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Jappe, Arlette

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Nature-Society Interaction: An Agenda for STI Research

Arlette Jappe

1. Introduction

The term »anthropocene« characterizes the current geological age in which humanity is a strong, or even the dominant driver of change in the Earth system. Most of the Earth's ecosystems are now dominated by the human species (Turner/McCandless 2004; Vitousek et al 1997). The accelerating pace of global environmental change is accompanied by what might be called an increasing knowledge-intensity of nature-society interaction. The Russian geochemist Vladimir Vernadsky coined the term »noosphere« to point to the fact that human cognition has become a phenomenon of geological significance (1945). Today, an important question is how science, technology and innovation (STI) can contribute to enhancing society's capacity for sustainable development (Cash et al 2003; Clark/Dickson 2003). While progress in knowledge and technology alone is not sufficient to solve the sustainability crisis, there is no doubt that STI has an important role to play in bringing sustainable development paths within reach (Berkhout/Gouldson 2003).

The growing knowledge-intensity suggests that STI research should devote more effort to questions of nature-society interaction. Yet the relevant space of knowledge has not been described in a way that presents a systematic agenda for STI research. The objective of this paper is to present a conceptual map of knowledge for sustainability. We argue that this map contains the outline of a more comprehensive programme that links topics in environment-related STI research and helps to identify gaps in current understanding.

The challenge of sustainable development is »the reconciliation of society's development goals with the planet's environmental limits over the long term« (Clark/Dickson 2003: 8059). A fruitful perspective for sustainability-oriented STI research consists in the investigation of problem-solving capacity (cf. Jänicke et al 1999). This perspective includes problem-solving in science and technology (S&T) proper, as well as a focus on the coupling of knowledge and action between different spheres of society, *id est* science, business, politics, law, mass media, and education. The coupling of knowledge and action is conceived as the capacity for environmental innovation (in a broad sense) and social learning, and includes the analysis of obstacles to progress in the direction of sustainable development.

There has been a tendency on the part of environmental historians and social scientists to conceptually divide »knowledge and communication about nature« from »material interaction of humans and their environment«. We believe that this separation is flawed, as large portions of the relevant knowledge are embedded in the ever-more sophisticated technologies deployed to transform natural resources in economic processes of production, consumption and waste disposal. In general terms, the knowledge for a sustainability transition comprises both (a) knowledge about natural systems and about anthropogenic changes in these systems and (b) technological knowledge implemented at the interface of nature and society. Technological knowledge should not be conceived separate from material interaction because technologies determine the flux of material and energy which affects natural systems. This can be demonstrated with the help of the »ecological interaction chain«.

2. Task Domains of STI for Sustainability

The »ecological interaction chain« is a generalized representation of the causal linkages in nature-society interaction which shows that perception, construction and valuation are inherent to nature-society interaction. This scheme was originally developed by William Clark and others as a »taxonomy of hazard management« (Clark et al 2001: 10ff.). The chain consists of six causal steps as displayed in Figure 1 and described in Table 1. A similar concept of a causal interaction chain is used in the more well-known DPSIR framework (with driving forces, pressures, states, impacts and responses).[1] However, Clark's scheme is more amenable to the purposes of STI research because it contains technology as a causal linkage and makes more explicit use of social concepts (such as demand, choice, practice, valuation, vulnerability).

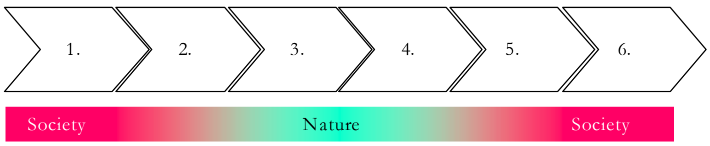

Figure 1: The Causal Chain of Nature-Society Interaction

1 See http://glossary.eea.europa.eu/EEAGlossary/D/DPSIR.

1. Demand for goods and services
2. Choice of technologies and practices
3. Flux of materials and energy
4. Environmental properties and ecosystem services
5. Vulnerability of people and things they value
6. Consequences to people and things they value

Table 1: Six Steps of the Ecological Interaction Chain

(Source: Modified and adapted from Clark et al (2001))

Following Clark et al (2001), we distinguish six steps in the causal interaction of nature and society. (1) The chain starts with human demand for goods and services, which comprises demand for artefacts and services created by society, as well as demand for natural resources and ecosystem services. (2) Humans develop and employ technologies and practices to satisfy demand. Technologies are embedded in institutions and infrastructures. (3) Depending on the choice of technology, practice and location, flows of materials and energy occur (extractions and emissions). Anthropogenic flows alter the flux of material and energy in the geo- and biosphere. The modification is not confined to direct effects, but includes catalytic reactions, as for example the greenhouse effect of CO2 emissions, as well as the removal or addition of biological agents, for example the introduction of alien species. (4) These modifications affect environmental properties and ecosystem services (cf. definition below). (5) Change in the behaviour of natural systems may have unintended consequences for people and the things they value. Vulnerability is the differential susceptibility to damage from hazards and environmental change, such as more frequent climatic extremes, pollution and resource degradation. Vulnerability is a function of diverse social and natural features. (6) Mediated by their vulnerability or resilience, people are subject to adverse consequences of changing environmental conditions. (1) The chain may be conceived as a closed loop, since many impacts of environmental change consequently cause shifts in human demand for goods and services.

In the past, many environmental sociologists and historians construed their subject matter by opposing material nature-society interaction to ideas and social discourse about nature (e.g. Buttel et al 2002; Cronon 1990). With the help of the ecological interaction chain, we aim to show that STI research needs a very different approach. Rather than artificially separating material nature-society interaction from knowledge and discourse, we use the causal interaction chain to distinguish four domains in terms of problem content: (I) ecological modernization and transformation, (II) ecosystem management, (III) environmental risk assessment, and (IV) adaptation to environmental change. Each domain demarcates specific problem-solving tasks in terms of knowledge, technology, innovation and related social discourse and each domain covers different sections of the ecological interaction chain. The label »task domain« signifies problem-solving to enhance sustainability.

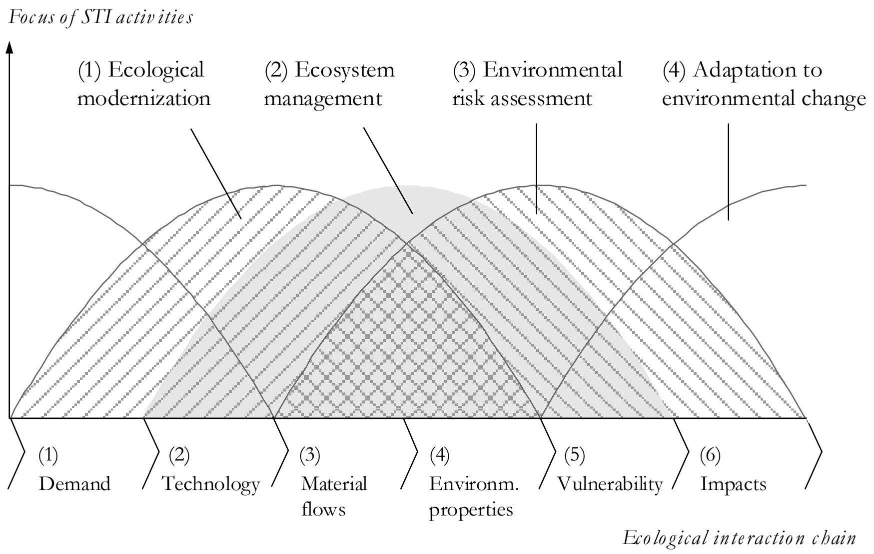

Figure 2: Task Domains of STI for Sustainability

(Source: Author)

The causal chain serves to define the place of knowledge in nature-society interaction. Direct material interaction is located at the middle of the chain (step 3 and 4), causally linked with demand from and consequences of environmental change for society at both ends (steps 1–2 and 5–6). Technological knowledge, social construction, and perception of environmental properties are inherent to the interaction, although these discursive aspects are not specified in detail. The scheme as such does not distinguish internal subdivisions on the side of nature (e.g. geosphere – biosphere, earth system compartments, ecosystems) or society (e.g. social or cultural groups, nations, social systems). Thus, neither natural nor social science conceptions are privileged in a fundamental way.

The basic idea displayed in Figure 2 is that each *task domain of STI for sustainability* can be characterized by its focus of knowledge production on the ecological interaction chain. This focus is represented in Figure 2 as the maximum of a schematic distribution curve. The idealized distribution shows that the core of each task domain extends over two causal steps on the interaction chain, and the two tails of the curve extend over the two adjacent steps to the left and right. Thus, the focus of knowledge creation in the domain of »ecological modernization and industrial transformation« (domain I) is on »technologies and practices« (step 2) and the resulting »flux of materials and energy« (step 3). More peripheral, the task domain includes knowledge creation on conditions of »human demand« (step 1) which determine the choice of technologies, and on »valued environmental properties« (step 4) that are affected by material flows. In contrast, issues of vulnerability (step 5) and consequences of environmental change (step 6) rarely figure prominently in R&D for ecological modernization. The four domains are shifted in relation to each other.

The selection of the domain labels is the outcome of an extensive review of STI topics in the areas of environmental innovation research, environmental sociology and social studies of science, history of environmental sciences, and research in the human dimensions of global environmental change. The four labels are taken to represent the same level of aggregation. The complete coverage of the interaction chain is an indication for comprehensiveness, although the value of this classification has to be proven against the diversity of empirical research topics. The schematic distribution does not express quantitative estimates for the respective knowledge demand or output – a question for empirical study. Each domain cuts across disciplinary boundaries of natural, social and engineering sciences. The areas of ecological modernization and transformation and of risk assessment are already more widely recognized as fields of STI research than ecosystem management and adaptation to environmental change. In this sense, our objective is not only to categorize existing literature but also to highlight upcoming or comparatively neglected themes.

Each of the four task domains stands for grand social challenges. We claim that the four task domains give a comprehensive picture of STI in nature-society interaction as of today, and on a high level of aggregation. In order to relate this scheme to more common subdivisions of knowledge creation (e.g. S&T fields), social discourse and action (e.g. business, politics, law, mass media, education), each domain may be further disagreggated into segments. Table 2 lists selected examples for the disaggregation of each task domain. Given appropriate subdivisions, the value of the scheme is that it provides a cognitive map on which a great diversity of STI research themes can easily be located and related to each other. In this way, the scheme can help to identify knowledge gaps and blind spots in current research.

(I) Ecological Modernization	(II) Ecosystem Management	(III) Environmental Risk Assessment	(IV) Adaptation to Environm. Change
– *Economic Sectors* e.g. energy supply, mining, construction, transport, chemical industries etc. – *Large technical infrastructures* e.g. for traffic, telecommunication, water, energy, waste – *Technology Fields* e.g. environmental engineering, energy & material-efficient technologies	– *Sectors of NRM* e.g. agriculture, fishery, forestry, eco-tourism, nature conservation – *Ecosystems* e.g. tropical rainforests, mountain ecosystems, marine ecosystems, river basins – *S&T Fields* e.g. ecology, soil sciences, agro-ecology, hydrology, marine & freshwater biology	–- *Environmental Risks* e.g. natural hazards, climate change, ozone hole, health risks, spread of pathogens – *Vulnerable Populations or Regions* e.g. people on small islands and coasts, poor people, age groups – *Scientific Fields* e.g. atmospheric sciences, meteorology, hydrology, ecology, epidemiology	– *Adverse Impacts* e.g. loss of investments, costs for restoration & substitution of ecosystem services, health costs, conflict over NR – *Economic Sectors* e.g. insurance & reinsurance, building sector, water and energy supply – *Markets* e.g. grain, livestock, water, timber, emission trading, fuels

Table 2: Disaggregation of Task Domains (Selected Examples)

(Source: Author)

A focus on social challenges and problem-solving inevitably introduces normative dimensions into STI research. However, this does not mean to suppress the empirical diversity of actors' views on what constitutes environmental problems and viable solutions in different social contexts. There are some good models in the literature for the treatment of normative dimensions in studies on the application of knowledge to social problems. We follow Clark et al (2001) who recommend the use of *metacriteria*: metacriteria are »criteria for evaluating efforts to link knowledge with action« and have been summarized in the literature under the headings of »adequacy, value, legitimacy, and effectiveness« (definitions of criteria ibid: 15). The authors state that this approach offers an »uneasy middle ground« between »imposing on our empirical material a rigid normative framework of our own making« and »giving up on the normative discussion by simply assuming that all outcomes are equal« (ibid: 14). Since there is presently no forceful social consensus on how to attain a »sustainability transition« (Parris/Kates 2003), there is a certain danger for sustainability-oriented STI research to become openly politicized and to lose credibility. On the other hand, STI research can offer valuable contributions to identifying and implementing feasible next steps.

The following sections 2.1–2.4 explain the content of the four STI task domains in more detail. Definitions and illustrations are based on leading research from STI research and from earth and environmental sciences. Section 3 discusses the concept of STI capacity and presents some topics for future research.

2.1 Ecological Modernization and Transformation

The defining task of the first STI domain is to reduce the environmental impacts of socio-economic metabolism and to disconnect growth of the economy from primary resource consumption. The focus of knowledge creation centres on the choice of technologies and practices and the resulting flux of material and energy (Figure 2). This focus is explicit in the definition of ecological modernization by Martin Jänicke: »›Ecological modernization‹ describes the wide spectrum of possible environmental improvements that can be achieved through technical innovations beyond end-of-pipe approaches« (Jänicke 2004: 201). This includes improved management of material and energy flows in the economy as investigated by »industrial ecology« (Daniels 2002; Haberl et al 2004). Strategies of ecological modernization often emphasize the exploitation of environmental-economic win-win situations where gains in eco-efficiency are connected with enhanced competitiveness at the level of firms, industrial sectors or national economies (Porter/van der Linde 1995; Taistra 2001). Proponents distinguish technology-based modernization strategies from deep change in economic structures. »Industrial transformation« is a term for the adoption of radically different technological development paths, or for »radical changes at the level of socio-technical regimes« (Smith et al 2004: 113). »Problem-solving in the form of ecological restructuring affects systems of behaviour which – irrespective of technical eco-efficiency improvements – stand out by their high environmental intensity«. (Jänicke 2000; 2005: 205) We estimate that most environment-related STI research is currently located within the domain of ecological modernization and transformation.

2.2 Ecosystem Management

The central task of the second problem domain is the long-term maintenance of essential ecosystem services. »Our future environment will largely consist of human-influenced ecosystems, managed to varying degrees, in which the natural services that humans depend on will be harder and harder to maintain.« (Palmer et al 2004: 1253). The Millennium Ecosystem Assessment gives the following definition of ecosystem services:

»An ecosystem is a dynamic complex of plant, animal and microorganism communities and the nonliving environment interacting as a functional unit. (…) Ecosystem services are the benefits people obtain from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting benefits* such as soil formation, photosynthesis, and nutrient cycling. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services«. (Millenium Ecosystem Assessment 2005: v)

The focus of knowledge creation is on anthropogenic alterations of material flows and species composition in the biosphere and resulting changes in ecosystem properties (Figure 2). Ecosystems are »managed« to varying degrees. An important question is how resource degradation or depletion can be prevented through improved institutional arrangements. The analysis of environmental institutions has made much progress in recent years.[2] An influential line of thinking features the development of design principles for the sustainable management of »common pool resources« (Dietz et al 2003; Dolsak/Ostrom 2003). (Re-)Designing environmental institutions also requires detailed case-specific knowledge. »Institutional diagnostics« has been advocated as a case-based approach to deal with the complexity of existing institutional arrangements and environmental conditions on local to global scales (Young 2002).

2 Institutions that deal explicitly with environmental or resource issues are called »environmental« or »resource regimes« (Young 2002: 5).

The domains of ecological modernization and ecosystem management are overlapping. For example, agriculture and ocean fisheries depend on cheap fossil fuels, and agricultural innovation systems could be vastly improved in terms of sustainability (Clark 2002; Pauly et al 2003; Raina et al 2006). The specific focus of ecosystem management consists in the impacts of human practice on certain environmental properties and ecosystem services (cf. overview in Andreae et al 2004). This implies a demand for knowledge of natural system functioning that is not inherent in the perspective of ecological modernization. Ecosystem management is not confined to natural resources in agriculture, forestry and fisheries but includes maintenance and restoration of many other ecosystem services, as in the management of water, urban areas, tourism, nature reserves, the control of species invasion, etc. (cf. Palmer et al 2004).

2.3 Environmental Risk Assessment

The central task of the third domain is the anticipation and evaluation of environmental risks, *id est* risks caused by variability and change in environmental phenomena. Environmental risks such as storms, floods, droughts or pests have always threatened human life and prosperity (Nigg/Mileti 2002). In addition to natural variability and long-term changes, environmental risk assessment treats the question if and where anthropogenic environmental change might lead to more frequent, more severe or entirely different calamities in the anthropocene. Knowledge creation in this task domain is focused on variability and change in valued environmental properties and the different vulnerability of people to hazards or negative consequences of changing environmental conditions (Figure 2).

The Social Learning Group – authors of a landmark comparative study on the management of global environmental risks – uses the following definition of risk assessment:

»A risk assessment provides information about the causes, possible consequences, likelihood, and timing of a particular risk. Risks by definition involve uncertainties, and especially for global environmental processes these uncertainties are so large that the usual features of risk assessment– namely, the calculation of probabilities of specific harm from particular activities, natural or manmade – are swamped by larger uncertainties and ignorance about key processes, interactions, and effects«. (Jäger et al 2001: 7)

Vulnerability is a term for the differential susceptibility of individuals or populations to loss from a given insult (cf. Kasperson et al 2001: 24; Luers 2005; Turner et al 2003a; 2003b). Vulnerability analyses explain why certain populations are likely to be adversely affected by changes in environmental conditions or environmental hazards and what could be done to enhance their resilience.

»Vulnerability is a function of variability and distribution in physical and socio-economic systems, the limited human ability to cope with additional and sometimes accumulating hazard, and the social and economic constraints that limit these abilities«. (Kasperson et al 2001: 5)

The IPCC defines vulnerability as a function of the sensitivity of a system to changes in climate, its adaptive capacity and the degree of exposure to climatic hazards. Resilience is the flip side of vulnerability (Houghton et al 2001: 89).

2.4 Adaptation to Environmental Changes

The central task of the fourth domain is the adaptation of society to long-term environmental change. In relation to the other three task domains, knowledge creation is focused on the consequences of environmental change and their implications for human demand in goods and services. Adaptation is more difficult to demarcate as a domain of STI because adaptation is located on the social pole of the ecological interaction chain (Figure 2).

In a book on »earth system analysis for sustainability«, leading GEC researchers give a clear but very general definition of societal adaptation:

»Throughout history, society has responded in two principal ways to environmental vagaries, flux, hazards, and drawdown, including resource depletion: *move*, either through designed mobility as in pastoral nomadic systems or ›forced‹ relocation owing to environmental or resource degradation (…) and *change techno-managerial strategies*, as in the adoption of fossil-fuel energy or genomics. (…) The second option – to modify or transform biophysical conditions in order to gain a measure of ›control‹ over some portion of the environment or to deliver a substitute for a depleted resource (…) (is) labeled technological fix and substitution«. (Steffen et al 2004: 331)

Regarded from a genuinely historical perspective, we realize that the two options, relocation and changes in »techno-managerial strategies«, are inseparably bound in modern history. In the 18th century, Europeans expanded the agricultural resource base of their economies to distant continents: North and South America for food, fibre, and timber production, and Africa for slave labor force. Leading scholars of world history[3] argue that this earlier expansion of the renewable resource base is essential to explain the later take-off of the industrial revolution and the historical divergence between development centres in Western Europe and East Asia (Pomeranz 2000). In other words, Europeans combined the »move« strategy of territorial expansion with »techno-managerial« innovations of early capitalism. As a result, the

3 World history is the emerging historical field of global connections.

most developed centres of the west escaped the growth constraints of limited renewable resources within their home countries, long before agricultural technologies were revolutionized in the 20th century.[4]

Viewed from this angle, trade has substantially supplanted »move« strategies in the modern world, at least for those who enjoy affluence in a globalized economy (cf. Pomeranz/Topik 1999). External trade in agricultural and manufactured goods implies exchange relations among countries with regard to their ecological carrying capacity. However, to date this ecological balance of trade is not explicitly accounted for. Although accounting tools are being developed to determine the overall »ecological footprint« of nations[5], it remains methodologically challenging to quantify export and import relations among countries for particular ecosystem services. Recent studies of »green water« flows are a good example (SIWI et al 2005) Markets and long-distance trade are among the most basic mechanisms for society to perceive and to adjust to changes in the abundance of natural resources, non-renewable (e.g. oil) and renewable. At the same time, »globalization enhances the likelihood that those parts of the world involved in active trade with each other will reach many of their limits more or less simultaneously« (Meadows et al 2004: 222). This situation only underlines the difficulty of separating broad issues of adaptation from the analysis of economic and power relations among nations and social groups.

The contours and core themes of this STI task domain will manifest themselves as the 21st century advances. For the more narrow purposes of STI research, »adaptation« can be confined to *technological fixes of environmental problems and new economic opportunities* that arise from altered environmental conditions and reduced abundance of natural resources. Adaptation processes in this narrow sense are often incremental, at least initially, and determined by multiple social factors (Smit et al 2000). Furthermore, adaptive responses are likely to trigger innovations in the STI domains of »ecological modernization« or »ecosystem management«, blurring boundaries between domains. For instance, an adaptive response to regional climate change might consist in technologies that increase the efficiency of agricultural water use. So, adaptation pressures might act as positive feedbacks that drive the ecological interaction chain towards more sustainable socio-technical trajectories.

4 Kenneth Pomeranz (2000) argues that in the early modern world, limits in the regional output of renewable resources constrained technology-based economic growth in the most developed regions, and that different ways to cope with this problem are essential to explain the historical divergence of development paths in China and Western Europe.

5 See http://www.footprintnetwork.org.

3. Investigating STI Capacity

In an elementary sense, the study of *capacity* is motivated by the existence of constraints on action and a desire to overcome them or to push them further. In the context of sustainability, typical constraints involve dimensions of technical, economic or political feasibility. Our definition of capacity draws on Jänicke's discussion of »environmental policy capacity« (Jänicke et al 1999). In the sphere of politics, an important constraint on actors' behaviour results from the powerful assertion of contesting interests (e.g. environmental protection interests against polluter interests). Following Jänicke, the assertion of political interests has structural and situational components. The structural component is referred to as the capacity of actors or actor coalitions to influence policy outcomes. *Environmental policy capacity* results from »the organizational strength, expertise and the supporting groups of environmental interests, as well as the sum of opportunities and obstacles posed by structured societal conditions«. Capacity enhancement is recommended as a general strategic goal of environmental policy (ibid: 79; translated by the author).

STI capacity is another distinctive aspect of a society's total problem-solving capacity for sustainable development. STI capacity comprises R&D capacity and the capacity to effectively link knowledge and action. R&D capacity as the core of knowledge creation refers to all S&T fields that are relevant for sustainability and includes (a) the professional scientists and engineers working in the field, (b) the cognitive content of fields, (c) the technologies and infrastructures needed to observe natural systems and nature-society interaction, and (d) the institutions which maintain and influence the activities of research, technological development and training.

The coupling of knowledge and action between different societal spheres is referred to here as the *»capacity for environmental innovation and social learning«*. Environmental innovation means the invention, adaptation and diffusion of new technologies, products, institutions, and practices that are beneficial for sustainable development, and includes both radically new solutions and incremental improvements. The scope of environmental innovation is not confined to the economic sphere but explicitly includes all social systems such as science, politics, law, or mass media. Social learning goes beyond innovation, in that it refers to cognitive changes in social discourse and in actors' beliefs. Cognitive aspects are important for the analysis of coupling, in particular with regard to the framing of problems by different actors and the definition of actors' interests and preferences. We adapt the definition of »social learning« by Clark et al as »those processes that deliberately utilize experience or information to bring about cognitive changes« (2001: 14). Social learning refers to all cognitive changes that are concerned with problem-solving in one of the four task domains.

The four domains described in this paper organize the field of STI research for sustainability. The concept of STI capacity could prove useful for efforts to connect the variety of existing approaches, but it is also apparent that much uncharted terrain remains. Therefore, the main value of a broader framework consists in the identification of knowledge gaps and new areas for research. There are many questions for future research in sustainability-related STI capacity and we aim to highlight just a few of them:
Topics of R&D capacity:

- *Development of intellectual fields:* a number of excellent studies of environmental fields have been published by historians of science (e.g. Bocking 1997; Doel 2003; Hamblin 2005; Oreskes/Doel 2003; Weart 2004). These studies present rich accounts of cognitive, personal and institutional developments but do not aim to assess R&D capacity. Less is known on the development of Earth and environmental observation systems.
- *Quantitative STI studies*: to date, fields of environment-related S&T are receiving less attention from innovation policy and policy-oriented research than new high-tech fields, for example biotechnology or nanotechnology. Nevertheless, the variables and indicators that were developed for innovation research (cf. Frascati and Oslo Manuals by OECD) can be adapted and exploited for the study of sustainability STI (e.g. R&D expenditures and personnel, scientific and technological specializations, international collaboration, institutional networks etc.)
- *R&D institutions*: institutional landscapes for R&D differ significantly across countries, and many countries have created new environmental research institutions in recent years (e.g. research institutes, observation systems, assessment programmes, funding schemes). There is a need for comparative studies on the design features of effective R&D institutions for sustainability (cf. Cash et al 2003). This includes the national level as well as international or bilateral institutions which support STI-capacity-building in emerging economies and developing countries.

Topics of environmental innovation and social learning:

- *Environmental innovation capacity of environment-intensive sectors*: the interaction of environmental policy and innovation processes is a subject of some debate among economists and policy analysts. However, there is a lack of more comprehensive studies of the sectoral capacity for environmental innovation (Jochem 2004 makes this point for energy-intensive sectors). The concept of »sectoral innovation systems« (Malerba 2004) could be modified and adapted for this purpose. Economic sectors are an appropriate category to investigate the coupling of economic, political, legal and technological conditions with regard to ecological modernization.

– *The use of expert knowledge in issue domains of environmental governance:* the concept of an »issue domain« was developed for policy analysis and serves to trace the development of sustainability issues in different social arenas (e.g. parliaments, executive branches of government, newspapers). An issue domain includes a set of actors, the institutional settings within which interaction takes place, the behaviours (e.g. decisions, policies, agreements), and the impacts of those behaviours on the world (e.g. improvements in environmental quality). This framework was elaborated in a comparative study on the design of assessment processes of regional and global environmental risks (Farrell/Jäger 2006). A similar approach could be transferred to many other sustainability issues. Furthermore, there is a need for more research on the integration of different sources of information and expertise in environmental governance. In addition to the important issues of local knowledge and citizen participation (Fischer 2000; Kasemir et al 2003), an interesting question is how government and other management agencies make use of independent scientific research as opposed to the information that is generated by operational observation systems and assessment routines in ecosystem management (e.g. Young 2003).

4. Conclusion

This paper presents a comprehensive outline of the problem space of STI research for sustainability which is equivalent to the place of knowledge in nature-society interaction. An aggregated overview like this is useful because the disciplinary niches of environment-related STI research are still very fragmented. We believe that STI research has the chance to evolve into a major social science field of human-environment relations and we would like to engage in a broader discussion on this prospect.

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