Chiang Mai Workshop on Sustainability Science: knowledge, technology and institutions for sustainability transitions in Asia

SYNTHESIS

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Executive Summary

1. For most sustainability issues in any given place there are multiple perspectives on the key problems, proximate and underlying causes and what would be considered valid solutions. Sustainability science, therefore, should expect to be challenged to justify its selection of problems to focus upon. At least as importantly, it should challenge society to re-examine its priorities. A good example of this in Asia is the series of controversies and re-interpretations of the sustainability "problem" of agriculture and forest use in upland watersheds.

2. For several decades, health, education and many other indicators of wellbeing have greatly improved in most Asian countries. Economies have grown at dizzying rates, agricultural productivity has soared, and supply of sanitation, electricity and other basic infrastructure has greatly improved for many. At the same time many natural resources have been over-exploited or degraded, air and water quality pollution became serious problems before efforts were made to tackle them, and what were once thought of as just local scale problems may now have transboundary, or international, causes and consequences. The remarkable capacity for farmers to adapt to climatic variability or entrepeneurs to succeed in new green markets is sign that there are still many opportunities and substantial inherent capacity to respond to there challenges.

3. Asia is diverse. As a geographical whole there is little that is both shared and unique to the region. Sustainability transitions in different parts and sectors in the Asian region will not be the same, because the starting points and contexts of change vary widely.

4. Some important shared features in the region are the openness of economies to foreign investment, large informal sectors, diverse and complex land-use systems, and despite rapid urbanization and industrialization still a continuing dependence of large sections of the population on agriculture in all but the wealthiest few nations in the regions.

5. Involvement of the corporate sector is crucial to any transitions to sustainability. In many ways improving environmental performance is good business. In many countries in Asia most of the investment in industry is still to come; guiding those investments into cleaner technologies is crucial and will require substantial institutional innovation.

6. Sustainability transitions will require greater public participation in how science agendas are set and how findings are used. As a consequence sustainability science will be more accountable, credible and relevant to the public and policy making at various levels.

7. Achieving sustainability often depends on changing the behaviour of the rich and powerful, both within and outside the Asian region. Thus, much more research and attention is need on the impacts of consumption. This will lead to new policies that reflect more closely where environmental adjustment is needed.

8. A transition to sustainability is not just a matter of getting the latest, or even the most environmentally appropriate, technology. It also requires a much better understanding of human behaviour, especially institutions, sources of knowledge, markets and politics.

9. Institutions are important as both drivers of, and responses to, environmental change. They guide, constrain and facilitate human adaptation to challenges from the environment and social system. Understanding institutional interplay will be an important part of sustainability science, because the most difficult issues involve cross-scale interactions in the social or ecological systems.

10. Adaptation is often most effective at relatively local scales, but at the same time there are growing problems which are transboundary in scope. Research is needed on institutional arrangements for tackling cross-scale problems in ways that facilitate local adaptation and responses.

11. The knowledge and wisdom required for transitions to sustainability reside in people and in their landscapes and cultural artefacts. Knowledge comes from experiences, traditional practices and formal experimentation, comparison and analysis or science. Memory and innovations, in technology and institutions, drive choice on how to use environments and resources. Education is a key to the prospects of sustainability becoming an important principle or criteria for decisions.

12. The sustainability of a livelihood, a national development pathway, or a particular land-use system or sector, does not just depend on a set of static quantities, such as finding some optimal mixture or configuration of economic structures, policies, institutions and international relations. It depends instead on a much more dynamic quality of maintaining adaptive capacity and opportunities. The capacity to adapt is crucial because the real world is full of surprises or disturbances and longer-term structural transformations that will test any solution posed for it

13. New tools and concepts are needed to understand transitions of complex adaptive systems. These highlight the importance of disturbances, diversity and novelty in determining the resilience, and hence, sustainability of ecosystems and their linked human enterprises.

14. Developing agendas for sustainability science in Asia should be based on broad consultation to establish needs, guide priorities for funding, and make best use of existing experience and opportunities. An Asian perspective on sustainability has its own regional flavours but there is much diversity within as well as similarities with priorities elsewhere in the world. At this stage we can offer some principles, proposed some organizing themes and framework and illustrate these with example research topics.

15. There are a number of barriers to the widespread adoption of science programmes that could guide and support research on transitions to sustainability in Asia. A significant number of these are related to conventions within science, whereas others are external, having more to do with how science interfaces with the rest of society, such as closed political systems. A few of the barriers, such as those for handling trade-offs and reluctance to examine ones own behaviour, are more fundamental in that they are near the limits about what can be usefully studied by science. This makes them all the more important to question and probe.

16. The pillars for developing effective science programmes that support transitions to sustainability in Asia are: participation, learning, communication and cooperation. Together these could help build a science that is relevant and credible.

Introduction

Overview

The purpose of this report is to synthesize the main issues and conclusions arising out of the *"Chiang Mai Workshop on Sustainability Science: Knowledge, technology and institutions for sustainability transitions in Asia"* held in Chiang Mai, Thailand, 4-6 February 2002. This report is intended primarily for research managers and researchers in Asia interested in thinking about how to incorporate sustainability issues in their research and development activities. The report itself should not be read as a beginning or an end, but as contribution to the process of improving collaboration on sustainability research within the Asian region. It is intended that this report be the seed for a synthesis paper with other authors for a journal article and also a concise guide for a broader, non-scientific, audience. In addition to this report a CD has been produced with background reading materials, participant presentations, working group notes and draft papers. Those interested in digging deeper into the debates and issues synthesised here are encouraged to explore the CD.[1]

Sustainability Science Initiatives

Since the World Commission on Environment and Development report[2] came out in 1987 and the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, the notion that development required balanced consideration of economic growth, equity, and environmental conservation goals if it is to be sustainable, has become a normal part of political rhetoric. Research and public concern about similar ideas to sustainability of course began much earlier than this. Examples of clear progress on the ground in meeting the complex and often ill-defined goals of sustainable development, however, are much harder to find. Thus, in 2001, the secretary-general of the United Nations could still assert that the three major global challenges for the century were: " *Freedom from want, freedom from fear, and the freedom of future generations to sustain their lives on this planet.*"[3]

In Asia there is a long history of research and experimentation relevant to sustainability, though much of it has gone under other names and has been outside mainstream western science. Over the past decade the number and breadth of both domestic and international formal research programs in the region relevant to the broad issues of sustainability has grown tremendously. Sectorial approaches, such as in agricultural, urban planning and industry, predominate, but there is also innovative research about traditional knowledge and institutions. On the other hand, well coordinated and integrated research across disciplines, sectors and scales is uncommon. As a result scientific understanding of the linkages between ecological and human systems is still weak, and the capacity of science to contribute effectively to public policy and management weak. A sustainability science initiative of some form is needed in the region.

There have already been some initial efforts to develop frameworks for science at the regional scale in Asia. The SARCS Integrated Study of Global Change and Sustainable Development in Southeast Asia[4] is an example of such an endeavour that arose out of the International Global Environmental Change Science Programmes.[5] Much of this research is aimed at sustainability issues involving changes in biochemical cycles and relatively large scale processes in the oceans, atmosphere and on land. The international programmes have focussed primarily on physical earth system processes, but over-time have come to realize that "human activities are equal to some of the great forces of nature in their extent and impact."[6,7] Now they are under going important changes with much better integration with social and political systems, and in engaging policy, but the primary strength of the programmes remains on issues of global sustainability.[8]

Other international science programs on sustainability have been much more bottom-up, place-based and development oriented. A good example is the research of the CGIAR[9] centres which has been very important for agricultural development in Asia.

The Sustainability Science Initiative is an informal network of independent scholars that aim to expand the research agenda, strengthen infrastructure and capacity for such research, and facilitate closer connections between science and policy. [10] In a large part the initiative has arisen out of interest in regional and place-based research within the international global environmental change science programmes.

The Chiang Mai Workshop was one of a series of regional meetings in Africa, Europe, North and South America, to explore the design and implementation of science programmes and related activities that would support transitions to sustainability. It is a direct contribution to the Packard Foundation funded project an "*International Initiative on Science and Technology for Sustainability*".[11] The immediate inspiration for these regional workshops was a meeting of international scientists who gathered at Sweden's Friibergh Manor in October 2000. A key conclusion of the meeting was the recognition that sustainability science would be substantially different from the way much conventional science is practised and this is reflected in the kinds of integrated questions it would address. The meeting also pointed to the many opportunities there were to enhance the development of the field by promoting discussion and exchange between disciplines and places.

At the same time, we recognized that there are a number of other activities already underway in the region that should be considered contributing to the development of a sustainability science. The Chiang Mai Workshop was designed to build on these existing efforts.

The Workshop, aimed to provide a **regional perspective** on four key elements of sustainability science:

- A *science agenda* for sustainability, including the core science questions and research strategies, that reflects the needs and priorities in Asia;
- The *identification of barriers* to sustainability, including scientific understanding and methods, technology and institutions;
- The development of *recommendations designed to remove or reduce those barriers*; and
- The identification of *opportunities to apply current knowledge* to support transitions to sustainability.

Workshop Goals and Process

The workshop goals stated more succinctly were:

1. To outline a research agenda for Sustainability Science that reflects needs and priorities in Asia
2. To identify strategies that should lead to effective science programmes that support transitions to sustainability in Asia.

The workshop program followed a logical sequence.[12] In the first part of the workshop we explored the participants' perspectives on what the sustainability problems are, and how they are identified, and also some of the opportunities to solve them in particular areas, sectors or places.

The second part asked what science can, and cannot, contribute in moving societies towards sustainability, recognizing that transitions must involve more than science. The third and fourth parts were dedicated to analysing the priorities, barriers and strategies needed for sustainability science given the critical challenges and the potential role of science. The final sessions were devoted to synthesis of the plenary and working group sessions. A feature of the workshop program is that a substantial amount of time was spent working in small groups. This resulted in excellent participation from a very disciplinary and culturally diverse group of participants.[13]

Another feature of the workshop process was that substantial effort was made to capture in electronic form notes, working group and prepared plenary presentations. This has made it possible for a more comprehensive synthesis report than is usual from a meeting with often six working groups, as well as providing foundation for follow-up activities.

Sustainability is primarily a problem about integration, about how to consider multiple stresses and goals, and thus often requires a more holistic approach than is conventional in many areas of science. Trying to find a way of breaking down such a problem into more analysable chunks, but not to forget how they contribute to whole could be done in many ways. For this workshop we tentatively adopted a two-way framework for analysis of challenges, opportunities and key research questions. Groups were divided along sub-system or sectors (Figure 1b) and each group was asked to consider a comprehensive set of structures (Figure 1a). The limitations imposed by the categories in the framework were reduced by maintaining flexibility in composition and scope of groups, and exchanges in plenary between working groups which helped re-emphasise linkages between sectors.

Organization of this report

The organization of the main body of this report does not follow closely the chronological sequence of the workshop or conventional sectors just outlined, but instead is an attempt to synthesise the various sessions and working group reports around several integrating themes. The report ends by drawing together these themes as a set of initial guiding principles and the outline of a conceptual framework for sustainability science agendas and the strategies to implement them in Asia.

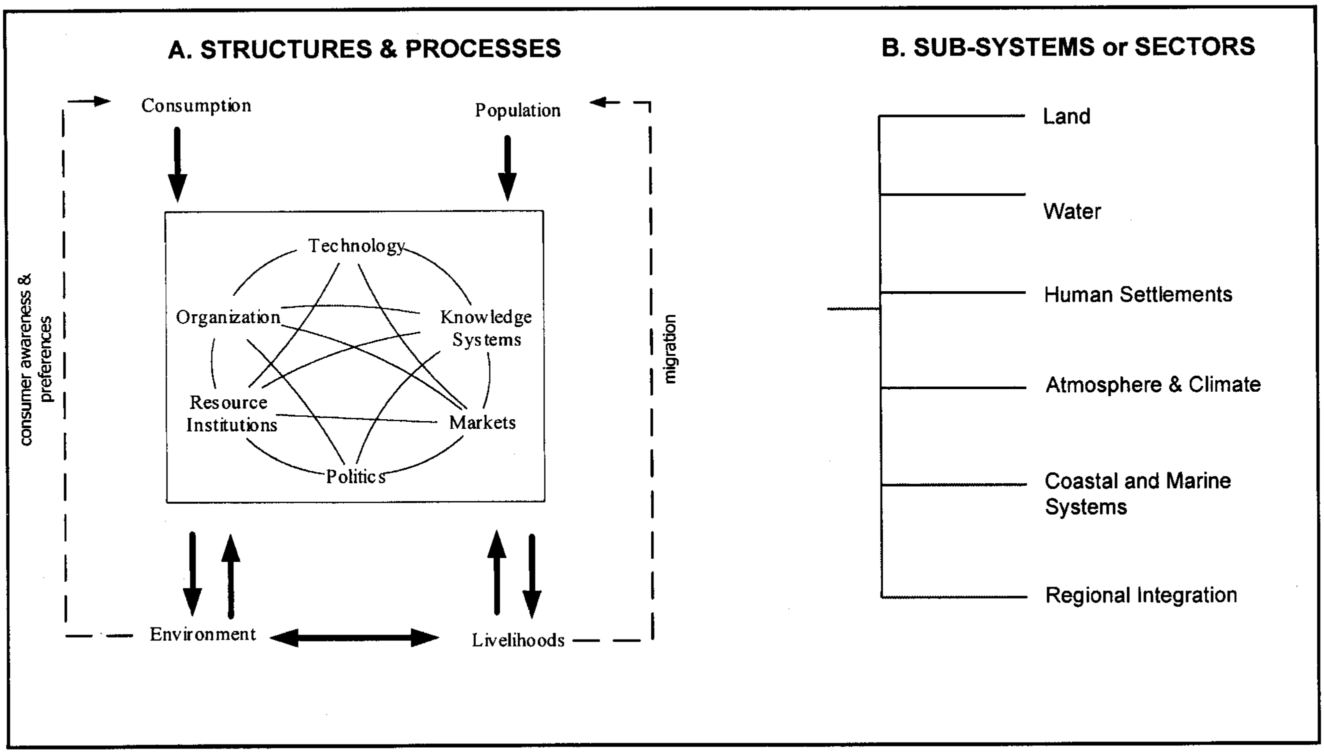

Figure 1. Analytical framework for structures and processes (a) used by working groups divided by sectors (b) to analyse the opportunities and challenges as well as key research questions for sustainability science.[14]

Sustaining what? For whom? For how long?

Sustainability

For most sustainability issues in any given place there are multiple perspectives on the key problems, proximate and underlying causes and what would be considered valid solutions. Even when it is possible to eliminate some of the perspectives as plan wrong, rather than just issues of preferences, power and vested interests, not science, often determines whose truth claims come to dominate. A good example of this is the historical and on-going series of controversies and re-interpretations of the sustainability of upland land-use systems in Asia (Figures 2,3).[15]

Sustainability science, therefore, should expect to be challenged to justify its selection of problems to focus upon. At least as importantly, it should challenge society to re-examine its priorities.

It is important to ask, and then debate: what exactly is to be sustained? For whom? And: For how long?

The concept of sustainable development is operationally vague and that is why it is so popular. Most variations derive from the idea that *sustainable development* is development that meets the needs of current generations without compromising the needs or options of future generations or neighbours. It thus, has both temporal and spatial components.

Figure 2. Diverse agriculture and forest landscape in an upland valley near Chiang Mai, Thailand.

Most people include an idea of balance in the concept, for example -- "Our conceptual view of sustainable development is that of achieving the "right" balance between the three pillars – economic, social and environmental. Imbalance in terms of the evolution of these three elements is likely to lead to instability in the short-term and un-sustainability in the longer term" [16]

However, in practice different groups put the centre of mass in very different locations, economic growth, equity and social development or the environment and conservation.

Figure 3. Partly deforested hillsides in Chiang Mai, Thailand.

Sustainability as a process rather than an end-point

One important change, as our appreciation of the behaviour of linked social-ecological systems has grown, is a shift from thinking of sustainability as an end-point, or a particular ideal state, to that of process of continual renewal (and destruction). Thinking of sustainability as a process or "bumpy" journey with destinations on the horizon that keep shifting as people make errors, change preferences, find new needs, adapt and innovate is more compatible with ideas of learning by doing and adaptive management. It is also more modest, recognizing us as clumsy, error-prone but capable of learning.

For whom?

The identification of "sustainability" problems is usually not as straightforward as one individual or group might hope. Problems depend on whose interests you are talking about, about who is being blamed as a cause, and who will have to pay or lose from making a response. It is not surprising therefore to find, again and again, that ecological crises, often framed in the language of un-sustainability, eventually turn out to have much more complex causes, consequences and patterns of change, than the dominant political constructions and actions would have us believe at first. Sustainability in the real world is often about high political stakes and science in this context, especially is at great risk of being coerced, mis-used or selectively ignored. The challenge for sustainability science is that those defining the problems, who allocate funding and human resources to solving its puzzles, are usually the rich and powerful. Their perspectives on what the priority problems are, what the important causes have been, and what are the best options for response are not the same as those of the poor and marginalized. This is crucial if society is working towards the noble goal of "sustainability" yet there is no justice in the identification of the problems to begin with, or in the way they are to be solved.

This has implications for what is chosen to be studied under the banner of sustainability science (see *Agendas in Asia*, p28) and also about the process for conducting science (see *Public Science*, p16).

Politics of Place and Scale

Consideration of place and scale is central to the analysis of many sustainability issues. Both ecological and social processes vary with scale, and cross-scale interactions are one of the main sources of complexity.

Scale, however, is not politically neutral. The selection of scale may intentionally or unintentionally privilege certain actors or groups. The adoption of a particular scale in assessment set bounds on the types of problems that can be addressed, the modes of explanations that are allowed, and which generalizations are likely to be used in analysis. This applies to both temporal and spatial scales. Researchers need to be aware and reflect the consequences of scale choices.

For example, the range of ecosystem services that are directly used and acknowledged as having important support functions is dependent on socio-cultural contexts and these are restricted in space. As we move to a higher spatial extent the number of services which are shared drops away. The same basic ecosystem processes can also be seen as providing different services at different scales and different types. For example, forests provide carbon storage and biodiversity (as public goods) and timber for a house (as an individual or shared private good).

Sustainability in practice is about understanding these potential trade-offs and requires understanding of politics and markets. Scale can be an argument that empowers the state institutions. Most states view indigenous knowledge and institutions as local in scope, relevance and power, or small scale, whereas as the rules and knowledge of the state as bigger in scale. The source of many ecosystem service management problems may result exactly from these centralization and uniformity in bureaucratic operation that hinders local adaptation and learning. Scale is thus critical for issues of governance.

Time

Choice of time scales is important too. If an assessment is focused on short term concerns then "important" goods and services are those which are already or about to be threatened, such as freshwater resources for drinking, or fuel wood supplies and food production. On the other hand, if the users are more concerned with decisions that may have longer term consequences, for example, out to 2100, then issues of alterations of carbon balance or opportunity and resilience costs of biodiversity loss become much more important.

Critical Challenges and Opportunities

Quick and Dirty Growth

For several decades, health, education and many other indicators of wellbeing have greatly improved in most Asian countries. Economies have grown at dizzying rates, agricultural productivity has soared, and supply of sanitation, electricity and other basic infrastructure has greatly improved for many. At the same time many natural resources have been over-exploited or degraded, air and water quality pollution became serious problems before efforts were made to tackle them, and what were once thought of as just local scale problems may now have transboundary, or international, causes and consequences (Figure 4). The remarkable capacity for farmers to adapt to climatic variability or entrepreneurs to succeed in new green markets is sign that there are still many opportunities and substantial inherent capacity to respond to there challenges. The complex goal of sustainability provides a missionary-like call to action but in practise will need the support of good science to explore, identify and tackle the more complex and problematic of these challenges in a timely way.

Figure 4. Chao Phraya river in Bangkok a very rapidly growing and dynamic city that despite conspicuous wealth has struggled with air and water pollution problems and providing basic services to the poor.

Regional Flavours

Figure 5. Map of Asia showing large continental areas as well as numerous archipelagic nations and coastal seas

Asia is diverse. As a geographical whole (Figure 5) there is little that is both shared and unique to the region, but nevertheless, it is argued that certain flavours or contexts are common which are relevant to sustainability. Proximity also implies similarities in ecological systems, overlap in use of particular ecosytems, and opportunities for cooperation and building partnerships as well as conflict over resources. The region is a mixture of transitional, fast-growing economies and a few established larger economies which they serve. Outside the slower growing large economies of Japan, Singapore, and Korea it is typical to find:

- A large informal sector in both urban and rural settings;
- A high proportion of the population still strongly dependent on agriculture that is often strongly orientation towards export markets;

- A history of complex land-use systems and landscapes intermediate between modern notions of forestry and agriculture;
- The likelihood of substantial new investment in industrialization in the next few decades;

And, in almost all countries:

- Several decades of rapid urbanisation, relatively high population densities by global standards, but now sharp falls in fertility, and ageing populations;
- Manufacturing industries that are strongly export-orientated
- Political changes tending to open-up what has been very closed public policy processes in both centrally-planned and more market-oriented states;

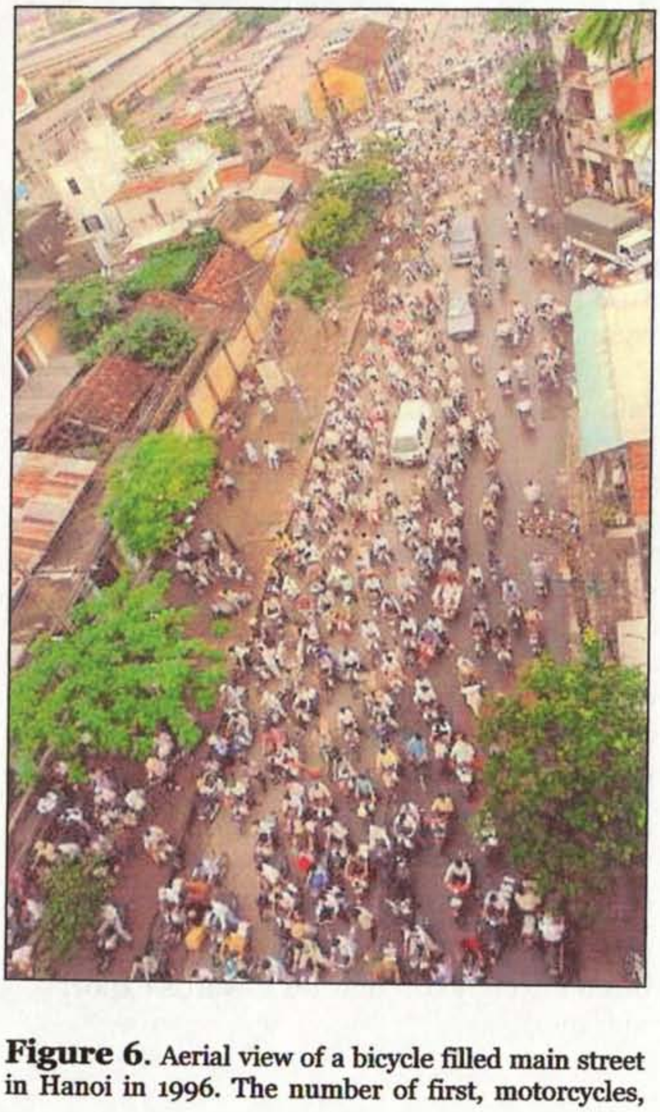

Figure 6. Aerial view of a bicycle filled main street in Hanoi in 1996. The number of first, motorcycles, and then, personal cars, increases very rapidly with economic growth.

Finally across countries:

- Significant within region trade, often among branches of the same multinational corporation, with complex commodity chains and division of labour among countries;
- Substantial investment by the richer nations in industry of the poorer nations, and often a relatively large role played by multilateral banks such as the World Bank, IMF, and the Asian Development Bank.

Sustainability Puzzles

In the context of these national and regional development patterns views about what are the most critical challenges and opportunities for sustainability transitions are diverse. Here I have arranged these according to the working group sectors (Table 1). [17] For each sub-system a mixture of resource depletion and degradation, pollution and waste, and human wellbeing issues were identified.

These were the view of participants in the working groups. It is worthwhile examining a few of the issues in more detail in light of the caveats in the previous section of the report. This is done in Table 2 for three different examples.

Some of the reasons change was considered a problem were:

- Changes are putting a system near a threshold that would be bad to exceed, i.e. Increasing vulnerability;
- Changes are in someway unfair to a part of the population or a sector;
- Process of change is difficult for individuals or small groups to respond without special intervention or assistance;
- Many people, or a few loud ones, say it is a problem;
- There are perceived threats to wellbeing, health, livelihoods or even life;

- Changes are cutting profits or making it harder to acquire resources;
- Changes are destroying natural ecosystems too much and this is wrong;
- Changes will reduce societies capacity to adapt and recover from future crises and surprises;

Figure 7. An old couple. With aging population structures and migration into cities for work, care of the elderly in rural areas will become a major challenge for many transitional Asian societies.[18]

Population movements, ageing and decline

Of the many trends identified in table 1, demographic are potentially the most profound because of their multiple and complex interactions with resources depending on technology, institutions and politics. One of the most important changes affecting many countries in Asia is rapid fertility decline (Table 3). Already or very soon many countries will have to deal with rapidly ageing populations and eventually likely declines in population size (Figure 7). When combined with the large movements of people from rural areas to cities, especially along the coasts, this often implies a depopulating of inland areas, or "rural collapse", a phenomenon most commonly discussed in advanced industrial societies.[19]

Rates of decline in fertility have been very rapid in countries like Singapore and Thailand as a result of rapid adoption of family planning.

Very little analysis has been conducted of the consequences of rapid aging and urbanization will have for agricultural productivity and industrial labour, key components of development strategies in the region.

Will the demographic changes bring about stagnant growth, as is being in some Japan, in other much less wealthy countries? How will these countries cope with ageing populations? How will this affect pressures on agricultural land? Will more land become available for conservation or be opened for shared use of the poor?

What are the consequences of migration for the spread of diseases, and for that matter new knowledge, and technical innovations? [20] And how does living in cities or having family links change risks of disease and access to knowledge?

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Table 3: Fertility declines in Asia. Fertility rate change patterns are similar, but at very different stages within Asia. Shown is expected fertility rate 2020-2025. [21]

Region/country	Total fertility
Asia	2.19
Eastern Asia	1.88
South-central Asia	2.33
South-eastern Asia	2.11
China	1.90
India	2.10
Indonesia	2.10
Pakistan	3.25

Table 1: Examples of critical challenges and opportunities identified by participants for sustainability transitions in Asia grouped by major social-ecological subsystems [22]

EXAMPLES OF CHALLENGES AND *OPPORTUNITIES*

LAND

- Food security , especially equity in distribution systems and factors influencing access to commons for poor and marginalized;
- Consequences for water, atmosphere and other ecological systems of further intensification of agricultural production systems to meet growth in demand and more standardized products for global markets;
- Deforestation as a result of expansion of export agriculture and industrial tree plantation for pulp and paper;
- Conservation of large mammals, such as tigers, that require large contiguous areas of cover of relatively undisturbed native forests, becomes increasingly difficult as a result of habitat fragmentation and degradation, and hunting for animal parts for Chinese traditional medicines;
- Increases in landscape diversity as a result of mixed agricultural and agro-forestry practices in uplands;
- Maintenance of biodiversity and production goals in landscapes given the inevitable losses in native biodiversity resulting from conversion, fragmentation and degradation of ecosystems and critical habitats;
- Developing frameworks and methods for evaluating and negotiationg trade-offs between various ecosystem goods and services that humans can obtain from parts of the landscape – for example in ways that will likely change the way industrial societies have viewed forsts as primarily sources of timber to instead, like many traditional communities, providers of wide range of services, including foods, non-timber products, source of biological pest control agents, protection of watershed and so on;
- *Wet tropical forests in Asia have high growth potential – source of fibre and way to sequester carbon;*
- *Release and abandonment of agriculture land as a result of urbanization and ageing rural populations or land speculation around growing urban centres;*
- *Development of complex agro-ecosystems based on hybrid traditional-industrial technologies for improving productivity, reducing risks of failure from pests and diseases, and creating livelihoods less prone to boom-bust cycles caused by shifting commodity prices;*

WATER

- Ratio of use to availability is very high in many countries;
- Continued growth in demand for water, especially from urban and agriculture sectors, will exacerbate existing conflicts especially at periods of lowest flow following the dry season;
- *Development of adaptive management systems and incentives (including pricing) for conservation of water resources;*
- *Long histories of experience with highly sustainable communit- based institutions for management of water as part of rice irrigation systems;*

AIR

- Transportation system and urban planning is critical for urban air quality and environmental health;
- Industrial emissions policies and controls on investments for both large and small scale operators and has international consequences already, for example, in northeast Asia, in the form of acid deposition;
- Biomass burning from domestic fuel and vegetation fires is important for both its local and transboundary effects;
- Fossil-fuel emissions are rising rapidly in the region, and although per-capita are still relatively low, the sheer number of people in the regions means that choices made about energy futures are important for global levels of greenhouse gases and climate change;
- *Although appropriate technologies are often available, finding the right mixture of policy instruments to bring about changes in corporate and consumer behaviour to control air pollution*
- *Very substantial reductions in air pollution problems can be achieved through promoting energy-efficient and environmentally-friendly technologies at the time of initial investments;*

Table 1: *Continued.*

	Examples of Challenges and *Opportunities*
URBAN	• Expansion of cities into wetlands, and disaster-prone coastal areas • Lack of environmental management capacity in smaller cities/towns • Urbanization of poverty; many incentives for wasteful and inefficient behaviour; while subsidies do not reach poor • Sustainability of urban development is in question as a result of increased demand for water supply and sanitation, and the stress on already inadequate waste water and solid waste treatment facilities. Continued neglect of these problems will have dire consequences with regional and global implications in the not too distant future.[23] • Investment in mass transit systems and waste water treatment are made to late (Untimely Investments) • Increased awareness of urban sustainability – there has been too much emphasis on rural areas in development discourse; • *Cities also hold a promise for protection of natural resources through their ability to support large numbers of people, while limiting their impact on the environment* • *Cities and urban populations are market driven and open to change – they are sources of innovations, and react to incentives and opportunieis from new technologies.*
MARINE	• Over exploitation of fisheries • Land-based pollution exceeding assimilative capacity of freshwater and coastal ecosystems with prospects of ecological changes that are irreversible or hard to restore especially when combined with impacts of fisheries; • Evaluating and negotiating just trade-offs between small and local fisheries and large boat commercial fleet. Designing institutions that can handle the cross-scale nature of ocean fisheries management. • Exploring the costs-and-benefits of different forms of aquaculture, in particular, their consequences for marine systems in terms of disease and resource inputs required in artificial feeds used in aquaculture production [24] • *Some places with history of long experience in cooperative management through local institutions, such as community tenure, or harvesting rules and sanctions, for fisheries and other resources in mangroves or coastal seas. In many other places such traditional arrangements no longer function, but may be re-built or inspire new forms of institutions more appropriate for changed market and lifestyle contexts of today.*
REGIONAL	• The economic, ecological and social trade-offs between harvesting food from the sea, as opposed to cultivating it on land or water have been little explored; • *Potential for restoration of riparian vegetation, floodplains and wetlands to help transform nutrients and pollutants before they reach the sea and reduce risks to poorly site urban settlements from floods;* • *Development planning of rural and urban areas has largely proceeded independently, but now needs to be integrated with the ecosystems in the surrounding land and sea-scapes; Urban-rural linkages in Asia are often very strong and work in both directions making integration imperative*

Table 2. Examples of some of the critical questions that should be asked about sustainability challenges identified by groups of people and the reasons often to justify choices. These are meant to illustrate the need for clear justification, problem definition as well as identifying the role and specific need for science. The views here do not necessarily match my own.

Critical Questions	**Proposed Critical Sustainability Challenges**		
What physical or social changes are observed or claimed?	**Transboundary air pollution** from vegetation fires - higher than normal levels of air pollution	**Over-exploitation of fisheries in shared seas** - declining yields per effort and evidence of stock declines, smaller fish sizes and fishing down the food chain	**Urbanization and sprawl** - permanent and circular migration of people from rural areas to major cities and towns Conversion of prime agricultural land to human settlements and infrastructure
Why are these changes considered a problem or a challenge to sustainability?	Short-term and possibly longer-term effects on health and agricultural and ocean surface productivity as well as effects on tourism and transport because of visibility decline	Changes may be irreversible or only with great difficulty; concern that aquaculture and other substitutes may be even less environmentally friendly;	Rate at which occurs is vastly outstripping provision of necessary infrastructure and services – especially for sanitation, water supply and housing; loss of agricultural land threatens food security.
For whom is it a problem ?	Various economic sectors in source and receptor locations; health impacts largest near source;	Commercial fishing sector in terms of profits, and for small coastal communities a threat to livelihood security.	Poor living in city slums; Rich that drive past – experienced as drop in quality of environment
What exactly is to be sustained? And for how long?	Clean air – visibility – light for photosyntehsis	Multispecies fish & other organism communities with reduced bust-boom cycles indefinitely into the future	Wellbeing of those who choose to move to cities for economic and various other reasons.
What are the sources or causes of change?	Burning of vegetation from land conversion activies, crop residues and wildfires;	Fishing gear and intensity of commercial fleets who have no long-term interest in maintenance of stocks in a particular place – especially along the coast.	Lack of opportunities and poverty in rural areas; industrialization creating and needing concentrated labour and hence urbanization; poor governance and budgeting mechanisms in cities;
Is their significant counter-evidence or counter-arguments?	Fire is a cheap and convenient tool to clear land, control weeds and remove wastes. Should we just put up with the inconvenience and health impacts ? Is the trade-off worthwhile? Is there an inexpensive way, eg. Through regulating timing of burning that would greatly reduce negative impacts?	Will recover without intervention and aquaculture will supply the needed differences in the mean time.	Cities if governed and managed properly may help protect environment because they can be more efficient and are centres of learning & innovation. Not clear that agricultural land is actually in short supply and other factors seem much more important to food security.

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Such demographic changes seem to contain many significant challenges and opportunities relevant to sustainability but they have hardly been investigated in a systematic way, beyond simplistic analyses of the effects or non-effects of changes in population size.

Transitions to sustainability need to consider the implications of demographic transitions. Research is needed to understand how "balanced" populations can be achieved without infringing upon the individual rights and opportunities for education and meaningful employment for women.

Just-in-time substitutions

Many of the counter-arguments to claims that current practices are un-sustainable rest on the assumption that man is able to substitute degraded or lost ecological functions or services just-in-time. Markets, through price increases, and local institution, through monitoring of resources or harvesting efforts, can provide advance warning of resource problems. A critical cross-cutting question for sustainable development is whether:

> Under current development patterns is our capacity to substitute new resources for old ones as they are depleted or degraded increasing or decreasing?

Diverse Transitions

Asia is a hot spot in both sustainable development and environmental change terms. The rates of economic growth have been faster than most parts of the world for several decades. As a result many parts are now more industrialized, diversified and integrated into the global economy than their counterparts elsewhere.[25] Although there are still many disparities in the size and effectiveness of different national economies within the region, and incomes are not necessarily converging, they are all rapidly becoming more inter-dependent through commodity trade, investment flows and exchange and division of labour.

There are many challenges and some opportunities to redirect current transformations of Asian society and ecosystems along trajectories which are more likely to be sustainable in the medium to longer-term (Table 1). Sustainability transitions in different parts and sectors in the Asian region will not be identical. The starting points and contexts of change often vary widely among regions within a country and among the rich and poor of a particular place. This has a major impact on how scientific agendas and strategies need to be developed. It cautions against over-generalizations about problems and solutions without comparative analysis and validation. It also warns against over-emphasising "the region" as if it were distinct entity and there is only a need to tackle the most obvious shared or regional scale problems (See *Politics of Place and Scale,* p8).

Scenarios are needed to analyze how the future may unfold, because there are many fundamental uncertainties in critical trends as well as how individual and groups will respond to early warnings and surprises from the environment and social change. Improving methods for scenario exploration will be an important part of sustainability science.

A great many of the challenges are not easily addressed by purely technical solutions, though improving crops, or engineering better cleaning equipment, or discovering new plant products, or making better use of current advances in information technology, are all potentially important contributions. Today appropriate technologies and good practices often already exist but education, institutional, political and markets together don't provide the right circumstances or incentives for them to be implemented. Many of the scientific challenges of sustainability will therefore be about studying critically institutional, political, learning and market processes, in addition to the conventional attention given to technology and engineering. Some of these themes are returned to in later sections of this report.

Public Science and Responsibility

Sustainability transitions will require greater public participation in how science agendas are set and how findings are used. As a consequence sustainability science will be more accountable, credible and relevant to the public and policy making at various levels.

Science and participation

In this report science refers to knowledge and research in both natural and social sciences. Science is structured knowledge that can be questioned.[26] In many areas, conventional science is "opening-up" in ways that are highly appropriate to tackling problems of sustainability. The "new" science differs from the "old" in a number of telling ways (Figure 8). One of the most important is science becomes more closely involved with society. It does this first by acknowledging itself as not value-free. Sustainability science is clearly a value-laden paradigm concerned with what ought to be, though all specifics are open to question and challenge.[27] Another way is that it becomes much more open to participation of users in defining problems, setting agendas and identifying solutions, and increasingly in monitoring and carrying out science.

OLD	NEW
EMPHASIS ON INDIVIDUAL RESERARCHER	EMPHASIS ON TEAMS OF RESEARCHERS
ACADEMIC CONTROL OVER RESEARCH DIRECTION	RESEARCH DIRECTION SHAPED BY INTERACTION WITH USERS
CURIOSTY AND DISCIPLINE DRIVEN	PROBLEM AND ISSUE BASED, MULTI AND INTERDISCIPLINARY
PROBLEMS DEFINED TO MINIMIZE UNCERTAINTY IN RESULTS	PROBLEMS ALL CONTAIN LARGE AND PERVASIVE UNCERTAINTIES
LOCAL ORGANISATIONAL KNOWLEDGE BASE	DIVERSE SOURCES OF KNOWLEDGE AND NETWORKS OF INFORMATION
QUALITY JUDGED BY PEER REVIEW	JUDGEMENT BY USERS AND PEERS
APPARENT DISINTEREST OF RESEARCHERS (VALUE FREE)	RESEARCHER ARE PARTISANS (VALUE LADEN)
COMMUNICATION BY SCIENTIFIC ARTICLES	DIVERSE FORMS OF COMMUNICATION
LINEAR LOGIC FROM RESULTS TO ACTION (ASSUMPTION)	HIGHLY NON-LINEAR RELATIONSHIP BETWEEN RESULTS AND ACTION (REALITY)
STAKES ARE LOW	STAKES ARE HIGH

Figure 8. New and the old Science.[28]

A common perception is that in the past: "*Science was a big part of identifying problems, but small part in identifying solutions*" [29] And, as a result "*People don't believe scientists*".

A public science of sustainability in Asia that emphasises participation and critical reflection on scientists as part of society will be much less likely to privilege the concerns of the wealthy.

It will challenge the way people think about development, and the way they think about science. Understanding of ecological and social consequences will increase. Ideas about opportunities, constraints and risks will be more precise. Science would become a more accountable service to society. Science would finally be recognized for what it is - a set of tools for questioning knowledge not so distinct from commonsense and experience.

Finally, for those places in Asia, with still relatively closed political systems, science itself may be used to create space for society to be involved in planning, monitoring and evaluation.

Science and Public policy

Scientists in Asia have generally thought more about interacting with bureaucrats and policy makers than local communities or the general public about their work. In part this is because, in Asia, academics and politicians are often from similar wealth, education and even family backgrounds. The similarities are much greater than with the poor farmer or urban slum dweller. Nevertheless, scientists can greatly improve the way the engage with public policy near the top.[30]

This should start be abandoning simplistic over-rationale mental models of the public policy process. Policies also come about through the actions of influential individuals, the influences of donors and aid agencies, notions about national and private interests and individual policy preferences.

A realistic view of policy recognizes that for most of the time there is no opportunity to introduce new issues on the agenda or get action for those already in the public eye. Windows of opportunity do, however, arise, sometimes because a problem becomes crises, and other times for unrelated reasons. Droughts and floods are often made into excuses for policy changes regarding land management. In either case, good knowledge on the shelf is essential. Thus, the relationship between knowledge, policy and action are very non-linear and hard to trace, even through history.

Scientists need to repeatedly ask:

- How can we more effectively communicate with and engage policy makers and resource managers?
- What can we learn from policy makers in doing the 'new' science?

Risks of engagement

Closer integration with policy at the top or through public at the bottom should not be an excuse for poor science. Indeed greater responsibility comes from carrying out needed and relevant research. Unfortunately, quality control is under threat from user demands and the role of private as opposed to more accountable public investments in science.

Closer engagement with policy-makers and powerful bureaucrats in Asia, and elsewhere, carries real risks of political interference and unintentional blinkering of research. It might be pleasant to dine and have golf, but will this affect your interpretations or outcomes of a policy analysis? The value of science to society is its determination to pursue evidence and counter-evidence and challenge society at every turn. Sustainability science must do this well.

Public science means researchers will be more open to challenge from society.

Responsible well-being[31]

Doing this is one way of leading towards ideas of sustainable consumption or *responsible well-being*. It acknowledges that achieving sustainability will depend at least as much on changing the behaviour of the rich and powerful, as the practices of poor farmers. Research on production-consumption systems, especially the later, will challenge conventional beliefs about where environmental adjustment is needed. This is one of the reasons such research is unfashionable. I would, however, argue that without this change in focus sustainability transitions are unlikely. There may be real value in scholars from developing countries in Asia, with less at stake (!), to do conduct such research in Japan, US and EU.

For example, most sustainability programmes about cities focus on pollution reduction but very few consider excessive or wasteful consumption of natural resources.

One way of examining the ecological consequences of consumption that underlines ideas about justice and responsibility is the notion of ecological footprints (Figure 9).

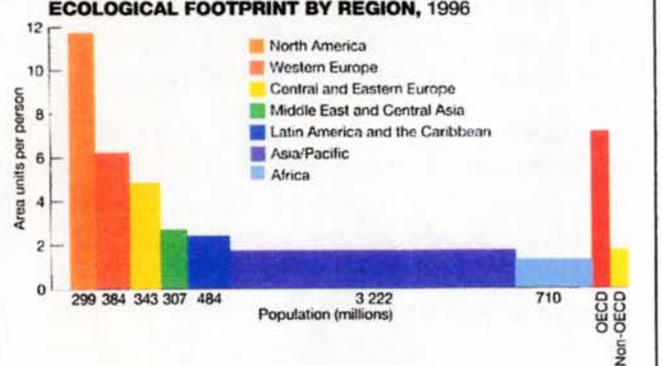


Figure 9. Ecological footprints by world regions can be used to argue that for global sustainability both the wealthy regions, with high per capita consumption, and poorer regions, with large population size, are important to consider (justice and equity considerations aside).

Business, Industry and Investment

Industrial Transformation

As rapid as industrialization has been in Asia, the base remains comparatively small. Most of the investment in industrialization in the transitional and developing economies in the region is still to come.[34]

Guiding those investments into cleaner technologies is crucial and will require substantial institutional innovation.

Industry has a crucial role to play in sustainability transitions through reducing materials, energy and pollution intensities of production processes.

A critical question for industrial modes of development and economic growth is:

> To what extent is it possible to un-couple economic growth and prosperity from growth of material and resource use as well as production of wastes? Or, for example: How can this economy be made less carbon intense?

Involvement of the corporate sector, therefore, is crucial to any transitions to sustainability. So far the business community has not been strongly involved in the development of sustainability science, though in some areas of technology their role is very large. One concern is always that private investment in science research is undermining rather than complimenting public science.

Education is crucial, and sustainability concepts are finding their way into business schools, but much more needs to be done. Business councils on Sustainable Development around the world have a role in educating peers abut sustainability and researchers about business. As a group they are clear that business is both part of the problem and part of the solution. [35] The business agenda in sustainability is maturing in promising directions, from a first steps based on compliance towards concepts of corporate responsibility (Figure 11).

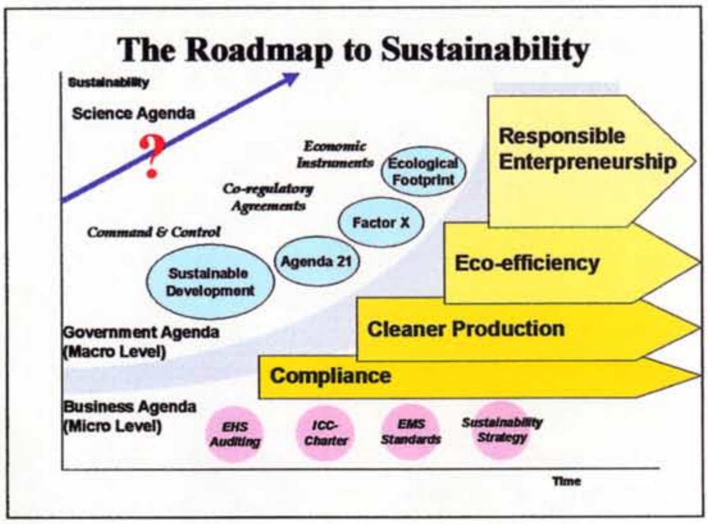


Figure 11. Parallel changes in concepts and agendas of government and business.[36]

Cleaner Production - Less wasteful consumption

The ecological impacts of production and consumption need to be studied as an integrated whole otherwise the full environmental consequences cannot be assessed, the points of leverage to improve the system may be missed, and responsibility cannot be attributed correctly. It is common for research to focus on the practices of producers in developing countries, for example in converting forests to export agricultural crops for human consumption or animal feed (e.g. cassava or corn), or conversions among different land-uses, such as from rice to shrimp aquaculture. It is much rare for consideration to be given to the importance of consumption, trade and market processes that are driving changes. The most important points of leverage may well be in changing consumer behaviour - towards less and less wasteful and environmentally damaging consumption.

Sustainability science must take a much more integrated look at production-consumptions

Sustainability science must take a much more integrated look at production-consumptions systems. This will often require tracing the material, energy, social and ecological consequences along different parts of the commodity chain starting with the raw inputs that go into making a product through to the handling of wastes when the consumer has finished. This logic is required not only for manufacturing, heavy or high technology industries and products, but also for more conventional agri-business and food industries as these remain large sectors in most of the developing and transitional Asian countries.

For example, the shrimp produced in aquaculture ponds (Figure 12) in former wetlands and mangroves along the coast and riparian margins of major rivers in Thailand and Vietnam involves a very long commodity chain before the shrimp is eaten on a plate in Tokyo, New York or London (Figure 13). The ecological and energy inputs to producing shrimp are very large and many of the services are obtained for free or at very low cost.

Figure 12. Intensive shrimp aquaculture pond in Trang Province, southern Thailand.

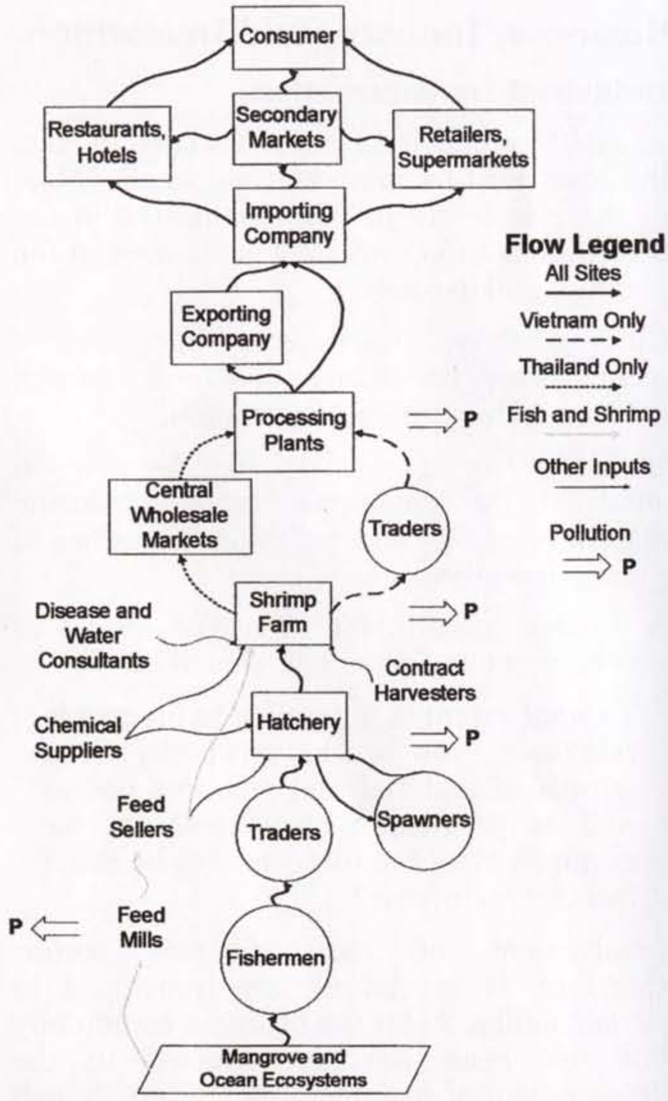


Figure 13. Shrimp aquaculture commodity chain and supply network showing structure of consumption-production system based on ponds in Thailand. Thick dark arrows represent the flows of shrimp. Energy inputs for transport are implicit in all the arrows and for storage or processing in each of the boxes. Most processes also produce wastes, but those of potential importance to local aquatic ecosystems are highlighted with a "P" labeled arrow.[37]

One of the key challenges is ensuring that private, and public, investments are timely. Experiences in Asian capital cities, strongly suggest that investment in mass transit systems and waste water treatment are usually made way too late.

Private investments in cleaner technologies, as plant upgrades or research and development, given appropriate incentives and governance, may mean that it makes good business sense to be early – markets that work can help ensure timeliness.

Institutions: bridges and ladders

Institutions are "*systems of rules, decision-making procedures, and programs that give rise to social practices, assign roles the participants in these practices, and guide interactions among the occupants of the relevant roles. They include both rules on paper and rules in use*". [38]

Institutions are important as both drivers of, and responses to, environmental change. They guide, constrain and facilitate human adaptation to challenges from the environment and social system.

Institutions are not fixed though they are often analyzed as such. Understanding their dynamics, how institutions are born, die and are transformed is crucial because most transitions to sustainability will require changes in institutions even when there is no necessity for changes in technology or knowledge.

Rules on Paper, not in use

Formal institutions, such as the laws and regulations of government that are written down and enforced by police, soldiers or inspectors, are in one sense the easiest form of institutions to see. But that is deceptive as many of the institutions that are supposed to govern use and access of natural resources or production of wastes and pollution in Asia are often implemented in entirely different ways or simply ignored.

At the regional scale, The Association for Southeast Asian Nations (ASEANS) is replete with institutions that are nice on paper. In 1985 there was the ASEAN Agreement on the Conservation of Nature and Natural Resources. A Cooperation Plan on Transboundary Pollution (1995) and Regional Haze Action Plan (1997) have done little to solve recurrent episodes of transboundary pollution from vegetation fires, especially during dry phases of the El Nino-Southern Oscillation. In Northeast Asia institutions are urgently needed for acid deposition and emissions control, but negotiations and cooperation has been slow and tortuous.[39] Why? Are there better ways forward?

Understanding the rules in use, not just those on paper, is a major challenge for sustainability science and often will require joint analysis of politics, because power is a major factor influencing compliance, and markets, because economic incentives often over-ride rules meant to protect the environment and people. The problem is not only one of non-implementation. In many cases the institutions themselves are seriously flawed on paper. In Asia, with a history of highly centralized governments, with top-down attitude to rural areas, development policies and institutions are often so uniform and general they are useless in any particular place or context. Sometimes, luckily local officials, enforcement agents, and communities are able to come to their own arrangements. A frequent source of conflict between the state and local communities is over property rights, especially in uplands and in coastal seas. Typically the growing nation states laid claim to land or coastal seas that were already settled and subjected to various indigenous or customary forms of private individual and shared or common property regimes. The performance of state and alternative institutions in terms of managing natural resources in a sustainable way can be compared but the truth claims of the state and local communities are often just political posturing. Good, independent, science is needed in many places and at many scales and contexts to untangle these highly politicised debates that are really about **who** should be managing for sustainability.

Apart from formal types of rules and rule sets, there is whole range of less visible, or shadow, institutions that again are critical for understanding the causes of un-sustainability and also the opportunities for change. These include things like corruption, patron-client networks, on the one hand, and changes in norms and values brought about progressive social movements and civil society networks. Sustainability science will need research on both informal and formal institutions and how these affect capacities to adapt.

Figure 15. A mobile street-side vendor selling "Kung Ten" or "excited prawn salad" in Phayao Province, Thailand. The informal sector is crucial to the sustainable livelihoods of large proportion of Asia's population and is understudied.

- Incorporating traditional knowledge and technologies to develop new and better practices for land management;
- Encouraging "informal" sector activities (Figure 15) and innovations as a valid way of securing a livelihoods and regional economies.

In some ways distinguishing traditional from non-traditional knowledge blinds us to the reality that all knowledge is tied to a particular time frame. It also can hide the political motivation for such a division, in the sense that knowledge coming from the state agency is in someway superior, more technical, more correct than that derived from experience by locals in managing and using local resources. This is a highly dubious presumption. Moreover, so called local or traditional knowledge has not remained stagnant but has always evolved to meet the challenges people faced, in much the same way as more centralized knowledge.

A key to the future is finding ways to hybridise and learn from various forms of knowledge. This is a tremendous challenge for science – it has to learn how to document, evaluate and think about much more context-specific as opposed to generalized information. Ethnobotany and studies of indigineous knowledge have already begun these important tasks.

Finally, under the framework of sustainability science Asian scholars need to study the "other" as well, the western nations, not just to learn from its dazzling experiences but also to help their societies avoid some of its worst mistakes.

Policy amnesia and non-learning

One of the most remarkable features of public policy in Asia is the almost universal capacity for non-learning in policy. Nobody pays attention to history -- otherwise there would see many examples of policy failure. Instead simplistic and long dis-proven mental models about the world continue to be wielded, against the face of evidence to the contrary, to design and implement policies.

The alternative, treating policies and management as experiments, from which we should learn is still very rarely practiced. In part this is understandable. Tracing the implications of policies and policy changes is often very difficult in a complex world with incomplete and transformed implementation, multiple forces operating sometimes in tandem, but others at cross-purposes, and the long delays for effects to become apparent.

Finally, if there is one feature of the current wave of "globalisation" that is truly unique from the past it is the incredible speed and access of information technology and communications. This has truly changed the way we perceive space and time. There are both threats and opportunities within this fundamental social and technological transformation for sustainability.

Building and maintaining adaptive capacity

> The sustainability of a livelihood, a national development pathway, or a particular land-use system or sector, does not just depend on a set of static quantities, such as finding some optimal mixture or configuration of economic structures, policies, institutions and international relations.
>
> It depends instead on a much more dynamic quality of maintaining adaptive capacity and opportunities. The capacity to adapt is crucial because the real world is full of surprises or disturbances and longer-term structural transformations that will test any solution posed for it.

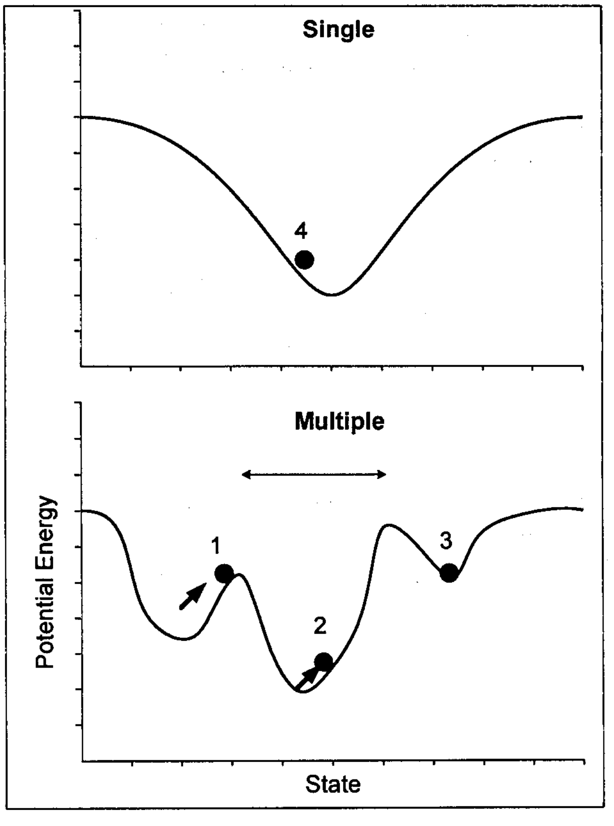
Complex Adaptive Systems

Most science has been devoted to studying single-equilibrium systems and this logic is now part of most laymen and political views of how the world works. In ecology we have focussed on ideas of succession to some final, proper or normal climax condition and this has become part of popular conscious in the ideas of balance of nature. In economics, a normal market economy is imagined as one where the flow of goods eventually stabilizes at an equilibrium between supply and demand. The philosophy of optimisation and efficiency, is pervasive in the way people try to manage and organise social and natural systems.

A problem with these abstractions is that they are often unrealistic in important ways. Change is not always continuous and predictables. We are not always living under "normal" conditions, and unique pathways to some optimal state may not exist. Many systems appear to have multiple equilibria and evolve.

Figure 16. Single and multiequilbirum state systems. While it is undisturbed a system tends towards its lowest energy state, that is, the bottom of a valley. In a single-equilibrium system there is only one valley. A system in state 1 if disturbed further could enter a new valley *or domain of attraction*, whereas the same disturbance would leave system in state 2 or 3 in an unchanged domain. Resilience can be thought of as the width of the valleys or domains of attraction.

The dynamics of **multi-equilibrial systems** is more complex than single equilibrium systems. The shifts from one domain (of attraction) occur around a critical threshold value for key variables. These can be thought of as boundaries where a particular configuration breaks down and is replaced by another. The **resilience** of the system can be thought of as a measure of the size of these boundaries, beyond which the system is beyond re-capture (Figure 16). At a higher level, a multiple-equilibrial system is considered to persist provided it stays in a domain from which it can return to its other domains.



The implications of thinking about the world in terms of multiple equilbrium are numerous. Dynamic behaviour can be much more complex. If the system is near a place where cross between domains (a threshold) then small differences between perturbations can lead leads to radically different system behavour, in other words, chaos.

A machine run by a computer program operates deterministically by a set of unchanging rules, for example, about how to respond to signals from other components of the system or the external environment.

Systems with people and other living organisms have a key additional feature: the set of behaviour rules themselve can change. Individuals and societies can learn. For this reason they are called **complex adaptive systems**.

Sustainability transition in the real world of surprises, crises and alternative pathways is an on-going processes rather than a drive towards a fixed end-point. There are tensions between processes which conserve, and others which create and destroy. Both are needed, for without disturbance and destruction there is no pressure or incentives to innovate. In short, sustainability science is a study of change in complex adaptive systems.

Adaptive Capacity and Resilience

Resilience is defined by three characteristics: [42]

- the amount of change a system can undergo and still retain the same controls on function and structure (still be in the same configuration - within the same domain of attraction).
- The degree to which the system is capable of self-organization.
- The degree to which the system expresses capacity for learning and adaptation.

Resilience therefore describes the potential of a system to remain in a particular configuration, to maintain its feedbacks and functions, involving the ability of the system to re-organize following disturbance-driven change. [43]

The Ping River Watershed around Chiang Mai, for example, can be imagined as a complex adaptive system with various living and non-living components (Figure 16). We can then ask questions about what features of its structure help maintain, or conversely, reduce the resilience of the system to particular types of disturbance, for example, financial crises, or droughts.[44]

Figure 17. Terraced paddy rice fields in upland valley near Om Goi, Chiang Mai, Thailand. Communal forest areas in background are important for collection of non-timber products.

Exploring complex adaptive systems requires developing models about the world. Pictures showing linkages between parts of the system often help. Sometimes we need to go further than this to explore how components interact and describe relationships between components in terms of mathematical expressions. Indeed we can build very complex models with hundreds of equations describing hundreds of processes, but these often become as difficult to understand then the reality we were trying to analyse in the first place. Often it is the model that captures just a few critical parts of the system and its behaviour that help us understand the system, and sometimes, suggest new ways to "manage"it in a more adaptive way.

Disturbance, crises and surprise

Starting with the world view in which disturbance and dynamics are normal (inevitable) then it is clear that it is important understand recovery and reorganization processes if you want to be able to say things about longer-term sustainability. Questions that arise include:

- Where does ecological and social memory reside?
- When might it be desirable to create or stimulate disturbance in a system?

Asia is replete with examples of big boom-bust cycles, in stocks, construction projects, "silver-bullet" development crops. Could some of these have been avoided, and been less damaging to society, if there had been a culture of encouraging small crises and challenging the system intentionally with smaller disturbances. A way of stimulating innovation and also demonstrating the value of maintaining adaptive capacity. Very large boom-bust swings are bad because they erode the capacity to such an extent that no recovery is possible before the next shock comes along – when this happens, as it has repeatedly in history, we document collapses of a civilizations.

Thresholds and limits

Disturbances and surprises are usually thought of a sudden events often triggered by events outside the system. Slower, cumulative on-set changes are also important on their own or in combination with disturbances when these events push a system past a threshold or limit.

The idea of limits arises frequently in discussions about sustainability. For example, as assimilative capacity, ecological limits or carry capacity. People ask: "What is the carrying capacity of the earth, Asia, the region and each country" What is the allowable limit?" How clean is clean? How eco-efficient is efficient"? [45]

The term *limits* implies an absolute boundary or edge or end-point, wherease th*reshold* suggests a transition or a starting point beyond which it may be difficult to return. Whether we think in terms of limits or thresholds the point is to measure or be able to detect them.

Sustainable Livelihoods and Adaptive Management

When the challenges to management and livelihoods are considered the central goal of sustainability could be seen as trying to find ways of maintaining and building adaptive capacity.

At the individual level an appropriate set of concepts is that of livelihoods, which are, "the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base." [46]

In the sustainability livelihoods framework the manager is seen as been the centre of the system if interest. In the adaptive management paradigm, it is more common to imagine the manager as some how being outside the system though this is not compulsory!

Thinking about sustainability in terms of multiple perspectives and complex adaptive systems, does not preclude the possibilities for action or intervention, but greatly increase the subtlety required. Concepts like sustainable livelihoods and adaptive management need to help guide further research on theory and practice of sustainability.

Agendas in Asia

Developing agendas for sustainability science in Asia should be based on broad consultation to establish needs, guide priorities for funding, and make best use of existing experience and opportunities. Asian perspectives on sustainability have a regional flavour but there is much diversity within as well as similarities with priorities elsewhere in the world. At this stage we can offer some principles, propose some organizing themes and framework and then illustrate these with example research topics

Principles

The agenda that will be described in this section is intended to guide debates about priorities. Participation in the refinement of this agenda needs to be widened and on-going or the process will fail.

The earlier sections of this report suggest the following principles about how sustainability science should be done.

- **Open** to wide public participation and scrutiny in agenda setting, monitoring and often, even in the conduct of research itself;
- **Responsible** to society for its findings, helping find solutions and understand trade-offs better, not just pointing out problems;
- **High quality** research is needed, in terms of standards of evidence and argument and in their interpretation for policy and public awareness;
- **Self-critical** so that it can learn, evolve and keep up with the shifting challenges and opportunities facing societies aiming to pursue sustainability transitions;
- **Modest** about its findings, about uncertainties and knowables, and the appropriate roles of science; science is not substitute for influencing and changing preferences through politics or markets, nor is it alone a driver of values and institutional changes.

These are a challenging set of principles for any science to follow, as they bring science down from as pedestal, but I would argue that where the issues are as complex, and important for human wellbeing, as the challenges and opportunities of sustainability, then principles like these are imperative.

Criteria and Scope

Research under the framework of Sustainability Science should be:

- **Integrative** because most real world problems are beyond the scope of narrow disciplinary domains or particular traditions in science;
- **Relevant** to policy, management and local decision-making;
- **Testable** so that is its propositions and models can be rejected and there is a possibility of learning;
- **Sustainability** oriented in focus.

Within Asia it is appropriate that the Science agenda,

- **Produces** usable information and understanding in a timely fashion;

And meets,

- **Needs**, that is, addresses the highest priority challenges and opportunities within the region.

Criteria like these are essential otherwise sustainability science is in danger of becoming the "*Science of Everything*". Fundamental research in narrow disciplines is still needed. Sustainability Science cannot and should not try to replace these efforts, but instead should focus on synthesis and integration. It is here that an agenda for Sustainability Science could add the most value. Integration of the end-to-end, or cut-and-paste, kind is unlikely to be enough. New studies will need to designed from scratch, starting from a problem focus rather than the tools of a particular discipline. In doing so, new concepts and tools of analysis will undoubtedly be developed, and these will probably change the way we perceive problems. Examples of some of these were hinted in the discussion earlier on analysing human – ecological systems as complex adaptive systems (see *Building and maintaining adaptive capacity*, p25).

The criteria and principles reinforce each other.

The kind of products envisaged for sustainability science include:

- information on trends and conditions, (assessments, indicators)
- improved scenarios at various scales;
- broadening of response options under consideration, from policy instruments, such as market incentives and regulations, through to actions that civil society groups might take;
- better understanding of the needs and capacities of the most vulnerable people to pursue sustainability transitions;
- capacity building (education, training , media, journalism, social marketing) [47]
- better understanding of structures and processes, that drive, cause, and constrain sustainability transitions;
- better appreciation of the behaviour of human societies and their ecological systems as complex adaptive systems.
- more open scientific process (see *Public Science and Responsibility*, p16)

Organizing Themes

Earlier in this report we summarized perspectives about the key challenges and opportunities in Asia (Table 1). The simplest way to organize the research themes is by sectors following the structure of the working groups, but this does not tell us much about linkages between sectors or which resource systems are affected.[48] A more informative way is to classify the issues or puzzles them according to the sub-system (or sector) of human activity they originate in and the component of the biosphere (or resource group) they have large impacts upon. This has been in Table 3. Also included in this table are some examples for each category. Of course some puzzles fit in many cells of the puzzle which is why we need to consider the "cross" issues.

This classification is practical, but does not help much conceptually, especially for those problems which cut across many cells. It also doesn't identify the structural similarities between many problems. For this, we need an organization that will be more helpful for theory and conceptualising.

In Table 4 I propose a set of organizing themes. Under each theme I suggest one or two **core questions** and give one or two examples of more **specific questions**. Core questions are those which can be reasonably asked for many sector-resource combinations and their interactions (in Table 4). Specific questions in contrast make sense primarily for one or only a few sector-resource combinations or refer to only a very specific set of social or physical processes. There are a very large number of possible specific questions. A few are given as illustrations.

An obvious feature of this table is that it argues that transitions to sustainability will not be just a matter of getting the technology right. It also requires a much better understanding of human behaviour, especially institutions, knowledge, markets and politics.

This agenda and the discussions that precede it suggest that sustainability science although built on a foundation of strong more disciplinary oriented science will be unlike conventional science in many ways (Figure 2).

Table 3. A classification of sustainability challenges based on the sub-system (or sector) of human activity they originate in and the component of the biosphere (resource group) they have impacts upon. Additional explanations in text.

	Land (L)	Water (W)	Atmosphere (A)	Marine (M)	Cross-Resource Group
Urban (U)	solid wastes soil compaction-destruction habitat conversion	waste water – sewerage water demand and storage	emissions from transport	run-off through rivers B/R - conversion of coastal habitats	L<->W: siting of settlements, reclaiming vs. flooding and water quality impact
Industrial (I)	persistent toxic/hazardous pollutants	toxic/hazardous pollutants	energy and other emissions	run-off; accumulation in food chains	
Rural (R)	pesticide contamination soil degradation + soil improvement	fertilizer run-off pesticide run-off water quality water demand, diversion and storage (irrigation, dams)	GHG emissions Biomass burning/haze	fertilizer/pesticide run-off sedimenation	L<->W: land cover, riparian structure interactions with flows;
Fisheries And aquaculture (F)	wetland conversion	over exploitation species introductions aquaculture intensification chemicals and nutrients (also Marine)	—	overexploitation fishing down food chain, by-catch	A->M Atmosphere conditions (pollution) on light and marine productivity W->M Diseases and pollutants from aquaculture to seas
Cross-sector	U,I -> R: land speculation, commodity preferences R, U -> F: competition with aquaculture for coastal lands	R -> U: sedimentation, flood risk, drought? U -> R: demand for flows away from irrigation; U,I,R -> F: water pollution affecting freshwater fisheries I-F: hydroelectric vs fishery trade-offs	I -> U: environmental health R -> U: environmental health – haze from biomass fires I,U -> R: deposition of industrial/urban emissions on agriculture and indirectly through impacts on climate	U-F : market /food security interplay	UR-LW: Urban-rural conflicts over land-uses needing water (eg. Irrigated orchards and crops) UIR-LA: Carbon storage in tree crops and forests versus emissions from urban, industrial,agricultural and deforestation sources; UIR-MA: Smoke-haze from urban-industrial emissions and biomass burning interacting to reduce ocean productivity LW-RF: Food security – from ocean or land

Table 4. Organizing themes and questions.

Organizing Theme	Core Questions and *Examples of Specific Questions*
Cross-scale interactions with long-term and large-scale trends	What long-term, large-scale trends and processes are most important in shaping the prospects for sustainability? How do larger scale economic and biophysical processes interact with regional and more local processes? *How will climate change confound efforts to adaptively manage water resources in the Mekong River basin in a sustainable way?*
Social Structures and Processes	How do institutions, politics, technology, markets, knowledge, organization and management drive un-sustainability and how can they be harnessed for sustainability? 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?
Adaptive capacity and Resilience	How do the assets and entitlements of individuals and groups affect their capacity to adapt to challenges and sustain their livelihoods? What determines the vulnerability or resilience of nature-society interactions for particular places and for particular types of ecosystems and human livelihoods?
Thresholds and limits	Is there a robust way of defining limits and thresholds and finding indicators that could provide early warning? Or is experimentation and learning from comparative experiences a more reliable way to detect thresholds in practice? How does human capacities to adapt through substitution of services, innovate and re-define their own environments alter the risks of exceeding "bad" thresholds? *Can one substitute physical materials by information resources?*
Lags and phase matching	What are the consequences of different components (eg political and ecological) of a linked system be in different phases of the adaptive cycle,[49] and how can these intertia effects be modelled?
Indicators, assessment and monitoring	If sustainability is an on-going process of transitions rather than a march towards a constant goal, then what are the most suitable indicators of key processes, not just changes of state? Is it realistic to expect to find a manageable set of indicators? How are indicators interpreted for monitoring and assessment? How reliable are they? What do they hide?
Consequences of interventions	What are the distributive consequences of interventions in the name of "sustainability science"? *If carry out this project or implement this activity who will benefit, and who will be left out?*
Institutions	How should conservation and environmental protection be pursued when creation of protected areas on land or in the sea cause direct conflict with existing forms of property rights?
Learning	How do people learn about changes in their environment? How do they recognize sustainability problems? What mechanisms are there in current insitutions for management of natural resources to learn about changes in configuration of resources and services? Is there any possibility of timely behaviour with foresight?
Tools and Methods	To what extent do methodological approaches in ecological and social sciences need to be modified to meet challenges in sustainability sciences ? What role should comparative case analysis studies and simple system models[50] have in arriving at generalizations?
Operations and Management	Under what conditions would closer integration of research, planning, monitoring, assessment and decision-support lead to better adaptive management, and when may it actually create more brittle systems? How can principles and design concepts, like maintain adaptive capacity or build resilience, be incorporated into operations and management for sustainability transitions? Is it feasible? *What is the most effective water management system for each basin? What new technologies are needed?, and when do we need them for each basin?*

Strategies for Sustainability Science

Barriers and Strategies

There are a number of barriers to the widespread adoption of science programmes that would guide and support research on transitions to sustainability in Asia (Table 5) Some of these barriers are internal or at least close to the organization or conventions in science, for example education and accountability, whereas others are external, having more to do with how science interfaces with the rest of society, such as closed political systems. Others have more to do with the values and mental models held about the world by those in power.

There wasn't consensus on the importance of the barriers listed. For example, the issue of funding, something which all scientists are fond of complaining about, could be debated by pointing out that there is a lot of funds directed at sustainability science though it doesn't necessarily go under this banner. Likewise, there is an un-stated wish that science should some how immediately turn into policy. Public policy in the real world is much more messy and complex and so it should be!

The converse of many barriers in the list can be thought of as opportunities. For these and other opportunities we are looking for strategies to take advantage or reinforce these trends or contexts. An example of an opportunity that isn't listed is the World Summit on Sustainable Development to be held in Johannesburg later in 2002.

It would be possible to consider for each individual barrier (or opportunity) some of the strategies that could be pursued to reduce those barriers (or enhance the opportunities). Most of these follow directly from an understanding of a barrier. Thus, to overcome barriers in the way science is taught in science and outside it, means changing curricula, incentive systems, providing opportunities for joint degrees, and so on.

Likewise, the barrier of inadequate coordination can be addressed by strategies like providing information technology support, running workshops to exchange ideas, promoting open sharing of data and models, and conducting collaborative comparative research projects. These strategies can work within as well as among countries.

Issue of trust and credibility require improved communication, dialogue and cooperation. This can be through processes to broaden participation as well as assuming responsibility, as has been argued at various places this report.

A few of the barriers, such as those for handling trade-offs and reluctance to examine ones own behaviour are more fundamental in that they are near the limits about what can be usefully studied by science. This makes them all the more important to question and probe. Some of the most important conceptual breakthroughs are likely to come from thinking about processes and mechanisms for reaching just agreements on trade-offs.

Finally, the simplest and most basic barrier within Asia, remains the strong adherence to economic growth (at almost any cost) models of development in cabinets, bureaucracies and boardrooms. Here is where education and research on decision-making with risks, power relations and social psychology is required. It is also where a huge amount of additional effort in dialogue is required. One promising avenue is through joint formulation and exploration of scenarios. Science needs to know much more about how decision-making in the real world and to start incorporating these insights into theories, models and scenarios of change.

Science of Everything

For the most part, the workshop focussed on what kinds of science are needed to support transitions to sustainability. An obvious question that arises is whether or not the current mixture of domestic and international science programmes, successful as they may have been in their own particular domains, is sufficient for tackling the multi-scale and inter-disciplinary challenges of sustainability in Asia. On the one hand more programs and more initiatives can needlessly stretch human resources, so it may be better to incorporate

Table 5. Barriers (and implied opportunities) to implementation of sustainability science.

Reluctance to dig deep or close or to investigate thoroughly underlying causes of unsustainability because of political sensitivities and the threats evidence may have for the lifestyles of researchers, who are often amongst the wealthy in Asian societies;	**Education** – basic understanding of sustainability science in many disciplines is weak and this is a constraint on these disciplines contributing to relevant research; Academia also tends to encourage narrow specialization of individuals and to a lesser extent teams which is a furather barrier;
Closed political systems in most Asian countries is still closed, and thus does not foster the kind of partnership between research, stakeholders and government agenices or the private sector that sustainability requires;	**Inadequate coordination and organizational support** for the sharing of experiences about integration and policy among individuals in different fields as well as organizations around the region involved in sustainability science;
Unaccountable science: agendas set with governments involve little participation or evaluation by public, and those private corporations essentially none, in Asia; accountability to society is low;	**Policy relevance** of science is not recognized or the transfer into usable policy is too slow. In practise must acknowledge the complexity of policy process and the limitations of many research projects to provide useful policy support, sometimes for no reason other than poor communication techniques of scientists.
Funding: for inter-disciplinary research involving significant community and policy interaction is not easy to secure, and continunity is difficult because sustainability is not considered mainstream part of science by most funding agencies;	**Economic growth** is the highest priority of governments in Asia, and issues of the environment and human well-being while acknowledged are secondary – there is a widely held mental model that it is better to grow first, the environment can be cleaned up later and the benefits of growth will spread (or trickle down);
Trade-offs and multiple goals – puzzles in sustainability often involve multiple goals that must involve trade-offs to resolve them; While analysing trade-offs and processes to resolve them are important areas of research the actual decisions in any particular case about preferences and how they are modified or used as a basis of collective action, requires political processes. Science cannot do it alone, but it has often tried to.	**Scepticism and lack of trust** of managers and scientists in Asia towards agendas that appear to originate from the "North" is strong and reinforced in Science by frequent failures to recognize local capacity and resources, and tendencies to preach, but not share the most important information, technologies or intellectual properties. In development and policy circles "sustainability" is sometimes seen as a way of the North arguing that the South should not get what it already has. These negative perceptions should be seen as a positive challenge to sustainability science that must demonstrate the value of its methods and a flexibility in agendas to accommodate within Asia priorities.

sustainability issues within current research, development and education programmes. On the other hand, one could argue that expecting sustainability issues to be incorporated in a comprehensive way is wishful thinking, and therefore, there needs to be a substantial effort to create new programmes especially those linking and coordinating existing enterprises. It is clear the strategy will have to be carefully worked out as a "***Science of Everything***" would contribute very little. I suggest the niche is very much in synthesis, integration and bridging the gaps between the global environmental change research community and other more local and development-oriented research programs. The Chiang Mai Workshop did not attempt to draw a conclusion on this emerging debate about how science should be organized. Further thought and open discussion is needed on this issue as it could greatly affect the efficacy of other strategies.

Integrated Strategies

In practice, following a one-by-one approach would be inefficient. A much better approach would be to seek a smaller set of integrated strategies that should help tackle most of the barriers in one shot. The best mixture strategies for breaking down barriers will not be identical for all countries, but hopefully some of them can be shared across Asia or tackled directly at the regional level, for example, through sub-regional organizations like ASEAN or APEC.

A somewhat surprising finding, at least for in Asia, is that many of the barriers to sustainability science are related to the organization and conventions of science. These should be tackled early, through dialogue in University boards, National Science Councils and Academy of Science fora.

Next Steps

There are many challenges and opportunities head and good foundations upon which to tackle them. In the short term there are a number of possible actions that could be taken that would greatly help future work in this area. Three, are suggested as priorities. First, to facilitate the establishment of sets of regional case studies for focussed comparisons to test and evaluate the core ideas of the evolving sustainability science framework. This should help identify more explicit and generalizable principles where current knowledge is suitable for application now. It should also test whether sustainability science, under the framework sketched in this report or within the sustainability science initiative globally, is worth pursuing.

Second, to consolidate a network for sustainability science within Asia through two or three small workshops aimed at writing synthetic papers or proposals on one or two of the key themes identified here.

Third, and most important of all, for each of us to stop and reflect.

Figure 18. Figure at the entrance to the forest-tradition temple, Wat Umong, Chiang Mai.

Acknowledgements

My sincere thanks to the participants who attended the Chiang Mai workshop for sharing their insights and experiences. A synthesis report of a meeting as rich in discussion and debate as this workshop cannot hope to represent fairly all the perspectives and points you raised. It is also difficult for me to acknowledge individual sources for all the point and insights expressed here, though I have done this on a few occasions where these came directly from individual presentations.

Special thanks also the steering committee. There constructive comments before the workshop were crucial to the final organization of the meeting. Thanks to my co-chair Mohd Nordin Hassan for his cooperation and suggestions. I would also like to extend warm thanks to Eileen Shea who gave useful feedback in the early planning stages, helped with the secretariat and then contributed scientifically to the climate working group. Greatly appreciated. Thanks also to Bob Corell and William Clark at Harvard for giving myself and colleagues here in Asia an opportunity to contribute our perspectives to the Sustainability Science Initiative. Finally, but not least, thanks to the secretariat team, led by my wife Phimphakan "Arjin" Lebel, for their superb efforts, that went along way to make a hard and interesting meeting fun!

Notes

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[1] Suggested citation for CD is: Louis Lebel. 2000 (Ed). Chiang Mai Workshop on Sustainability Science: Synthesis Report and Background Documents. CD-ROM Electronic Publication. March 2002. Faculty of Social Sciences, Chiang Mai University, Thailand. If you received this report in electronic form on CD then you can follow many of the hyperlinks in the end-notes below to open individual presentations, background papers and other "raw" workshop notes on the CD.

[2] World Commission on Environment and Development. 1987. Our Common Future. Oxford University Press; Oxford.

[3] Kofi Annan, *We, the Peoples: The Role of the United Nations in the 21st Century.* (UN, New York, 2000). www.un.org/millennium/sg/report/full.htm.

[4] Lebel L, Steffen WS. 1998. (eds) Global environmental change and sustainable development. Science Plan for a SARCS Integrated Study. Southeast Asian Regional Committee for START (SARCS). Bangkok: Thailand.

[5] The main programmes are the International Geosphere-Biosphere Programme (www.igbp.kva.se), The International Human Dimensions Programme on Global Environmental Change (www.ihdp.org), The World Climate Research Program (www.wmo.ch/web/wcrp/wcrp-home.html) and START (www.start.org). See respective web-sites for more information.

[6] Amsterdam Declartion – Challenges of the Changing Earth Conference. Available at www.igbp.kva.se

[7] Tyson PD, Fuchs R, Fu C, Lebel L, Mitra AP, Odada E, Perry J, Steffen W, Virji H. 2001. The Earth System: Global-Regional Linkages. Global Change – IGBP Series. Springer-Verlag: Heidelberg, Germany.

[8] See for example, IGBP. 2001. Global change and the earth system: a planet under pressure. IGBP Science 4. International Geosphere-Biosphere Programme: Stockholm.

[9] CGIAR – Consultative Group on International Agricultural Research. In Asia examples of key organizations are the International Rice Research Institute (IRRI), International Centre for Research on Agroforestry (ICRAF) and the Center for International Forestry Research (CIFOR). See www.cgiar.org

[10] See: Robert Kates et al. 2001. "Sustainability Science" *Science* 292: 641-642; Jane Lubchenco. 1998. "Entering the century of the environment: A new social contract for science." *Science* 279:491-497. and visit: www.sustainabilityscienece.org/ for additional articles and materials.

[11] Activities coordinated by the Kennedy School of Government, Harvard University, USA.

[12] A detailed programme is available on the workshop CD or at : www.icsea.org/ssi/

13 Of course there could always be more diversity. Participation was also restricted because of need to share English as a common, but second language for most. A list of participants is at the back of this report, and more detailed contact information is provided on the workshop CD.

14 Left part of figure modified from Lebel et al. 2002 (in press). *Industrial Transformation and Shrimp Aquaculture in Thailand and Vietnam: Pathways to Ecological, Social, and Economic Sustainability. Ambio.*

15 See for varied examples: Johda NS. 1997. Mountain agriculture. Chapter 14 in: Messerli B, Ives JD (Eds) Mountains of the World: a global priority. Parthenon: London; Forsyth T. 1996. Science, myth and knowledge: testing Himalayan environmental degradation in Thailand. Geoforum 27:375-392. Blaikie P, Sadeque Z. 2000. Policy in high places: environment and development in the Himalayan Region. International Centre for Integrated Mountain Development, Kathmandu: Nepal.

16 Working definition from one of the working groups at the workshop (Integration, III)

17 Much more detail can be found in the reports of the individual working groups on Land, Water, Atmosphere & Climate, Human Settlements, Coastal and Marine Ecosystems, and Regional Integration.

18 Photograph courtesy of Tieng Pardthaisong

19 Tieng Pardthaisong plenary talk.

20 Yap Kieo Sheng in human settlements working group citing WHO statistics.

21 Yap Kieo Sheng lead presentation to human settlements group;

22 See lead presentations and reports from each of the sub-system working groups for more additional examples.

23 Yap Kieo Sheng lead presentation to human settlements working group.

24 See for example: Naylor, R.L., Goldburg, R.J., Primavera, J.H., Kautsky, N., Beveridge, M.C.M., Clay, J., Folke, C., Lubchenco, J., Mooney, H. and Troell, M. 2000. Effect of aquaculture on world fish supplies. *Nature 405*, 1017-1024.

25 Knight M. 1998. Developing countries and the globalisation of financial markets. World Development 26:1185-1200; Rock M. 2000; Angel, D. P. and Rock, M. T. (2000): (eds) Asia's Clean Revolution Industry, Growth and the Environment. Greenleaf: Sheffield, UK.

26 Robert Wasson

27 Kriengsak suggested that it might be better called "Sustainability Studies" to distinguish it from conventional science.

28 Figure courtesy of Robert Wasson

29 Working Group report on Land

30 Lebel L. 1997. Living with Global Change: linking science and policy in Southeast Asia. Workshop summary and synthesis. 13-15 August 1996, Bogor, Indonesia. GCTE Report No.14. GCTE: Canberra.

31 An interesting term used by Robert Chambers for contrasting concepts of well-being for the rich with those of the poor.

32 Yap Kieo Sheng, lead talk to Working Group on Human Settlements

33 Yap Kieo Sheng, lead talk to Working Group on Human Settlements

34 Angel, D. P. and Rock, M. T. (2000): (eds) Asia's Clean Revolution Industry, Growth and the Environment. Greenleaf: Sheffield, UK.

35 Integration ("Ideas"

36 figure courtesy of Niven Huang

37 Modified from Lebel et al. 2002 (in press). *Industrial Transformation and Shrimp Aquaculture in Thailand and Vietnam: Pathways to Ecological, Social, and Economic Sustainability. Ambio.*

38 Young OR 1999. (Ed) Institutional Dimensions of Global Environmental Change. Science Plan. IHDP Report No. 9. IHDP: Bonn, Germany.

39 Lebel L. 2002. Acid rain in Northeast Asia. Pages 81-111 in Noda J. (Ed) Cross-sectoral partnerships in enhancing human security. Third Intellectual Dialogue on Building Asia's Tomorrow, Bangkok, June 2000. JCIE: Tokyo.

40 Contreras AP, Lebel L, Pasong S. 2001. The political economy of tropical and boreal forests. IDGEC Scoping Report No. 3. IDGEC: Dartmouth, Germany.

41 Adapted from 40.

42 Holling, C.S. 1996. Engineering resilience versus ecological resilience. In: Schulze, P., editor. Engineering Within Ecological Constraints. Washington (DC): National Academy, p. 31-44.

43 For additional discussion of resilience concepts and applications of the adaptive cycle for analysis of sustainability and resource management problems at various scales see: Gunderson LH, Holling CS. 2001. (Eds) Panarchy: understanding transformation sin human and natural systems. Island Press: Washington; Berkes, F. and Folke, C. (eds) 1998. Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience. Cambridge University Press, Cambridge, UK; Many other articles in the on-line journal Conservation Ecology are available through the Resilience Alliance website: http://www.resalliance.org/

44 See Report of Resilience Alliance Workshop on the Ping River Basin available at: www.icsea.org/ra/

45 Niven Huang, final panel presentation

46 Chamber & Conway 1992. Sustainable rural livelihoods: pratical concepts for the 21st century. IDS Discussion Paper 296. Institute of Development Studies: Brighton, United Kingdom.

47 Human Settlements Working Group presentation

48 See the Indivdiual Working Group reports for lists of research themes by sectors: land, water, atmosphere, human settlements, marine and regional integration.

49 In the adaptive cycle (see refs in 43) change in systems is thought to proceed through a series of phases: exploitation, conservation, release and re-organization. Processes that are important depend on which phase you are in. Phase matching is the idea of synchrony between phases. Lags and intertia imply differences in phase. If many parts of a system are in the re-organization phase than rapid and profound transformation may be possible – a so called window of opportunity. At other times major change may be hard to bring in because of constraints from other parts of the system which are not in a "flexible" phase.

50 Robert Wasson in plenary talks: "Models not substitute for thought; but world is being redefined by what computers can do."

Appendix

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