be aware that, depending on the relevant unit of analysis, a multiplicity of scales exists. Whenever possible, strategies should not be delineated by institutional or geopolitical boundaries, but by those

determined by the dynamics of processes and systems. Units of analysis must vary to take into account the characteristics and complexity of processes.

- It is essential to mobilize scientific and technological know-how in order to identify and achieve alternative forms of integration into the world economy, using technological innovation as a contribution to sustainable development. Opportunities must be sought to link the most dynamic sectors of the economies with the practice of sustainability. In this respect, it is particularly important to deal with the issue of intellectual property.
- Any strategy must take into account the effect of the reduction of the role of the State on research. There is a need to design options to secure financing for knowledge generation in order to preserve biological and cultural wealth and monitor and control the appropriate use of resources. Proactive public policies are needed to enable the development of S&T for sustainability.
- Efforts should be made to overcome the structural limitations arising from the fact that only a small percentage of young people enter higher education. It is strategically essential to expand human capital, especially at the skilled level, and to develop an institutional infrastructure for that capital. The use of strategies suited to the local situation could mitigate the brain-drain problem. To bring this about, among other solutions, it is important to promote the formation of national and international networks involving a variety of actors and disciplines, in order to make the best possible use of human resources and infrastructure. In this sense, horizontal cooperation must be encouraged in order to share the knowledge that is generated among sectors and countries that suffer from comparable problems.
- Civil society and its organizations should be engaged in all the phases of scientific research that affect them or is pertinent, from the conception of the project and the definition of objectives, rationale and expected outputs, to the enjoyment of the benefits resulting from the research. This will require a combination of research and societal learning, including elements of collective action, innovative public policies and broad social experimentation. It is essential to work with all social groups to understand how they develop their know-how and conduct social practices. In this context, mechanisms should be created to report on the social relevance of scientific and technological research and to secure the transfer and return of knowledge to all the actors involved.
- The major issues that define the particular features of Latin America –poverty and biodiversity– call for the design of special strategies. An alliance-building cognitive effort is required in order to understand and address poverty, inequity and the violence that it generates, together with the regional distortions of the democratic system and the resulting asymmetries in power distribution, against the backdrop of the region's rich biogeophysical environment. This means working jointly with the different disciplines that are engaged in generating economic, political, technical and cultural proposals which constitute alternatives to the dominant model, such as research into the effectiveness and efficiency of different energy uses in order to guarantee an energy system that is sustainable and accessible to the whole population, or research into markets which could capitalize on the region's biodiversity (such as the production of rubber in tropical forests, cacao with certificates of origin, etc.) and other comparative advantages that mitigate the adverse effects of globalization, such as global environmental services.

F. Institutional Innovations

This section revisits many of the elements discussed previously, especially those of a methodological and conceptual nature, and seeks to encompass them in the framework of institutional design for sustainable development.

By way of introduction, it should be noted that the innovations needed to make institutions involved in implementing R&D and human resources activities, and in development, planning and management, more consistent with the points discussed in the previous sections would imply a significant turning point in their history.

Historically, in Latin America and the Caribbean the research community has shaped and channeled the structure, organization and operation of these institutions to a much greater extent than occurs in the developed countries, and has naturally done so in keeping with the values that it views as most important. In fact, the structurally peripheral nature of the Latin American and Caribbean region has lead to a situation in which production activities in general (with the exception of agriculture and health care) do not demand locally generated know-how in the way that the industrialized countries' sectors of production do.

In the advanced countries a social network of actors (industrial enterprises, state bodies, the military, organized social movements, agricultural producers, etc.) which has been tightly and comprehensively woven over many decades, influences scientific and technological activities by means of an array of "signals" as to what is and is not relevant, required, and cost-effective there. In Latin America and the Caribbean the social network of actors (emitting agents) is very fragile and more loosely woven and patchy than in the advanced countries, which means that the research community tends to be influenced more by what is desirable by its peers outside the region. The result is that the research agenda of Latin American and Caribbean institutions does not adequately reflect the knowledge needs for the region's development.

The particular research needs of sustainable development exacerbate this distortion. In order to remedy this, in addition to completing and reinforcing the social network of actors and channeling their signals, it is important to act jointly with the receiving agents (institutions involved in S&T) to amplify that signal and decodify it using methodologies for strategic innovation management that will enable the institutions of the Latin American and Caribbean region to meet the S&T needs of sustainable development in a more satisfactory manner. A number of pitfalls, ranging from voluntarism to paternalism, must be avoided in the pursuit of joint action on both social demand and scientific and technological supply.

The changes needed require methodologies for the strategic management of innovation which, by helping to establish a new institutional culture, will make it possible to optimize existing potential for innovation and to help S&T activities gain the impact needed to contribute to sustainable development. Three sets of methodologies have been identified:

The first set is intended to make the research agenda reflect, through the identification of priorities and opportunities, current and anticipated knowledge demand arising from production activities related to sustainable development. It is essential that this set should include at least three of the actors who are directly involved with R&D activities: researchers, public innovation policy managers and the private sector (both business and non-governmental organizations).

The second set of methodologies concerns the identification of the potential users of the results of research, in order to engage them in the design and development of projects. Users will then be supportive of the activities of the institutions and ensure that the research outputs have a better chance of being used effectively.

The purpose of the third set of methodologies is to increase internal efficiency and the capacity for establishing relations between institutions and with S&T decision-making bodies and other agencies. The methodologies needed to accomplish this include: the identification of problem situations, definition of key actions, identification of crucial areas of governance, recognition of actors and flows related to the generation and use of knowledge and power (inter- and intra-institutional), Situational Strategic Planning (SSP), structural analysis, scenario-building, etc.

Most of the methodologies mentioned have yet to be used in public institutional innovation in S&T, although they have been used to some extent in private organizations and in other public policy spheres. Some of the methodologies are in the process of development throughout the world, including Latin America and the Caribbean. A small number of others have already begun to be employed in institutions in the region. For this reason, a necessary activity –and one that is relatively easy to implement– is to produce an analytical inventory of the methodologies mentioned here, which could be made available to Latin American S&T institutions to aid the process of institutional innovation for sustainable development.

It should be emphasized that institutional innovations are important to ensure the viability of the objectives proposed in the other aspects of sustainable development analyzed in this report.

Scientific and technological institutions need to undergo a renovation in order to be able to respond to the problems identified within the framework of sustainable development.

This renovation must include, in addition of what it was already said:

- Adequate lines of financing.
- Efficient mechanisms to mobilize funds.
- Inter-institutional coordination.
- Training on the STSD approach in institutions that manage, promote and raise funds for science and technology.
- Generation of effective institutional channels to transmit social demand for science and technology to the relevant agencies.

The generation of knowledge for sustainable development requires efforts that transcend national borders and institutional and financial mechanisms that can operate at a supranational level. Sources of funding that are stable and reliable over time are also crucial for scientific and technological research activities. This, in turn, requires an entity (a fund or program) to be responsible for mobilizing and assigning resources. This does not necessarily mean creating new institutions, but making better use of those that already exist.

1. Financing

It would be advisable to create a Latin American and Caribbean Research Fund for Sustainable Development, to support research projects, technological development and projects implementing sustainable development strategies.

These funds should be used to encourage projects that are open to international competition, and which place a high value on cooperation among institutions and work groups from different disciplines and countries of the region. Cooperation should be encouraged between social groups, sectors of production and academics.

The institution administering the funds must be independent of the institution(s) responsible for implementing projects, in order to avoid conflicts of interest.

Among other avenues of funding to explore, the following are worthy of consideration:

- Fixed contributions from the governments of the region, preferably in the form of pledges complemented by means of additional contributions. These could be used to create an endowment to guarantee the sustainability of funding.
- Funds created within financial agencies based or operating in the region, which would allocate a portion of their net income to this purpose.
- Charges for the provision of environmental services and the use of natural resources by net importers of environmental space.

2. Rules and priorities

- To alter the "rules" of funding assignment and national research competitions so that interdisciplinary or trans-disciplinary projects in the area of sustainable development can be admitted and adequately classified.
- To develop mechanisms to promote and assess long-term research projects. The current system is incompatible with this type of project.
- To propose subjects that bring together efforts, funds and institutions at the regional level in areas such as biodiversity, water and alternative energy. Today the region's institutional networks are still weak.
- Join regional and subregional efforts to create networks for the production and transmission of sustainability know-how.
- In general, design coordination with the private sector (associations of producers, committees, business) to reflect the relevant objectives. For example, generate research which enables the certification of private-sector production activities.
- Ensure that existing knowledge reaches the institutions and groups responsible for making decisions, as there are no systemic channels for this purpose at the present time.

3. Participation

The participation of other social actors, in addition to S&T professionals, at the different phases of the scientific and technological research process and in related decision-making, can be crucial for a number of reasons:

Ethical reasons. The undeniable right of the sectors affected to participate in decisions that have a bearing on their wellbeing (such as the installation of a nuclear or chemical plant in their area).

Political reasons. It is essential to guarantee society's control over R&D outputs, particularly those that have an impact on health and the environment.

Pragmatic reasons. In certain cases (e.g. new agricultural technologies, new health treatments), it can be especially important to encourage the social groups who are the intended beneficiaries to have a sense of ownership over the scientific and technological knowledge. For this it may be essential to engage these groups at the R&D phases in order to incorporate their interests and perceptions into the process.

Epistemological reasons. The complex nature of the sustainable development problematique, in which biogeophysical and social processes usually overlap, often makes it necessary to consider the different perceptions and objectives of the social actors involved. Also, it

is increasingly clear that it is important to combine empirical knowledge built up by traditional farmers, other cultures and ethnic groups, etc. with modern scientific and technical knowledge (the constructive combination of diverse types of relevant knowledge).

From the foregoing it can be concluded that it is not necessary or appropriate to broaden participation in all cases and for all phases of R&D; the kind and degree of participation is a question to be analyzed in relation to each particular problem and context.

The specific recommendations made at the workshop included the following:

- Greater societal control over the outputs of research, through the creation of channels for citizen participation in research funding and orientation.
- An active participation by the scientific community in the creation of mediation forums for sustainable development problems, whose complexity requires the reconciliation of conflicting and disparate interests.
- Promotion of societal involvement in research (i.e. research action). Participatory research involving all the social actors and points of reference in cases where it is appropriate.
- Combination of research with societal learning that includes elements of collective action, innovative public policies and social experimentation. This means working with all the social groups in order to understand how they build their knowledge and social practices.
- Build capacity in the institutions involved with the implementation, promotion and management of R&D in the above mentioned methodologies, in order to promote the institutional change required to contribute to sustainable development.

G. Concluding Remarks

- Clearly, not all the sustainable development problems of the Latin American and Caribbean region can be resolved by means of science and technology. However, S&T have much to contribute in many cases, and the ability to generate and use them is increasingly a key economic factor in today's world.
- Sustainable development far transcends the environmental sphere and the challenge to science and technology is therefore much greater than simply incorporating environmental considerations into development. The socioecological system has to be approached in its totality, encompassing its social, economic, institutional and ecological dimensions. No less important and complex is the need for the design and implementation of comprehensive policies based on new knowledge and S&T potential. This was stressed in a number of different ways in several of the workshop's conclusions.
- The challenge that sustainable development poses to science and technology in the region is real and serious. In Latin America and the Caribbean it is necessary not only to reinforce (and in some cases rebuild) scientific and technological capacity to boost growth and economic competitiveness, but to do so while redirecting a large fraction of efforts towards the generation of a new scientific and technological capacity: science and technology for sustainable development.
- There is no established STSD tradition in either north or south. It is therefore necessary to create it, which represents an opportunity for international cooperation.
- Although a number of groups can be found in Latin America and the Caribbean that propound interdisciplinary studies, it is necessary to move beyond rhetoric and implement

effective measures to make the training of human resources, allocation of funding, and setting of R&D priorities conducive to the understanding and resolution of sustainable development problems in the region.

- The above implies much more than defining priority issues. A serious approach to the challenge posed by sustainable development to science and technology has major repercussions at the level of theory and methodology, the practice of scientific and technological research, the definition of research agendas and the organization and operation of institutes that research and promote science and technology.
- This report analyses some of the implications and makes recommendations to the scientific and technological community and to institutions that generate and promote scientific and technological research.
- It is important to bear in mind that the STSD challenge, while by no means trivial, represents an area of action that is both feasible and accessible for the region, unlike other scientific and technological challenges which require very expensive and sophisticated equipment, or a critical mass of researchers and resources. The challenge is technically and economically manageable for the region.
- In this respect, the Latin America and the Caribbean region already possess a substantial knowledge base. Although there are crucial information gaps, in many cases the main obstacle to progress in sustainable development is ignorance of knowledge and techniques that are already available. In parallel with research to generate new knowledge, it is therefore also urgent and necessary to improve the availability, dissemination and integration of existing relevant knowledge.
- Another key point is that STSD refers to a type of knowledge that must be generated endogenously in the region. This knowledge cannot be taken “out of the shelf” from other countries or from the stock of universal knowledge.
- We cannot, however, ignore the serious structural obstacles in the region that hinder scientific and technological development, and which set Latin America and the Caribbean apart from the industrialized countries.
- Given the overlapping and complex nature of sustainable development problems, in many cases (though not all) it may be necessary to seek the participation of different sectors and coordinate different sources of knowledge (not only different scientific disciplines, but also the perspectives of civil society, indigenous groups, business, politicians, etc.) in the science and technology endeavor.
- This represents a major scientific and technological challenge, because it is essential to ensure that this coordination is not perceived as an attempt to justify lack of scientific and technological rigor, which could gravely damage the weak scientific and technological system in Latin America and the Caribbean. A serious and far-reaching scientific analysis of systems is required. In addition to material and energy phenomena, this must include an irreducible variety of perspectives and knowledge sources, and even of intentions and objectives.

III. Proposals for follow-up and future actions

The possibility of promoting the creation of a Latin American and Caribbean STSD network was discussed. Among its functions could to help to obtain financial and other support for STDS research in the region, to promote local and regional STSD agendas, to serve as a forum helping to legitimate and support the active incorporation of STSD into the governmental political agendas, and contribute to the dissemination of information and capacity-building of the researchers of the region. Other ideas included performing a periodic updating of electronic publications such as the Reader distributed in the workshop, to create an itinerant chair for the countries of the region, to produce a prioritized list of the problems for STSD in the region, and publish a book on the subject making use of the expertise of the members of the network.

The workshop recommended that ECLAC explore the political viability of a regional network as defined above.

The idea of preparing a collective document containing a Latin American and Caribbean perspective on STSD, based in the ideas presented at the workshop, was supported by the participants. It was agreed that such paper should be brief and it should be submitted for publication to a journal reaching the S&T systems of the region.

Annexes

Annex 1

Participant profiles and areas of interest

Albornoz, Mario. Researcher, National Council of Scientific and Technical Research (CONICET). International Coordinator of the Ibero American Network of Science and Technology Indicators. Has been engaged for a number of years in the study of scientific and technological policy in Latin America and the relationship between science, technology and society. Within this framework, one of his main activities concerns the construction of indicators, with a view to establishing an empirical basis on which to evaluate the record of the region and its countries in the effort to create, implement and adapt scientific and technological knowledge to resolve priority social and economic problems. He also studies institutions of higher education. His interest in the workshop topics relates to his activities, involving various aspects of the problem of sustainable development: first, as a contemporary manifestation of the region's quest for new paths for development, which has been a feature of Latin America and the Caribbean since the post-war period and has generated major accomplishments of theory construction (the story of the establishment of ECLAC is an example of this). Second, as a core of contemporary problems with regard to science, society and nature. Lastly, as evidence of the risks that are inherent in a model of industrialized society that undermines its own foundations of sustainability, lacks adequate oversight mechanisms and disregards major opportunities to achieve a more equitable form of societal construction, within the framework of a more harmonious relationship with the natural environment.

Banus, Eduardo M. Project Manager, Inter-American Institute for Global Change Research (IAI). Has worked for the last 10 years on tasks relating to Global Change and Climate Change in Latin America and the Caribbean with: (a) the Government of Argentina (Science and Technology Department) and CONICET; (b) United Nations UNDP/GEF/WMO; and (c) IAI. His interest in the workshop issues lies in seeking to develop an international strategy on a sustainable science for development. The regional actors have a very important role to play in this, through potential for joint actions. These actors include ECLAC, with its record in the United Nations system in the region, IAI with its 10 years of experience in developing a scientific agenda within continental global change, together with other players in the countries who are in a position to develop this important initiative.

Bárcena, Alicia. Currently Director of the Sustainable Development and Human Settlements Division of the Economic Commission for Latin America and the Caribbean (ECLAC). The principal focus of her career has been public policies for sustainable development, with a particular interest in the spheres of environment, environmental economics and citizenship. She holds a Bachelor's Degree in biology and a Master's Degree in Ecology from the National Autonomous University of Mexico and a Master's Degree in Public Administration from Harvard University. Her previous posts include Coordinator of the United Nations Environment Programme (UNEP), in which she was responsible for a global programme entitled Environmental Citizenship, in coordination with parliamentarians, consumers' groups, religious orders, local authorities, the media and educators. Together with Maurice Strong, she was a founder of the Earth Council, a global non-governmental organization based in Costa Rica, which has a mandate to follow up the agreements of the United Nations Conference on Environment and Development from the perspective of civil society. She worked on the preparation of this Conference as Chief Programme Officer, holding responsibility for a number of Agenda 21 issues. In Mexico, her native country, she was Director General of the Government's National Institute of Fishing and Under Secretary

for Ecology within the Ministry of Urban Development and Ecology during the term of President Miguel de la Madrid. President of the NGO Cultura Ecológica, Coordinator of South-East Regional Studies for the Institute of Political, Economic and Social Studies, PRI, and Regional Director for the South-East of Mexico of the National Institute for Research on Biotic Resources, based in the state of Yucatan. She has conducted research in the fields of botany and ethnobotany and has designed programmes for ecology and botany degrees offered by the Autonomous Metropolitan University of Mexico. She has published a number of articles on sustainable development, economics and environment, conservation and natural resources management, and ecology and environmental citizenship.

Breulmann, Gerhard. Scientific Officer, Inter-American Institute for Global Change Research, IAI. Works in the planning of IAI programmes and the development of short- and long-term scientific plans, including new initiatives. One of the main objectives of IAI is to understand the interactions between nature and society in order to develop and finance, among other activities, science for sustainable development in the region. IAI thus has a specific interest in the identification of priorities within sustainable development science and in defining how IAI may contribute to progress in this area.

Carrizosa Umaña, Julio. Full Professor, National University of Colombia, Institute of Environmental Studies. Researcher and head of courses on Development and Environment, Environmental Systems and Environmental Awareness. Civil Engineer, Master in Economy from the Universidad de los Andes. Master en Administración Pública de la Universidad de Harvard. He directed the Instituto Geográfico Agustín Codazzi and the Instituto del Desarrollo de los Recursos Naturales y del Ambiente (INDERENA). Member of the Colombian Academy of Exact, Physical and Natural Sciences. His main research areas are environmental policy and sustainable development. Currently on a sabbatical year preparing a research project on regional and local sustainability and territorial imbalances. His interest in the subject area of the workshop concerns the possibility of participating in a network that could contribute to his research activities.

Cimoli, Mario. He was born in Buenos Aires, Argentina in 1956. His nationality is Italian. His degrees are: Laurea Degree in Economics, University of Venice; D. Phil. (Doctor of Philosophy), University of Sussex, Professor of Economics, University of Venice. He has been Professor at the Faculty of Economics of the University of Udine of the annual Mathematical Economics course, Professor of Economics at the University of Venice, Profesor Visitante Titular "C". Maestría en Economía y Gestión del Cambio Tecnológico, Universidad Autónoma Metropolitana, Unidad Xochimilco. Módulo II, Tecnología y Economía II, Economía del Cambio Técnico,, Organización Industrial y Cambio Tecnológico. He has published extensively on Economics Innovation Growth and Trade. He is actually working in the Division of Production, Productivity and Management, ECLAC

Corell, Robert. Researcher with the Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University and with the American Meteorology Society's Atmospheric Policy Program. He was Assistant Director of Geosciences at the National Science Foundation (NSF) and chief delegate for the United States in international bodies with responsibilities in research programmes on global climate change. He is currently researching the areas of global change science and the relationship between science and public policies, methods and models of vulnerability, and analysis and assessment of the vulnerability of Arctic communities, mainly regarding UV radiation studies. He is involved in the Initiative on Science and Technology for Sustainability. He is an oceanographer and an engineer by training, and holds a B.S., an M.S. and a Ph.D. from the Massachusetts Institute of Technology (MIT).

Dagnino, Renato. Department of Science and Technology Policy, State University of Campinas (Unicamp). Full Professor at Unicamp and at the Maestría Virtual Latinoamericana de

Ciencia, Tecnología y Sociedad. A researcher with the Brazilian National Council on Scientific and Technological Development (CNPq), he created and directed the Unicamp Department of Science and Technology Policy, and served as Guest Lecturer at the Universidad Nacional de Quilmes, Universidad Nacional del Nordeste (Argentina), Central University of Venezuela, and Universidade Federal do Rio Grande do Sul. He has also served as a consultant to Brazilian government agencies, such as Programa Sociedade da Informacão, CAPES and Finep, and international agencies such as UNU, UNIDO, UNIDIR, ILO, UNESCO, ECLAC, UNDP, OAS, IDRC, World Bank, IDB, UNAID, USIS, CONICIT Venezuela and Costa Rica and COLCIENCIAS. His interest in the workshop subjects relates to technological prospective – seeking to identify knowledge demands for a socially and environmentally sustainable scenario in Latin America– strategic innovation management –directed at changing the institutional design of Latin American science and technology– and contributions to an essay (or book) on the non-neutrality of science and technology.

Díaz-Rossello, Roberto. Supervisor in the area of arable agriculture, National Institute of Agricultural Research (INIA). International coordinator, Environmental Sustainability Platform, Cooperative Programme for the Technological Development of Agriculture in the Southern Cone (PROCISUR). Works on planning, follow-up and evaluation of research projects aimed at the technological development of field crops in Uruguay. The bulk of the institution's sustainability-related projects are conducted in this area. He coordinates an Environmental Sustainability programme, which began in 2001 and in 2002, will establish a platform for the implementation of a number of cooperative research projects that are now underway. His interest in the workshop issues is to contribute to the coordination of national and regional experiences and activities that come under the heading of sustainability. The main mission of the institutions in which he works is to provide science and technology to society. The workshop issues explore the economic and social dimension of sustainable development and serve to link these research fields with the sustainability of natural resources.

Díaz, Silvia. Assistant Professor at the Department of Biological and Ecological Diversity of the National University at Cordoba and researcher with the Multidisciplinary Institute of Plant Biology, of the National Council of Scientific Research of Argentina. Her field of expertise is plant ecology. Her research relates to the interaction between functional biodiversity and ecosystemic processes and how these interactions may be modified by changes in climate and land use. She has participated in several international initiatives on these subjects, such as IPCC (Group II, Impacts), the IGBP Global Change and Terrestrial Ecosystems Group (GCTE) and the Convention on Biological Diversity (CBD). Her interest in the workshop concerns a number of initiatives that she has spearheaded, both in her individual research group and within the framework of IGBP, directed at analyzing the sustainability and vulnerability of agricultural ecosystems established over natural and semi-natural ecosystems.

Dickson, Nancy. Research Associate at the John F. Kennedy School of Government, Harvard University. Her main interests lie in institutional arrangements and processes for facilitating more productive interactions among the research, assessment and decision-making communities involved in problems of environmental change and sustainable development. She conducts long-term research on the evolution of social responses to global change. She is Executive Director of the Research and Assessment Systems for Sustainability Program, which seeks to contribute to strategies that will enable the next generation of national and international global change programmes to be integrated more effectively. Associate Director, Global Environmental Assessment Project, a research and training effort to improve the effectiveness of scientific advice in international environmental policy-making. She is a member of the Secretariat for the Initiative on Science and Technology for Sustainability. She trained as an environmental planner at Cornell University.

Elizalde Hevia, Antonio. Rector of the Universidad Bolivariana. He has worked for almost three decades on development issues and their ethical and epistemological dimensions, taking a critical stance to developmentism (economic growth), mainly because of its high environmental and social costs. He heads an academic community which pursues the quest for sustainable societies and seeks to generate knowledge collectively, by developing complex thought with an ecosystemic vision and inter- and cross-disciplinary approaches. His interest in the workshop relates to the search for answers to questions such as: How can scientific and technological research be conducted on and for a human scale? How can we develop a science of peculiarity, i.e. one capable of recognizing specificity and diversity as the only possible form of sustainability? How can scientific interest be shifted and analysis be angled away from mainstream, centralist measures and towards measures of dispersion, towards the peculiar, the marginal, the eccentric and the novel?

Gallopín, Gilberto. Currently Regional Adviser on Environmental Policies in the ECLAC Sustainable Development and Human Settlements Division, working in the area of Regional Sustainability Assessment. He obtained a degree in Biological Sciences from the University of Buenos Aires (Argentina); a Ph.D. in Ecology from Cornell University (United States); and was a Post-Doctoral Fellow at the University of British Colombia (Canada). He has been the Director of the Systems for Sustainable Development Programme of the Stockholm Environment Institute (SEI) based in Stockholm, Sweden; Leader of the Land Use Program of the International Center for Tropical Agriculture (CIAT) based in Cali, Colombia; a Senior Fellow of the International Institute for Sustainable Development (IISD), Winnipeg, Canada; Senior Expert on Environment and Development at the International Institute for Applied Systems Analysis (IIASA), Austria; Full Professor of the University of Buenos Aires and of the Fundación Bariloche, Argentina, in addition to Executive Director and Chairman of the Board of the latter. He is a founding member of the New World Dialogue on Environment and Development and of the Inter American Group for the Sustainable Development of Agriculture and Natural Resources. Until 1991 he directed the Ecological Systems Analysis Group (Argentina). He co-authored Latin American World Model. He has carried out research, consultancy and assessments, providing technical assistance and guiding post-graduate students in fields such as ecological systems analysis, ecological theory, environmental impact assessment, environmental and land use prospective, the environment-development link, environment and quality of life, sustainable development indicators, impoverishment, sustainable development and global, regional and local scenarios. At present, as well as Regional Adviser on Environmental Policies in the Environment and Human Settlements Division of the Economic Commission for Latin America and the Caribbean (ECLAC), he is coordinator of the Global Scenario Group (GSG).

Garea, Bárbara. Degree in Physics, 1979, Moscow, Master's Degree in Physical Sciences and Mathematics, Doctorate in Technical Sciences and Senior Researcher. Professor of Physics at the University of Camagüey from 1979 to 1993. Her research work from this period is related to thermophysics and the use of renewable energy. She was employed as an expert on energy at the Academy of Sciences of Cuba (1993-1994), where she directed national-level research on renewable energy and peat fuel as Head of the respective expert groups within the Academy's Scientific and Technical Programmes. From 1995 to 2000 she was Director of the Division of Natural and Basic Sciences of the Science and Technology Agency, where she headed Cuba's National Scientific and Technical Programmes on Global Change and Evolution of the Environment and Sustainable Development of Mountainous Areas. In 2000, she was appointed Director of the Programmes and Projects Management Centre within the Ministry of Science, Technology and Environment. This centre oversees 19 National Scientific and Technical Programmes which constitute Cuba's priorities in science and innovation. Dr. Garea is also Chief of the Programme on Global Changes and Evolution of the Environment. She is a member of the Advisory Committee on Science and Technology to the Cuban Ministry of Science, Technology

and Environment. She was involved in the preparation of Cuba's Science and Technological Innovation Strategy and the definition of priority issues for scientific research and technological development in the coming years. She has worked on a number of research projects for FAO and UNDP and has served as an expert adviser for some of these. She represents Cuba at the Inter-American Institute for Global Change Research (IAI) and is a Vice Chairperson of its Executive Council. She chairs the IAI Communications Task Force and is a member of the Editorial Board of the IAI Newsletter. Dr. Garea's interest in the workshop issues relates to research strategies, particularly given that research in the Latin American and Caribbean countries should not be a copy of what is being done in the rest of the world, but be capable of taking successful experiences and adapting them to the future interests of the Latin American and Caribbean countries. The region has an abundance of natural and human resources and scientists, professionals and decision-makers need to determine how to move towards authentic sustainable development with the active participation of all agents. This poses methodological and conceptual challenges which were addressed at the workshop, but this is only the beginning of a task which, although complex in every way, requires immediate, clear-cut definitions that encompass all spheres, including politics.

Gligo, Nicolo V. University of Chile, Institute of Public Affairs. Researcher responsible for the coordination of Chile's Country Report on the State of the Environment. His interest in the workshop subjects concerns the theorization of the issue of science and technology in relation to the environmental sustainability of development, the study of science and technology policies as environmentally inherent in public administration, and the deepening of epistemological aspects of sciences, particularly the relationship between social and natural sciences.

Hall, Michael. Director of the National Oceanic and Atmospheric Administration's (NOAA) Office of Global Programs in the Department of Commerce, United States. Dr. Hall holds a Ph.D. and an M.S. in Physical Oceanography from the University of Washington, and a B.A. in Physics from Rice University. He has served as the Director of the United States Tropical Ocean and Global Atmosphere Programme (TOGA) Project Office, NOAA; Program Manager, Ocean Climate Technology, Office of Ocean Technology and Engineering Services, NOAA; Chief Researcher and Executive Scientist of the United States Committee for the Global Atmospheric Research Program (GARP), National Academy of Sciences; Chief Scientist, NOAA Data Buoy Office; Research Scientist, Shell Development Company; and Research Scientist, Boeing Scientific Research Laboratories. He has received numerous awards for his scholarly work including the Presidential Rank Award of Meritorious Executive (1998), the American Meteorological Cleveland Abbe Award (1999), the American Meteorological Society Special Award (1991), the United States Department of Commerce Gold Medal (1989) and the American Geophysical Union Ocean Sciences Award (1986). Since the late 1980s, Dr. Hall has been an active member of the Sub-committee for Global Change Research (SGCR) of the United States Global Change Research Program (USGCRP). Dr. Hall is spearheading the establishment of the International Research Institute (IRI) for climate prediction, which is designed to provide experimental climate forecasts for application by decision-makers in affected sectors.

Katz, Jorge. Born in Buenos Aires, Argentina in 1940. He received a First Degree in Economics at the University of Buenos Aires and completed his Doctorate at Balliol College, Oxford in 1967 with a dissertation entitled "Production Functions, Foreign Investment and Growth" which was published by North Holland Publishing Company in 1969. He has been Professor on Industrial Economics at the University of Buenos Aires during the period 1968-1992 and is now the Director of the Division of Production, Productivity and Management, ECLAC Santiago, Chile. He also teaches a Graduate Course on Technology and Innovation at the University of Chile. He has published extensively both on the subject of Technology and Industrial Restructuring in Latin America and also on Issues related to the structure and behavior on the Health Sector.

Lara Lara, Rubén. Centre for Scientific Research and Higher Education of Ensenada (CICESE). Dr. Lara has conducted research in: (1) Ecology of planktonic processes, photosynthesis and grazing, carbon flows, etc.; (2) Impacts of climate variability and change on Mexico's marine resources; and (3) Resource conservation in the north-east of Mexico. He participates in the committees of Mexico's National Council for Science and Technology (CONCYT). Involved in the founding and establishment of the Inter-American Institute for Global Change Research. He is a co-researcher of one of the IAI networks – the Eastern Pacific Consortium for Research on Global Change in Coastal and Oceanic Regions. Director General of PRONATURA, Mexico's largest environmental NGO, for the north-east and Mar de Cortez region. His interest in the workshop issues is to learn from the initiative of science and technology for sustainability and hear the opinions of colleagues from other disciplines and countries. He is keen to gain a better understanding of the interactions between science and technology and natural resource conservation and to contribute examples from the Mexican spheres of resources and environmental policy.

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Muelbert, Josi H. Fundação Federal do Rio Grande (FURG). Researches and teaches Biological Oceanography, specifically the ecology of eggs and larvae of estuary and marine fish (ichtioplankton). He directs the Ichtioplankton Ecology Laboratory of the FURG Department of Oceanography and participates in the following projects: (1) Recruitment, seeking to understand the dynamics of ichtioplankton in the Lagoa dos Patos estuary; (2) Southwest Atlantic Climate Consortium (SACC), which studies processes of climate change in the South Atlantic and is coordinated by Dr. Edmo Campos of the University of Sao Paulo's Institute of Oceanography and financed by the Inter-American Institute for Global Change Research (IAI); and (3) Effects of Natural and Manmade Disturbances on the Ecology of the Lagoa dos Patos Estuary, coordinated by Dr. Ulrich Seeliger (FURG). This is a 10-year project that is being conducted within the framework of the Long-Term Ecology Programme (PELD) financed by the Brazilian National Council on Scientific and Technological Development (CNPq). In addition to these activities, he oversees disciplines of the FURG graduate course in Oceanology and the post-graduate course in Biological Oceanography. Currently supervises three masters students and 3 graduate students. His interest in the workshop topics lies in learning more about the issue of sustainable development and contributing the knowledge he has acquired over his years of study in estuarine and marine environments in the south of Brazil.

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Quiroga Martínez, Rayén. An economist by training, with a Master's Degree from Rutgers University, she specialized in development and sustainability, researching development, poverty alleviation, gender relations and environment. She has worked in the academic field as a teacher, researcher and director of the School of Economics of the Universidad Bolivariana. She organized the Clean Technology Transfer Center and served as its first Environmental Manager. With respect to public policy, she has worked on a number of projects with the Environment and Human Settlements Division of ECLAC (particularly studies and seminars on sustainability indicators, and management and teaching at regional sustainable development courses). She has also worked as Strategic Development Adviser to the executive management of the Chilean Government's National Environment Commission (CONAMA). Her main interest throughout her career has been the incorporation and effective application of knowledge from different disciplines in order to understand and improve the management of sustainable development at different scales. The contribution of economics to the science of sustainability, from both a conceptual and an instrumental perspective, is the central challenge of her work.

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Ramírez, Patricia. Independent consultant. Coordinator of Regional Climate Forums for the Regional Committee on Water Resources of the Central American Isthmus/Central American Integration System (CRRH/SICA). During the last two years she has been involved in a regional effort to apply the information generated by global climate forecasting centres to the prevision of the impacts of climatic events. In the process it has become clear that in order to mitigate the vulnerability associated with climate change and variability it is necessary to expand our knowledge of the mechanisms of the region's climate systems, and of the resilience and adaptability of natural systems. This need must be translated into priorities on the science and technology and sustainable development agendas in the coming years in Latin America and the Caribbean. Her interest in the workshop topics relates to the social and economic impacts of climate change and variability which hinder development.

Rattner, Henrique. Full Professor of the Faculty of Economics and Administration of the University of Sao Paulo, Brazil. He is Projects Coordinator of the Brazilian Association for Leadership Development (ABDL). (1) Designer and coordinator of a leadership training programme for sustainable development in MERCOSUR (PROLIDES). (2) Designer and coordinator of a leadership training programme for sustainable development in the northeast of Brazil (PRONORD). (3) Preparation and publication of educational material for these programmes. His interest in the workshop issues is connected with the study, research and debate on how to form partnerships among civil societies (NGOs, social movements, unions, parties) at all phases of scientific research, from the conception and definition of the project and its objectives to the enjoyment of the results. He is concerned with how to combine research with societal learning in a way that involves elements of collective action, innovative public policy and experimentation, working with all the social groups in order to understand how knowledge and social practices are built.

Sagasti, Francisco. Director of Agenda: PERU, Lima, Peru and Special Adviser to the Rector of La Paz University, San José, Costa Rica. His work is in the fields of development strategies, institutional reform and democratic governance in the national sphere. He is also working on the issues of financing for development, reform of international cooperation, scientific and technological development in developing countries, and the relationship between development, peace and security. His interest in the workshop topics lies in seeking responses to the questions of how science and technology can contribute to sustainable human development and how to organize capacity to forecast and plan strategically for development. His long-term concern focuses on redefining concepts of development and progress from a historical perspective and using the ability to generate and utilize knowledge as the main explanatory variable.

Sarukhán, José. Senior Researcher at the Department of Functional Ecology of the Institute of Ecology, National Autonomous University of Mexico (UNAM). He studied Biology at UNAM and holds a Master's Degree in Agricultural Botanics and a Doctorate in Ecology. He has pursued an interest in population ecology, systems ecology, biogeochemical cycles in seasonal forests, biodiversity and global ecological problems. He has also studied the role of higher education and scientific research in the development of Latin American countries. His interest in the workshop topics relates to his work and experience in global ecological problems and biological biodiversity, and global environmental problems. His latest responsibility within the Government of Mexico as coordinator for the Cabinet of Social and Human Development has enabled him to combine the social dimension with global problems and sustainable development in a particularly interesting manner.

Sebastiani, Federico L. Empresa Tendencias & Actitudes S.A.C., Lima. Scientific University of the South, Lima, Peru. Biologist and university professor. Short post-graduate studies in Brazil, Chile, and Ph.D. and post-doctoral training in the United States. Specialized in plant biotechnology and genetic resources, and lately in the use of market research techniques in order to determine the perceptions, behaviour and attitudes of consumers and users of different services, and their application to the social and agricultural domains, mainly in rural environments. His interests lie in the use of biotechnological techniques to increase production and productivity, conserve genetic resources and define biodiversity, and the use of native plants for environmental recovery. This is from the perspective of technology transfer as a strategy for national development. His interest in the workshop issues relates to the topics of methodological and conceptual challenges, and research strategies. In addition, he has an interest in institutional innovations, given his work preparing research proposals at the helm of the National Genetic Resources and Biotechnology Programme of the National Institute of Agrarian Research (INIA), and his involvement in the preparation of scientific strategies for Peru's National Council of Science and Technology (CONCYTEC).

Strong, Ned. Executive Director, LASPAU: Academic and Professional Programs for the Americas. LASPAU designs, organizes and conducts academic exchange programmes within the Americas. Of the 30 projects currently underway, most provide scholarship resources for post-graduate studies in the United States and other countries. His interest in the workshop topics relates to opportunities for scholarship programmes for teachers and scientists, in 29 countries of Latin America and the Caribbean.

Vessuri, Hebe. Researcher and Head of the Science Studies Department of the Venezuelan Institute for Scientific Research (IVIC). She has served as Vice President of the International Union of Anthropological and Ethnological Sciences (IUAES) and is currently a member of the Board of the United Nations University Institute of New Technologies in Maastricht, Netherlands, and of SciDev.Net in London. She is a pioneer of the sociology of science in Latin America. Her principal areas of interest fall into two main groups: (1) The recomposition of research and development systems in Latin America; and (2) Nature and dynamics of the creation of scientific knowledge in the contemporary world. Her studies include: research and development laboratories in different institutional contexts; bibliometric evaluation of scientific trends; researcher/research profiles in the region; institutionalization of certain scientific fields in Venezuela and Latin America: agronomic engineering, catalysis, immunology; gender in Venezuelan science and technology; the internationalization of Latin American national research systems; university research and development and contract research in higher education. Her interest in the workshop topics relates to the interactions and interdependence between nature and society and challenges for the scientific institution. Anthropology and environmental sustainability; engineering and sustainability. Exploration of meanings and practical, political and epistemological values of different forms of knowledge outside conventional science.

Annex 2

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Annex 3

Science and Technology for Sustainability: A Preliminary Reader for Latin America[6]

Santiago Workshop on Sustainability Science:
Knowledge, Technology and Institutions for Sustainability Transitions in Latin America
Santiago, Chile
March 5-8, 2002

I. Introduction

This draft reader for Latin America is the first step in an interactive effort to document an emerging consensus regarding the roles of science and technology in the transition to a sustainable society. The process will culminate with the production of a family of region-specific readers (one each for Africa, Asia, Europe, Latin America, and North America).

With this vision in mind, the current draft reader aims to:

- Stimulate thinking about how to increase the contribution of scientific research and technological innovation to the transition towards sustainability.
- Facilitate constructive follow-up to regional sustainability science workshops.
- Initiate a participatory process to compile a critically annotated bibliography of the most relevant sustainability science literature.

The reader will evolve as our collective understanding of knowledge-based strategies for sustainable development deepens; this early draft is meant to be provocative, not definitive. We invite participants in the Latin America workshop to share their impressions and suggestions, in particular with regard to two sets of questions. Your contributions will be used to select papers for future versions of the reader, and to frame those papers with a critical discussion.

First, we are eager to incorporate participant's views regarding the concept of sustainability science articulated in the following articles. Is the notion clear and well formed? What core questions should sustainability science engage? How can effective multidisciplinary efforts best be facilitated? What institutional infrastructure is most critical? What articles and papers best describe the concept of sustainability science?

Second, we request your assistance in mapping how the concept of sustainability science applies to Latin America. What sustainability-related questions are most relevant to Latin America? Which research efforts would, with a moderate increase in resources, bear the most fruit? What texts capture the unique challenges and opportunities for sustainability science in Latin America? In the following pages you will be asked to consider a dozen or so questions in this vein. Please give your written thoughts and comments to the workshop organizers for inclusion in future iterations of the Reader.

By way of introduction to the thinking on sustainability that underpins the concept of sustainability science, we include Chapter One of Our Common Journey: A Transition Toward Sustainability (BSD 1999; attached as Reading # 1) This chapter provides one of the most

[6] This annex refers to the contents of the CD-ROM: "Reader. Revised version" distributed at the workshop.

thoughtful overviews of the origin and current form of the concept of sustainable development, and discusses how a transition toward sustainability will require "slow, interactive accumulations of scientific knowledge, technical capacity, management institutions, and public concern" (BSD 1999, p.49). Our Common Journey's US focus limits its relevance; indeed, one of the goals of the larger initiative of which this reader is part is to develop an internationally nuanced articulation of the nature of sustainable development.

The outline of the rest of the reader is as follows. Section II presents a rough outline of a conceptual framework for understanding what sustainability science means and presents three exemplary papers. Does this framework ring true? What are some additional highly relevant papers? Section III contains illustrative examples of methodologies currently employed by sustainability science practitioners. What are some additional examples from Latin America? Section IV discusses ways of thinking about how science and technology can be harnessed for sustainability. Once again, we invite workshop participants to contribute examples from Latin America. Section V presents three case studies that build on themes introduced in previous sections. In lieu of a conclusion, Section VI reiterates our request for participant input.

II. Conceptual Framework

How can the following three-part framework for thinking about sustainability science be improved or clarified? What categories of sustainability-relevant scientific activity do not fit into the three tasks outlined above? What additional texts regarding the nature and scope of sustainability science should we include in future drafts of the reader? How is the challenge of doing sustainability science different in Latin America than elsewhere in the world?

Three principal challenges for sustainability science have emerged out of a lively international conversation regarding the place of science and technology in the transition to sustainability (see, e.g., the Declaración de Santo Domingo; attached as Reading # 2, Gallopín 1992, attached as Reading # 3, and Academia Brasileira de Ciências; attached as Reading # 4):

- *Understanding* the nature-society system;
- *Using* scientific and technological knowledge to solve sustainability-related problems; and
- *Building capacities and institutions* that are capable of accomplishing the first two tasks around the world.

In what follows we briefly consider each of these tasks, making reference to several seminal discussions of the conceptual framework behind sustainability science.

The first task is to improve our understanding of the nature-society system that comprises the human realm. Chapter 6 in Our Common Journey emphasizes that four traditional research programs are relevant to sustainable development: biological, social, geophysical and technological. The challenge embodied in sustainability science is to build on this existing foundation, with the ultimate aim of understanding "how, over the large scale and the long term, the earth, its ecosystems and its people can interact for mutual sustenance" (BSD 2000; attached as Reading # 5). To achieve this level of understanding of global trends and interactions, sustainability science practitioners will need to carry out extensive research at the local and regional level. In addition, and as underscored by Gallopín et al. (2000; attached as Reading # 6), this understanding must be grounded in a deep appreciation of the complex adaptive nature of the nature-society system. Holling (2001; attached as Reading # 7) posits that the complex adaptive character of social-ecological systems clarifies the concept of sustainable development.

The second task is to use scientific and technical knowledge to foster a transition towards sustainability. For example, a conference of the InterAcademy Panel on International Issues concluded that scientific knowledge is necessary for the design of intelligent sustainable development strategies including measures for reducing fertility, accommodating growing urban populations, protecting agricultural productivity, improving the use of energy and materials, and conserving ecosystems (see Reading # 8).

Another facet of the second task is policy design. For example, Friibergh Workshop on sustainability science pointed out that one of the core questions facing sustainability science is what incentive structures can best guide society towards sustainability (Kates et al. 2001; attached as Reading # 9). One approach that makes sense in the abstract but that has proven rather difficult to implement is to use indicator systems that monitor and report on progress towards sustainability.

A third task facing sustainability science –or more precisely, sustainability scientists– is to create institutions and capacities that can carry out the multidisciplinary, multi-approach agenda sketched above and in the attached articles. This challenge is particularly significant in developing countries, where the human cost of non-sustainability is highest and where support for science is weakest.

III. Methodology—Understanding the System

Are the questions that we use to structure this section relevant, or are there others that seem more pressing? Do the papers we present help provoke careful thinking about the tasks faced by sustainability scientists? What are the strengths and weaknesses of these papers? Can you suggest additional papers that would exemplify current methods of doing sustainability science, in Latin America or elsewhere?

This section presents three papers that illustrate distinct methods of analyzing nature-society systems. Our aim here is not to endorse specific approaches, but rather to show how scientists around the world are grappling with the complex and difficult questions that lie at the core of sustainability science.

The questions are adapted from the Friibergh Workshop on sustainability science (Kates et al. 2001).

In what follows, two key conceptual tensions are highlighted:

- The tension between research that attempts to uncover general characteristics of nature-society systems and place-based studies that may have limited bearing elsewhere.
- The tension between integrative multidisciplinary research and work that falls within the boundaries of traditional academic disciplines.

Again, our aim is not to suggest which of these alternatives is preferable (or indeed, that there is always a tradeoff), but rather to draw the reader's attention to how successful research can resolve these dilemmas.

Question 1: *How can complex interactions between nature and society be incorporated into models of the nature-society system?*

Schellnhuber (2000; attached as Reading #10) explores a provocative approach to modeling the major biogeochemical cycles of the Earth using simulation techniques. His paper epitomizes a highly aggregated, relatively disciplinary approach to sustainability science.

Question 2: *How are long-term trends in environment and development reshaping nature-society interactions?*

While they share Schellnhuber's (2000) interest in biogeochemistry, Matson et al. (1998; attached as Reading #11) take a place based, data rich approach. They analyze the effects of an important long-term trend– the increased application of nitrogen –on both economic and ecological variables in northern Mexico. Note, however, that they suggest that their work is relevant to "other high productivity irrigated cereal systems of the developing world" (Matson et al. p. 112).

Sala et al. (2000; included as Reading # 12) develop a series of scenarios that offer insight into how long term trends, including land use change, climate change, biological exchange, nitrogen deposition, and elevated carbon dioxide concentrations, will affect biological diversity in different regions of the world. They underscore the magnitude of our ignorance regarding the interactions between these drivers of biological change.

Question 3: *What determines the vulnerability/resilience of local nature-society systems to external shocks?*

Batterbury and Forsyth (1999; attached as Reading # 13) propose a general framework for examining how adaptations occur and why they succeed or fail. Kates (2000; Reading # 14) uses a series of case studies to generalize about the ability of poor farmers to adapt to climate change. His approach illustrates how multiple case studies can be analyzed inductively to generate insights of considerable generality.

IV. Policy and Technology—Managing the System

Are the questions that we use to structure this section relevant, or are there others that seem more pressing? Do the papers we present help provoke careful thinking about the tasks faced by sustainability scientists? What are the strengths and weaknesses of these papers? Can you suggest additional papers that would exemplify current methods of doing sustainability science, in Latin America or elsewhere?

We here consider three examples of efforts to use scientific and technical knowledge to move the nature-society system (at some scale) towards sustainability. Questions 1 and 2 are adapted from the Friibergh Workshop on sustainability science (Kates et al 2001).

Question 1: *What public policies will encourage a cost-effective transition towards sustainability?*

Economic theorists have shown that incentive-based environmental policies should, under certain circumstances, achieve a given environmental target in the least-cost manner. Montero et al. (2000; Reading # 15) study the effectiveness of an incentive based air pollution policy in Santiago, and conclude that the success of the policy actually had little to do with its reliance on incentives, and more to do with a shift towards natural gas.

Question 2: *What indicator systems will aid in the transition towards sustainability?*

While indicator systems are often thought of as tools for assessing the sustainability of entire economies, they are also useful at smaller scales. Franklin (1995; Reading # 16) reviews how an understanding of the structure and function of forest ecosystems can lead to the identification of key indicators which allow both the selection of appropriate forest management techniques and the long term evaluation of the success of the management strategy.

Question 3: *What changes in production technologies will move society towards sustainability?*

Chertow (2000; Reading # 17) uses an inductive approach similar to that of Kates (2000) to propose strategies for creating industrial systems where waste streams from one industrial process serve as input streams for another process.

V. Case Studies

Do the case studies that we present add to an understanding of the scope and role of sustainability science? Do they strike you as good examples of the sustainability science process? Are there other cases that would do a better job? What are some cases that illustrate the nature of sustainability science in Latin America? What are the strengths and weakness of these case studies, and what are the strengths and weakness of the sustainability science processes that they describe?

The aim of this section is to provide examples of how the three tasks of sustainability science (analysis of the nature-society system, technology and policy development, and institution-building) come together in real world processes. Sustainability science is a relatively new enterprise, and well-developed case studies that directly consider sustainability science are still being written. Thus the cases that follow do not explicitly discuss sustainability science.

Also, note that we are not implying that these are examples of good sustainability science; rather they show the kinds of activities that are currently underway. We invite workshop participants to form –and share– their own opinions about the scientific validity and social utility of the activities described in the following papers.

The first case study traces the impacts of a policy in Mexico City that required the use of reformulated gasoline (Bravo and Torres 2000; Reading # 18). The data suggest that the rule may have done more harm than good. This case illustrates numerous themes of interest; one of particular relevance is the importance of understanding local conditions for policy formulations. The authors argue that urban air pollution policies that work well in some places may have unintended negative consequences in other places.

The second study included here (Kaimowitz 1996, attached as Reading # 19) reviews efforts to develop and disseminate sustainable forest management practices in Latin America. Kaimowitz systematically considers the challenges faced by the natural resource management research community, and presents a cogent set of ideas regarding future efforts.

A third study by Díaz Rossello (1997; included as Reading # 20) analyzes the relationship between agricultural research centers and what he calls the scientific-technological system. His analysis is particularly attentive to the social and political context within which agricultural research occurs.

Finally, a study by Adger and Luttrell (2000; attached as Reading # 21) shows how social science –specifically, the analysis of institutions and property rights– plays a critical role in formulating intelligent wetlands conservation efforts.

Conclusion

We are leaving the conclusion unwritten to reflect the fact that the concept of sustainability science has not been conclusively articulated. As we describe above, the primary goal of this reader is to document the emerging consensus regarding sustainability science. Workshop participants are invited to draw their own conclusions, and, critically, to share those conclusions with one another and with the workshop organizers.

Your feedback will shape a critically annotated bibliography that reflects the best thinking about the nature of sustainability science in Latin America. The success of this project depends on your input. To facilitate the selection of additional or replacement articles, we include a longer list of references as the final reading.

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