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New Interdisciplinary Perspectives in Social Ecology

Karl Bruckmeier

Natural Resource Use and Global Change

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NATURAL RESOURCE USE AND GLOBAL CHANGE: New Interdisciplinary Perspectives in Social Ecology

Natural Resource Use and Global Change

New Interdisciplinary Perspectives in Social Ecology

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22 21 20 19 18 17 16 15 14 13

Contents

Illustrations

Boxes

Figures

Tables

Preface

Social ecology is an interdisciplinary subject investigating the human use of natural resources and the interaction between nature and society. The interdisciplinary nature of social ecology and its development in the context of environmental research are the themes of this book. The issues are tackled in a critical review of the scientific discourses on nature–society interaction in the 20th century, and of the knowledge sources and research of the new social ecology that developed rapidly in the past two decades in some European countries. The interactions between society and nature are specified in terms of natural resource flows and resource use practices in the economy and society. A theoretical knowledge synthesis shows how the conceptual framework of social ecology developed.

The book is the fruit of a sustained effort to follow the development of social ecology in my teaching and research. Several courses in human ecology, social ecology and environmental sociology that I taught at the University of Gothenburg in Sweden and at the Russian National Research University Higher School of Economics in Moscow were preparatory steps for this volume. From research and cooperation in international projects I gained the impression that the new social ecology and its knowledge profiles, theoretical perspectives and research results are insufficiently known and covered in the social-scientific and environmental research literature. To show the development of social ecology from a historical perspective I discuss the continuity and ruptures of the discourses on nature and society in human, cultural, social and political ecology, which can be understood as scientific variants of the interdisciplinary study of nature–society interaction.

Karl Bruckmeier
Gothenburg, July 2012

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Abbreviations

CORASON	A Cognitive Approach to Rural Sustainable Development (a European research project)
EC	European Community
EROI	Energy return of input
EU	European Union
HANPP	Human appropriation of net primary production
HEP	Human exe(m)ptionalism paradigm
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IRSA	International Rural Sociology Association
ISA	International Sociological Association
ISOE	Institut für sozial-ökologische Forschung (Institute for Social-Ecological Research), Frankfurt
ITQ	Individually transferable quota
MEFA	Material and energy flow accounting
MFA	Material flow accounting
NEP	New ecological paradigm
NGO	Non-governmental organisation
OECD	Organization for Economic Co-operation and Development
SES	Social-ecological systems
TEEB	The Economics of Ecosystems and Biodiversity

Introduction – The Development of Social Ecology

Interdisciplinary social ecology investigates the human use of natural resources and the interaction between nature and society in theoretical terms of "societal relations to nature", "societal metabolism" and "colonisation of nature". The concepts of nature and society relate to each other; however, the differences between them are not dismissed in social ecology with a unifying term such as that of "social-ecological systems" in recent ecology, but analysed with the "relational" terms above. In the new sociological literature society is described as a network or knowledge society, with global flows, "hybrids", "actants" and "socionatures", in a terminology that claims to indicate the recent changes in society and nature. This post-modernist terminology is not used in social ecology when knowledge from the social and the natural sciences is combined. Instead of simply changing concepts, social ecology tries in interdisciplinary analyses to lift the cognitive barriers between natural and social sciences, and between science, policy and social practices of resource use. This cognitive programme is the theme of this book, which is guided by the hypothesis that the theory-guided thinking, interdisciplinary research and knowledge synthesis of interdisciplinary social ecology are required to understand the changing interaction of society and nature in the era called "the anthropocene". Social ecology seeks in complex approaches to connect different epistemologies, theories and methodologies that generate knowledge on society–nature relations, in a cognitive programme that is exceptional in several regards:

- in its focus on global, social and environmental change, addressing the complexity of global systems and interactions;
- in its interdisciplinary approach with the use of knowledge from biology, ecology, physics, economics and sociology;
- in its historical perspective, whereby modern, industrial societies are understood in a historical comparison of societal resource use practices through their specific socio-metabolic regimes;

- in its cognitive interests as a heterodox, critical science of society and nature that opens up new possibilities for investigating problems of natural resource use, social inequality, and of another “great transformation”, to global sustainability; and
- in its consequences for natural resource use, which requires another understanding of policy, management and governance processes in reaction to the global processes of social and environmental change.

This programme is influenced by the discourses and the research in several disciplines and research fields that are reviewed in this book. A characteristic feature of the new social ecology, developed 25 years ago in Europe, particularly in Germany and Austria, with intellectual roots in other interdisciplinary discourses, is the use of theoretical concepts in the formulation of a new research agenda that are modifications of concepts from earlier critical theory: “societal metabolism” and “societal relations to nature” can be found in the theory of Marx and in the later critical theory as it was defined by the founders of the Frankfurt School of Sociology, Horkheimer, Adorno and Marcuse, nearly a century ago (Görg (1999) reviews this nature–society terminology in its variations in critical and traditional sociological theory, whereas Castree (1999) tries a more limited reinterpretation of Marxian political economy to connect it with post-modern theory). Social ecology is not continuing the older sociological discourses, either in a dogmatic sense of cultivating a theoretical heritage of a critical or Marxist theory, or in another sociological dogmatism of using conventional theories of society and modernity. Its theoretical concepts aim to renew a critical discourse on nature and society that did not advance far in earlier big discourses of modernity – in the Enlightenment discourse of a society formed after the ideal of nature and in the following philosophical discourses, in the Marxist discourse of a society formed after the ideal of the free association of people or in the discourse of newer critical theory that had difficulties in identifying a new subject of societal change. In the 1970s global environmental problems came onto the agendas of science and policy. The new environmental movements initiated a less Eurocentric and theoretical discourse on nature and society, in which theories of society did not receive much attention. In the new environmental discourse social ecology unfolded as a new variant of a science of society and nature with more systematic use of social-scientific and natural-scientific knowledge.

The theoretical terms of society and nature are constructed anew in the social-ecological discourse, which is a long-term project, not promising quick results. In this work social ecology does not aspire to become a new master discipline for environmental research in fights for epistemic hegemony. Different disciplines (e.g., biology and ecology) have aspired to that over the 21st century, which is perceived in environmental research as being one of large changes in society, nature and human resource use. Social ecology, being part of the multifaceted "mode 2" science or transdisciplinary knowledge production (Nowotny et al. 2001), deals, as do other forms of environmental research, with interdisciplinary questions of interactions between society and nature, tracing these interactions through theoretical and empirical research from global to local levels. The social-ecological terms differ from the post-modern terminology in their analytical capacity, not in the cognitive intentions to understand "hybrids" or "socionatures", as, for example, in the sociology of global flows and in actor network theory. The sociological authors see only indeterminate and de-territorialised flows in which material, symbolic and information components are blended in inseparable ways. Social ecologists investigating the historically specific forms of "colonisation of nature", of the social and cultural transformations of nature in human resource use processes, do not stop with such preliminary interpretations of global resource flows. The complexity of society–nature interaction through resource flows can gradually be understood with interdisciplinary research and knowledge synthesis. The notion of social-ecological systems should be used critically and cautiously in this research work. The "holistic" intention to overcome the analytical separation of society and nature and analyse the complexity of their interaction is a cognitive aim of ecology. But how far a combination of two system concepts helps to create a holistic research programme is doubtful. In contrast to a holism "ex ante", based on definition and combination of concepts and hardly changed ecological research, social ecology represents a holism "ex post", one that results in new knowledge only after theoretical analysis and knowledge synthesis. The concept of social-ecological systems seems doubtful when the historical and social reality, with various forms of differentiation and separation of society and nature in human history and in modern societies, is annihilated with the view that the conceptual distinction is wrong, analytically and empirically. Significant differences between society and nature continue to exist and cannot be overcome through an empirical research programme for nature–society interaction with simplified conceptual models such as that of the "adaptive cycle" in resilience research. These differences do not vanish from societal practices of natural resource use with the choice of a holistic concept, or with the re-adoption of traditional and local ecological knowledge of resource users. The cognitive practice of environmental movements that follow similar devices of a "new ecological paradigm" or "man as part of nature" is also not sufficient to identify the societal changes required for a reconciliation of society and nature. Nor do the differences between society and nature vanish when ecologists attribute cultural functions and services to ecosystems, using in functionalist reduction the multifaceted culture term. With the notions of society and nature, a historical memory of the changing interactions of society and nature is kept in social ecology that seems lost in other forms of sociological and ecological research.

The work programme of the book

To describe the interdisciplinary nature of social ecology and its development in the context of interdisciplinary environmental research is a controversial issue, and little of that has been done in social ecology. This book tackles the issue, first, in a general description of interdisciplinary environmental research in the 20th century, of which social ecology is part (Chapter 1), and, second, in a more detailed description of the knowledge sources of social ecology in social and natural scientific research (chapters 2 and 3) before, third, social ecology is described in more detail. In the first chapters the guiding question for reviewing environmental research is the same as in the following core chapters (4–6), in which the main themes of social ecology, the research on resource flows and land use and the theoretical synthesis, are summarised: How are the interactions between society and nature interpreted – in the research areas that were forerunners of social ecology, in the social, economic and ecological research that is used in social ecology, and in social ecology? The development of social ecological research is not a linear process ending in a closed theory; it remains an open cognitive programme. Its contours have been formulated by social ecologists, but not much has been revealed about its future development and directions except for such negative delimitations as that a new theory of society is not on the agenda. Social ecology develops from the critical analysis of controversies about natural resource use and the reasons and causes of problems with natural resource use. The Malthusian themes of population growth, scarcity, overuse of resources and collapse of societies have been discussed in political economy and ecology for the past 200 years in varying forms: in recent decades, for example, in Hardin's (1968) "tragedy of the commons", in the "limits to growth" debate and in the more recent popular-scientific debates about "overshoot and collapse" of societies (Diamond). The Malthusian and neo-Malthusian themes are part of the social-ecological discourse, but not with the aim of verifying or falsifying them as theoretical approaches; rather, with the intention of critical evaluation to show their relative, historically and socially situated cognitive achievements.

To describe the development of social ecology, such controversies about natural resource use and its limits can be used, directing the cognitive interest towards a theoretical elaboration of nature–society interaction in historically varying forms. The controversies are about the critical questions discussed in this book: changing social relations of power and inequality at different levels of societal organisation, especially at global levels; problems of knowledge production and utilisation in science and resource management; cultural mediation of resource flows through the perception, interpretation and discussion of resource use problems by social actors. Some controversies about the interaction of society and nature seem never-ending, kept alive through "essentially contested concepts" such as the debates about how to achieve sustainable development.

To limit and specify research fields and discourses in characterising social ecology, two criteria guide the selection of themes:

1. Themes and research fields that social ecological authors refer to and use in their research, including parts of ecological economics, environmental sociology, environmental anthropology, political economy and political ecology, industrial ecology, physical resource analysis, systems ecology, ecosystem research and the broad field of research about human use of natural resources that includes common pool resource research.
2. Themes and research fields that overlap social ecology but are not (or less intensively) discussed by its authors. The fields used to broaden social-ecological research include cultural anthropology, environmental policy research and the epistemological discourse of knowledge production.

The distinction between the two types of research fields is not precise and is sometimes a matter of subjective assessment. Practically seen, it is difficult to delimit the approaches reviewed, as many of them are diffuse, broad and interpreted differently. Some research areas that seem important in environmental research are glossed over or not covered in the following chapters: geography, political science and climate research are covered to a minor degree; environmental psychology, environmental history and historical ecology are hardly covered at all. The main reasons for this selectivity are, first, thematic – the focus on present global resource use problems in social ecology excludes a series of thematically differently specialised research; second, the directions and limits of the author's own specialisation in sociology and human ecology, which as a consequence lead to natural scientific research being reviewed less.

The social-ecological core theme of analyses of historically varying interactions between nature and society with regard to the resulting environmental problems is only the first part of the work. The historical and cultural comparison of resource use practices does not provide easy solutions for complex global problems that require knowledge syntheses. Until now, the reorganisation of practices of resource management with knowledge about sustainable development is not advanced. With the results of social-ecological research the directions of new learning can be clarified and policy-related conclusions can be drawn, as attempted in the last chapter of the book, in which the limits of policies to regulate social-ecological interactions as well as the limits of scientific research to produce knowledge for this regulation are discussed. Ecological research and knowledge integration show the interdependence of social and biophysical systems in the approaches of "adaptive management" and "adaptive governance".

Social-ecological knowledge for regulating social-ecological interactions and transitions to sustainability is not yet included in these approaches, only the simpler ideas that result from ecological and resilience research. The metaphoric notion of "navigating social-ecological systems" (Berkes et al. 2003) indicates a crisis of management thinking. Also, the newly developing research on social-ecological resilience (Folke 2006) is not yet sufficiently advanced to address problems of global transformation to sustainability – assuming that sustainability is not reduced to resilience. The basic ideas of cooperative and participatory research and adaptive governance are open processes to produce knowledge, but whether the resulting knowledge is sufficient to deal with the societal changes for transformation to sustainability is doubtful as long as no clear criteria are formulated for the knowledge required.

Social ecology creates expectations of advancing beyond the limits of sociological and ecological research in new knowledge syntheses for transitions to sustainability. However, the epistemic status of this knowledge is not sufficiently clear. Epistemological controversies pave the way towards interdisciplinary knowledge synthesis, articulated as fights between constructivism and realism or subjectivism and objectivism, the dualistic pattern known from earlier epistemological debates of knowledge from the natural sciences and the humanities. Such controversies are followed in the description of the development of social ecology only to the degree necessary to show their limits and consequences for interdisciplinary environmental research.

The socially constructed and culturally situated qualities of scientific concepts are recognised in social ecology, but doubts remain as to whether the constructivist epistemology can become a general model for interdisciplinary ecological research. Constructivist thinking, with its anti-theoretical motivations by "small narratives", incompatible perceptions, anti-dualism, cultural and linguistic relativism, is not exclusively social-scientific thinking, as the radical constructivism in physics shows. However, constructivism, with its variants of strong or weak constructivism, blocks rather than supports the analysis of material and energy flows that make up a large part of the exchange between society and nature in social-ecological analyses. A constructivist analysis may end with sceptical conclusions, as, for example, in the sociology of global flows, that the nature of these flows can never be fully understood and quantified because of their complexity and the varying social perceptions and constructions of resources and resource use by the many resource users.

Using the terms "society" and "nature" to reformulate the societal practices of resource use can be seen as keeping social-ecological research open in epistemological terms. When society and nature represent two differentiated and distinct – though interacting – spheres of reality, it seems also possible to work with different epistemologies, both constructivist and realist.

Moreover, it can be assumed that no epistemology determines the whole theoretical and empirical research that is carried out under its guidance. The cognitive qualities of theoretical and empirical research are not fully determined through an epistemology. This may be part of an answer to how to deal with epistemological controversies in social ecology – showing their limited influence on the research process and relativising their aspirations as determinants of scientific knowledge. Research in social ecology can use different, also competing, epistemologies.

In many scientific disciplines conflicting epistemologies, theories and methodologies are found and require choices. Researchers need to choose between these conflicting approaches under the premise that their paradigm, theory and methodology need to be coherent. A combination of several contrasting epistemological approaches, theories and methodologies appears illogical. But interdisciplinary research and knowledge integration would not be possible with strict epistemological criteria of coherence of integrated knowledge. Such demands can only be formulated for limited forms of integration, for example, of statistical data. The epistemological discourse during the 20th century, with its large variety of approaches, has tended to maintain a multiplicity of competing forms of empirical research, but has not contributed much to the interdisciplinary knowledge integration. In the epistemological cleavage between constructivism and realism the constructivist discourse tends to separate the social sciences and humanities from the natural sciences that study environmental problems – physics, biology, ecology and the newly emerging environmental research on climate change. Although epistemological debates about the subjective construction of reality in the human perceptive system are known in physics and other disciplines, they seem to be less essential there, or limited to certain questions and domains of research, and do not cover the whole discipline. Abstract epistemological debates on knowledge generation hardly spell out the concrete methodology, choices of research methods and practices of combination of knowledge. Combinations of heterogeneous epistemologies found in environmental research give hints that other ways of dealing with epistemological controversies can be sought.

In the epistemology-intensive scientific 20th century, many epistemological approaches that analyse and criticise knowledge production can be found. Not many of these approaches achieved general and lasting influence on scientific practice and research. A critical reflection of the epistemic basis of interdisciplinary environmental research and social ecology (in Chapter 1) shows ways out of dilemmas of choice between realist and constructivist epistemologies, for example, to work with different epistemological positions for specified purposes of research.

Having traced the unfolding of the new social ecology through a series of chapters until a theoretical synthesis is reached (in Chapter 6), the concluding chapters take up questions of deficits and of the application of social ecological research. Potential weaknesses of social ecology include:

– difficulties in fully realising the complexities of the social, in particular around issues of culture and agency;
– a sometimes insufficiently critical analysis of resource flows and the social relations which underpin these;
– lack of an attempt to formulate a theory for the present development of society after the end of "grand theories", but a simultaneous attempt to clarify nature–society interaction in theoretical terms.

At present several variants of social ecology and similar approaches exist that do not use the programmatic term of social ecology – for example, ecological research into common pool resources (Ostrom 2007a, 2007b), resilience research (Folke et al. 2002) and sustainability science (Kates et al. 2001). To deal with the confusing situation of multiple social ecologies, the new social ecology is discussed in a systematic way throughout this book: initially summarising the traditions of interdisciplinary research that adopted (during the 20th century) the label of social ecology; then following the knowledge sources of new social ecology in environmental research; and, finally, describing in detail the discourse of social ecology in its empirical and theoretical core components. This methodology reflects the author's understanding of a critical, interdisciplinary environmental science and is carried out with the following analysis:

1. In the critical analysis and discussion of the sources of social ecology, a method of summarising important controversies, discussions and results in different disciplines and subject areas is used to identify the contributions of that research to the analysis of problems in the interaction of society and nature: in rural and environmental sociology, ecological economics, environmental policy research, and political economy as social-scientific approaches, and in natural-scientific and interdisciplinary research on ecosystems, analysis of social-ecological systems and resilience.
2. The reconstruction of the discourse and research agendas of social ecology starts from the controversies identified in the core discourses, which are reformulated in terms of global resource flows, colonisation of nature, societal metabolism and societal relations to nature. The empirical parts include research into global resource flows (material and energy flow analyses) and unequal global exchange with regard to population growth and destruction of the environment, and into globalisation and food production with regard to controversies over global land use change and competition between food and energy production (biofuel and other renewables). The theoretical part includes the theoretical synthesis

in social ecology, combining concepts and ideas from different theoretical traditions (critical theory, world system theory and theory of social-ecological systems).
3. In the discussion and assessment of strengths and limits of social ecology and its potential future development in research, methodology and theory, the questions of theory of society and of anthropological knowledge for the development of social ecology are taken up. Some important research in these subject areas, not sufficiently discussed in social ecology, is reviewed. The macroscopic approach to dealing with societal metabolism and global resource flows needs to be mediated with more specific analyses of historically, culturally and locally varying social practices of knowledge use and resource management.
4. The discussion of practical and policy relevance of social ecology for the global transition to sustainability is a part of the analysis of deficits of social ecology. Social ecology is seeking ways to understand the difficulties of global transformation processes towards a new socio-metabolic regime which can solve the problems of limited natural resources that became apparent in the present process of global industrialisation. Social ecology participates in the broader discourse of sustainable development to show that it is not the discursive concept of sustainable development that constitutes the main problem, but the pathways of a global societal transformation in historically unprecedented forms where a new socio-metabolic regime is to develop.

The work programme does not include all contributions and research areas that influence the pluralistic social-ecological discourse. Some approaches of potential relevance to social ecology will be discussed only briefly in some chapters to round out the cognitive map of social ecology, which should be seen as an interdisciplinary field with open and changing boundaries. The global trend towards urbanisation and mega-cities with contradictory consequences for natural resource use is touched upon in fragmentary form in several chapters, but it becomes clear how urbanisation can be connected to social-ecological research. The insufficient involvement of the humanities and philosophy in the social-ecological discourse also deserves additional discussion. The exemplary discussion of philosophical questions of epistemology and environmental ethics does not systematically cover the theme; it deals only with the question of integrating normative knowledge into environmental research.

The method of critical analysis that forms the rationale of this book uses elements of several forms of critique from the epistemological discourses and the practice of the disciplines and subject areas reviewed. These elements of critique include the critique of scientific knowledge according to methodological criteria for verification and falsification of knowledge; the critique of the construction, interpretation and operationalisation of abstract and theoretical concepts, including that of society and nature and their interrelations; and normative critique summarised in the question: How can the societal use of natural resources be organised to meet the ethical criteria of fairness and justice, equal opportunity and universal rights? The critical normativity includes a critical valuation of scientific knowledge production and application of social practices by specific actors. In the ideas of social critique formulated by Bourdieu and Wacquant such forms of normative critique are taken up from older debates of critical theory but modified.

1
Interdisciplinary Research in Society and Nature in the 20th Century

The cognitive interests of social ecology in a historical perspective

Social ecology as the science of the interaction of society and nature is part of the interdisciplinary environmental research that developed in the 20th century under such names as human, cultural, social or political ecology. The term "social ecology" was used in several discourses in science and policy.

1. Scientific social ecology was at first a multidisciplinary approach for studying how humans were affected by their physical and social environments (Moos and Insel 1974). In this early form it remained a diffuse and broad area of research differing from older approaches of human ecology (sometimes also called social ecology: Alihan 1938) through its focus on the social environment, using mainly sociological and psychological knowledge to study the context of human behaviour changes. It included the physical environment as affecting human behaviour, but did not focus on environmental or global problems. Social ecology in this broad sense still exists today. The recent publication by Wright et al. (2011) shows again the idea of applying ecological thinking to every aspect of human life by studying the relations between individual, social, spiritual and ecological components of the human condition. This research, with an abstract conceptual framework, collects a mass of empirical data that is difficult to transform into coherent theoretical and integrated knowledge about the human condition. Parts of that research are relevant for the analysis of global environmental problems. But the narrow framework and the microscopic perspective, with a focus on individual and small group social interaction, limit the analysis of complex societal and ecological systems and interactions. Bronfenbrenner (1979) also uses the term "social ecology" for his psychology. It can be seen as part of the above approach, but is more specific with regard to the study

of individual human development as personality development through socialisation and the problems emerging in that process. A similar understanding of social ecology as the study of people–environment relations in community-based psychological studies is found in the work of Binder (1972) and Stokols (1992). The country-specific tradition of social ecology in India (Guha 1994) is limited to sociological research into natural resource use, especially agriculture.

2. In the political discourse and as part of environmental movements, social ecology is connected with two names. The North American social ecology movement inspired by Bookchin cultivates an "eco-anarchist" political philosophy in which the older idea of a society free of domination and repression is extended to an emancipatory idea for the reconciliation of society and nature. Another movement under the name of social ecology in Germany is linked with Bahro, showing its normative profile in a combination of ideas from European environmental movements with the cosmological ideas of Sri Aurobindo. Both of these movements, with their political and cosmological visions, are less oriented towards research, although members of the German movement participate in the national social-ecological research programme (Hosang et al. 2005). These authors argue for a theoretical integration of social-ecological approaches in a "trichotomic" theory of nature, man, culture/society, although strong differences between socio-ecological concepts and theories are seen. Clark follows a similar understanding of social ecology as holistic philosophical reflection about man, although he explicitly connects it with the empirical investigation of global political, economic and technical systems (Clark 1997: 32). A blending of sociological, philosophical and normative approaches is also found in the history of social ecology (e.g., Burch 1984).

The variants of social ecology mentioned above will not be analysed in this book. They did not significantly influence the new social ecology of global resource use emerging in the mid-1980s with the guiding ideas of "colonisation of nature", "societal metabolism" and "societal relations to nature". Its cognitive interests are described as follows (ISOE 1999: 13): (1) to reconstruct with empirical knowledge the relations between people and their social and natural environments; (2) to develop the concept of "societal action" to allow improved agency in the environmental crisis; (3) to analyse the conditions for the reproduction and further development of societies; and (4) to analyse the natural conditions of life that need to be maintained for further development of nature and society (see also, Becker and Jahn 2003). The empirical research includes the themes of human use of natural resources and its consequences and limits, with a focus on late modern society, in which overuse of resources and destruction of the environment reached global dimensions.

Before the development of social ecology, empirical research on natural resource use was carried out in different disciplines – for example, in resource economics, cultural anthropology and ecology. In the second half of the 20th century, when the public, scientific and political discourses about environmental problems unfolded and environmental movements emerged in Western countries, global environmental problems of climate change, biodiversity reduction and land use change appeared on the agendas of research and policy. Ostrom (2007a) diagnosed a deficit of environmental research in addressing problems in large-scale and complex social-ecological systems. However, her research is focused on local problems of common pool resource use and management. The concept of social-ecological systems to which she refers indicates the intention to address complex and global problems, but methodologies for that purpose develop slowly. The idea of coupled social and ecological systems has spread in studies of human resource use during the past decade, but the theoretical contours and the implications of this conceptual innovation are not yet clear, as the discussion on resilience research shows (see Chapter 3). The interpretation of nature and society as closely coupled spheres in modern industrial societies is found in human and social ecological research and in the theory of the anthropocene. According to this theory (Steffen et al. 2007), the human impact on global ecosystems through industrialisation has reached dimensions that justify a new geological term for the short period of industrial society. The concept of the anthropocene remains contested, among other reasons because of the difficulty of conceptualising and measuring the coupling of the systems.

Global systems and environmental problems are described as complex, but there are methodological problems and limits to understanding the complexity of the system. Whether the formal term of complexity is sufficient to study societal and environmental problems is rarely questioned. In social ecology, specific theoretical terms are used to study the interaction of society and nature – for example, societal relations with nature. In the critical theory of society, this relational term marked less an area of empirical research and more a philosophical discourse connected in Marxist theory with the themes of human alienation, society as "second nature" and nature as the "inorganic body" of man. In classical political economy in the 19th century, the big topic of nature–society relations was investigated only unsystematically, to the extent that it came up in the economic analyses of the capitalist mode of production, asking how nature and human labour together generate the doubling of value as value of use and value of exchange. In social ecology the older political-economic controversy about the labour theory of value is not continued and the analysis of society–nature interaction is detached from the framework of political economy. In a new theoretical and empirical research programme, society-related analysis is performed under the guiding concepts of socio-ecological regulation and colonisation of nature, and nature-related analysis under the guiding concepts of societal metabolism and societal relations with nature.

Social ecology uses theoretical concepts inherited from the natural and social sciences to decode the interactions between society and nature in historically specific analyses. Global environmental change as it is studied in environmental research does not sufficiently take into account societal action and agency. Although anthropogenic causation is seen in the current climate change and reduction of biodiversity, it is insufficiently understood how human societies affect, modify and socialise nature to produce global environmental change. Much less is known about how this change can be influenced through the strengthening of agency to control, correct or reverse the negative impacts of human resource use. Further questions regarding the interface of science, policy and resource management come up in the discourses of societal adaptation to global change and sustainable development. Knowledge from social ecology (its empirical and theoretical results are discussed in detail in chapters 4–6) shows advances in social ecology as seeing more because others have already done preparatory research. Social ecology opens new possibilities of knowledge generation through the integration of various disciplines and through its methodological developments (material and energy flow accounting, analysis of human appropriation of net primary production) for researching linkages between natural resource flows in the global economy and the resulting social inequality at country level (ecologically unequal exchange).

The new social ecology discussed here works with interdisciplinary studies of interactions between society and nature in a specific sense: analysing societal systems, global environmental problems and natural resource use practices in a systemic context that includes societal and ecological systems at different scales. This thematic scope of social ecology is sometimes abbreviated in the formula "biophysical analysis of socioeconomic systems and dynamics" (Haberl 2006), or, from a theoretical perspective, as a reflection of environmental consequences of societal action (Fischer-Kowalski 2004: 323). The three concepts already mentioned – societal relations to nature, societal metabolism and colonisation of nature – will be described and discussed in detail as constituents of the knowledge profile of social ecology in the following chapters. The new social ecology appears from this description as a European discourse developing in German language countries. The institutional location in these countries, however, does not adequately reflect the international discourse and global research themes. Furthermore, the discourse of the new social ecology includes a number of individual scientists in different countries who do not always use this label (e.g., Ostrom, Haila, Martinez-Alier). In the new social ecology large and multi-scale environmental problems of modern societies are analysed in theoretical and empirical studies across several spatial and temporal scales.

Several attempts at an interdisciplinary social-ecological theory have been found (Becker and Jahn 2003, 2006, Fischer-Kowalski 2004, Hosang et al. 2005).

Obviously there will never be sufficient knowledge to understand and solve the global problems that are studied in social ecology. Only a gradual improvement in understanding and problem-solving can be attained through research and knowledge synthesis. At some point in the future, when larger changes in society and human resource use may already have happened, either catastrophic changes or ones that demonstrate successful co-evolutionary development of nature and society, research into the global interaction of society and nature may no longer be as relevant as it is today and the topic may lose priority. The significance given to it today is a consequence of growing concern about the crisis in societal relations to nature. This environmental crisis has happened in parallel with changes in science, paradigm changes, epistemic turns and ruptures, indicating a crisis of knowledge production that has finally initiated a debate about the limits of science. Theoretical innovations of the past decades (chaos theory, complexity theory, resilience theory and more social-scientific discourses such as post-structuralism, postmodernism, ecofeminism, transdisciplinarity and post-normal science) were among the attempts to renew social and environmental research. They did not always open new long-lasting perspectives for research, but remained as critical comments on prior discourses of modernity or sometimes short-lived attempts at "scientific innovation". Reducing cognitive aspirations and showing the limits of scientific knowledge, as in several of these discourses, converges with attitudes such as that of the "sceptical environmentalist" (Lomborg 2001), with doubts that environmental action is meaningful. Social ecology develops from epistemic controversies, despite being part of or profiting from several of these epistemic innovations (such as transdisciplinarity, by opening environmental research to include the local knowledge of resource users). This social ecology combines continuity and renewal in its development. It develops through the critique of earlier studies of nature–society interaction, formulating ideas for a renewal of critical social and environmental research after the fading away of grand and critical theory traditions and the innovative ambitions of prior human and cultural ecology.

Interdisciplinary trends in environmental and anthropological research

Interdisciplinarity developed after the Second World War outside academic institutions. But the crossing of knowledge boundaries in various forms, transferring concepts, theories, methods, data, ideas and knowledge between disciplines, is an older phenomenon found throughout modern sciences since the 16th century. The topic of environment and natural resources is not new, but became more important in research and policy during the 20th century. The older interdisciplinary discourse of political economy analysed natural resource use for problems of scarcity, overuse and pollution of the environment, and distribution of resources between humans, including questions similar to those found today in environmental research. The interaction of society and nature during the first half of the 20th century brought new approaches in sociology (human ecology in the Chicago School of Sociology of Park, Burgess and MacKenzie) and anthropology (cultural anthropology and cultural ecology of Steward; European philosophical anthropology of Scheler, Gehlen, Plessner), in biology (holistic biology, Uexküll) and in interdisciplinary philosophical theories of the biosphere (Teilhard de Chardin, Vernadsky). These approaches paved the way for current interdisciplinary environmental research, although most of the researchers were influential in mainstream science for a short time, if at all. In the second half of the 20th century, environmental research unfolded in worldwide interdisciplinary trends emerging from environmental sociology, ecological economics, environmental policy research and systems ecology, and in "hybrid ecologies" (human, cultural, social, political ecology).

All these earlier scientific discourses can be seen as providing ideas and knowledge for the new social-ecological discourse. A direct source is industrial ecology, which was broadened and systematised by social ecology in its development from the 1980s. That development included a critical reflection and discontinuation of older traditions without denying their achievements. A reformulation of the global environmental crisis in a more theoretically nuanced diagnosis as "crisis of the societal relations with nature in the globalising industrial system" became the starting point of a social-ecological research programme. From the 1970s the international and global networking of movements, policies and environmental action advanced after the alarm bell of the "Limits to Growth" report (Meadows et al. 1972). A breakthrough of global movements and action happened with the Brundtland report in 1987, which opened the new discourse of sustainable development, in which many movements could participate. It created a thematic focus for such scientific movements as social ecology, with their interdisciplinary research on global social and environmental problems.

Social ecology, learning from the failures and achievements of environmental research, reacted critically to the development of environmental science and its application, with the following reflections:

1. Interdisciplinary environmental research is epistemologically and methodologically insufficiently prepared to cross the boundaries between social and natural sciences. Knowledge synthesis remains methodologically difficult.

2. Deficits of environmental research are a consequence of disciplinary knowledge practices, and of a strict separation of research and decision-making (which dissolves with transdisciplinary research and other forms of cooperation between scientists and decision-makers).
3. Interdisciplinary environmental research has tended to downplay theoretical analysis and reflection in favour of empirical research. The critique of panaceas and standardised managerial solutions (Ostrom et al.) does not imply an integration of theoretical and empirical knowledge.
4. Selective and eclectic knowledge practices by decision-makers and by environmental movements in environmental policy showed that no systematic transfer of scientific knowledge for environmental decisions happened.

With these reflections, social ecology reacts indirectly to further problems that undermined the continuity and success of environmental problem-solving efforts:

1. Many of the social movements that brought environmental problems onto policy agendas cultivated an idealism of environmental thinking that allowed them to ignore the social complexity of environmental action. Movement activists were less interested in understanding how modern societies work, and more interested in seeking knowledge and orientation from outside science (from native people, traditional lifestyles, rural simplicity, esoteric philosophies and religions, charismatic persons), supported by ecological or ecocentric worldviews (such as deep ecology).
2. Neglect of politics and power dimensions of environmental action were camouflaged as another way of changing society, through cultural change, in "value revolutions", and in lifeworld-centred individual behaviour changes that characterised the orientations of many social and environmental movements. This orientation towards individuals and individual action seems to be an involuntary imitation of the institutionalised individualism in Western culture, and does not take into account social structures that enhance collective or societal action and agency in the environmental crisis.
3. A lack of knowledge about global environmental change kept the resulting problems off research and political agendas for some time, although their potential significance and possible consequences (e.g., climate change) had been known for considerable periods of time. After some successful agenda-setting in early global climate policy, the policy process has collapsed de facto in recent years under the obstructive power of some governments and economic institutions, which renders attainment of its goals doubtful.

The new environmental movements and their scientific supporters in the 20th century followed a normative understanding of ecology and society to criticise the neglect of nature in social practices of resource use. In the early years of new environmentalism, ecology became a variant of critical normative thinking about modernity. More than the development of ecology as science, the movements have adopted knowledge for orientation (in Scheler's term). This resulted in the rediscovering of older views of man as part of nature for a criticism of modernisation. In the scientific discourses other developments could be observed. Ecology as a scientific discipline went through a paradigm change, in the sense of Kuhn, from the 1980s, with a transition from the guiding idea of "balance of nature" towards non-equilibrium ecology and a view of an interdisciplinary science adopting social scientific knowledge and drifting away from its biological origins (Scoones 1999). These changes date back to earlier interdisciplinary debates. Social ecology does not refer to all of these debates, but they need to be reviewed to show how the understanding of nature–society interaction changed in the scientific environmental discourse.

Forerunners of social ecology

The early 20th century

In the following review the early forerunners of social ecology, human and cultural ecology and philosophical anthropology are discussed with the question: How do they analyse the interaction between nature and society?

Human and cultural ecology. Human ecology emerged in the early 20th century as an interdisciplinary subject, with the theme of interaction between man, society and nature that later on became the theme of social ecology. How this interaction was studied, with what questions, theories and methods, differs over the course of time. The history of human ecology has been described in detail several times (e.g., Young 1983, Tengström 1985, Bruckmeier 2004) and will be reviewed here only in summarised form. Human ecology has differentiated into many variants, which makes it difficult to review the development of the subject. In a trial to assess the common critical ideas, Eisel (1992: 109) sees interdisciplinary and holistic forms of thinking as common features, revaluing nature and life as important conditions for human existence. This results in a normative model for a "soft" coexistence of nature and society, in which nature and culture together create an alternative to the misleading ideas of modernisation, technical and scientific progress and subjection of nature to technology-based resource exploitation.

Human ecology reacts with criticism to the preceding differentiation into humanities, natural and social sciences. Towards the end of the 19th century, an influential epistemological reflection by Dilthey had identified two incompatible scientific cultures of hermeneutic sciences (ideographic, particularistic, interpreting cultural documents) and natural sciences (nomothetic, formulating universal knowledge and laws). The new social sciences were at that time not yet established between the two dominant cultures. Interdisciplinary human ecology developed through a combination of knowledge from sociology, biology and other disciplines (e.g., anthropology and geography) in the analysis of interactions of nature, man and society. The conceptual separation between individual and society is a point of discussion between biologists and sociologists. From a sociological perspective the separation becomes doubtful when the individual lifeworld is seen as being outside society, not as a societal sphere that is socially structured and constrained. An empirical separation of individual and society would, from certain theoretical perspectives in the social sciences, appear as a fallacy that denies the social nature of humans.

Cultural ecology did not merge with the human ecology of the Chicago School, but remained, since its early development in the 1930s with the work of Steward, a specialised branch of human ecology in the larger context of anthropology, mainly for studies of non-Western local societies and cultures. As an approach that represents the anthropological tradition of human ecology, cultural ecology studies in empirical research the interaction of local culture and nature in subsistence activities. The syntheses of knowledge in human ecology were not carried out with knowledge from cultural-ecological case studies. However, there have been some important attempts to integrate the study of local cultures and resource use practices in historical studies of the modern world system that enriched the political-economic systems analysis of modern capitalism. The study of local resource use practices showed that the system of a globalising modern economy – according to world system theory, the globalisation process started with colonial capitalism in the 16th century – did not imply a standardisation of local economic practices of resource use and exploitation, but rather a successful adaptation of the new mode of production to local cultural, social and ecological conditions. Throughout its development, and until the late phase of present globalisation, capitalism appeared as a social "patchwork" when studied from cultural anthropological perspectives. Below the economic surface of global exchange, trade and resource flows can be found cultural differences and variations in the processes of subsuming human labour and natural resources under the capitalist economy. A model for such studies was given by Wolf ("Europe and the People Without History", 1982), showing that macroscopic system analyses and microscopic culture studies are relevant to the analyses of global exchange that is culturally situated and mediated.

Human ecological synopses and syntheses showed the difficulties of integrating knowledge from different disciplines when paradigm changes interrupted the continuity of knowledge production. Sometimes synthesis was reduced to developing a conceptual framework (Young 1989) or to the advances of human ecology in epistemological terms from multidisciplinary to interdisciplinary research (Tengström 1985); sometimes it happened in the form of encyclopaedic synthesis, thematically compiling and structuring knowledge in the broad fields of evolutionary and environmental connections of humans (Freese 1997a, 1997b). From the construction of a broad interdisciplinary research field it is not yet apparent how this research is carried out, or what the guiding assumptions, paradigms and concepts that guide research may be. With the selection and critical interpretation of the guiding terms of man, society and nature, human ecology appears as a critical reaction to the development trends in Western modernity. The individualisation of man within society and human separation – also understood as emancipation – from nature in the course of modernisation are critically assessed. This separation was seen as a reason for the environmental crisis and justified the focus on nature as the critical sphere for human development. With the expected reintegration of humans in nature, their reintegration in society, a new form of solidarity, could also be expected. The orientation to nature shows similarities to the later social ecology in its reflection not on developing a new theory of society, but on focusing on the interaction between society and nature as the specific ecological theme of research.

With the adoption of new knowledge from various disciplines, the boundaries of human ecology became less and less clear. Competing approaches unfolded under that name, as in many other disciplines. Combining knowledge from different scientific traditions and paradigms happened in epistemologically and methodologically unsafe forms. Whether human ecologists share the postmodernist antipathy to "grand narratives" and theories, as some do ("no grand theory but transdisciplinarity", Steiner and Nauser 1993: 16), is controversial. Other human ecologists attempted a synthesis of knowledge about man, nature and society, including theoretical knowledge. The difficulties in theoretical and epistemological reflection are partially those of epistemologies and methods for interdisciplinary knowledge integration, a neglected field in human ecology, in theory of science and in epistemology.

The historically oriented human-ecological knowledge synthesis of Freese (1997a, 1997b) results in the argument that man with the double nature of biological species and social being, or "*zoon politikon*" in Aristotelian terms, is "born" several times in biological and cultural evolution, in various forms that are inexactly classified as "*Homo sapiens*". Man is not yet known when one looks at human history in terms of biological evolution – the human condition needs to be interpreted. The review of human evolution in human ecology ended without a coherent or theoretically based view of man. To see man as becoming, developing, unfinished was a widespread idea in the philosophy formulated before human ecology. With the cultural variation of human evolution, contrasting interpretations of the human condition became possible. Nietzsche (1878) criticised the inherited fault of all philosophers to see man as "*aeterna veritas*" (eternal truth) although their knowledge about man is from a very limited historical time of human existence; they forget that man is always becoming. The critique does not tell much about Nietzsche's view of man, but rather more about a weakness of philosophical thinking about man manifested in jumping to general conclusions from limited empirical knowledge that can be overcome through research on human history.

The future of humans, seen as their potential to be developed with the help of scientific knowledge, resulting in a "good society", has been a stimulating idea throughout modernity, not ending after the Enlightenment discourse. The idea is closely linked with the development of modern natural sciences, and it re-emerges in ecological discourse. History and present society reveal a suppression of human capacity, and therefore the future becomes important as open time and space for the realisation of human potential (Honneth and Joas 1980: 24ff, 38f). The anthropological leitmotif of man as becoming conscious and rational, of man as an expectation, as a non-realised capacity, as chance, has vanished today with a mass of empirical knowledge that shows differences of cultures and societies, and with the pessimism and scepticism that spread with the collapse of misguided projects of social emancipation. With the rise of environmental movements in late modernity, social emancipation was replaced by ideas of maintaining conditions for human survival. But an anthropological perspective of man as becoming is not necessarily connected with utopian thinking. It can also be justified with an ethic of responsibility for our common future and with a historically informed view of man as realising human capacities through sociocultural variation. The debate about social emancipation or survival tends to generate doubtful alternatives in simplified optimistic and pessimistic views of man that do not offer a perspective for integrating knowledge about the human condition.

The critical question with regard to society in human ecology is that of how culture and society, terms often used inexactly and without differentiation, influence human use of natural resources in socially structured practices. Limitation of natural resources for human consumption has long been a theme of science, before human ecology in political economy and in the "dismal science" of Malthusian economics. Against this perspective of limits, the idea developed that resource scarcity can be overcome through science and technology by way of the substitution of exhausted resources – a guiding idea in the thinking of modernisation and industrial and economic development. Whether it was assumed that the resource base was unlimited, or that resource use could be expanded and intensified with the help of scientific knowledge, makes no essential difference with regard to the neglect of ecological knowledge about natural limits of biophysical systems and their production of resources. During the 20th century the cumulative negative effects of industrialisation, rapid degradation of the global environment, exhaustion of fossil resources, exponential population growth and the potential of mass extinction with military technology raised awareness of problems of resource use and human survival. The "doomsday prophecies" in a renewed Malthusian thinking of limits to growth have been neglected for a long time in environmental policy and the environmental discourse, but have been spreading in recent years in other forms. The "degrowth" movement approaches the view of John Stuart Mill in classical political economy, that a stationary state economy with zero growth of economy and population and a non-diminishing stock of natural capital is a condition for a sustainable global economy. The idea of human autonomy from nature ends at a time when the life sciences are celebrating new triumphs and making humans creators of themselves and nature through genetic manipulation of life forms (Table 1.1).

What Catton and Dunlap called "new ecological paradigm" (NEP) is reflected in the renewal of an ecocentric environmental ethics of humans as part of nature. To differentiate anthropocentric and ecocentric ethics requires more exact terms. The arguments seem to be rather clear in anthropocentric ethics when the status of a moral subject with rights and duties in relation to other species or to the natural environment is attributed solely to man. However, the historically changing perception of man is a source of confusion – how far-reaching is the ethical responsibility of man with regard to nature? Also, the contrasting position of ecocentrism covers variants that are not easily summarised in one NEP. Environmental ethics can be formulated as physiocentric and biocentric, pathocentric and theocentric (Reusswig 1993: 228ff), and in different variants of deep ecology as holistic environmental ethics. All of these variants codify historical and cultural differences that vanish in the construction of generalised worldviews.

Anthropocentrism, as the tradition of Western culture may be characterised, is not synonymous with economic or utilitarian views of man but includes different views. Ecological or ecocentric worldviews that articulate the dependence of humans on nature often retain a diffuse understanding of this dependence in functional terms of biological dependence. With the conclusion that humans have to adapt to natural laws or conditions that govern their lives, nature translates easily into ideas of an authoritarian biology and repressive social and natural order. That happened in Malthusianism and social Darwinism, in modern philosophical anthropology (e.g., Gehlen), and in modern environmentalism with some irritating ideas about authoritarian ecology (e.g., Ehrlich, Hardin), with worldviews and paradigms that spread with ethology (Lorenz), sociobiology (Wilson) and evolutionary psychology (Dawkins). These approaches build to a large degree on determinist and reductionist views of man and human behaviour as determined by an inherited archaic, primitive and aggressive human nature that cannot be changed significantly through the cultural transformation of man. This type of thinking is criticised in human ecology and among large parts of the new social movements (see Box 1.1).

Table 1.1 Modernisation as change of worldviews

Weber's sociological interpretation of modernisation as "disenchantment" of the world or "rationalisation" implies, for the historical process in Western culture, changes of worldviews that drive societal development through a progressive domination of nature by man.

1. *Enlightenment–rationality paradigm*: Many of the consequences of defining man as rational, as creative, productive and nature-modifying, were not foreseen by the Enlightenment philosophers; the contrast of nature and society in which society was associated with destruction of nature was not yet a dominant view.
   In Linnaeus' "*economia naturae*" (nature's economy) nature is, without seeing a contradiction, understood as the sphere of divine harmony and of human domination of nature. In this view, taking up the Christian divine mandate to dominate the earth, man is seen as improving nature, creating order in it, as physico-theological thinking in the 17th and 18th centuries celebrated the human-made balance of nature (Lepenies 1983: 547).
2. *The transformation of ecological worldviews* with an upgrading of human rationality through ethical arguments for human domination of nature and nature's subjection under the mechanical view happened in Enlightenment thinking from the 16th century. But already during this period non-dualistic, anti-mechanistic ideas of dynamic and living nature cropped up (Vietta 1995: 76ff). Both nature and society have been seen in a variety of views, in contrasting theories and interpretations of scientific knowledge.
3. *Capitalist industrialisation*, which appears in economic and ecological perspectives today as transformation of society or as a new socio-metabolic regime, was a complex and contradictory process. A long period of changing interpretations passed before the industrial society appeared, for example, in Spencer's evolutionary worldview, as the highest stage of human development that will continue forever.
4. *Human domination of the earth* was in the pre-industrial era not seen as disturbing divine harmony in nature or as causing destruction of nature, although environmental destruction by humans (e.g., through deforestation) was already manifold and visible at that time. The abstract construction of worldviews in Western societies that change over time (dominant Western worldview, human exceptionalism paradigm and new ecological paradigm: Catton and Dunlap 1978) does not account for the varying interpretations of nature and society that are found within one and the same worldview, showing the dynamic of sociocultural evolution more than can be seen in contrasting worldviews.
5. *Goethe commented on the emerging ideas of progress and emancipation in modernity with irony*: Humans esteem things according to their utility, and, as man is the last product of creation, why should they not think that they are creation's last purpose? Why should their idleness not allow them this fallacy? (Goethe 1983: 438). In early modernity it seemed difficult to imagine the consequences of anthropocentrism that has heterogeneous motives. The ecological fundaments of culture changed in the practices of industrial production with accompanying changes in the social lifeworld of humans.

Source: mentioned in the table

Box 1.1 Critique of Western culture and science

The critique of Western culture that unified human ecology and many environmental movements included that of the roles of science and the forms of scientific knowledge as a wrong triumph over nature. Such critique was supported by epistemological and philosophical debates, for example, in feminism. Although heterogeneous in arguments and positions, feminist thinking has several common tendencies: to criticise objectivism and universalism in science; to highlight the subjectivity of cognitive agents and the quality of knowledge as socially constructed with differing cognitive interests (e.g., Lorraine Code); to analyse power relations in the spheres of science and knowledge; and to conceive knowledge as situated and embodied knowledge (e.g., Mary Mellor). With the eco-feminist discourse the reduction of subject capacity attributed to nature and society once again came under discussion. In Western culture human subjects became dismantled from all natural and social connections that once made subjectivity and integrated man in nature and the transcendental world of religion. All that remains in the end is an abstract human rational actor as a model of man that guides scientific as well as political and economic thinking. The unfolding of the human exceptionalism paradigm (HEP) is the final stage of that process, in which the origins of thinking about man, as in the ancient Greek philosophy of man as rational animal, with reason and language, have been forgotten or modified into a motive for human domination of nature.

The development of rational thinking and science is perceived in large parts of modern sciences as a linear process, as development without alternative, resulting in an understanding of man, nature and society in abstract, universal and de-subjectivised concepts. In critical and heterodox traditions of science a more realistic perception of human subjectivity is found. In the feminist philosophy of Butler (2001: 15ff) the ambivalent ideas of subject, changing between the subject as a condition of human action and as subjecting man to power relations, have been critically reflected. Contradictory trends of making humans epistemologically a dominant subject, as masters of nature, and of a degradation and limitation of the subject quality of man have been apparent since Enlightenment philosophy with the formulation of the mechanical view of humans as machines (Vietta 1995: 44f). Nature was seen as something to decipher, and society as an order that showed either the "domestication" of humans, which allowed them to leave the "state of nature", or the improvement of nature through human labour in agricultural and other production. Later on, the different constructions of scientific observer, rational actor and economic man became abstract models of man that did not account for social and gender differences, or for human interaction with nature. They can also be seen as constructions that neutralise the social nature of man.

The processes of reducing subject capacity and ethical responsibility and the simultaneous growth of large-scale social systems – urban agglomerations, national societies, bureaucratic systems in politics and economy, international institutions, world system and globalised economy – seem to complete each other. The attribution of subject qualities to anything other than human actors becomes difficult. Some variants of social theorising try to reduce the differences between man and nature conceptually. Actor–network theory has, in the analysis of environmental problems, worked with an extended subject and actor category including ecosystems components, but this happened more through constructing new concepts than through analysing the interaction of society and nature empirically, as social ecology tries to do.

Source: mentioned in the text

Changing relations between man and nature and modification of nature by man in modernity have been accounted for in the formula of a "human history of nature" developing from older variants in critical theory or Moscovici's interdisciplinary theory. This theory brings to the forefront that which vanishes with the simplified contrasting views of HEP and NEP: a historical, co-evolutionary process with a transformation of the nature of man and of the nature of nature in the course of societal development. A shift from HEP to NEP indicates the beginning of critical thinking about man and nature, and not a final result. For social ecology it is not as relevant as in earlier human ecology, as it does not help to understand the complex crisis of modernity, unless in the doubtful form of a moral crisis that results from "wrong thinking" about nature. The complexity is reflected neither in human ecology nor in the sociological concepts of "second modernity", "reflexive modernity", "postmodernity" or "post-industrial society". What these sociological terms obscure, and what the NEP shows in a common-sense view of man, is the lack of devices from science for integrating nature and society in the "soft system" that Eisel (see above) identified as the human ecological idea of human future.

The following conclusions relate to the limited success of human ecology with a synthesis of knowledge about the human condition:

1. The normative critique in human ecology of the separation between nature and society or man can be read as another variant of the alienation

theme. This diagnosis of a separation between man and nature in modern society needs to be reinterpreted and matched with the contrasting idea of a growing interdependence between nature and society found in recent environmental research.

2. Conceptual frameworks to integrate the analysis of interrelations between man, society and nature, such as "population, organisation, environment, technology" (POET), HEP and NEP, remain loose frameworks. Attempts at knowledge integration by Olsen (1993a, 1993b) with a conceptual model for socio-ecological and sociocultural structuring of human action use general and abstract frameworks too, and not a historically specified theory. The adoption of evolutionary and process perspectives was the main achievement in the analysis of societal interaction with nature.
3. In human ecology society was described with inexact concepts, often exchangeable with that of culture. That culture and society require two analytical categories was insufficiently reflected, following rather the condensed notion of culture-and-society from the early period of sociology and anthropology critically reflected by Parsons and Kroeber (1958). Only in exceptional cases were elaborate theories of modern society used – for example, in political-economic approaches (Schnaiberg 1980, Wolf 1982). Society was seen as dependent on nature, but this dependence was not shown sufficiently clearly by use of social-scientific knowledge.
4. In human ecology the processes of natural resource use have been investigated, but less systematically than in the new social ecology. The interdisciplinary approaches in human ecology are rarely connected with economic analyses of the modern capitalist system. The analysis of societal metabolism and global resource flows, which has become a core theme in social ecology, is not advanced in human ecology.

Philosophical anthropology. Answering the traditional philosophical question about human nature with anthropological knowledge seems impossible today, not because of a lack of knowledge, but because of an overabundance of scientific knowledge from cultural anthropology that allows multiple and contradictory interpretations of the human condition. The question of human nature has been reinterpreted continually during the 20th century, denounced as an unanswerable question of speculative philosophical character, or answered with new metaphysical reflections of man in existentialist philosophy by Heidegger and Jaspers in Germany and in French existentialism by Sartre, Camus and Marcel. These philosophers proceeded in a similar way as did philosophical anthropology, using empirical knowledge for interpreting the human condition, but supplementing it with philosophical reflection. A renewal of philosophical anthropology remained a contested project in the controversies between existentialism, critical theory and philosophical anthropology. The protagonists of critical theory, Horkheimer and Adorno, as well as Heidegger, tried to block a philosophical anthropology with the argument that the human condition is a continually renewed question and can never find a definite answer (Plessner 2000: 144). Critical theory moved towards a critical social science of man to provide the knowledge for a realisation of human potentials, that is, for the social emancipation of man from domination and for the reconciliation between man and nature. For Heidegger the critical statement aimed to deny philosophical anthropology the privilege of reflecting on man, reclaiming it for the metaphysical speculation about man.

Modern philosophical anthropology collects the knowledge about human nature from different sources. Anthropology had a long tradition in philosophy, with which the new philosophical anthropology connects in its efforts to integrate knowledge about man from the philosophical traditions with empirical knowledge from modern natural and social sciences. In contrast to a simple narrative of the history of ideas about man (Pojman 2006), philosophical anthropology works with theoretical knowledge synthesis. It can complete the preliminary syntheses in human ecology which do not go beyond synopses of views of man and a synthesis of empirical knowledge from human evolution. Philosophical anthropology was renewed from the 1920s to the 1970s as an interdisciplinary study of the biological and socio-cultural evolution of man. In this discourse, the limits and the incoherence of empirical knowledge about man were reflected through supplementary conceptual, theoretical, epistemological and ontological analyses, progressing through a review of the historical development of anthropological knowledge. Although philosophical anthropology is hardly discussed in the present socio-ecological discourse, it paved the way for a social ecology by showing how society–nature interaction is reflected in knowledge from the humanities, from biology and from sociology in attempts to specify societal relations to nature as being inscribed in human nature. Philosophical anthropology developed in Germany in three variants before a new synthetic science of man was discussed in French anthropology in the second half of the 20th century by Morin and Moscovici.

After the Enlightenment epoch anthropology became an empirical discipline, as attempted by the scientific "society of observers of man" in France under the guidance of Jauffret in the aftermath of the French Revolution (Moravia 1977: 209ff, in an interpretation of this movement that has since been contested). The modern disciplines of cultural and social anthropology developed this empirical orientation further, but without creating an interdisciplinary synthesis of knowledge, which starts in philosophical anthropology with a description of the distinctive features of man as a living and conscious being. The biological concept of life is seen as too vague to characterise the specific qualities of organic nature and humans. Plessner (2000: 130) argues that the realisation of a personal, biographical project to conduct an individual's life in a distinct society in a conscious way cannot be analysed using the biological concept of life. To centre the discourses about man on one of the two abstract concepts of life or existence results in two lines of thinking, which should be integrated in philosophical anthropology: biological-ecological interpretations of man as animal and sociocultural interpretations as a conscious and rational being. These interpretations inherited the dualisms in modern Western science – nature or culture, body or soul, matter or mind. Connecting the different knowledge spheres in a synthetic science of man had been attempted only in philosophical anthropology and human ecology. A non-dualistic understanding of the human condition requires further reflections to connect philosophical anthropology and human ecology. These include epistemological reflections about the forms of knowledge used to interpret man, and a review of the historical knowledge about man.

The new philosophical anthropology in the 20th century was interpreted in various ways, as a philosophical theory or as an empirically based synthesis of knowledge from biology, cultural anthropology and sociology. The modern philosophical approaches of existentialism (Sartre) and phenomenology are included in it, as is the German philosophical anthropology of Scheler, Cassirer, Gehlen and Plessner. These traditions of philosophical anthropology are counteracted by a naturalistic epistemology that acknowledges only empirical knowledge from natural sciences (van Quine) or the epistemologies of the "Vienna Circle", analytical philosophy and, towards the end of the 20th century, the postmodernist criticism of the "grand narratives" of modernity that mark varying ideas of anti-metaphysical and culture-based reasoning. An anti-metaphysical understanding of science often came to mean that scientific knowledge was limited to empirical knowledge, rejecting all but empirically answerable questions as non-scientific and meaningless. A consequence of this is that the human condition can no longer be interpreted philosophically, and nature is thought of less and less as a coherent substance, system or subject – the concepts with which nature had been described earlier in philosophy.

The discourse of philosophical anthropology in Germany by Scheler, Gehlen and Plessner went through different interpretations of the human condition that reflected to some degree the differentiation of knowledge spheres between humanities and the natural and social sciences. In the ideas of Scheler one can see a predominantly humanitarian and metaphysical interpretation of man, society and nature, in which society is understood as a sociocultural matrix from which the spiritual capacity of humans grows; in the ideas of Gehlen society is reduced to the functional mechanisms of interaction that can be described with biological knowledge; and in the ideas of Plessner it is described with a more complex interdisciplinary interpretation of man, but still in an individual-environment perspective that does not fully grasp societal complexity. Philosophical anthropology unfolds in steps towards a construction of nature–society interaction with a generalised notion of man, requiring further steps with theoretically elaborate concepts of man and society (Table 1.2).

Table 1.2 Philosophical anthropology: Metaphysical synthesis of the human condition (Scheler)

1. *The context*: When philosophical anthropology was renewed in the 1920s, starting with Scheler, the interpretations of human evolution by the Dutch anatomist Bolk were discussed in biology. Bolk, like Geoffrey St Hilaire before him, observed the phenomenon of retardation and foetalisation (neotonia) in comparing humans and anthropoids. The similarities between an anthropoid and a human being are striking in the foetal phase, but changes occur rapidly after birth, with humans being characterised by a continuity of the foetal characteristics in post-embryonic development, with extended childhood and youth phases, relative continuity of the foetal appearance with regard to the absence of pigments, sparse hair, shape and size of the head, and a small face in relation to the entire head (Bolk 1926). Scheler's philosophical anthropology includes a stepwise development of psychic life through the evolution of nature from dead energy-matter through different vegetative and organic levels and forms.
2. *The philosophical concept of mind* is used to interpret the human condition, with mind meaning everything in humans that is not dependent upon biological capacities, instincts or drives. All differences between humans and animals in intelligence, memory, imagination, the ability to choose and to use instruments are only gradual. A principal difference for Scheler is given for the mind, which enables humans to be open in their relations towards the world, to detach from their natural environment, their lifeworld not being as limited by nature as is the case with animals.
3. *Scheler's hierarchy of forms of the mind* includes "feeling", "instinct", "associative memory", "practical intellect" and "mind". What makes this hierarchy of emergent forms of consciousness different from earlier thinking is its inclusion in a complicated ontological diagnosis of the human condition in which the mind and the human ability to love are seen as human capacities that cannot be understood as part of simple organic life.
4. *Scheler's criticism of naturalistic and biological thinking*: With mind and love together representing the specific character of man, Scheler has, as Gehlen critically comments (1961: 16), not overcome but only modified the dualism of body and soul. Still there remains Scheler's specific interpretation of the human mind, which differs from rationality-based interpretations of man in modernity: man's distinctive capacity is not rationality, but an ability to love another human individual, for which a quasi-philosophical term of "*ens amans*", or a loving being, is created. Scheler interprets love as an original capacity of man, as an emergent property that requires a holistic view for which that property offers the key element of explanation, and which is missing in naturalistic accounts of man (Scheler 1994: 296). He defends his view against the psychoanalytic interpretations of man as including different forms of erotic and holy love, neither being completely derivable from innate drives or sufficiently explainable through the classical psychoanalytic model of the structure of mind in the components of ego, id and superego developing through socialisation.

Table 1.2 (Continued)

5. *Comment*: Scheler's interpretations of man make visible the difficulties of the multifaceted notion of anthropocentrism. Nuances of meaning are decisive when he denies human exceptionalism and criticises the understandings of man as having separated from animals and that man has capacities that could not have developed from an animal nature. For him man will always remain an animal, and, if we want to understand the difference between man and other animals, human "organological dilettantism" or organic weaknesses are important (Scheler 1994: 56), as Scheler takes up the classical argument by Herder that resurfaces more elaborately in Gehlen's and Plessner's anthropology. For Scheler this organological dilettantism provides for an argument that the human condition requires further explanation than the biological, which he finds in human spiritual capacity. With that argument he becomes exposed to the criticism of traditional metaphysical speculation about human nature seen from the perspective of an individual person.

Source: mentioned in the table

As can be seen from Scheler's arguments, philosophical anthropology takes up interpretations that complement the older hypothesis of man as a being with biological deficits: *Homo sapiens* does not appear as the result of an accelerated evolution continuing in the footsteps of primate development, but as developing through retardation, as an exception and a sidestep, as human genesis representing an evolutionary anomaly. These ideas complement the assumptions of heredity and environment as factors of development: humans are open towards the world, have an "eccentric positionality" (see below), and develop reflexivity, different forms of intelligence and knowledge for adapting to the environment, allowing them to adapt to heterogeneous physical and ecological environments and spread over the earth. All these human specificities require a reflection of the interaction of nature and culture for human evolution as it happened in philosophical anthropology (Table 1.3).

In spite of his formulation of philosophical anthropology as a sociological theory of action, Gehlen elaborates sociology in a functionalist biological reasoning. This functional reductionism in interpreting culture and the derivation of his anthropological model of action from an individualistic, non-interactive social situation marks the limits of Gehlen's anthropology (Honneth and Joas 1980: 61). Gehlen formulated in an extreme variant the diagnoses of modernity by Weber and Parsons in which power, in archaic or modern forms, is an omnipresent phenomenon, or, as Parsons formulates, the "Hobbesian problem of order": since common values as basic cultural regulatory forces are not sufficient to maintain social order, power is required to maintain social order. With regard to the human use of natural resources and the societal metabolism analysed in social ecology,

Table 1.3 Philosophical anthropology: Biological synthesis of the human condition (Gehlen)

Gehlen started from evolutionary biology and ethology to formulate his anthropology unfolding in a sociological theory of action with the core concept of institutions as cultural inventions of man. 1. *Institutions are interpreted as "cultural organs" to compensate for man's biological deficits*. That humans lack instincts or organic tools necessary for survival is a common point in the philosophical anthropology of Scheler, Gehlen and Plessner (based on an argument from Herder). 2. *Gehlen formulates two properties of humans to characterise their condition*: Humans have biological deficits as individuals and as a species, but in spite of such natural deficits they are the only biological species to spread all over the world, colonising, transforming and controlling nature (Gehlen 1942: 237–241). The compensation of organ deficits by way of culture and social institutions transforms humans into "acting beings" with the capacities of anticipation and creation of culture and the ability to adapt to different physical environments. Humans' compensatory capacities become their nature. The human situation is characterised through stimulus satiation that requires regulatory cultural mechanisms, among which language is one of the most important, providing for orientation and reflexive guidance. 3. *Gehlen's functional reductionism*: The interaction between extra-human nature and humans is not direct, but mediated by symbols. Interpreting symbolic communication and language, Gehlen does not see these as creative mechanisms, but only insofar as they are functional in biological terms as a means to survive. Otherwise they become risks to human development. He reproduces a picture of the human mind as a biologically reduced variant of Hegel's analysis of the steps of development of mind (ibid.: 246). The human mind is not analysed genetically, historically and by its different components to apply and reflect knowledge, but the analysis remains within a biological frame of reference in which reason, thinking, language and communication are directly bound to the biological conditions of human life which help humans to survive. From this functionalist biological perspective, human development with culture, civilisation, society, abstract thinking and science is seen as problematic and risky, as it allows the detachment of humans from their nature that is described with biological knowledge. That humans have developed many more capacities than required for their simple survival is a source of disturbing experience in this anthropology, which tends to dissolve the tension between the biological weakness of humans and their cultural capacity to dominate nature in an authoritarian design of society. Gehlen characterises society with formulations from Hobbes and Bachofen as a necessary system to "domesticate" humans by way of mores and morals, punishment and authority, the force of the Leviathan (ibid.: 248), being nearly as mechanistic in his view of humans as Hobbes when he identifies in every component of culture and society nothing else but an artificial form of nature with the meaning of imitating a facet of nature.

Table 1.3 (Continued)

4. *Comment*: Gehlen's philosophical anthropology is a kind of biology in philosophical form that can be seen as a commitment to an authoritarian biology in which moral and political order are zoologically interpreted with the help of ethological knowledge (Plessner 2000: 118). Humans are continually reminded of their primitive nature and evolutionary origins, which they are not able to overcome, but only to become domesticated with the help of authoritative and repressive institutions. From this diagnosis derives a theory of institutions that affirms the necessity of institutions to exercise power over humans. Power relations as an underlying rationale of human society are, in this view of humans, not creatively transformed as in other theories of power through civilisation, but keep humans in a condition of continuing archaic fighting, war and struggle for survival reminiscent of the Hobbesian view of the human state of nature as "war of all against all".
Gehlen's biologically rooted interpretation of human action and society tends to a rigid understanding of institutions in analogy with biological mechanisms of behaviour programmes that do not allow for rational communication or building of institutions and consensus in more democratic forms – a criticism formulated especially by the critical theorists Adorno and Habermas. At one remarkable point, however, Gehlen differs from the otherwise positively commented ethology of Lorenz. Lorenz reduces humans consequently to animals and postulates that wild humans had the same well-functioning regulatory mechanisms of instinct as Lorenz found in many animals, assuming that humans have lost these in the course of civilisation. Gehlen denies this; for him humans have never lived in a wild state as culturally non-regulated beings. Humans were from their evolutionary beginnings culturally regulated beings (Gehlen 1961: 58). While this argument and his understanding of humans as bound to and changing with a historical time (ibid.: 55f) bring Gehlen into philosophical anthropology and keep Lorenz out, Gehlen's understanding of society and culture remains biologically modelled; both are other forms of nature insofar as their essential function is, for Gehlen, to force humans into life after their (too) early birth. Biological knowledge is the source of interpreting culture as a suppressive order that corresponds at best to an archaic model of institutions as suprapersonal systems of force in early human societies. Culture, as he says (1961: 21), is "nature modified by man through his actions".

Source: mentioned in the table

Gehlen's "biological sociology" allows arguments that take the Darwinian metaphor of "struggle for life" literally, as a violent struggle for resources (Table 1.4).

With the three authors discussed, the guiding questions and problems of modern philosophical anthropology seem to be sufficiently elaborated to characterise that discourse in its relevance for human and social ecology: as circulating around the core question of how to interpret human nature by way of reconnecting philosophical reflection and empirical scientific knowledge in non-dualistic interpretations of the relationship between biological and cultural components of man. The three interpretations of the human

Table 1.4 Philosophical anthropology: Interdisciplinary synthesis of the human condition (Plessner)

Plessner developed a non-dualistic interpretation of the human condition in which a broad variety of disciplinary knowledge is combined with a synthetic philosophical anthropology.

1. *Synthesis of philosophical anthropology*: Plessner refuses the dualism of mind and life by Scheler as well as the "biologism" of Gehlen, but he takes up arguments from both authors. With Scheler he shares the analysis of love as specifically human, and with Scheler and Gehlen that of humans as a species having a biological deficit. The understanding of love and affection in man, as based on drives but differentiated from them, requires Plessner to separate zoology and the biology of man. The ability to love and hate presupposes that humans have a specific relation to the world which is not found among animals: that they can consciously differentiate between subject and object and can identify or distance themselves from someone or something (Plessner 2000: 115f). From this unfolds his core argument of "eccentric positionality" of man different from plants and animals, continuing the reasoning that Scheler has started with man being open to the world.
2. *Eccentric positionality* can be described as the ability to take a distanced position from oneself and one's own natural and cultural environment. The argument is developed from that of a complicated intrasomatic separation and integration of body ("*Körper*") and "body with soul" ("*Leib*"; Plessner 2000: 141). "Body with soul" connects the discussion about human body and nature to philosophical and phenomenological debates about humans, such as in the phenomenology of Merleau-Ponty, or to older debates about body and soul. With the understanding of a human being as a union of "body with soul" and body, Plessner denies the traditional dualism that has still influenced Scheler's anthropology; his terms should help to describe the integrated nature of humans. Eccentric positionality demands from humans that they live consciously and fully use their cultural capacities to compensate for their biological deficits; it also implies that humans have to identify themselves in cognitive acts; their identity is not directly given by the biological description of their life.
3. *Changing nature of humans*: The interpretation of humans, their situation and behaviour as empirically open to experience, future, historical changes and development is directed against a biological (Gehlen) or ontological fix (Heidegger), in which humans are always and eternally the same and doing the same (Plessner 2000: 142f), struggling for survival or living a similar life. His argument is that the double nature of humans cannot be understood as contrasting, static or unchanging. It requires reconstructing human evolution as the integration of "body with soul" and body; of humans being zoological as well as transcending zoology; of the idea of humans as continuously transgressing their boundaries; of the threefold relation of humans to the world as external world, internal world and social lifeworld ("*Mitwelt*"); and of a human being as a threefold subject with perception, experience and action (Plessner 2000: 11) which generates the complex quality of a person. With such reflections return, in other terminology and reasoning, ideas found in Hegelian dialectics and similar interpretations of "man as becoming" through successfully overcoming his deficits by learning.

Source: mentioned in the table

condition show characteristic limits: they do not sufficiently account for the complexity of society in the interaction between man and nature, in material and symbolic processes that require a more differentiated description of societal relations to nature. For human ecology the project of philosophical anthropology with a synthesis of knowledge about the human condition remained a cognitive challenge. For the new social ecology it became more of a reason to keep the discussion of human nature off the core research.

Philosophical anthropology is not complete with these three authors – Cassirer's concept of "*animal symbolicum*" or symbolic animal can be referred to as an important step in its unfolding, as well as Hartmann's ontological philosophy of subject and cognition, and additional authors, such as Kamlah. Cassirer has extensively commented on the holistic philosophies to which his writings belong, such as Goethe's philosophy of nature and the biology of Uexküll, which he saw as close to his own thoughts. With regard to the epistemological questions of interdisciplinarity and unity of science, Cassirer rejected the physicalism of the Vienna Circle, for example, and of logical positivism: "the unity of science could neither be interpreted to mean the supremacy of one science above all the others nor the natural sciences over the cultural sciences . . . The unity of the sciences is functional, not substantial as physicalism proposed" (Krois 2004: 280). This idea can be a starting point in social-ecological reflections of interdisciplinarity.

In the 20th century empirical anthropological research has, with different interpretations and arguments, described the manifold cultural variations of man. Whether this means that cultural variations of man only cover his yet unknown nature, or whether they already witness that there is no common nature of man, remains unclear. In structural anthropology the difficult notion of structure, as used by Levi-Strauss, may be understood as articulating the idea of a last but not yet positively known nature of man. But the possibility that human nature can ever be identified has been doubted in other discourses. In critical theory Horkheimer discussed the idea of an anthropological science of man. He saw philosophical anthropology as an impossible project, with the argument that several anthropologies show that there is no unified or common nature of man throughout all times and cultures; man is historically and culturally varying, and this prevents the search for a general nature of man. To combine a philosophy of man with a social philosophy is less problematic for critical theory and existentialism than combining it with a philosophy of nature. This can be understood to a certain degree from two motives characterising the early critical theory that has emerged since the 1920s: first, the historical catastrophes in modern society reflected as the "dialectics of Enlightenment", with the guiding idea that Enlightenment has ended in totalitarian thinking and a collapse of the process of civilisation (Horkheimer and Adorno 1971: 7–10), which supported an inclination to refrain from general definitions of man; second, the trials to formulate a philosophy of nature as part of an interdisciplinary science of the human condition have been disappointing. The denial of a philosophical anthropology was followed in critical theory by trials to formulate a "negative anthropology" (Sonnemann 1969) based on the hypothesis that humans are determined neither through nature nor through history or society. The question of how a "general nature of man" can be understood finally becomes the critical one, as it covers a variety of ambiguous interpretations. It can be understood as being formulated in a theory of constant factors of man as biological descriptions and classifications of man that can be understood, or as being formulated from a cultural-anthropological perspective that ends up in the argument that the "nature" of man is one of cultural variation that cannot be reconstructed in biological universals – and each of these basic ideas can again be interpreted in different ways. As commentators of philosophical anthropology have emphasised, the project ended in the 20th century in a dead end where the dilemma of philosophy of nature or philosophy of history to approach the human condition could not be solved (Marquard 1971, Kamper 1973). The discussion was opened again with Moscovici's socio-genetic synthesis of the human condition.

The late 20th century

A neglected discourse – the social anthropology of Moscovici. While philosophical anthropology was unfolding in Germany from the 1920s to the 1970s, the philosophical discourse in France was under the influence of Kojève's authoritative dictum – the aim of philosophy is to account for the fact of history (Descombes 1981: 68). In whatever form this dictum is transformed into philosophical programmes, it directs the anthropological project more towards human history, culture and society than towards nature and natural sciences.

Outside the debates of existentialism, structuralism, post-structuralism or postmodernism that have developed since the 1960s, a synthetic, ecologically based science of man was developed in the works of Morin and Moscovici. Morin postulates a synthetic science about man that is identical with human ecology. However, the synthesis seems to be realised more in the work of Moscovici (1972, 1974, 1982) than within the work of Morin (1973), who lays the ground for a non-anthropocentric and non-naturalistic anthropology with his analysis of hominisation. This is seen as an interaction between biological and sociocultural factors that together make *Homo sapiens* specific with regard to the size and complexity of his brain ("cerebralisation"); his long juvenile and socialisation phase ("juvenilisation"); and the cultural opening of man–environment relations ("culturalisation") that require consciousness and knowledge to manage everyday life (Morin 1973: 101, 152ff), but which are also open to the possibility of irrational behaviour based on excess, affects, force, hatred. These features of man do not fit into the picture of *Homo sapiens*. Therefore Morin constructs a double nature of "*Homo sapiens-demens*", or a rational and irrational man (ibid.: 131, 155ff). This anthropology does not separate contradictory elements of human behaviour, but argues for their inclusion in an interpretation of man that takes up motives also found in German philosophical anthropology: factors of being open towards the world and of eccentric positionality (which he summarises as part of "*homo demens*"), characterised by an evolutionary integration of biological and cultural factors, not reducing man to a biological or a cultural being. Moscovici (Table 1.5) formulated a more theoretical and critical synthesis of nature–society interaction.

Table 1.5 Socio-genetic synthesis of the human condition in connection to nature (Moscovici)

1. *Moscovici summarises the main facets of human development*: Humanity has not gone over from the realm of nature to that of society, but from a realm of nature where the presence of man had no advantages in relation to other species to one where it had such advantages (Moscovici 1982: 53). He asks in consequence of that diagnosis of the human condition: What are the laws that the human history of nature is subjected to? (ibid.: 56). His analysis ends by showing society as a form of nature in different stages of evolution, and of social processes as an extension and mediation of natural processes (ibid.: 500). This shows similarities to as well as differences from the arguments of German philosophical anthropologists, with the common point being the focus on mediating the relations between man and nature and the difference being in analysing this with an extended concept of nature that encompasses society.
2. *Moscovici's critical synthesis of the interrelations between man, nature and society*: He formulates a concept of nature in historical development and change which is structured through the guiding idea of human modification of nature. Thus he denies the idea of a passive and one-sided dependence of man on nature that is deeply rooted in ecological and biological thinking and adopted by some authors from philosophical anthropology (especially Gehlen), by ethologists, sociobiologists, evolutionary psychologists and sections of ecological movements. A consequence of such reductionist variants of anthropology is interpreting man through his early evolutionary and archaic stages, implicitly following a hypothesis of constancy in human behaviour programmes that resemble animal behaviour programmes, directly or indirectly neglecting the possibility of the modifications of man and of his relations towards nature though biological and sociocultural evolution.
3. *Moscovici and critical theory*: In contrast to such views, also found in the emerging counterculture of ecologism in Western Europe since the 1970s, Moscovici reformulated ideas of a critical theory of man, society and nature for which, earlier in the 20th century, the unfinished project of a critical theory of society was elaborated by authors of the Frankfurt School. Moscovici's analysis shares some similarities with one of these critical theorists, Marcuse, and the ideas unfolding in his late work; for example, when nature is understood not as the

dominating power man should be subject to or which makes him aware of his genetically programmed primitive properties, but as an emancipatory power, it becomes a partner in co-evolution and in the human fights against exploitation, domination and inequality in present societies. This line of thinking about a unity of man and nature, starting from a critical analysis of society, has predecessors in the understanding of modern society by Rousseau, and is elaborated by Hegel and Marx in the ideas of "societal relations to nature" and historicity of man and nature that allow thought about a humanisation of nature and a natural history of man. Such thinking became interrupted when both Marxism and critical theory developed as theories of society or modern world systems and neglected the critical analysis of man–nature relations.

4. *Comment*: Moscovici is not alone in his critical synthesis of a human history of nature, although he formulated it years before an environmental movement began in France. Godelier's influential economic anthropology could also be introduced into the debate, as could the influences of current authors. In the conclusions from his study written in the 1960s Moscovici refers to Vernadsky and his "geological force" of man (Moscovici 1982: 498, 512), although at this end of the historical analysis of the interaction between man, nature and society the thoughts begin to become pale and thin, demonstrating once again that the sciences, such as synthetic science and human ecology, have no privileged knowledge to show an easy and short way towards the sustainable society of the future, but only a more systematically connected and synthesised knowledge that shows the limits and deficits of scientific knowledge as well as its progress. According to Moscovici (1982: 532), "patient action" is required. After him, in a critical theory of the subject, Arnason formulated similar ideas in a more traditional and more complicated terminology. Arnason's "dialectics of identity and difference" calls for a concept of structure which is not that of an extra-historical or suprahistorical quality, as in structural anthropology, but shows the development that Moscovici called the "human history of nature" as a continuous restructuring of the horizons of human action, "natural relations" and "sociality", as creative transformation of natural distinctions into sociocultural distinctions (Arnason 1976: 77).

Source: mentioned in the table

The syntheses of the knowledge about the interactions between man, society and nature by Plessner, Morin and Moscovici cannot be reduced to new views of man and nature in the normative meaning of worldviews or paradigms. These authors worked with knowledge from different disciplines and times and reflected specialised knowledge available for synthesis. It seems that since their syntheses there has been little substantial progress in the discourse of an interdisciplinary science of man.

1. The ecological anthropology of Emilio Moran supports the research from which the anthropological syntheses are built with regard to

empirical knowledge about human adaptability to different climate zones and ecosystem types, and it supports the aims of reintegrating knowledge about man, counteracting the fragmentation of specialised science (Moran 2000: xxiii), but it does not add new ideas to a synthesis.

2. The biological epistemology of Maturana and Varela, like the broader discourse of "radical constructivism", does not open a different anthropology and view of man, but seems in that regard more repetitious and derivative of prior thoughts and ideas of "cognition as a relational process" in which the world is constructed in the eye of the observer and in the interactively constituted human consciousness generated in interaction with other men. Their formulation in natural scientific, cybernetic or biological perspectives of relational thinking about man has been formulated before with other terminology in social sciences and in philosophy. However, their epistemological and philosophical ideas leave the impression of thinking which can be interpreted either in the way of "ego-logical subject philosophy", with the impossibility of explaining the transition from neuronal to semiotic processes, as Schneider (1998: 202f) criticises, or as similar to the social-scientific reconstructions of interactive subjectivity that the formulations of Maturana simulate.
3. More recent debates about man in the aftermath of genetic and brain research and neurosciences do not approach new syntheses of knowledge. Rather, these debates are in danger – due to reductionist and specialised views of man – of becoming new variants of mechanistic views in understanding man either through his genetic design or through brain capacities, thus neglecting the social constitution of humans. They allow the critical argument that too much explanatory significance is given to single components of man, his brain or his genetic programme. What seems more interesting from this research for a reflection of the development of knowledge about man is as follows: as soon as one goes beyond the specialised field of present research towards interdisciplinary comparison and reflections (e.g., in Damasio's "Looking for Spinoza", 2003), it can be seen that present research is moving in old philosophical tracks. The recent discourses can be seen as natural-scientific confirmation of the hermeneutic circle of cognition of the relations between man, society and nature, in which each of the concepts requires the others. Human ecology has, in that respect and in spite of its critical aspirations, an uncomfortable role in completing an interdisciplinary science of man, not only suffering from its own selective receptions of knowledge, among which a neglect of philosophy of nature is one component. It can only show the necessity of interdisciplinary synthesis of knowledge about man, but cannot arrive at a final explanation of the nature of man that ends all debate, just as prior trials of interdisciplinary analysis of theories about human nature (e.g., Stevenson 1974) have shown.

The social-ecological theme of a nature–society interaction before the new social ecology. In the early 1970s, when environmental movements and interdisciplinary environmental research rapidly developed in Western countries, there appeared the first diagnoses of global environmental problems similar to those later appearing in social ecology. Smith et al. (1974) approached the idea that it was not the environment or nature that was in crisis, but the relations between society and nature as created by man: "the ecological crisis can be seen as not merely an imbalance in the system produced by man nor simply a problem of exhausted, misused or dirtied resources. It is a crisis resulting directly from man's own social ecology – his economics, his technology, his science, his culture" (ibid.: 4). At this time social ecology was not meant as an elaborate scientific programme, but remained a vague idea of the systemic quality of the crisis as one of the societal developments, as summarised in the formulation: "The same tendencies towards simplification, uniformity, technological manipulation, and an advanced division of labour that occur in man's social ecology are carried over into man's approach to his natural ecology" (ibid.: 14). As mechanisms that represent this systemic quality of the crisis in the relations between society and nature, for Smith et al. "growth, expansion, and domination remain the central sociocultural objectives of most advanced societies and comprise the aspirations of the developing societies" (ibid.: 186). From that idea the connections to the "limits to growth" debate are apparent, and the conclusion that "the long-term relationship between man and his environment is produced by forces that are not immediately governed by piecemeal administrative action" (ibid.: 190) seems a clear consequence of the systemic view of the crisis. This view implies that "there is no technical solution for the current environmental problems" (ibid.: 190), but one from "ecological principles . . . (that) must lead to a fundamental reordering of our social patterns" (ibid.: 190f). Still, ecology is thought of here in terms of a traditional paradigm of balance and stability, which is nonetheless viewed critically.

The more recent research influencing social ecology is reviewed in the following chapters. Social ecologists have not systematically reviewed the manifold sources of knowledge and influences on their new science. This can be seen as a principal difficulty, not to say an impossibility, in accounting for all the influences that lead to a new discourse. One risk is that of becoming dogmatic and ascribing to social ecology a more unified and closed thinking than it aspires to. In conventional academic disciplines, competing theories and discourses are constructed not only for pure motives of creating and improving scientific knowledge, but also to generate epistemic identities and gain influence in a discipline. Social ecology is a more open knowledge system that is in continuous development and changes with the knowledge generated and interpreted in discussing and synthesising interdisciplinary research on social-ecological systems. The coherence and specificity of the new social ecology can be seen at an epistemological discourse level at a distance from the postmodern discourse and at a theoretical discourse level in a combination of the guiding concepts: colonisation of nature, societal metabolism and societal relations with nature.

Empirical knowledge used, connected and reconnected in the social ecology discourse is not exclusive to social-ecological themes. The core theme of material and energy flows that dominates social-ecological research can be found in other and neighbouring research areas, such as in ecological economics. In a critical analysis of industrial ecology Rejeski (1998: 13) has developed a line of reasoning that comes close to the paradigmatic nature of social ecology: industrial ecology has a rich repertoire of analytical tools but exerts little influence on environmental policy; the flow of materials across national borders is the main challenge of research, and the spreading of harmful emissions that are embodied and dissipated through consumer goods; the dangers of arbitrary assumptions about drivers of material flows need to be faced. These points are summarised in the formulation, which can be read as a programmatic formula of the emerging social ecology:

> another possibility is that we have been captured by intellectual traditions that can no longer adequately inform the public policy. Although a consensus is emerging that the environmental problems we face are increasingly cross-scale in both space and time, there are few tools capable of allowing us to understand such systems and even fewer instances when these tools have been applied successfully to policy decisions.
>
> (ibid.: 14)

The science of global environmental complexity that Ostrom later demanded (2007a) is described in this formulation.

Political ecology is a broad interdisciplinary discourse intersecting with many environmental, economic and political discourses – with ecology and human ecology, geography, ecological economics, old and new political economy, and policy research. The new social ecology overlaps to some degree with the discourses of ecological economics and political ecology. Agrawal (2005: 209f) has summarised the development and changing nature of political ecology in two phases. Political ecology entered environmental studies in the 1960s with the "Malthusian themes" of population growth and shortage of natural resources as global problems, paradigmatically with the "Limits to Growth" study (Meadows et al. 1972). Since the 1980s a new political ecology has developed, with several thematic foci – social marginality and access to resources; political causes and effects of resource allocation; sociocultural, political and economic contexts of human resource use – that were later complemented through the studies of politics and adoption of post-structuralist theory. These developments emphasise the somewhat diffuse quality of political ecology as guided more by changing themes than by coherent theoretical perspectives.

Discussion and conclusions

The distinctive features of social ecology that can be developed from a critical review of the history of interdisciplinary environmental science are not simply given with a description of its thematic fields and institutional settings. What came out of the discussion of interdisciplinary traditions, especially human ecology and philosophical anthropology, is a series of critical questions that have not been answered sufficiently within these approaches. These questions guide the detailed description of social ecology in the following chapters:

1. How social ecology develops, reflects and uses its critical cognitive interests and its guiding questions of nature–society interaction: the concepts of nature and society have not been clarified in preceding discourses, but they enter social ecology as multi-semantic terms that can only be dealt with through constant interpretation and reflection in working with these concepts.
2. How social ecology reacts to controversies about the relations between man, society and nature that characterise the broader human ecological discourse: in this trinity, or broken trinity, of concepts another complicated theoretical term, culture, has become apparent that has not been clarified in the prior discourses and has not been given much attention in social ecology up to this point.
3. How social ecology reacts to epistemic dichotomies and controversies: social constructivism or realism, grand theory or small narratives, universalism or particularism, anthropocentrism or ecocentrism and situated knowledge need critical reflection as to whether they affect social ecological knowledge processes.

The three questions are interlinked with knowledge problems and can be connected through a more general question: Which knowledge is required for social ecology to decode the interaction between society and nature? The question of knowledge in this interaction has not often been analysed (in sociology: Irwin 2001). As a consequence, a thread of critical questions runs through this book to discuss changing social relations with regard to (a) problems of knowledge production and utilisation in science and resource management; (b) power and inequality at different spatial levels of societal organisation; and (c) cultural mediation of resource flows when it comes to the perception and interpretation of resource use problems by social actors. These questions will help in discussing a critical approach to social ecology. Accepting a plurality of theories, perspectives and approaches as necessary for the understanding of complex processes of global social and environmental change, for a reality that can only be understood to a limited degree, is a feature of human ecology. In a similar way, social ecology is open to knowledge from other disciplines, different discourses and many knowledge practices – to mimic a formulation from philosophical anthropology: social ecology is open towards the world. To develop somewhat safer ground for knowledge reflections in social ecology, at least two questions need to be discussed epistemologically: that of complexity and its understanding (Cilliers 2005) and that of social constructivism and its consequences for environmental research (Jones 2002, Sutton 2004).

1. Cilliers' (2005) suggestion for dissolving the complexity dilemma without falling back on simple and methodologically uncontrolled reductionism is: to work with explicit conceptual models of complex systems, and to make explicit the normative assumptions guiding the analysis. This allows controlled reduction of complexity while avoiding the cultural relativism connected with postmodernism, deconstructivism and social constructivism, and assuring against the argument of performative contradiction (the contradiction that the arguments against reason and rationality need to be rational to become acceptable).

    > If complexity is aligned with notions of chaos, randomness and noise, the accusations of relativism and vagueness will start to hold water. If it is aligned with notions of structure as the result of contingent constraints, we can make claims about complex systems which are clear and comprehensible, despite the fact that the claims themselves are historically contingent.
    >
    > (ibid.: 264)

    Limits of knowledge are in this perspective not seen as final knowledge deficits but as conditions for generating and developing knowledge (ibid.: 263).
2. Jones (2002) inspected the variants of constructivism to solve the cognitive dilemma of using either a realist or a relativist epistemological position in environmental research, with the latter often being seen as incompatible with valid foundations for environmental problems and environmental activism. She follows the intentions of Woodgate and Redclift to avoid the choice between realist or relativist epistemic positions (ibid.: 247). The result is "that by adopting an ontologically realist yet epistemologically relativist position, the naivety of 'pure' realism is avoided and the impracticality and absurdity of 'pure' relativism adverted. This paves the way for the negotiation and reconciliation of environmental problems exhibiting a high degree of constructedness" (ibid.: 250). The epistemological solution is somewhat general and simple, but cannot be criticised without going deeper into an epistemological debate of knowledge generation and validity, which is not intended here. Jones' idea is taken here at its face value, allowing the flexible combination of ontological and epistemological arguments.

3. Sutton (2004: 67ff), after detailed discussion of constructivism and realism for theorising the social and the natural, found more attempts to transcend the dualism, for example, by Macnaghten and Urry (1998) or Irwin (2001). Arguing from a sociological perspective, however, he sees continued difficulties in going beyond the dualistic horizon. Both epistemological approaches continue to generate differing ideas of society–nature interaction, and the divide may be bridged only in the long run. However, in environmental sociology it has been argued (Lidskog 2001, Dunlap and Marshall 2007) that one can work simultaneously with both epistemologies. Lidskog (2001) used the somewhat simple argument that social reality is discursively and materially constituted (ibid.: 125). His conclusion shows one possible way to dissolve the controversy, that different levels of constituting and structuring reality do not exclude each other but can be complementary, or: "that one level can offer a partial explanation of another level, but that at the same time a level has a relative autonomy in relation to other levels" (ibid.: 127). For Dunlap and Marshall (2007: 335) the realism–constructivism battles of the 1990s ended when the moderate constructivists argued that the reality of environmental problems should not be denied, which made it possible for realists and constructivists to move towards common ground.

With these conclusions it no longer seems difficult to use both epistemologies in social ecology and to connect a realist analysis of environmental problems with a constructivist analysis of the same problems in which knowledge claims of different researchers and actors are analysed, for instance, as controversy-generating constructions. Jones achieves similar conclusions, arguing against ontological relativism (implied in extreme constructivism: that there are as many subjective and incompatible realities as there are persons). Material and symbolic processes, objective problems and those with higher or lower degrees of subjective constructedness are part of the formulation of environmental problems. Instead of concluding from epistemological relativism the impossibility of coherent knowledge from different "narratives", a step towards an epistemological synthesis can be made – to work with a plurality of perspectives in interdisciplinary and transdisciplinary research, combining different epistemologies, theories and frameworks for the analysis of complex systems and problems.

2
Sources of Social Ecology – Discourses on Society and Nature in Sociology

Environmental themes are analysed in several sociological subdisciplines, but only two of these are relevant to social ecology's themes: environmental sociology with the investigation of natural resource use and environmental problems, and rural sociology with the investigation of land use and food production. The questions of society–nature interaction that guide social ecology appear in sociology with its many subdisciplinary specialisations as big philosophical questions that can be interpreted and answered in many different ways, as the continuing controversies in the ecological discourse show. The history and development of environmental and rural sociology with its themes, perspectives and theories is documented in recent handbooks (for environmental sociology see Redclift and Woodgate 2010; for rural sociology see Cloke et al. 2006). The following discussion does not aim to review the development of the subdisciplines, but is selective according to the core problems and themes of social ecology. The mass of specialised research in environmental sociology – on environmental awareness and behaviour, environmental movements, environmental policy, conflicts and risks – is not the knowledge that is driving the thematic research in social ecology. That knowledge is structured in the three guiding concepts of analysing nature–society interaction and in complicated notions of "societal action".

Environmental sociology in the form of its renewal through Catton and Dunlap was seen as part of human ecology, with the general theme of nature–society interaction representing the human-ecological tradition in environmental sociology (Buttel 1987). For social ecology, specific research on this interaction is of interest: it is the research on human use of natural resources in socially structured practices and the theories developing around that theme. This research is driven by a controversy between the more conventional theory of ecological modernisation (which shows by its very name the programme of a renewal of sociological modernisation thinking) and the critical theory (which includes analyses of resource use in the capitalist economy by York and Rosa, and of unequal exchange by Rice, that connect to the tradition of political economy). Schnaiberg (1980) was the first to renew critical political economy in human ecology with the theory of the “treadmill of production”, and since then further variants of political economic and neo-Marxist theories have developed in environmental sociology. The controversy between the discourses of ecological modernisation and critical political economy is discussed below as being paradigmatic for the development of social ecology, because it helps to clarify the forms and conditions of analysing global resource flows. Rural sociology in its longer history has not lived through such intensive theoretical debates and controversies as environmental sociology, but its research documents the transformation of rural societies and agricultural production in industrial and late modern societies. In Western countries the environmental problems caused through agricultural modernisation have become more and more relevant – modern agriculture has become a dependent part of the food processing industry and an environmental polluter. From this diagnosis begins the following discussion of rural sociological research.

Society and nature: basic controversies

Sociology inherited from earlier discourses on nature and society a series of controversial questions that do not seem to be finally answerable. The answers given are characteristically dependent on selective use of sociological and other knowledge, and keep the controversies continuing. Basic controversies – in contrast to controversies between specific theories, approaches or methods – include those discussed in the following chapters:

- on the relations between man and nature: whether, when and how they have been connected or dissociated;
- on human nature: whether it is biologically or socioculturally determined;
- on the relations between society and nature, social and ecological systems: whether they are separate in their modes of functioning, reproduction and development, or whether they depend on each other.

The three controversial themes can be understood in connection with the “Malthusian controversy” on population growth and limited availability of natural resources for human use (discussed in Chapter 3). With the specialisation of science into new disciplines and subdisciplines, general questions like relations between man and nature tend to be rejected as speculative and inherited from older philosophy. That human and social ecology continue to investigate the big questions is a consequence of their interdisciplinary nature, their focus on environmental problems, and their working with various perspectives, theories and methodologies. Material and energy flow accounting (discussed in Chapter 4) is an example of difficulties in analysing societal metabolism from a specialised disciplinary perspective and with data from economic statistics. These statistics for monetary and physical flows are standardised through theoretical definitions, concepts and measurement criteria. The data need to be transformed and reinterpreted in the broader interdisciplinary perspective of social ecology to provide information about unequal exchange and unequal appropriation of resources and for the social and environmental consequences of natural resource use.

In environmental sociology the interaction between man, society and nature as the human ecological theme dissolves into specialised empirical research into fragments and dimensions of knowledge and resource use processes. In ecological anthropology the human interaction with nature is framed in culturally specific practices of natural resource use that do not support general answers to the question of human nature and culture–nature relations. In rural sociology natural resource use is analysed in the socially organised and specialised practices of agriculture, fishery and forestry, not in an ecological perspective of interacting social and ecosystems. In the routines of research going on in these fields the basic controversies appear as "background noise" that affects knowledge production, interpretation and communication. Controversial ideas come up at certain points of research, often in the discussion and assessment of research results.

In social ecology the relations between humans, nature and society have to be interpreted from a theoretical perspective and contextualised in history, society and societal practices of changing nature to answer the controversial questions. In this reinterpretation some controversies dissolve as outdated or meaningless, whereas others continue in renewed formulations or as controversies that can never be finally answered, as witnessed in the course of discussion of human nature in philosophical anthropology (Chapter 1). The controversies include a series of questions that cannot be answered from positive knowledge but require further ontological, epistemological, methodological and ethical debates.

The reframing of the debate about nature–society interaction in the concepts of colonisation of nature, societal metabolism and societal relations to nature implies modifications of the underlying terms of society and nature. Although a conceptual distinction between society and nature is regarded as meaningful to grasp their material and immaterial realities, the concepts require each other, become "relational", and manifold relations between them appear possible. Nature and society affect each other in historically varying forms, and these varying forms of interaction entail varying environmental problems. The search for knowledge for the solution of present global environmental problems is, however, impossible if it is based on analyses of semantic relations between the concepts in different theories. The solution requires further analyses in terms of resource use processes and related social practices, use of power and knowledge, conflicts and cooperation, communication and negotiation between social actors. In environmental sociology some of these analyses have been carried out for global resource flows.

Environmental problems and natural resource use in sociology

The human use of natural resources has become a critical question in industrial societies. That industrial development results in a global crisis of society–nature relations is not only found from environmental research; in societal practice it is articulated by the new social and environmental movements emerging in the second half of the 20th century in many countries. The development of new social movements is among the themes of environmental and rural sociology, but still their activist perspectives, positions and strategies of action are not fully accessible with empirical sociological knowledge, especially the complicated “dialectic of movements” between transformation of and integration in modern societies. For the environmental movements, the laconic comment of Luhmann (1986: 234) that they “are in lack of theory” may be less valid today. His theory of ecological communication (Luhmann 1986) confirms the impossibility of adequate reactions to environmental problems in functionally differentiated modern society. Each functionally specialised subsystem can only react selectively, according to its own functional criteria, to environmental problems – no concerted action seems possible to transform society. For environmental movements, this theory is not much better than their lack of sociological theory. More than lack of theory, a lack of interdisciplinary reflection of environmental problems in terms of nature–society interaction could become a problem for the movements.

Environmental sociology

After pioneering work by Catton and Dunlap in the USA, environmental sociology has developed differently in European countries. Buttel’s (1987) attempt to describe an international research agenda is still influenced by the environmental sociology dominant at that time in the USA. The five main themes he discusses, however, can also be found in European countries:

1. new human ecology or interaction between nature and society,
2. environmental awareness and behaviour,
3. environmental movements,
4. political economy (environmental regulation, environmental policy, environmental conflicts),
5. technological risks (chemical, nuclear risks, genetic engineering).

In the practice of sociological research the first theme of human ecology became a framing theme that melted into the other, more empirical themes. Although the research agenda is outdated today, the themes are important in the development of environmental sociology. More recently further themes have gained importance, including climate change, biodiversity loss, global flows of resources, energy systems and sustainability. Natural resource use and resource flows tend to disappear in the specialised themes that Buttel describes, possibly due to the differentiation in the USA between the sociology of natural resources and of the environment (Buttel 2002), which no longer seems important. Social ecology has not developed through a systematic reception of research in environmental sociology, but more in relation to the theoretical controversy discussed below.

In environmental sociology a variety of theories have been discussed, and, with regard to these theories, more differences have become apparent between countries. In European countries important theories, such as the theory of reflexive modernisation by Giddens, the theory of risk society by Beck, and the theory of social systems by Luhmann, are theories of society from general sociology. Today these three theories are not among those most intensively discussed in environmental sociology. In the international discourse of environmental sociology the theory of ecological modernisation (or its updated version "sociology of global flows") and the competing critical political economic theories of unequal exchange, ecological distribution conflicts, and the modern economic world system seem more important. From the 1990s, following earlier debates in environmental policy research, ecological modernisation theory (Mol et al. 2009) developed, originating in European countries. The controversy between ecological modernisation theory and critical environmental sociology in the political economy tradition developed after Schnaibergs' precedence in the past decade, with new analyses of environmental problems in capitalism (ecological Marxism, e.g., Foster, Burkett), ecologically unequal exchange (Rice 2007) and the political ecology of ecological North–South conflicts (Martinez-Alier 1995). The theories of unequal exchange, ecological distribution conflicts and the modern capitalist world system can be connected in a more integrated theory that may become of interest for the social-ecological discourse because it allows a theoretical framing of the global resource flow analysis that has so far been insufficiently theorised in social ecology.

Ecological modernisation – a policy programme developing into a sociological theory. Since the 1980s a policy-related discourse has spread through European countries with the key message that environmental destruction in industrial societies can be solved through the use of science-based and technological innovation, the very means of industrialisation. To make possible a decoupling of economic growth and environmental destruction, using environmental standards as drivers for modernisation of industry, the dematerialisation of production, cost reduction and quality improvement industries should be achieved by technical innovation in a joint strategy for research and development that includes universities, governmental institutions and private companies (Jänicke 1984, Barry 2003, Fisher et al.

in Mol et al. 2009: 141ff), similar to the "triple helix" innovation strategy (Etzkovitz 2002, Leydesdorff 2005). The pooling of human, political and financial capital to meet the requirements of economic globalisation and that of sustainable development is the core idea of these modernisation strategies. While ecological modernisation theorists such as Mol are critical of the term "dematerialisation" from the renewed modernisation perspective, it was more relevant in the ecological discourse, in environmental economics and environmental policy. Ecological modernisation policies imply as one of their components the reduction of the throughput of energy and material resources in industrial processes, resulting in less use of natural resources, less pollution and less waste. Thus, ecological modernisation strategies have two aims: to reduce pollution of the environment through support for new, environment-friendly technologies, and to mitigate human pressure on nature and natural resources in a country. These political debates about ecological modernisation and dematerialisation of production seem to follow the "simplistic" construction of environmental problems criticised by Buttel as the "ecological additions and withdrawal" perspective. But, as Dunlap and Marshall (2007: 331) commented, the three ecological functions of supply depot or sustenance base, waste repository, and living space or habitat continue to be essential in the interaction between society and nature.

Through the work of Mol and Spaargaren, ecological modernisation has developed into a broad and flexible sociological theory of how industrialised countries try to solve environmental problems (Mol et al. 2009): by innovation and technological modernisation of their economies, and in the policy process by mainstreaming the environmental movements to accept further modernisation and growth strategies when they allow the environment to be protected and the natural resource base to be maintained for continued human use. Mol has described this mainstreaming in a contested review of the development of environmental movements in European countries in which they gave up their "radicalism" and the critique of the capitalist system. The early theory of ecological modernisation is constructed around this integration theorem to take up results from social movement research. This theory learned from the earlier history of capitalist development in Europe that the integration of the critical working-class movements became a stabilising factor of capitalist industrialisation, in which a unique coincidence of the welfare state, the Fordist accumulation regime and mass consumption produced the temporary success of the system. Whether this success of capitalism in its core countries can be repeated under the auspices of globalisation and global environmental change as the second modernisation of capitalism is, however, doubtful. Also, the prior success lasted only for a short time, under exceptional economic conditions, in some countries with privileged positions in the global economy. This integration dismantled Weber's idea of supporting the ascent of the working class into the light of culture (Weber 1968: 199). In reality, integration of the working class was creating a class of consumers functional for a new capitalist accumulation regime and contributing to the destruction of the environment and intensified use of natural resources, with culture reduced to the mass media industry. This alienated mass consumption system became the main theme of critique by the new environmental and other social movements.

With its further development, the theory of ecological modernisation has become elastic, with changing, even contrasting meanings, as Buttel (2000) observed early in the discourse. In recent years the theory has been reformulated in ecological terms and trials to integrate further ideas. The diagnosis of political integration and de-radicalisation of environmental movements in Europe (Mol 2000), in the face of apparently continuing industrialisation, modernisation and economic growth, is open to question. Mol described a mainstreaming of environmental social movements and non-governmental organisations (NGOs); others (Hajer 1995, Young 2000, Barry 2003) saw a marginalisation and exclusion of the more critical environmental movements from policy processes and the environmental discourse.

Two further important elements of ecological modernisation are the idea of the environmental state and the claim that ecological rationality has become a new structuring principle in developed industrial societies (Bruckmeier and Tovey 2010), integrating environmental issues into economic processes. Mol (2008: 61) claims a growing autonomy or independence of an ecological rationality from other types of rationality. In the context of the environmental sustainability debate, ecological rationality has replaced the traditional emancipatory ideas of modernity such as the emancipation of labour or the abolition of inequality (Mol 2008: 6). Earlier diagnoses of societal changes are found in Inglehart's (1977) thesis of the rise of post-material values as societies become more affluent, or in the hypothesis of the environmental Kuznets curve in economics, which defined a reduction of environmental pollution as modernisation and industrialisation progress. Empirical evidence for such assumptions is limited (Ekins 2000, Barry 2003, York et al. 2003, 2005, Johnston 2004, Rice 2007). A broader problem is that the concept of ecological rationality remains vague, often meaning little more than that more discussion and more administrative action on environmental problems are taking place than a few decades ago. If it means that societal relations with nature are becoming more "rational", it remains unclear whether this is meant to be a system-transforming process or a variant of instrumental rationality supporting economic growth in capitalist modernity, as in the "green economy" debate today (Brand 2012). Rationality remains an idea at the abstract level of worldviews or value orientations; what happens in the reality of resource use, in the concretising of values in social rules, structures for collective action, and economic systems, would require further critical analysis. Social-psychological theories of environmental behaviour (Stern 2000) are not sufficient for that purpose – the reality to be shown would be economic growth eating up the "ecological gains" of dematerialisation of production.

Mol's analysis captures important tendencies of contemporary environmental management and policy, but the "informational environmental governance" remains controversial, is relativised in his own conclusion (Box 2.1). Concentrating on actors and their rationalities in Western

Box 2.1 The environmental state as symbol of ecological rationality: Mol

The environmental state idea implies that the institutionalisation of an ecological rationality since the mid-1980s has happened to a significant degree in policy and economy and has changed the ecosystem management and resource use practices in economic, social and political processes. The ecologically modernising state could be seen as the successor to the welfare state in European societies (Barry 2003). Its role would be to compensate for market failure, now understood as environmental degradation rather than social exclusion, by the political regulation of production, and, increasingly, consumption, but whether this translates into solving economic-environmental problems becomes secondary (Rice 2007: 56). At this point, ecological modernisation theory meets up with broader theories of knowledge society, sharing the widespread view that information technologies are less dependent on matter or nature than prior industrial technologies have been. Mol (2008), analysing environmental reform in the information age, reinterprets and upgrades ecological modernisation by integrating it with knowledge society issues and with new theories of informational governance. He tries to incorporate both Beck's view of knowledge societies as societies organised around knowledge conflicts and Castells' (1996) account of information as central to explaining the conformation of contemporary global society, although the influence of Castell is dominant.

Mol rejects Castell's restriction of nature to local space, but sets out to show how global flows of material and immaterial resources are increasingly exhibiting ecological rationality. First, the environmental state idea is replaced by a more fluid understanding of governance as encompassing a diversity of actors and information sources at global, local and national levels. Second, information and information flows are seen as starting to play an important role in environmental governance, not just as a new technology available to actors and institutions but as "a crucial, causative and formative resource" (Mol 2008: 19) in their own right. Together, the two changes add up to

Box 2.1 (Continued)

"informational environmental governance". Information technology and "the digitalisation of our lives" expands our ability to monitor, measure and report on the environment, and can be used "to visualise, emphasise, articulate, communicate and co-ordinate ecological interests and rationalities in products, production and consumption" (Mol 2008: 93). The increased ecological rationality is seen as a greening of the networked economy, where nodal firms within commodity chain networks, such as retailing corporations within the food chain (Mol 2008: 165), increasingly include environmental impacts. The analysis ends with the conclusion that "it is not possible to give any general and overall conclusion on how effective informational governance protects environmental quality or governs environmental flows" (Mol 2008: 286).

Source: mentioned in the text; Bruckmeier and Tovey (2010)

countries neglects part of the realities and non-intended effects of resource use revealed in indicators for global material and energy flows. Environmental effects are not analysed, but how information flows and informational processes "reconfigure, restructure and govern social processes and dynamics of environmental reform in the twenty-first century" (Mol 2008: 79). With that reconceptualisation he seems to give up the analysis of global environmental resource flows in the quantitative forms used in critical environmental sociology and in social ecology. Ecological modernisation theory bypasses the critical question: how far do changes in governance result in reductions of material and energy flows, and, if this is happening to some degree in Western economies, what are the global trends? While some social changes have happened in Western countries, in forms of governance and regulation, in relations between policy, science and technology, in the role of environmental social movements and NGOs, and so on, it is still an open question what is happening with natural resources in the global economy (Box 2.2).

Box 2.2 Ecological modernisation theory and sociology of flows

Mol and Spaargaren (2005) commented on the controversy between ecological modernisation theory and the critical political-economic theory of the "treadmill of production" by Schnaiberg, attempting to integrate components of both in a reframed theory of global flows (thereafter elaborated in Spaargaren et al. 2006), where the governance of global flows is analysed in the relations between globalisation, state and environment – a cognitive perspective more limited than that of interaction between society and nature, one leaving out the systematic analysis of the physical economy and physical flows.

Mol and Spaargaren (2005: 93f) saw abstract similarities between the theories of "treadmill of production" (Schnaiberg) and ecological modernisation with regard to focus on production, consumption and environmental disturbances or the material flows in these processes. The similarities should show that both differ from constructivist and postmodernist approaches by seeking solutions for sustainability: "the core clusters of modernity: science and technology, are . . . ties between the industrial organization, the capitalist mode of production, modern systems of values and culture, and the nation-state system" (ibid.: 94). The similarities seem to be based on doubtful abstractions in the concepts referred to – what industrial organisation, capitalist mode of production, modern values and cultures mean differs between the two theory traditions, and may not become offset by conceptual abstraction. What the authors call "sociology of flows" aims to move beyond the controversy, integrating both perspectives in common research agendas.

The sociology of flows is seen as emerging from the work of Castells, Urry and Sassen. "Although the theoretical traditions of Castells and Urry differ, they unite in emphasizing the growing relevance of networks and flows in understanding and interpreting modern society at the recent turn of the millennium. Several conventional categories in 20th-century sociology (nation-states, societies, capital accumulation, actors) are abandoned, reinterpreted, or replaced (by new concepts), fundamentally altering the sociological tradition" (ibid.: 96). The concept of environmental flows should replace the older "additions and withdrawals" perspective that is seen as region-focused, static and place-bound. "As the sociology of flows perspective would have it, material substance flows become the genuine unit of analysis in the environmental social sciences, around which actors and social practices – labelled in terms of nodes and moorings, institutional developments and scapes, discourses, and networks – can be identified and analyzed to understand these fluids sui generis and the (policy) issues of management and control they bring along with them" (ibid.: 98).

In the notion of environmental flows materials are seen as socially structured, renouncing to interdisciplinary analysis of flows from different perspectives without setting the social perspective as absolute. The social transformation of flows in practices for natural resource use

Box 2.2 (Continued)

cannot neglect the physical quality of flows that is not accounted for in abstract terms of social nodes, moorings, discourses and networks. "An environmental flow is not only or just material substances and technical infrastructures but also the scapes, nodes, networks, and discourses that go along with the flows in question. In this respect, it distinguishes itself from most environmental sciences/studies models and paradigms, such as environmental system analysis, substance flow models, and industrial ecology. In analysing flows, the sociology of flows concentrates on the social embeddedness while at the very same time emphasizing the material dimension" (ibid.: 98). Environmental flows appear "as constantly moving, deterritorialised fluids" which are "left undertheorised" in the traditional additions and withdrawals perspective (ibid.). Environmental flows are not only material, "can be for the most part social, or a combination or hybrid: a social-material flow" (ibid.: 99).

Source: mentioned in the text

The arguments Mol and Spaargaren used in the revision of the logic of ecological modernisation do not revise the earlier diagnoses of a changing nature of environmental movements, of the industrial system and the modern state. A strategic cognitive interest throughout the development of the theory seems to be motivated by ideas and assumptions of mainstreaming a discourse with the help of the hypothesis that a new reality has emerged through policy reforms and globalisation of flows. The arguments for a sociology of flows, in grasping some of the changes that happened, become doubtful at the point where the debate about real effects of flows is cut off in favour of a limited disciplinary perspective of sociological knowledge production.

In ecological modernisation thinking, knowledge problems are now addressed from the theoretical perspective of a new network society (Castells 1996) made up of networks and flows around information. This new global society is imagined as one increasingly detached from nature. Here sociological theory touches on a relevant theme for social ecology – whether and how the nature of capitalist industrial society has changed with what is called the new society of the information age. Despite his critical reflection of "informational capitalism", Castells appears to be captured by a traditional view of knowledge that can progressively emancipate humans from nature. "After millennia of a prehistoric battle with nature, first to survive, then to conquer it, our species has reached the level of knowledge and social organization that will allow us to live in a predominantly social world" (Castells 1996: 478). Through the development and application of knowledge humans can live in a society which is progressively eliminating human dependence on nature. In contrast to such views of society, ideas of a socially mediated materialism are formulated in the Marxist and critical theory discourse, by Moscovici and in recent ecological debates about the "anthropocene" (Steffen et al. 2007); nature and society are seen as interacting human-environment systems or as coupled social-ecological systems. Rather than assuming that modernisation is superseding human dependence on nature, critical and ecological analyses identify a changing, not decreasing but intensifying, dependence of society on nature and vice versa. This becomes a core point of the controversy between the sociology of global flows and the critical theories in environmental sociology and social ecology. How can the interaction between society and nature be interpreted in these extremely differing ways of less, changing, or more dependence of modern society on nature?

In a critical review Marcuse has assessed Castells' theory as reification: "It is a move that suppresses the political, in the broad sense of the dynamic between the exercise of power and the resistance to it, and moves toward a determinism that undermines the relevance of political action. Power and conflicts over power disappear from view; classes, when they appear, have a very subordinate role. Capitalism is conflated with globalisation, but in an ambiguous and a historical fashion; technology, the media, demographic changes, the state appear as homogeneous, autonomous entities, actors themselves, behind whom actual actors are not to be seen. It is a classic case of reification, making the relations among human beings appear as a relationship among things, the relationships of social and economic position appear as relationships to or against technology, to or against the ascendance of 'information'" (Marcuse in Ritzer and Atalay 2010: 252f). From this critical perspective of political economy the diagnosis of a network society is dismantled as a loss of analytical capacity instead of describing a transformation of capitalism. The abstractness and inexactness of theoretical concepts such as those of network society and global flows have as (non-intended) consequences a reductionist analysis that bypasses critical questions of the development observed. Marcuse sees this as theoretical eradication of human agency; from a social ecology perspective, another deficit can be seen, the incapacity of analysing global resource flows.

The theory of ecological modernisation (or the sociology of flows) is not open to interdisciplinary communication, knowledge integration and attempts to create knowledge for problem-solving as in social-ecological research. Development of sociological theory through new terms for the changing reality of globalisation is limited to describing the governance of flows with changing constellations of political actors and institutions (e.g., Fisher et al. in Mol et al. 2009: 141ff), but does not answer the question of whether changing governance adequately reacts to global problems. In the abstract terminology of flows, the strategic method of abstraction keeps out of the analysis those aspects of resource flows that are required from a sustainability perspective, to assess the consequences of global environmental change. The attempt to match the theory with the critical perspectives of world system theory and political economy remained a reformulation of selected aspects of these theories in other terms, reinterpreting and bypassing key arguments of the theories rather than integrating their differing interpretations, explanations and results.

Critical alternatives to ecological modernisation theory. Ecological modernisation and sociology of flows touch the interaction of society and nature only through governance and other social relations and actions that constitute material and immaterial flows. The kinds of natural resources that are part of these flows are irrelevant to the sociological discourse. In the abstract term of flows, the qualities of material and energy resources that count in the environmental discourse are extinguished. The price of this abstraction seems to be a curtailing rather than a broadening of cognitive interest, remaining sceptical about interdisciplinary knowledge integration, and explicitly renouncing assessment of the state of the environment in terms of improvement or deterioration of the functions and services of ecosystems.

In critical environmental sociology global resource flows are investigated in another way, showing the ecologically unequal exchange that Rice (2007, 2008, 2009) has found in the strategies of ecological modernisation and greening of the economy in industrial countries. This theory of ecologically unequal exchange opens up further perspectives that are developing outside sociology, in ecological economics and political ecology (theory of ecological distribution conflicts) and in social ecology (theory of societal metabolism operationalised in material and energy flow accounting). All these critical theories for analysing nature–society interaction reject the "technical fix" and technology-centred ideas to solve environmental problems. Instead of transformations of environmental governance (Mol), the important things seem to be globally strengthening environmental agency and the saving and redistribution of resources. The cognitive aspiration of this critical research can be described as exploring the conditions and possibilities of societal adaptation to global environmental change and of societal transformation to sustainability.

York et al. (2003, 2005) used ecological footprint indicators from 142 countries to test theoretical approaches from human ecology, ecological modernisation and political economy with their differing explanations of the environmental impacts of modern societies. In their analysis the environmental impacts of countries are consistent with factors highlighted in human ecological and neo-Malthusian approaches and with political economy and world systems theory, summarised in the argument: environmental impacts "are not directly the result of capitalism or world system position per se, but rather are generated by more basic material conditions, which in turn may be mediated by capitalism and world system position" (York et al. 2003: 294). This conclusion was rejected by Mol and Spaargaren with a methodological critique.

> Empirical validations often simplify the theoretical refinements, contrasting empirical evidence in the same range can often be identified, and methodological arguments within a quantitative style of sociological neo-Malthusianism (York and Rosa) have different meanings when compared to methodologies applied in the context of a qualitative style of historical sociology approach (Mol and Spaargaren). With respect to such more encompassing theories, the relation between theory and empirical evidence cannot be done away with via a naïve positivist "verify or falsify" claim: the black swan is never the falsification.
>
> (Mol and Spaargaren 2005: 94)

This somewhat vague critique avoids the main question of whether and how a quantitative analysis of global resource flows can be carried out.

The first step towards a more critical analysis of global exchange and resource flows happened in the mid-1990s with the introduction of the notion of ecological distribution conflicts by Martinez-Alier (1995) and the subsequent elaboration of a theory of the "environmentalism of the poor" (Martinez-Alier 2002) that contrasts with the analysis of environmental problems and movements centred on Europe and industrial countries in the theories of Mol or Beck's risk society theory. It marked the beginning of a new critical discourse on North–South conflicts after dependency theory and World System Theory. The new theory specifies the abstract notions of intragenerational and intergenerational distribution conflicts in a more historically concrete analysis of the consequences of economic globalisation. Ecological distribution conflicts are conflicts around the extraction and transport of resources, pollution and waste that link local levels of extraction with global trade and consumption. The phenomenology of ecological distribution conflicts is somewhat diffuse: these conflicts are multifaceted and often not seen as primarily ecological conflicts, exhibiting social, cultural, political, economic, local and global dimensions simultaneously. Linked with these conflicts is Martinez-Alier's (2002) analysis of environmental movements in the global South, the "environmentalism of the poor". The identification of new global cleavages is not just an argument for new forms of governance and policy (as argued, e.g., by Edelman 2001). The new societal conflict line at global level is outside national society contexts – a cleavage in the global capitalist society, articulated in recent years in a global civil society that developed through transnational networks of social movements (Adaman et al. 2003: 372).

Ecological distribution conflicts show problems connected with global distribution and redistribution of natural resources between countries. These conflicts need to be analysed, starting from the diagnosis of the unequal ecological exchange and global material and energy flows to show what is required before global sustainability is possible: mitigation of manifold ecological conflicts that imply redistribution questions. Martinez-Alier's concept connects with unequal exchange and critical world system analysis. Unequal economic exchange between core and periphery countries has been discussed in earlier critical political-economic theories of dependency. Later writers broaden the concept of unequal ecological exchange to refer to the unequal exchange of ecological advantages and burdens between core and periphery countries (also part of the environmental justice debate), in which core countries exhibit both disproportionate appropriation of global natural resources and a disproportionate capacity to externalise negative environmental consequences (Rice 2007, 2009).

Exchange of natural resources takes place within a world system structured around unequal and uncompensated use of global environmental space, of resources and sinks. Thus the argument of unequal ecological exchange challenges Mol's conclusions: the increasing capacity of rich countries to conserve their domestic environmental assets and resources is rooted, not in the increased institutionalisation of environmentalism or in the spread of ecological rationality, but rather in the greater power to do what Rice (2007) calls "environmental cost-shifting": displacing or externalising the social and ecological costs of natural resource extraction, of waste and pollution from their consumption to poorer countries. In countries with high levels of natural resource consumption, domestic degradation of natural resources is generally lower (Rice 2007: 54; see also Martinez-Alier 2003 and Jorgensen 2006). While extractive economies experience pressures to constantly over-exploit nature, more and more of the landscape within productive or industrialised countries can be "liberated from the imperative to yield a profit and rather become the object of conservation programs" (Hornborg 2001: 29). This produces a "rich country illusion effect", the belief that rich countries are becoming more sustainable through their own efforts, while they can support their population size, standard of living and domestic environmental conditions only by drawing on the resources of other countries. "By importing natural resources and exporting sink capacity demand and environmental costs, inhabitants of core countries can mistakenly perceive their lifestyles as sustainable, as their consumption rates are not tightly linked to domestic environmental conditions" (Rice 2007: 63). Core countries can support high consumption rates of natural resources, and simultaneously maintain their own domestic environmental assets, only at the expense of countries more marginally situated within the world system.

The focus on technological improvement in ecological modernisation thinking derives from and sustains the myth of industrial societies: that human welfare can be increased through continued industrialisation and economic growth. More critical debates about whether changes of life, production and consumption styles are necessary to solve the crisis in societal metabolism, in the interaction between society and nature, are not supported. Global statistics on material and energy flows reveal the dematerialisation and the ecological modernisation debates as wishful thinking and technological utopianism. Empirical data and trends in resource use in the globalising economy do not support these perspectives, although they may be valid under highly specific, historical circumstances to a limited degree. Without doubting that efficiency gains in the use of materials in production have occurred in economies of the global North, in the countries with the highest consumption of material and energy resources, global materials and energy consumption and pollution of the environment are still increasing. They are increasing not just as a consequence of global population growth, but more as a consequence of the global spreading of the growth economy that stimulates high consumption levels through industrialisation in further countries.

The analysis of global material and energy flows and unequal ecological exchange opens the view towards alternative understanding of societal transformation in the global economy and in countries in the North and South. This analysis is mainly based on information from statistics and indicators that are produced in official documents and data on national economies, their growth and development. Such statistical material raises methodological and theoretical questions. Is it capable of indicating the ecological problems adequately, or is it distorted, masking environmental and resource use effects under the dominant logic of measuring economic growth in standardised and monetary terms? It has long been known (e.g., Trainer 2001) that conventional gross national product accounting for national economies neglects the costs of environmental pollution or treats the defensive costs of ecosystem restoration in doubtful ways as growth factors. Improving environmental quality and "cleaning the environment" through investment, work and new firms appears in such accounting as contributing to economic growth of the national economy – destruction of the environment appears as a growth factor and environmental restoration too. Viewed practically, this cleaning and repairing may make sense to a limited degree, and it creates work and income. But finally it seems inconsequential, the only goal remaining that of maintaining growth whatever the consequences. It is more relevant to deconstruct the institutional complex of modern growth-based economies in the search for alternatives to environmental destruction.

Something of the distorting logic of growth has become apparent with ecological modernisation and with the idea that technology-based environmental adaptation of the economy can sustain growth. Externalisation of the environment happens at other levels, not shown in national economic growth indicators. Sustainability cannot be discussed only at the levels of governance changes, growing environmental awareness of consumers, establishment of monitoring, audit and control institutions and bureaucracies, or at the level of technological innovations of national economies. All that is important, but it bypasses critical questions about the aggregate and non-intended effects of natural resource use in production and consumption. This becomes still more blurred with the abstract notion of environmental flows as deterritorialised and hybrid flows. At global levels, in global resource use and in the global economy, valorisation of nature has a higher price and more negative external effects than are accounted for in national growth statistics. The externalised costs of production and consumption become somewhat more apparent in a critical analysis of global resource flows in monetary and physical terms and in the theory of ecological unequal exchange. Efforts have been made in social ecology to develop the economic indicators into more adequate indicators of environmental effects (see Chapter 4). This offers a broader view of natural resource use practices, at national levels and at the level of the global economy. But the statistical data available are still insufficient for an analysis of societal metabolism and need to be accompanied by further critical analyses of unequal exchange and distribution conflicts. The available analyses of global resource use support the conclusions in Table 2.1.

The transformation of modernisation and development research into a more critical and theoretical discourse can be designed along a path from material and energy flow accounting to analysis of socio-ecological regimes, societal metabolism and societal interaction with nature in the present world system, components of the emerging perspective and theory of social ecology. Further answers on how to achieve sustainable development, accepting this as the guiding idea that unifies many scientific and political actors, can be expected with the theoretical synthesis in social ecology (Chapter 6).

The critical approaches in environmental sociology use knowledge from human ecological analyses of interaction between man, society and nature in theoretical and empirical studies of natural resource flows and their social and environmental consequences. Such analyses are not carried out in the sociology of deterritorialised global flows by Mol et al. Energy flows, the critical resource flows in energy-intensive industrial societies, become a core theme of social ecology, more than in sociological studies of unequal exchange, continuing a critical interdisciplinary discourse that dates back to political economy in the 19th century and critical studies of energy and society relations by Cottrell (1955), and more recently by Debeir et al. (1986). However, the use of energy resources is densely interwoven with use of material resources in industrial production and in private consumption. A discussion of changing energy regimes without touching the whole process of resource use, as in large parts of the present discussion on renewable energies, seems irrelevant.

Table 2.1 Trends in global resource use

1. *Global material and energy consumption trends* (Haberl et al. 2004, Weisz et al. 2006, Erb et al. 2009, Jorgensen et al. 2009, Krausmann et al. 2009, Rice 2009, Schandl et al. 2009): The trends show that, with all the technical improvements in materials use, global material use has grown eightfold throughout the 20th century and has grown faster than the population (Krausmann et al. 2009: 2696). Using socio-ecological indicators for material and energy flows and land use intensity (human appropriation of net primary production, HANPP), it is possible to go beyond ecological footprint analysis, on which the analysis of York et al. (2003) is based, to show that the spatial disconnection between biomass consumption and land use creates further problems for sustainable development (Erb et al. 2009: 257). Accelerated urbanisation, modernisation and industrialisation, especially in big Asian countries such as China and India, undermine sustainable development strategies – there it would be necessary to strengthen sustainable development in rural areas and for rural populations (Schandl et al. 2009: 279). Transnational organisation of production and unequal ecological exchange are threatening sustainable development in the periphery of the world system (Rice 2009: 230).
2. *Global energy use analysis*: Benefits from resource use are unequal, especially in countries in the periphery that are unable to reap the benefits of improvements in energy use and efficiency (Lawrence 2009: 352). The environmental degradation paradox that countries in the centre can improve the environment on their own territories only by degrading the environment in periphery countries by resource imports is confirmed (Jorgensen et al. 2009).
3. *Continued growth eats up efficiency gains from dematerialisation*: The continued productivity improvements that are measured in economic reporting, mainly for the modernised OECD economies, bring incremental improvements for the environment that are mainly visible in calculation exercises but do not materialise in significant and measurable changes of environmental quality. Efficiency gains from dematerialisation in some countries and reduced consumption by some environmentally aware groups of consumers are eaten up by more resource use in other countries, more consumption by other groups, and more consumption linked with the continued, though slowing, global population growth. So far no global redistribution of resources or more equitable consumption has happened. The ecological footprint and other environmental indicators can give an idea of how many natural resources and how much sink capacity, how much environmental space or how many earths, would be required for global industrialisation.
4. *Economic globalisation supports the economic growth mechanism*: Dematerialisation so far has only been possible within that dominant economic framework. Ideas of limiting growth, of zero growth and steady state economies, as demanded by ecological economists (Daly et al.) to achieve globally sustainable levels of resource use, still seem to be utopias, in spite of raising doubts about economic growth. Limiting growth, zero growth and degrowth happen, now as throughout the history of industrial capitalism, but in the form of periodic economic crises and social catastrophes, nowadays with enforced impoverishment of more and more social groups in the industrial core countries. The solution, sought but still unknown, can be formulated as the paradox of “realising degrowth in

Table 2.1 (Continued)

non-catastrophic forms", of development and social welfare without economic growth. So far many forms of non-intended effects of social action in the globalised economy that counteract dematerialisation have been observed (such as Jevons effect, rebound effect, tragedy of the commons and tragedy of enclosures, social dilemmas of resource use, individual vs. collective rationality of resource users, etc.). As long as no decommodifying and redistributive policies exist at global levels to equalise consumption and standards of life, the costs of continued growth under conditions of unequal exchange are paid by growing parts of the populations in Northern and Southern countries in the form of poverty, hunger, marginalisation, social exclusion, and their consequences. Economic globalisation without subjecting economic mechanisms to societal control helps to perfect externalisation processes at global levels.

Source: mentioned in the text; Bruckmeier and Tovey (2010)

Rural sociology

The rural economy and society have been dominated throughout modernity by agriculture, forestry and fishery as societally transformed practices of natural resource use, but the economic forms of agriculture and food production changed dramatically during the industrial epoch or the "anthropocene". Food production for the whole population happens in the countryside. The major part of natural resource use in modern societies in terms of using land, landscape, water and biomass still takes place in rural areas despite all the changes due to industrialisation, urbanisation and globalisation. The socio-ecological term of "colonisation of nature", encompassing the modification of natural resources in all economic sectors, transforms the paradigmatic case of agriculture as human modification of plants, animals, ecosystems and landscapes to a more general and abstract term for transformation of nature through societal practices. In these practices cultural valuation, scientific knowledge, political regulation and economic production all together change nature. Sociological concepts, constructed for the analysis of modern industrial societies, do not always work well for the study of rural societies, including the classical term of social class applied to the peasantry as "awkward class" (Shanin). The cultural traditions – social life and neighbourhood, ownership systems, forms of work and local knowledge of agriculture – have been described as specific in rural communities, changing only slowly in the societal modernisation process. After the marginalisation of the peasants in the economy, their culture is still present in rural communities, although much less than in the Global South, where large parts of the population are agricultural producers.

The industrial and urban transformation of rural resource use, industrialisation of agriculture and food production, and domination of rural land use by interests of the urban population subject rural resource use to non-rural interests. The resources that the majority of the population consume are, furthermore, located in the countryside, outside industrial and urban metropolitan areas, but their use is now dominated by the interests of urban populations and industrial producers. The original purpose of food production became a by-product of the economic interests of the food industry and the recreation-oriented interests of the urban populations in the amenity of rural landscapes. The dissolving of boundaries between urban and rural areas and the visible and invisible spreading of cities into rural areas, for example, through their ecological footprints, show some of the problems of urbanisation as it changes rural economies.

The research agenda of recent rural sociology includes themes of importance for social ecology, such as food production and its industrialisation, land use change and land grabbing, bioenergy production, and interaction between rural and urban development. The changing functions and roles of farming during modernisation prompted theoretical reflection on agriculture in industrial societies. These reflections showed the contradictory influences on rural society and rural areas. Rural areas were marginalised during industrialisation in European countries, becoming the non-industrialised hinterland. But, in terms of space, of location and use of natural resources, and of food production, the rural economy is still an important part of modern societies. This is not adequately indicated by the small percentages of farmers who are counted today in modern societies. The contradictory forms of agricultural modernisation brought about the end of peasant farming with the industrialisation of agriculture, completed in the 20th century, in Western and socialist countries. Large-scale farming, mass production, Fordist agriculture and the productivist paradigm in European agricultural policy are some forms of the transformation of agriculture during industrialisation. From a global view, the process of transformation from agricultural to industrial production has not yet happened for the larger part of the global population, and, according to the results of ecological research, cannot be completed because of scarcity of natural resources. The global spread of industrial and urban economies is destabilising agriculture and food production – the consumption of natural resources in these dominant sectors of modern economies results in the crisis of societal relations to nature diagnosed in social ecology.

In Europe, agricultural modernisation according to the productivist paradigm ran into crisis in the 1980s, with surplus production and accompanying environmental damage. The equivalent modernisation processes in "developing countries" have been called the "green revolution". Agricultural policies, economic production processes and organisation of farm work became subjected to similar forms of formal organisation as in other sectors and branches of modern economy and policy. The changing forms of modernity are described in environmental sociology with the concepts of network society, risk society, post-modernity, globalisation and socio-ecological hybrids. More conventionally, the new realities in rural areas can be described as those of changing social structures with reduction of primary production and "third sector economies", indicating the cultural occupation of rural areas by urban populations and their dominant recreational interests that support a growing service and leisure time economy. From an interdisciplinary perspective, the changing realities of rural lives and livelihoods have been perceived as changing societal practices of natural resource use, of cultural landscapes, of knowledge and management systems for rural resources. Using the concepts of resource systems (including natural and other resources), knowledge systems and systems of resource use and management in a similar way as in common pool resource research (see Table 2.2) provides a conceptual framework to analyse the societal changes affecting rural development. The systems of reference that shape rural livelihoods are the large-scale ecosystems and societal systems.

Characteristic *conflicts* in rural development are found between different modes of production – for example, between traditional, small-scale and organic agricultural production and modernised, large-scale and rationalised agricultural production; between protection and use of resources; or between nature and species conservation through definition of protected areas or through zones of environmentally adapted and regulated resource use with restrictions on agricultural production. As a result of political and administrative regulation of land use and landscape development, the resource use conflicts are blended with conflicts of administrative origin. Conventional conflicts and cleavages between producer groups and production systems in the rural economy are overlaid by new ones, resulting from changing forms of resource use that are spreading with a multifaceted "leisure-time economy", including tourism and services linked with it. With the changes in social structures, lifestyles and economy, such a leisure economy uses more and more rural resources, land, landscapes and water areas. The accompanying problems of infrastructure development, economic services and practices of multiple resource use cause more local conflicts.

Food production and agricultural land use as the most important forms of human use of natural resources have in recent decades come under the influence and control of global enterprises. Many small and local producers of food and biomass for energy use have become dependent producers for the global food and energy industry. As early as 1967 "the end of the peasantry" was diagnosed in the French rural discourse (Mendras 1967), describing the historical processes that have been observed during the 20th century in industrial countries. But in the modern economic world system, where nearly half of the global population are small and poor peasants and subsistence producers in the countries of the global South, it is not yet time to speak of the end of peasants and farmers, although through

Table 2.2 Components of resource use practices

1. *Rural resource systems* include natural and man-made resources, natural resources being those that make the human resource base. Other resources can be described as socially transformed resources, including technologies, knowledge, economic and social capital. The resource systems in rural areas include those of primary importance for the whole society: water, land-based resources and ecosystem services. The main problems of quality and quantity of resources are the overuse of living resources and the degradation of soil and waters through pollution and eutrophication.
2. *Rural resource use systems* are often characterised by multiple resource use, extraction or appropriation within different property systems for land, water, landscape, living resources and complex resources such as biodiversity or climate. With its social complexity and multiplicity, human resource use tends to create dilemmas and conflicts linked with access and ownership rights in resources. Conflicting interests of dominant resource user groups in rural areas relate to the changes in use of land and water for agriculture, horticulture, sylviculture and aquaculture, for industry, settlement and urban development, for energy production and nature protection, infrastructure and transport, tourism and recreation.
3. *Knowledge systems* for rural resource use and resource management, whether formally defined or informally practised, are of different origins, ages and kinds, from the scientific and managerial to the local knowledge of various resource users. Knowledge systems, with their disciplinary specialisation and social differentiation, influence resource management systems contingently through the definition power of actors. The suppression and marginalisation of older local knowledge through scientific and bureaucratic knowledge has become controversial, and is transformed in ecological research and under the guiding idea of sustainable development.
4. Because of the complexity of resource use processes, *managerial rule systems*, for instance in agricultural policy, cannot balance and integrate all interests, claims and relevant knowledge as they are intended to do. They have the non-intended effect of reproducing and sometimes reinforcing the conflicts inherent in resource use practices. Management rules for rural resources are today based on a variety of formal and informal rule systems. Rural areas in Europe are subjected to different management rules from international laws and contracts, regulations from the European Union or the member states, relicts from older or traditional resource use regulation, and newly created rules derived from continuing research. The complexity of rule systems can create conflicts of rule application.

Source: Ostrom (2007a, 2007b, 2009)

the “modernisation of rural poverty”, such as in development strategies supported by the World Bank, they become market and industry-dependent producers. There are also recent debates in European rural sociology about a “re-peasantisation” of agricultural production (e.g., van der Ploeg), which relates to hitherto rather unnoticed processes of migration from urban areas back to the countryside, indicating contradicting trends in urbanisation and globalisation.

The contradicting trends in the development of agriculture and food production require a more in-depth and critical analysis, which is partly achieved in rural sociology, but needs to be completed by the more systematic analyses of resource use in social ecology. The critical discourse about the future development of agriculture in rural sociology and neighbouring disciplines includes the interconnecting themes of food production, land use change and bioenergy production, and urbanisation, taken up in the socio-ecological discourse that develops in parallel to rural sociology (Chapter 5). These themes are summarised in the following sections.

1. *Industrialisation of food production.* The history of agriculture in the 19th and 20th centuries shows significant changes of spaces and places in rural areas in the social practices of resource use. Nature has been transformed in three major changes of agricultural production since the 19th century. The first big step of modernisation of agriculture happened with the "nitrogen revolution" based on the scientific knowledge from agricultural chemistry (Liebig) that brought significant changes in plant nutrition or fertilisation practices, allowing higher yields in European agriculture than had been possible with prior improvements of agricultural fertilisation techniques. The second step came with the technical and economic modernisation of agriculture in the 20th century in European countries, after the Second World War and through political efforts of the Common Agricultural Policy of the EC/EU since the 1960s. Similar modernisation projects in the global South happened under the name of the "green revolution" as a capitalist industrialisation of agriculture. In a critical analysis, the modernisation processes should be seen as a slow expropriation of the producers, which in European agricultural policies was formulated as a structural change of agriculture: in the process of modernisation and economic rationalisation, smallholdings and non-modernised, labour-intensive forms of agriculture were terminated, with a dramatic reduction in numbers of agricultural holdings. Not only have peasants and farmers decreased dramatically in number within a historically short time, but those who remain have become dependent producers, dependent on other knowledge and actors – scientific, governmental and companies in the food processing industry. The third and completing step in this technical modernisation, building on the preceding steps of agricultural modernisation, is the genetic modification of plants and animals in agriculture – motivated by the easily applicable argument of feeding a rapidly growing global population. This strategy is still controversial in European rural development policies and is not supported by all governmental institutions or by large sections of environmental movements and the population.

All steps of agricultural modernisation imply that agriculture has come under the control of science with regard to knowledge and is economically under the control of food processing companies and international corporations. Industrialisation of agriculture does not only involve large-scale, mass production of food; it also subjects agriculture to control by the private capital of international corporations that are patenting seeds and species. Such quasi-privatisation of the genetic material for agricultural production is continuing with the expropriation of farmers. This trend towards industrialised agriculture is not the only trend in the development of food production, and is not without conflicts and a search for alternatives. Several counter-movements emerged during the 20th century – organic farming, new forms of local, community-based agriculture, local quality food production, "re-peasantisation" of agriculture, urban agriculture, and new forms of producer–consumer cooperatives at local and international levels, such as the fair trade movement.

The ecological consequences of the standardisation of biological means of production include an accelerating reduction of agro-biodiversity and risky strategies for ecosystems through the introduction of genetically manipulated, not environmentally adapted, species of plants and farm animals. Scientific knowledge for agricultural production is instrumentalised for specific interests and is seizing power, just at the same time that the idea of objective, universal scientific knowledge is being critically deconstructed in the postmodernist discourse, though in forms that do not necessarily support the ecologically critical analysis of agricultural modernisation. More than revaluating scientific knowledge for the purposes of strengthening local or practical ecological knowledge (e.g., in ecological and resilience research) would be required to deconstruct the powerful knowledge coalitions that appear, for instance, in the "triple helix" of cooperation between governmental, scientific and private companies in research for producing knowledge for genetic manipulation of plants and animals. With such cooperation it is easy to transfer knowledge effectively in applied technologies and economic standards for production of food. Space and nature are, in this last modernisation project, modified in combined material and symbolic social forms that require critical analysis, theoretical knowledge and reflection, as is provided in the interdisciplinary analysis of societal relations to nature in social ecology.

2. *Land use change* is analysed as a phenomenon of global environmental change (e.g., the Millennium Ecosystem Assessment 2005) and in more specific forms in rural sociology and other disciplines, with contradictory development trends. In European countries large parts of agricultural land are left fallow or are not used for food production to reduce the agricultural surplus. The land set free from production is still managed by farmers, and, in a search for alternative forms of land use, bioenergy production

on agricultural land has become an alternative that evokes manifold controversies and conflicts. Bioenergy production is part of the larger project of transforming societal energy systems or metabolic regimes in search for environmentally sustainable energy systems through the use of renewable resources. However, this global process of a transition towards new energy systems is going to come into conflict with its commercialisation. Less in Europe, more in the countries of the global South, the use of agricultural land for bioenergy production evokes conflicts over whether land should be used for food or for bioenergy production. Besides that, bioenergy production raises questions over whether it is as environmentally friendly as its promotion as "green energy" promises. The means of producing bioenergy, by smallholders or in large holdings, for local use or for export, evoke further conflicts. Analyses of global environmental change demonstrate that agricultural land is not an abundant resource, as may appear from the European experience with fallow land as a consequence of higher productivity, but has become a scarce resource in the global economy. The transformation into agricultural land through continuing deforestation has reached its global limits. New phenomena of environmental colonialism are appearing, such as land grabbing, with the buying of agricultural land by governmental organisations and private companies in foreign countries. Land for food production is no longer the property of and controlled by local producers, but has become a globally traded resource.

3. *Urban and rural development* can be separated less than ever before, in Europe as well as in other parts of the world. The territorial and administrative separation of areas and regions in these terms, which continues to shape the everyday perception of problems and action, is misleading with regard to the ecological consequences of urbanisation as a concomitant process of industrialisation. The relation between urban and rural areas has been described by the generic term "division of labour". This term needs to be specified and broken down into typologies of labour in terms of actors, scales and specialisation forms: technological division of labour that rules the industrial production regimes; social division of labour that comes into existence in gender and class-specific forms; regional or territorial division of labour, under which the older forms of urban and rural division of labour continue in specific forms, connecting with or overlaid by newly emerging divisions of regions and local economic centres in the globalisation process. Urban development appears from a socio-ecological perspective not only as a process of functional differentiation and specialisation; it also requires the analysis of functional integration and reintegration of the separate parts of economy and industry.

As critical as the view of cities and urban life in the early writings of Marx – resulting in the conclusion that cities are unsustainable forms of living and working – is the view found in the ecological discourse today. In Odum's ecology (Odum 1997), cities have been called parasites upon the countryside and the biosphere, and in the environmental movements a negative valuation of urbanisation seems to prevail: urban areas are constantly dependent upon and using resources from rural areas, cannot survive from a local resource base and are "colonialising the countryside", as happened in parallel to the modernisation of agriculture under the control of scientific, political and economic bureaucracies and for urban consumers. The view of cities as unsustainable forms of social life, dependent on resources from outside the area, has meanwhile been discussed more critically in ecology. Few ecologists, for instance Rees (2003), have investigated in more detail the positive ecological effects of urban forms of settlement that occur together with negative ones, such as efficient use and reduction of using space and other resources. From that ecological perspective, cities appear as man-made ecosystems with contradictory consequences for the natural environment. In some regards they support an "ecologically rational" use of natural resources, especially land, and in other respects they result in overuse and environmental damage. This allows better interpretation of the problems of urban development and can also be connected with social-scientific analyses of the contradicting development of urban areas. Critical analyses of the historical processes and development trends that create such contradicting forms of land use would be required in social ecology.

Another argument to conclude from the interpretation of urban development is that the separation between city and countryside as two different forms of life, production and consumption, cannot be understood sufficiently when the functional interdependencies between the separate areas are not taken into account. City and countryside, towns and villages may have existed in a contradictory unity throughout human history since the development of agriculture, marking the origin of class society and of connected social differentiations that resulted in social and economic contrasts and conflicts. Beyond the social differentiation and spatial separation, the functional interdependencies in resource use and consumption cannot be ignored. In future, with accelerated urbanisation and large urban agglomerations or mega-cities, the situation becomes more complicated. The global trend of rapid urbanisation bears the risks of catastrophic forms of urban collapse – social collapse because of unsustainable urban economies and ecological collapse because of climate change – before it comes to turns towards sustainability. Although counter-urbanisation phenomena are discussed by rural sociologists and others, and remigration from urban to rural areas is found in Europe and elsewhere, these phenomena do not show a picture of the possible sustainable future – which is probably not that of city dwellers dispersing into the countryside to take up subsistence production and local economy-based livelihoods. This is possible for a minority of urban dwellers, but most of those leaving the cities in Europe do not do this to become small rural producers again, but for an urban life outside the cities, consuming the amenities of rural landscapes and nature. They are still dependent on workplaces in the cities and commuting or doing distant work for urban-based firms. Also, the rather differentiated service economy developing in late European modernity does not necessarily support ecologically sustainable forms of rural dwelling.

Counter-urbanisation and remigration to the countryside under the auspices of globalisation is only a minor part of the solution of the problems to be tackled, as will be the new forms of producer–consumer cooperation developing with organic farming, community-supported agriculture, urban agriculture and consumer cooperatives. The food link is the most important connection between urban and rural areas. Sustainability cannot be achieved through relocalisation of food production and consumption alone; further changes are required. Changes in everyday life and culture, in the sphere of the lifeworld, towards environmentally friendly and resource-saving social behaviour – also in the strategies of social and environmental movements – are one part of the social changes that are happening. Other parts include the transformation of societal systems, especially the globalising economy, which needs to become a theme of scientific and political discourses about the environment, as is happening in social ecology with the term of a “great transformation” of socio-metabolic regimes.

To summarise the critical trends in food production, land use change and urbanisation that are studied in rural sociology and other disciplines, a social-ecological analysis of rural development is directed towards analyses of several processes:

1. The continuing colonisation of nature with the intensification of agricultural resource use requires research with new questions and indicators to show the limits of human resource use or its aggregate environmental effects.
2. The continuing colonialisation of the countryside through its social dominance and control by actors, resource users and institutions other than rural ones – urban dwellers, political institutions, economic firms, scientific institutions – is a consequence of capitalist modernisation of agriculture, in which social marginalisation of rural populations and producers reinforces ecological degradation of the land.
3. The changes in land use, continuing processes of deforestation and desertification of land, as well as the economic land-grabbing phenomenon show the depth of the natural resource crisis in the globalised economy at the beginning of the 21st century. This crisis is not a “normal” economic recession or a crisis of a long wave (Kondratjev cycle). Both may influence the resource use crisis, but its dominant factors are more long-term consequences of global environmental change evoking a global competition for agricultural land use.

4. The question of alternatives to the dominant model of industry, capital and science-based modernisation of agriculture and food production requires continued search for alternatives. The answer has not yet been found in the discussion about future agriculture (Chapter 5). More alternatives are shown in analyses of use of common pool resources.

Common pool resource research

Interdisciplinary research into natural resource use with the guiding term of common pool resources is influenced by the local resource use studies of Ostrom and her co-researchers. Her concept of common pool resources has been constructed from the economic terminology of private and public goods, implying qualities from both (subtractability through use, lack of private property), but the problems go beyond economic resource use, and also beyond the interdisciplinary perspective originally found in these studies combining economic and political science concepts such as that of individual and collective rationality of resource use. Common pool resource research has become a paradigm for social-ecological systems analysis, but restricted by local limitations in which little attention was paid to global exchange and resource flows. To broaden common pool resource research into a science of complex global resource flows between society and nature requires studies of global resource flows similar to those performed in social ecology.

In common pool resource research, paradigmatic forms of resource use have been fishery, fish being traditionally a common pool resource without private property rights, forestry, wildlife use, use of water resources in agriculture, and other forms of local production. These types of resource use overlap with the resource use studied in rural sociology, but in a broader perspective and through inclusion of further resources, not only natural ones. As common pool resource management has been focused on local case studies and local, community-oriented approaches to resource management (Table 2.3), it is difficult to draw conclusions for the governance of global resource flows from a sustainability perspective. Global resource flows influence the availability of resources for local users and communities, and local strategies are part of the manifold attempts to govern the global flows. But which forms of local resource use are effective as components of global governance is less clear. The simple rule of "local resources for local users" that is often assumed in the ecological discourse, and the more differentiated principles of sustainable resource use found by Ostrom et al. (Table 2.3), are not sufficient to address the global resource flows. Global resource flows and unequal exchange give rise to conflicts at local level that differ strongly between the countries from where resources are exported and those – in the global North – into where they are imported. In the "extracting economies" of the South, the conflicts often remain unsolved as such

Table 2.3 Design principles for institutions of sustainable resource use

The principles are derived from studies of long-enduring institutions for governing sustainable resources.

1. *Clearly Defined Boundaries*
   The boundaries of the resource system (e.g., groundwater basin or forest) and the individuals or households with rights to harvest resource products are clearly defined.
2. *Proportional Equivalence between Benefits and Costs*
   Rules specifying the amount of resource products that a user is allocated are related to local conditions and to rules requiring labour, materials and/or money inputs.
3. *Collective-Choice Arrangements*
   Most individuals affected by harvesting and protection rules are included in the group who can modify the rules.
4. *Monitoring*
   Monitors who actively audit physical conditions and user behaviour are at least partially accountable to the users and/or are the users themselves.
5. *Graduated Sanctions*
   Users who violate rules are likely to receive graduated sanctions (depending on the seriousness and context of the offence) from other users, from officials accountable to the users or from both.
6. *Conflict-Resolution Mechanisms*
   Users and their officials have rapid access to low-cost, local arenas to resolve conflict among users or between users and officials.
7. *Minimal Recognition of Rights to Organise*
   The rights of users to devise their own institutions are not challenged by external governmental authorities, and users have long-term tenure rights to the resource.

   For resource users that are parts of larger systems:

8. *Nested Enterprises*
   Appropriation, provision, monitoring, enforcement, conflict resolution and governance activities are organised in multiple layers of nested enterprises.

Source: Becker and Ostrom (1995: 119)

between local resource users and multinational companies in mining or agricultural production. In the North the conflicts are often not perceived by the consumers of imported goods. The resolution of such ecological distribution conflicts requires discussions about social and environmental justice and redistribution of resources between countries.

Ostrom's description of principles for sustainable resource management derived from local case studies is a first step of knowledge synthesis in common pool resource research and in developing a theory of natural resource use and management from a multi-scale perspective. In further syntheses by Ostrom (2007a, 2007b, 2009) the limits of common pool resource research for the study of global resource flows become more clearly apparent as problems for the management of large-scale and global common pool resources and for the analysis of global complexity of resource flows, which is more a social than an ecological complexity, resulting from global exchange and trade of resources and unequal exchange.

Common pool resource research supports the conclusion that institutional forms of common pool resource management that rely only on theoretical models are insufficient and inefficient because of their simplified and "decontextualised" approaches. Another important result is that the individual rationality model widespread in economics, the "*homo oeconomicus*" model, is empirically valid only in a limited range of common pool resource management cases and under specific conditions that do not allow its formulation as a universal principle. Common pool resource research has produced knowledge about the behaviour and learning of resource users in dilemma situations and for achieving cooperation, but it does not provide much knowledge of the management of complex and global common pool resources and resource flows. Also, Ostrom's (2007b, 2009) recent "multi-tier" framework of concepts to guide resource management is only an interim step in approaching the social, ecological and global complexity of resource flows. It is in that complexity, which is reflected in environmental sociology as the sociology of material and immaterial global flows, that the limits of knowledge and the limits of theoretical concepts are apparent, as well as those of the conventional management concept.

Changing views of resource management. A breakthrough from management ideas derived from local common pool resource research (see above, Table 2.3) towards ideas of adaptive governance – catalysed through the debate about adaptive management as experiment-based resource management that takes into account complexity and uncertainty in ecosystems (Hatfield-Dodds et al. 2007, Allen and Gundersen 2011) – came with the critical review of prior approaches to resource management (Acheson 2006, Ostrom 2007a, 2009). The review provided arguments for the development of a new science of complexity, of complex global systems, required for the future transition to sustainable resource use regimes. The three institutional alternatives of government, market and community-based resource management discussed in the past decades follow the dominant institutional structures configuring in late modern societies – the state, the market economy and civil society – modelling resource management from the societal system structures, not from the perspective of connected social and ecological systems. These ideas are now criticised as idealisations and simplifications, as decontextualised generalisations, widely practised, but not effective for the requirements of management from the perspective of interaction of social and ecological systems and under conditions of global change.

Social-scientific research that supports the emerging ideas of adaptive governance revealed the changing nature of these institutional complexes: to put it simply, all these institutional complexes became multi-scale phenomena in late modernity. The nation state, a symbol of modernity, differentiates into a multi-level state with local, regional, national and international action components (e.g., Aretxaga 2003). The modern economy has long since been a global phenomenon, a world system that transgressed the national spheres, from as early as the past epoch of European colonialism to the present globalisation (Wallerstein 2004, Held and McGrew 2007). Civil society, historically developing at local, community level through direct involvement of citizens in policy and decision-making, develops towards a multi-level phenomenon with the idea of global civil society emerging with global social movements and as a consequence of globalisation. Transferring the three modes of governance to the sphere of natural resource management, a first step towards a more complex and context-sensitive perspective, seemed to have already been done with these insights into the cross-scale nature and development of modern institutions, to which further governance debate added another idea: instead of one approach, selective combinations of the three approaches are required to create site and situation-specific solutions for resource management. The three approaches continue to be practised, reformulated under a variety of terms, as ecosystem-based management, adaptive management, adaptive governance or social-ecological systems analysis. These terms express two requirements in natural resource protection and management: to manage coupled social and ecological systems and to manage the complexity of multiple and interacting spatial and temporal scales for sustainable resource use under conditions of insecurity, low controllability, turbulence and surprise. The term of management itself is criticised because of its top-down, hierarchical, power-based perspective, and the premises of controllability of complex systems and availability of sufficient (scientific) knowledge for this purpose. Ludwig's (2001) description of adaptive management as management for the era when management is over aims at the limits of resource management, but still few ideas are found to formulate new governance strategies, except for some more or less inspiring metaphors such as navigating social-ecological systems or accounting for the non-computable. The "end of panacea" ideas fit into the critical epistemological debate about the limits of scientific knowledge that has gained momentum with the post-structuralism and postmodernism debates. These are over, but there is not yet another epistemological theory or paradigm to renew the knowledge claims of science (for climate research, see Grundmann 2007).

Environmental sociology and interdisciplinary common pool resource research have reached similar limits in their specialised knowledge production, which are apparent in the governance debate with preliminary concepts and ideas for which conventional strategies and methods of complexity reduction do not work well. The broadening and combination of resource management methods with participation of local resource users (Fisher et al. in Mol et al. 2009: 141ff) has not yet proven its social and ecological efficiency. Rather than the achievement of new procedures for knowledge production and management that can deal with global complexity, the new governance discussion indicates the authority crisis of environmental science that has accepted participatory and transdisciplinary knowledge production and utilisation in a situation where science and research alone cannot fulfil the expectations of politics, economy and society.

Transferring sociological knowledge in transdisciplinary discourses

Some theoretical conclusions for sustainable management of natural resources have been formulated from recent research in rural sociology supporting the conclusions from the review of environmental sociology. The resource use problems analysed in research into sustainable rural development (Bruckmeier and Tovey 2009) showed the significance of knowledge use and different knowledge forms in resource management. Also relevant is research into the dissolution of spatial boundaries between rural and urban land use and the changes of cultural landscapes with the modernisation of natural resource use.

Not much theoretical reflection and discussion of knowledge practices and knowledge use in natural resource management has been found in rural sociology so far, although many processes of changing agricultural and food production include knowledge practices and knowledge conflicts. In common pool resource research more attention is paid to knowledge problems, but not in an encompassing sense; rather, knowledge problems from the dominant cognitive interest are selected to identify conditions for cooperation of local resource users to avoid overuse and environmental damage. For the analysis of knowledge generation and application in natural resource use, concepts and models from epistemological and science studies can be used, although these could be seen as remote from the themes of rural research. One of the few discussions that aim to create conceptual models to interpret rural development is Marsden's (2003) preparatory study of "the condition of rural sustainability", in which he identified three competing dynamics of rural development (ibid.: 4). Two of these are based on data and experience from recent decades in European and global rural development, the agro-industrial and the post-productivist dynamic. Both identify trends and development trajectories that to a large degree still influence or even guide rural development, but they suggest a temporal sequence, with post-productivism replacing the agro-industrial dynamic. The third dynamic, called the "rural development dynamic", is less derived from historical experience but constructs a potential future for rural development under the auspices of sustainable development.

Science and technology studies with a variety of approaches (Van House 2004: 6ff), epistemological studies of science as social knowledge generation and use (e.g., Longino 2000), and social epistemology, which aims to bridge the gap between facts and values in knowledge production, barely address the questions of knowledge in natural resource management or in rural and environmental policies in their thematic specialisations. The research in the CORASON project (Bruckmeier and Tovey 2009) on knowledge processes in rural development – where scientific, managerial and local knowledge flow into each other – comes closer to the social-ecological questions of resource use. The aim is not so much to show the constructivism in knowledge processes, but rather how knowledge in different forms and combinations can help to reconnect social and ecological systems from the perspective of sustainable resource management. This reconnection is not achieved by use of local knowledge and traditional resource management practices, but requires inventing a new socio-metabolic regime (e.g., Fischer-Kowalski and Haberl 2007).

The CORASON research revealed the blending of knowledge types and the difficulties of demarcating type boundaries, but also the problems of conceptualising knowledge dynamics or knowledge-building processes in rural development. Only preliminary conceptual models were used to interpret the processes studied, especially the "epistemological bridges" framework, making use of the idea of sustainable development as a discursive platform concept that allows different actors to follow similar practices with their different interests. Ideas of situated knowledge can be used to study conditions of knowledge generation, communication and application. Concepts such as these to describe knowledge management processes can be found in epistemological and science studies, but some of these have been elaborated more closely to resource use discussion in interdisciplinary environmental research, for example:

1. the "collaboration and social learning" model of sustainability science and similar ideas of building social and ecological resilience in analysing the development of social-ecological systems (Folke et al. 2002, Berkes et al. 2003),
2. the concepts of co-evolution, adaptive management and adaptive change as a guide in studying practices of sustainable resource management (Becker and Ostrom 1995, Gunderson and Holling 2002),
3. studies of social metabolism, material and energy flows, and socio-ecological transitions which assess these for their consequences for sustainable resource management (Haberl et al. 2004, Weisz et al. 2006, Fischer-Kowalski and Haberl 2007).

To (re)connect ecosystems and social systems and maintain "sustainable linkages" between them over time seems to require the sort of knowledge combinations and practices discussed here. One step in the direction of interdisciplinary analyses of socio-ecological changes could be to develop indicator systems which would support joint learning by resource users. Refined frameworks and concepts for measuring progress towards sustainability have appeared in recent years through reflections on experiences with available and applied indicator systems, through analyses of multifunctional agriculture (Cairol et al. 2006) and societal metabolism and material and energy flow accounting (Haberl et al. 2004, Weisz et al. 2006). The construction of indicators to measure progress in the transition towards sustainability creates a link between scientific and policy discourses.

Conclusions

Research in environmental and rural sociology and common pool resource research has resulted in some similar ideas about natural resource management that indicate the difficulties of dealing with the controversies about natural resource management and transformation to sustainability or sustainable resource management:

1. In environmental sociology the idea of ecological modernisation has been supported, including a transformation of governance towards participatory approaches, which has been contested by critical approaches to unequal global exchange.
2. In research into common pool resource management, new resource management ideas in the search for locally adapted approaches have been formulated as adaptive management and governance.

   > Adaptive governance . . . focuses on the evolution of formal and informal institutions for the management and use of shared assets, such as common pool natural resources and environmental assets that provide ecosystem services. As such, the notion encompasses both the "efficiency" and "adoptability" of potential institutional arrangements, contributing to a clearer understanding of options for addressing different types of market and institutional failures which may impede the development and implementation of welfare-enhancing policy options.
   >
   > (Hatfield-Dodds et al. 2007: 1)

3. In rural sociology several conceptual models for sustainable rural development show the difficulties of formulating conditions for a societal transformation towards sustainability. As in the other two fields of research, new problems of knowledge deficits and of knowledge use have been identified.

Social ecology cannot directly connect with these research fields, but needs to take a step forward in interdisciplinary knowledge generation, taking up the theme of global resource flow analysis from environmental sociology and looking for improved knowledge and knowledge use strategies in areas social-scientific research does not cover: in finding epistemological solutions for knowledge synthesis and in discussing new requirements for global regulation of resource flows. The following ideas need to be developed further:

1. A reinterpretation of sustainable development, focusing on changing relationships between local actors and the emergence of new normative commitments to justice, empowerment, corporate responsibility and accountability to address questions of knowledge practices. It requires a theoretical framework for the analysis of boundary processes between social and ecological systems. A new sustainability perspective that connects resource use more critically to the ecological limits of natural resource use can develop from the present degrowth discourse.
2. To deal with the interaction of local and global processes of natural resource management, learning processes of actors cooperating in resource management need to take into account critical analyses of global resource flows. Analyses of cooperation and the combining of different knowledge forms need to address more critically the problems with achieving successful cooperation – problems of inequality, social exclusion, power differences, conflicts and incompatible interests. Cooperation and knowledge use happen under conditions of inequalities, differentiated ownership, and unequal access to and control over resources.
3. In the discussion of knowledge processes in resource management the distinguishing of scientific and other types of knowledge helps to identify problems in achieving sustainability, although one difficulty is that the boundaries between knowledge types are not sharp and there is exchange of knowledge and interaction between them. It seems useful to open the analysis towards more process-oriented views of knowledge generation, dissemination and application processes.
4. The future of sustainable development and natural resource management, independently of how these concepts are interpreted by the actors, becomes a question of knowledge-based resource use practices in which the interaction between and combination of different knowledge forms is decisive. This decisive issue requires a kind of transdisciplinary capacity for cooperation and knowledge use from the respective actors. In the end, cooperative knowledge management needs to meet the criteria for environmental and social sustainability: to maintain functioning ecosystems where the operationalisation of limits to resource use is the critical component, in terms of carrying capacity of ecosystems or formulations of ecological boundaries; and to develop sustainable livelihoods that reflect the conditions and constraints not only of ecosystems but also of social systems.

3
Sources of Social Ecology – Ecosystems and Natural Resources in Ecological Discourses

Social ecology is first of all ecology with a knowledge core coming from natural scientific ecological research. Ecology is the study of relations between organisms and their environment, according to a classical definition of Haeckel, which has been criticised as abstract or circular by Wiegleb (1992: 66). Wiegleb looked for more empirically oriented definitions, such as that of Begon et al. (analysis of the distribution of individuals, populations and communities in space and time) or Peters (prediction of biomass, productivity and diversity in ecosystems; ibid.). Ecology has during the 20th century become an interdisciplinary subject with a combination of natural and social scientific knowledge, in human, cultural and social ecology, adopting concepts and perspectives from general systems theory, economics and anthropology. Using a double perspective seems characteristic of ecology as well as social ecology today – that of understanding human nature as biological and cultural, studying man–environment relations (including the natural and the social environment) with the core concepts of organism and social actor and coupled social and ecological systems. The trend towards interdisciplinary ecology included several approaches:

– American human and cultural ecology at the beginning of the 20th century;
– philosophical anthropology in Europe in the first half of the 20th century;
– the holistic biology of Uexküll, which did not become influential in biology, but paved the way towards an interdisciplinary ecology (a heterodox variant of biology which, in its organism–environment analyses for plants, animals and humans, worked with sociological concepts of subjective actor–environment relations);
– ethology, and in the second half of the 20th century sociobiology, which, analysed in biology the social relations between animals, animal cultures and languages;

- the new human ecology globally spreading since the 1970s;
- systems ecology, including Odum's (1997) interdisciplinary ecology as the science of the total (biological, physical, human) environment where energy flows are seen as the main connection between social systems and ecosystems.

The question of the scientific knowledge bases for environmental research and investigation of human resource use has not remained an exclusively scientific one. In the environmental policy discourses, the formulation of knowledge requirements and expectations for resource management strategies has become a key issue. Whereas in the scientific discourses the opening of science to other forms of knowledge came under discussion with the transdisciplinarity and similar debates, the dominance of scientific knowledge was reconfirmed in policy discourses and programmes such as the global action plan "Agenda 21" (Box 3.1).

Box 3.1 "Agenda 21" – science for sustainable development

> A first step towards improving the scientific basis for these strategies is a better understanding of land, oceans, atmosphere and their interlocking water, nutrient and biochemical cycles and energy flows which all form part of the Earth system. This is essential if a more accurate estimate is to be provided of the carrying capacity of the planet Earth and of its resilience under the many stresses placed upon it by human activities. The sciences can provide this understanding through increased research into the underlying ecological processes and through the application of modern, effective and efficient tools that are now available, such as remote-sensing devices, robotic monitoring instruments and computing and modelling capabilities. The sciences are playing an important role in linking the fundamental significance of the Earth system as life support to appropriate strategies for development which build on its continued functioning.
>
> (United Nations 1993: 257)

Comment: This quotation from chapter 35 "Science for Sustainable Development" of the global environmental programme "Agenda 21" (resulting from the United Nations Conference on Environment and Development in Rio de Janeiro in 1992) shows that science is credited as the main knowledge source for environmental policy and sustainable development. Mainly natural-scientific and ecological knowledge is seen as necessary, summarised under the notion of "the sciences". Knowledge from the social, cultural and humanitarian sciences seems less important. Little attention is paid to interdisciplinary knowledge generation and use, and non-scientific forms of practical or local knowledge are also widely neglected (although local knowledge is mentioned). This understanding of environmental research is widespread among the powerful global players and environmental actors.

Source: mentioned in the text

In the scientific environmental discourses the search and integration of knowledge from different disciplines and sources include a series of controversies that can be traced back to the classical question of philosophical anthropology about the biological or cultural nature of humans. The main and continuing ecological controversy concerns the Malthusian question of population growth and limits of resources for human subsistence. In this controversy older questions come up: about man and nature – connection or dissociation; about human nature – biological or social and cultural; about the relations between society and nature, in present terminology between social and ecological systems. The growth of ecological, anthropological and sociological knowledge caused changes in concepts and problem formulations that altered the basic questions and shifted the lines of controversy, but the controversies are not finally solved – there is no epistemological consensus about scientific knowledge in environmental research.

Ecosystems and natural resources: basic controversies

Social ecology, analysing the interaction of humans with their natural and societal environment, aims to generate knowledge to safeguard capacities of reproduction and development of society and its natural basis of life (ISOE 1999). This interdisciplinary approach is developing from heterogeneous knowledge sources, theoretical systems and analytical perspectives. Social ecology inherited epistemological and theoretical controversies over knowledge production from ecological research. A classical controversy related to human resource use which has continued for more than 200 years concerns the Malthusian question of whether and why population growth exceeds limits of resources for subsistence and how the resulting social problems can be solved. As in other cases of enduring scientific controversies, this one, instead of finding definite answers, has been interpreted in different ways and updated with new scientific knowledge.

The view of Malthus that population growth always exceeds subsistence was rejected several times, in the 20th century in agricultural research by Boserup (1965), who developed a causally and historically more refined explanation model for historical societies, in which improved agricultural productivity and population growth interact in causal circularity: population pressure causes agricultural intensification so that the problems are temporarily solved until they emerge again with further population growth. The model has simplifications, as has been pointed out in the anthropological debate: "sequences of agricultural intensification" can be influenced by "market systems, political pressures, and environmental variables" (Orlove in Haenn and Wilk 2006: 208). Such factors are also important for modern capitalist society with its economic world system, for which the population growth controversy has not been solved. In spite of the demographic transition and slow-down of population growth in industrial countries, the global population has grown exponentially in the 20th century and is expected to peak in the mid-21st century. This population growth is part of the discussion of reasons and causes for the global environmental crisis. The "population bomb" debate (Ehrlich and Ehrlich 1968) and the study about global "Limits to Growth" (Meadows et al. 1972) intensified the controversy. The discussion has shifted from Malthus' question about resources in a country at the beginning of industrialisation, before the demographic transition and with the agricultural knowledge of that time, into one for the present world society, as a question of environmental pollution and for a broader resource base that includes the main industrial resources. The core question has become whether the quantity and intensity of resource consumption in Western, industrialised countries can be spread to all countries in the non-industrialised global South. In that form it is waiting for more exact answers from environmental research, to find solutions for a global transition to sustainability.

The Malthusian controversy contains several further controversies (see Chapter 2) about the relations between nature, society and man as paradigmatically formulated in older philosophical anthropology and in interdisciplinary human ecology. These controversies over man and nature, human nature, and the relations between society and nature or social and ecological systems need to be dealt with in developing the social-ecological perspective of interaction between society and nature. In the natural-scientific sources of social ecology these controversies about scientific knowledge are not always manifest.

The natural-scientific sources of social ecology include (1) ecological, biological and physical research about man–nature interaction and (2) thematically focused, more interdisciplinary research about specific aspects of society–nature interaction, emerging from the former. This chapter focuses on the second group of sources, as these approaches include knowledge needed for the syntheses of social ecology. Several natural resource theories – physical resource theory, systems ecology and ecological anthropology – provide knowledge for (partial) answers to the controversial questions about limits to growth. Physical resource theory contributes with theory-based answers to the question of natural limits of human use of natural resources in a more systematic sense and for more physical resources than in the Malthusian debate. As in systems ecology, energy resources are a core theme, since these are seen as critical resources in the global economy and for industrial development. In ecological anthropology, questions of societal and individual reproduction are taken up in historically specified studies of sociocultural resource use practices. Ecosystem research is a summary term for several applied research approaches to provide knowledge for ecosystem management (such as resilience research). More interdisciplinary perspectives in ecological research are illustrated below, with examples from sustainability science and analysis of social-ecological systems (SES).

Natural resource theories

Physical resource theory

Physical or non-living resources – minerals, soil, water, air – are not systematically investigated in physics but rather in geology, physical geography and resource economics (e.g., Perman et al. 2003, Tietenberg 2003; Hall and Klitgaard 2011), with questions of availability and distribution of natural resources in ecosystems and in society, or for human resource users. "Resources" is a very broad term, used in several disciplines and research fields, with multiple classifications. Giddens' distinction between allocative resources, which include natural resources, and authoritative resources, which refer to social organisation and the human body and life, uses the terminology of economics for the first and political science for the second resource type. According to Giddens, both types together show the unfolding power relations in societies and their resource use practices (Lawrence in Steiner and Nauser 1993: 223). For physical and ecological resource use research, this interdisciplinary classification seems hardly relevant. These approaches work with the concept of natural resources classified in physical or non-living and biological (or living) resources, renewable and non-renewable resources, stock and flow resources and material and energy resources. The term of natural resources is applied in ecology for humans and other species, from a perspective of biological reproduction and maintaining life. It is broadened in recent interdisciplinary ecology to include life-supporting functions of ecosystems. With that the resource concept becomes more controversial, as the relation of a resource to a clearly identifiable user is vanishing. The resource concept has been critically discussed in theoretical human ecology by Freese (1997a), showing that this functional term is difficult to replace. The term may only be converted from "the orthodox utilitarian idea of resource into the unorthodox systemic idea of resource function and turning it from an entity into a process concept" (ibid.: 236).

Physical resource theory is a multidisciplinary field of research that has sometimes been seen as part of human ecology. This research refers to systems in nature and society that convert energy, material and information. The resources and resource use processes studied include both living and non-living resources, and these are analysed in a broader perspective than individual resource use, including the industrial and societal metabolism that is more systematically investigated in social ecology. Physical resource theory works with theoretical variants of functional systems theory and complex systems analysis. In social ecology there are more options to apply social and natural scientific theories. Although physical resource theory and social ecology have similar questions and themes, including use of energy, biomass, land and mineral resources, they differ significantly. Social ecology makes systematic use of social and natural scientific theories to analyse the systemic nature of resource use processes, as is indicated in the terms of societal action or practices and agency, whereas in physical resource theory society in its dimensions of modern societal systems remains a black box.

Specific physical resources, especially fossil energy resources (coal, gas, oil), have become the natural resource base of industrial production processes. With industrialisation and the concomitant processes of urbanisation, human resource use increased greatly compared with earlier modes of production, made possible through scientifically based resource use technologies, use of hitherto unused fossil resources, and global exchange of resources. Industrial production is the paradigmatic economic type of human resource use, also including agricultural production, which has through its modernisation become subjected to industrial principles of high external input of energy and resources in terms of oil, fertiliser and agrochemicals. The forms, limits and environmental effects of industrial production give a main reason for physical resource analysis and, in social ecology, analyses of resource flows between society and nature, from the "physical economy" perspective (Chapter 4).

Discussion. In physical resource theory a variety of themes are discussed that are connected through their relevance for sustainable resource use practices. It is difficult to summarise the results of the research, dispersed among case studies and model-based analyses, which is not as focused as in social ecology on core processes of globally relevant resource flows from economic and ecological perspectives. This seems to be a consequence of a disciplinary perspective that is not fully open to inclusion of social scientific knowledge. Society is, for physical resource theory, sufficiently understood as a variant of complex systems. Whether complex adaptive systems represent a new social-ecological perspective to include the knowledge about societal systems, as assumed by Smith et al. (2011: 73), is doubtful. A variety of themes are included in research under the abstract umbrella terms of complex systems and sustainable development, often using modelling methods (e.g., Berndes et al. 2005). The modelling approaches include the search for technical solutions to resource use problems and limits. The unifying concept of complex systems, understood as systems with many interacting components, encompasses systems in nature and society, but its theoretical contours are rather vague. It is specified for analysis mainly through examples of such systems, without theoretically systematising the components of complex systems in nature and society and their specific differences. For the overarching theme of social ecology, interaction of society and nature, physical resource theory delivers natural-scientific knowledge, which is relevant to the resolution of certain environmental and resource use problems and can be translated into resource management strategies. But the specific connections between high levels of energy and materials use, capitalist industrial production, globalised markets and mass consumption in modern societies – all of which support the economic growth mechanism – are not analysed further and more critically in physical resource theory. This theory shares with social ecology the study of industrial metabolism as an area of research in which material flow analyses become important for the understanding of economic mechanisms. Connections to the theory of societal metabolism exist; however, the societal metabolism perspective is not systematically applied in physical resource theory.

Systems ecology as ecological resource theory

An ecological resource theory broader than physical resource theory is unfolding in systems ecology as a holistic approach to deal with the complexity of ecosystems, including physical resources in the analysis of ecosystems and biological resources including food resources. The reproduction rates of these resources can be modified by humans in the processes of colonisation of nature, including plant and animal breeding and genetic modification of plants and animals. The modification of nature through human labour and knowledge has resulted in colonised ecosystems that exclusively produce food for humans, or for the animals produced in agriculture and aquaculture that deliver human food or become food for humans. Natural resource use for human subsistence is studied in systems ecology and in social ecology with regard to the energy and material flows in ecosystems, but social ecology has created more systematic theoretical concepts to measure the human appropriation of material and energy resources.

Odum's holistic ecology, described as analysis of relations between parts and wholes in a system-theoretical terminology (Odum 1997: 34), is an integrative science to connect knowledge from ecological science and the broader spheres of human society, similar to the analysis of ecological interactions between society and nature in social ecology, but less interdisciplinary. The core processes in ecological analyses of human resource use are energy flows that maintain primary production of ecosystems as a basis for human food production and the material cycles of water and biochemical cycles as physical conditions of life. The ecological descriptions of life-support systems, food chains and food webs and conditions of human resource use – within the limits of physical and biological laws – include basic knowledge about biogeochemical processes that maintain human life. But ecological analysis does not say all there is to say about human appropriation and use of natural resources. The social and cultural complexity and the historical changes of human societies in which humans modify nature under specific social relations are only selectively, not systematically, studied in systems ecology, to the extent that they result in modifications of ecosystems through agriculture, fishery, forestry, industry, urbanisation and the knowledge or technologies used in human production processes. Furthermore, this analysis does not include the systemic complexity of society as described in political economy and social ecology, where the social distortion and manipulation of natural resource use are more systematically analysed in quantitative terms and with regard to power relations. Odum's ecology ends where the historical complexities of socio-economic systems, modes of production and socio-ecological regimes begin. It remains an analysis of the interaction between human society and nature in terms of ecosystem functions and processes, although it takes up important problems for the regulation of the interaction between nature and society, such as the multi-scale ecosystem processes. His discussion of human societies (Odum 1997: 231, 305f) derives from a comparison with ecosystems, but he underlines the different cause–effect relations in both systems. The formal term of complex systems does not make it possible to understand the historical complexity of societal systems, which appears in system-ecological analyses only as single examples of socially structured resource use processes (such as agriculture) that change ecosystems. Societal system structures, capitalist economy and scientific technologies differ from ecosystem structures and processes, supporting the impression that societies become more and more independent of nature (e.g., Castells 1996), although this only masks the human and societal dependence on nature and the ecological processes that maintain human life. The human capabilities to modify and redirect resource flows so that the natural limits of production of a given ecosystem are no longer decisive for human subsistence contribute to this masking of the interactions between society and nature. Dependence on local ecosystems can be overcome through production technologies, trade and exchange of resources and food, and mechanisms of reappropriation and unequal exchange that have become fully effective in present globalisation and require more interdisciplinary approaches, such as social ecology.

Discussion. Systems ecology and Odum's holistic perspective do not give significant new answers to the controversial questions about human–nature relations, society–nature relations, human nature, or the Malthusian ideas of population growth. Ecological research, following a biological paradigm of humans, confirms the assumption that humans as biological species and as social beings are part of ecosystems and embedded in nature. But in this research, although the human modification of ecosystems is analysed in detail, the consequences of the societal transformations of nature that happened in human history cannot be assessed beyond the changes of ecosystems in terms of functional disturbance of ecosystem services and primary production, reduction of biodiversity or pollution. In this analysis of human modification of ecosystems, human culture serves to explain two opposing processes: the embedding of societal resource use practices in ecosystems, and their dis-embedding in forms of pollution and overuse.

Regarding measurement of human modification of ecosystems and ecological functions through withdrawal of resources, ecological research has achieved limited progress. Humans need to share the resources and the food available on earth with other species; human subsistence becomes part of a complicated food web in which species eat other species to survive and maintain the functions and the reproduction of ecosystems. Discussion of the limits of human appropriation of ecological primary production has only recently begun, analysing how much of the biomass in a given area is harvested by humans and how much can be harvested without disturbing ecosystem functions and the reproduction of other species. And attempts to formulate "planetary boundaries" of human resource use are still more recent (Rockström et al. 2009). Analysing the interaction between society and nature, the interdisciplinary ecology of Odum has little to say in terms of a more in-depth analysis of why and how human modes of production or socio-ecological regimes affect or disturb global ecosystems, ecological functions and cycles.

Ecological anthropology

Moran (1990, 2000) has summarised the development of ecological anthropology and noted the problems and difficulties with a shift to ecosystem ecology in anthropology, which he attributed to Geertz (Moran 1990: 11ff):

– a reification of the ecosystem concept, which tended to be conceived of as having organism properties;
– a "calorific obsession" with measuring energy flows in ecosystems;
– ignoring historical time and structural change in the construction of ahistorical models that overemphasised stability and homeostasis;
– focus on populations and neglecting the action of individuals;
– lack of clear criteria for defining boundaries of ecosystems;
– not resolving the dilemma of level and scale shifting that Moran saw as a major problem to deal with in phenomena of global environmental change.

A "global approach to environment is necessary, given that the problems posed by industrial emissions cut across national boundaries and require concerted, or global, agreement on what each nation will do to combat the problem . . . On the other hand, it would be a mistake to think that resource management will be adequately addressed by these broad policies. Resource management is ultimately a site-specific task in which social, political, legal, and historical dimensions are at least as important as environmental ones. Local actions have global consequences when they converge in given directions, but corrective actions have to deal with the motives for the actions of individuals who act rationally, within the incentives and experience within which they live" (Moran 1990: 24). He saw the global change theme as a domain of future research in ecological anthropology. But it seems that he has instead formulated the research area of the emerging social ecology.

In his later summary of new directions in environmental anthropology (Moran 2000: 307ff) he takes up the question of global change and its effects on society, but it remains again a listing of desired and required research for which concepts and methods from various environmental research fields are compiled. From this summary of the state of the art, ecological anthropology appears as a synthetic discipline that makes use of knowledge from many fields of specialised research: human adaptation to global environmental change, remote sensing and geographical information systems (GIS), land use and ecological landscape analysis, global circulation and integrated assessment modelling, urban ecology, experimental approaches, common pool resource research and knowledge from political economy for studying human adaptability. In somewhat modified formulations, programmatic questions for future research are again formulated that mark a more specific area of future research in ecological anthropology, including questions for social ecology:

> What are the limits of our flexibility as a species? What are the effects of perception and cognition on adaptability? And what are the most significant changes in the twenty-first century that will impact our species? To address these questions will require that researchers broaden their perspectives beyond biological considerations and socioeconomic surveys to include concerns from cultural anthropology about meaning, perception of resources, and modern economics. New perspectives will have to include investigation of the social and psychological concerns of populations and not merely their fitness and wellbeing. Research needs to include multi-scale analyses, linking households to communities and national and international considerations. Seen as crucial to its future relevance is a more critical examination of the goals of research with due consideration for the relevance of the research to the people studied and a more activist stand by researchers and their responsibility to the study community. This will mean a more active role, and participation, by the local community in the research.
>
> (Moran 2000: 331f)

These formulations show how anthropology, developing from local studies, struggles with the investigation of global change. What exactly ecological anthropology can contribute to global change research remains somewhat unclear. Moran's formulations are reminiscent of what is being broadly discussed in interdisciplinary environmental research, in sustainability science and elsewhere. For studying problems of global environmental change Moran's proposals show similar difficulties to those of cultural anthropology in addressing questions of globalisation that are beyond its traditional approach of studying local systems and areas.

Discussion. Moran's review of ecological anthropology does not answer in detail the basic controversial themes and questions framing this chapter. It is obvious that ecological anthropology, like cultural anthropology more generally, takes specific, distanced stances on these questions. It follows the methodological traditions of cultural anthropology, studying local cultures, communities and areas. Big questions of nature and society cannot be answered sufficiently by empirical anthropological research. Global problems appear from the "bottom-up" perspective of micro-social empirical studies, as problems to deal with, but without showing their systemic nature. Ecological anthropology, with all its arguments for interdisciplinarity reaffirmed by Moran, has not come far in addressing the complexity of societal systems in their interaction with nature; this remains to be done in social ecology. Also, the controversies about human resource use and overuse are not finally answered or solved by empirical knowledge from ecological anthropology.

Ecosystem research

Moran notes the future research requirements in ecological anthropology that will help to study and solve global environmental problems. With that he also approaches the work and methods of ecosystem research (studying functions, services and management of ecosystems, e.g., adaptive management and environmental governance) and resilience research (ecological, social and social-ecological resilience). Searching for practices and strategies of natural resource use that allow sustainability, to maintain services and functions of ecosystems as life-support systems, may be seen as an implicit normative perspective of this ecological research. This commitment is not always reflected as a normative or ethical issue, but is often seen as a functional prerequisite of life support and ecosystem development. Continuing in the tracks of earlier environmentalism, with a new ecological paradigm, such naturalistic thinking is struggling with the epistemological heritage of ecological fallacies: that nature gives the direction for society and man needs to follow or to obey. When controversial interpretations of nature are discussed, as in the older ideas of biosphere and noosphere (sphere of life and spiritual sphere: de Chardin, Vernadsky) or in Lovelock's more recent

Gaia hypothesis in which the global biosphere appears as a super-organism and part of living systems, such normative implications are taken up more explicitly.

Ecosystem approaches

"Ecosystem approach" is a shorthand term for manifold applications of knowledge from ecosystem research in the management of natural resources, rural and urban, on land and in the water, in many policy approaches, and under the guiding idea of sustainable development. The guiding ideas or principles (Table 3.1) remain in doubt as to whether they are derived from empirical ecological research or circumscribe a management philosophy that uses an ecosystem terminology in vague and in often unclear meanings.

The principles summarised below (*refers to Table 3.1*) are formulated normatively as action principles in a policy-oriented language. Like all principles, they are abstract, requiring resource managers to interpret them or make guesses and their own valuations when applying them, thus exposing ecosystem management practices to contingency – they can be applied differently. This form of principles for resource management was characterised long ago by Simon as proverbs of administration. Warnings from ecologists about the use and misuse of ecosystem ecology in environmental policy and resource management are important, but devalued through the

Table 3.1 Principles of the ecosystem approach

1. The objectives of management of land, water and living resources are a matter of societal choice.
2. Management should be decentralised to the lowest appropriate level.
3. Managers should consider the effects of their activities on adjacent and other ecosystems.
4. Potential gains from management should be recognised; there is usually a need to understand and manage the ecosystem in an economic context.
5. Ecosystem structure and functioning should be conserved in order to maintain ecosystem services. This should be a priority target.
6. Ecosystems must be managed within the limits of their functioning.
7. Action should be undertaken at the appropriate spatial and temporal scales.
8. Objectives for ecosystem management should be set for the long term.
9. Management must recognise that change is inevitable.
10. Action should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
11. Action should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations and practices.
12. The approach should involve all relevant stakeholders of society and scientific disciplines.

Source: Shepherd (2008: 5); Macintosh et al. (2010: 2) conventional understanding of science as the exclusive producer of objective knowledge that works in strict separation from society, policy and practice, where values prevail (see Box 3.2).

Box 3.2 Ecosystem research (ecosystem ecology)

> Ecosystem ecology has been particularly successful in providing management information about some of society's most serious and vexing environmental problems such as acid rain, eutrophication, nitrate pollution, and resource management at large scales (e.g., forestry and fishery resources). . . . The future of the world's human societies still depends upon natural resources. In fact, water, croplands, forests, and grasslands underpin the world's economy. Except for fossil fuels and minerals, they supply all of the raw materials for industry. Moreover, natural, vegetated landscapes reduce erosion and filter pollutants from air and runoff water. They reduce extremes of flooding and provide food and fiber – all for "free" because these natural systems are powered by the sun . . . These ecosystem services are provided by nature, but are not included in mainstream economists' cost/benefit analyses. Such benefits should be included, because these life support systems comprise our most valuable asset. When these natural life support systems are degraded or destroyed, then as a society, we must burn fossil fuels for energy to replace the functions provided by the natural ecosystem – for the construction of flood control dams and levees, for water purification systems, for air conditioning systems, and so forth. In addition, the enormous consumption of fossil fuels by humans is the basic cause of several of society's most serious and expensive environmental problems, e.g., acid rain, pollutant ozone and global warming. . . . Environmental degradation is not inevitable; it is simply cheaper and easier for some in the short term. Environmental health also is not inconsistent with economic imperatives and political realities. In fact, a healthy environment is the basis for a healthy economy. Ecosystem ecology provides an important and useful approach both for assessing and for helping to restore the "health" of the biosphere.
>
> (Likens 1992: 144f)

Comment: The final sentences by Likens exemplify a blending of fact-based and normative reasoning that the author otherwise disparages as value-based thinking of environmentalism. As it cannot be assumed that value-based thinking is better in science than in politics or social

Box 3.2 (Continued)

practice, this can be seen as contradictory reasoning that appears at a critical point in ecological knowledge practice: when it comes to translating ecological knowledge into resource management strategies, the ideas and recommendations become openly normative, some also vaguely and metaphorically formulated, as with the term health. The criteria for assessing ecosystem states seem rather unclear and unrealistic – as if it were possible to restore ecosystems to an original, undisturbed or pristine state.

Source: Likens (1992)

Ecosystem analysis in ecology has developed into the broader interdisciplinary streams of systems ecology, systems theory and systems thinking, with classical interdisciplinary approaches such as the general systems theory in biology by Bertalanffy. The renewal of systems thinking in recent development of a new ecosystem approach adopts the heritage of systems thinking with the core ideas of complexity, holistic thinking, managing for sustainability, and bridging science and values (Waltner-Toews et al. 2008) and connects ecosystem research with that of SES. The conceptual integration of the notions of nature and society in SES is built on a single assumption, formulated in the metaphor of humans as dwelling in ecosystems, that is another variant of the "new ecological paradigm". "Humans-in-ecosystem . . . , or the 'dwelling perspective' in the evocative terminology of the anthropologist Tim Ingold . . . refers to the practical engagement of humans with others of the dwelt-in-environment. This practical engagement, building knowledge and ecological relationships, is the basis for putting humans back into the ecosystem" (Berkes and Davidson-Hunt in Waltner-Toews et al. 2008: 110).

The study of human–ecosystem interaction and adaptation has a longer tradition in anthropology. Moran (2000) compiled the knowledge from ecological anthropology of how humans adapted to different ecosystems and biomes. This opened into the new direction of human adaptability to global climate change. For Moran, the "ultimate goal of human adaptability studies is to discover generally applicable systemic properties and to understand the processes of human coping behavior" (Moran 2000: 338). This goal was still unachieved for Moran, but the newer approaches discussed here seem to be further steps on the way towards that goal. The "practical engagement perspective" summarised by Berkes and Davidson-Hunt (in Waltner-Toews et al. 2008) refers to the long history of human adaptation to the environment and tries to bring back lost ecological knowledge and capacities to humans in late modernity to enable them to live sustainably in a world of globalisation and global environmental change. Traditional ecological knowledge is the term for documenting the historical connections between ecosystems and humans with their manifold cultures, abbreviated as "a knowledge-practice-belief complex" (ibid.). The argument is not to bring back traditional ecological knowledge to the majority of humans who have lost it during modernisation, industrialisation, urbanisation and globalisation, although there are frequent arguments for maintaining and strengthening the local ecological knowledge that still exists in the context of ecosystem approaches and social-ecological system analysis. Rather, Berkes et al. (2003) search for equivalent knowledge–practice–belief complexes that work under present conditions of historically changing social and nature–society relations that are described as "anthropocene".

Discussion. Interdisciplinary ecological research, with the variants discussed, appears as a melting of different ideas and knowledge components, not reflected systematically in epistemological and theoretical terms. In ecosystem research a variety of questions come up with the integration of ecological, social-scientific, normative and epistemological knowledge. The problems of knowledge integration include the following:

1. Attempts to develop with the help of the ecosystem concept a more holistic understanding of processes in nature and of interaction between society and nature than with the more elementary concept of natural resources.
2. Attempts to fuse two incompatible conceptual systems or scientific languages, that of a generalised, abstract and universal systems theory and that of a contextualised, locally and culturally specific knowledge culture.
3. Attempts to connect science and practice in such ideas and practices as ecosystem management, adaptive management and adaptive co-management (Armitage et al. 2007).

The trials of a synthesis of knowledge from ecosystems research by Waltner-Toews et al. (2008) are cautious. This synthesis and the more critical epistemological reflections by Funtowicz and Ravetz – who participated in that discussion by reflecting ecosystem approaches with the help of their idea of post-normal science – do not come together. The new or emergent complexity ecosystems research tries to grasp is not fully explainable in mechanistic and functional terms (Waltner-Toews et al. 2008: 311). The differences between ecological and social complexity increase when emergent complexity is further characterised by the interplay of techniques, consciousness, domination and control, when power factors are accounted for, and when contradiction, as part of dialectics in the sense of coexistence of antagonistic forces, is described (ibid.: 313). The notion of emerging complexity is brought under social-scientific guidance with the post-normal science concept in describing "new conceptions of scientific practice, involving its epistemology, methodology, and power relations" (ibid.: 315), which finally make it necessary to bridge the gap between science and social practice with the help of symbolic representations and ethical reflections to approach the idea of sustainability (ibid.: 318ff). This contact between ecological and epistemological discourses leaves the impression that the problems with power relations can be solved through normative or ethical reasoning – which may not be sufficient.

Resilience research

The relations between resilience research and social ecology are complicated. Discussing them implies figuring out the contributions of sustainability science and SES, both of which are connected to resilience research. The resilience discourse is reviewed first and in more detail than sustainability science and SES. Holling (1973) brought the idea of resilience into ecological research. Only towards the end of the 1990s did a more intensive debate begin, which spread quickly in the following decade. A first review by Gunderson (2000) showed resilience still to be conventional ecological research, and even the overview by Gunderson et al. (2010) is oriented to ecosystem research. Resilience became an interdisciplinary concept and was touched by controversies between realist and constructivist epistemologies when Adger (2000) asked "Are social and ecological resilience related?" and Haila (2000) discussed the substitution of dualistic thinking about nature and culture through a contextual socio-ecology in which social and ecological systems are seen as integrated in different forms and degrees, which is already an established idea. Both debates show the trajectories laid out for the resilience discourse when crossing disciplinary boundaries between ecology and the social sciences with the conceptual framework of SES. Empirical studies of local SES are found in ecology; more theoretical variants of SES analyses develop in social ecology with new interpretations of the interaction between society and nature. From theoretical analyses of SES new ideas can be expected to differentiate between continuation, change, irreversibility and collapse of complex SES, which is difficult because of differing criteria for defining state and change in social and ecological systems. Discussion of such criteria connects resilience research to the broader research on complex systems that includes sustainability science, epistemological (Cilliers 2005), anthropological (Lansing 2003) and sociological research (Urry 2003) (Box 3.3).

Box 3.3 Terminology – ecological resilience research

In ecology resilience was first conceived of as a way to maintain the stability of an ecosystem after disturbance, then as the possibility of changing stability domains after disturbance (Gunderson and Pritchard 2002: 4). In a critical discussion of variants of the ecosystem concept which influence the understanding of resilience, Pickett and

Cadenasso (2002) differentiate between meaning (definitions), model (specification and application of the concept) and metaphor (informal use in scientific and public debates). Among the properties of a system measured as resilience, the "stability–persistence–change" nexus is the core for theoretical descriptions of system states and their evolutionary or disruptive change under the criterion "capacity to absorb disturbance". Social and ecological resilience refer to dynamics, functions, structures and behaviour of a system at different points in time, with changes in behaviour affected by factors internal and external to the system.

Two basic variants of resilience of ecosystems have been called

– "engineering resilience" (Pimm 1984), assuming an equilibrium or steady state of ecosystems, measuring resilience as return time to that state after disturbance (e.g., the return time of a parametric factor such as population size of diverse species in an ecosystem after a catastrophe), and
– "ecological resilience" (Holling 1973), assuming conditions far away from steady state where disturbances can result in a shift towards another of many possible equilibrium states, measuring resilience as magnitude of disturbance that the system can absorb before it shifts to another state (Gunderson and Pritchard 2002: 4, Janssen and Anderies 2007: 45f).

The differences between the two types of resilience refer to systems with one equilibrium state and systems with several potential stable states or multi-stability. Whether alternative states of stability or balance are theoretical constructions or can be derived from empirical observations is controversial (Scheffer and Carpenter 2003). Holling broadened the concept in more recent debates to analysis of SES and formulated the influential idea of the adaptive cycle to model resilience of ecosystems, specifying the notion in a process model (Janssen and Anderies 2007: 47f). The adaptive cycle model oscillates between operational definition, theoretical codification and normative model and metaphor (Krasny and Tidball 2009: 469). It includes a conceptual model of ecosystem dynamics with two system states, stability and change, with ecological resilience appearing as a combination of stability and change or stability through change. The normative assumptions and constructions in defining (eco)system states are meanwhile discussed critically (Scoones 1999, Cilliers 2005, Bakker and Bridge 2006, Manson 2008) – for example, the premise that a functioning life support system is required to maintain social and economic development (Leach 2008).

Box 3.3 (Continued)

In a review of resilience types, Brand and Jax (2007) differentiate between descriptive variants of resilience (ecological resilience as original ecological, extended ecological, systemic-heuristic, operational; social resilience as sociological and ecological-economic term), hybrid variants (related to ecosystem services and social-ecological systems) and normative variants (metaphoric, sustainability-related). This typology shows several features of the broader resilience discourse: it is dominated by ecological meanings of the term when analysing ecosystems and social systems; in the sequence of descriptive, hybrid and normative concepts resilience becomes a vague and unclear notion that can be interpreted arbitrarily.

Sources: mentioned in the text

Interacting and complex systems in nature and society. The resilience discourse unfolded with discussions of resilience of large-scale systems (Gunderson and Pritchard 2002), panarchy (Gunderson and Holling 2002) and the navigation of SES (Berkes et al. 2003). The broadening of the ecological resilience debate with SES brought critical debates about the application of the concept to social systems, where the social-ecological core theme of global resource flows comes into view. To maintain the ecological concept in analyses of SES, with human behaviour reduced to enhancing or reducing ecological resilience, seems sufficient for specific classes of SES where natural resources use is the main purpose: in fishery, aquaculture, agriculture, horticulture and forestry. For these practices the materiality of nature and natural resources may not be a question as controversial as in epistemological debates about the nature of materiality (Bakker and Bridge 2006). For many other types of coupled and complex SES, such as for large parts of industrial production and urban systems, for national economies, for global level analyses of interacting social and ecological systems and for sociocultural systems in which symbolic interaction of nature and society is important, the application of the ecological resilience concept seems more difficult, as is generally the case for systems designed and planned by humans.

Complexity questions accompanied systems theory from the beginning. Earlier system analyses in the social sciences – for example, in Simon's (1962) "architecture of complexity" or in sociological systems theory (Luhmann 1984) – consequently did not include ecosystems in the analysis, in spite of their terminology transferring concepts and ideas from biology to social research. That complexity is a basic quality of social and ecological systems is evident, but not how complexity affects resilience, beyond the basic idea that complex systems are said to be continually changing, not reproducing in identical states (e.g., Urry 2003, Cilliers 2005).

The broadening of the resilience debate for SES evoked a controversial discussion about different stability domains in ecosystems influenced by humans (Gunderson and Pritchard Jr, 2002: 257): whether alternative stable states and decreasing resilience exist only in systems with humans or also in systems without humans. Furthermore, ecological and social resilience may require contradictory behaviour of human individuals, groups and resource management institutions (e.g., Sapountzaki 2007), and the application of resilience research in resource management may be complicated (e.g., Anderies et al. 2006). Possibilities of matching social and ecological resilience need to be sought in complicated experimental means of improving resource management to meet conditions of resilience and sustainability (Acheson 2006, Ostrom 2007). Problems of terminological variation, incoherence and contradiction were discussed early in resilience research (Peterson 2000: 325), but results remain unclear and controversial. Given the heterogeneity of interacting systems and actors, the specificity of cases and contexts, and epistemological differences, a common concept for all kinds of human, social and ecological resilience seems unlikely. Masten and Obradovic (2008) opted for that possibility. Regarding disaster management, they highlight parallels in what they call (human) developmental and ecological sciences. Their conclusion that similarities can be found from research in different disciplines risks a levelling of differences between social and ecosystems.

Critical questions of relations between different system types cannot be avoided when adaptive capacity, (ir)reversibility of state changes, temporal and spatial scales of resilience are discussed, approaching the complexity of SES (Gunderson and Holling 2002) and introducing a conceptual differentiation between resilience of ecosystems and robustness of human-designed systems. It is assumed that the term “resilience” is difficult to apply to systems with consciously designed components (Carpenter et al. 2009), where “the reflexive nature of humans” (Janssen 2006: 128) is included and coupled cycles of change interact across several scales (Gunderson and Holling 2002). The term “robustness” does not clearly show the differences between systems with its emphasis on “the cost-benefit trade-offs associated with systems designed to cope with uncertainty”, or how “SESs can deal with disruptions” (Anderies et al. 2004: 1, Perrings 2006: 217f) beyond multiple managerial, institutional, technical and design components to respond to perturbations (Janssen and Anderies 2007: 46).

Designed systems governed by humans are characterised by conscious or planned human interventions, based on abilities of anticipation, reflection, elasticity, variability and modification of resource use practices that vary more than the behaviour repertoires of other species or of ecosystems. Human action can support or block ecological resilience, consciously or as a non-intended effect, through the potentials and limits of cooperation and collective action, through unequal power and irreconcilable conflicts between interests and actors, through social and system structures – as in the present global economy – that enhance overuse and resource crises and block sustainable solutions. The heterogeneity of human systems, including organisations, economic and political systems, institutions for resource use and resource management, and cultural systems and societies, is not reconstructed in resilience research. Many SES are not local systems of extraction of resources, production in farming or aquaculture, but parts of various large-scale resource management systems, industrial, urban and economic. For such systems resilience analysis has to deal characteristically with complex forms of social action, social and system structures, antinomies, non-intended consequences of human action, and specificity of human carrying capacity that is determined not through biological but through socioculturally varying consumption levels (Rees 1996).

Social resilience includes various forms, some of which are connected to ecological disasters, others not. Adger saw one of the difficulties of linking social and ecological resilience as being that "it is not clear whether resilient ecosystems enable resilient communities" in situations of natural resource dependence (Adger 2000: 347). Langridge et al. (2006), reducing social resilience to the way communities cope with ecological or natural resource use problems, identify rights of ownership, control and access to natural resources as one of the factors enhancing community resilience. With that come questions of inequality of access, of economic and political power, requiring analysis of the full range of problems and conflicts related to resource ownership. Difficulties in distinguishing between social and ecological resilience can be observed in further debates, such as in economics and environmental education by Krasny and Tidball (2009). Qualities of resilient SES which seem coherent at more abstract levels of analysis turn out to become unclear or contradictory at more concrete levels, so that the resilience framework needs to be adjusted: Krasny and Tidball (2009: 476) refer to different implications of diversity and self-organisation in social and ecological systems and to the examples of ethnic diversity and social capital that are inversely correlated but both proposed as attributes of resilient SES. In economic debates the resilience terminology oscillates between ecological (Peterson 2000) and social meanings. The review of Perrings (2006) and the discussion of Rose (2004) show resilience either as an autochthonous quality of economic systems or as ecological resilience that affects economic systems as parts of ecosystems and through their coupling as resource using SES. Economic resilience as "inherent and adaptive responses to disasters that enable individuals and communities to avoid some potential losses"

(Rose 2004: 307) may also imply environmental disasters, but as the capacity to avoid losses it is not ecologically determined. Other forms of societal disturbance in different market situations are connected with ecological disturbance and resource problems to a limited degree, if at all. Whether resilience of SES requires similar behaviour for all types of subjects, individuals, communities, organisations, economic systems and societal and ecological systems is unclear. Rose gives the impression of an impure or hybrid notion (Brand and Jax 2007), one for which different interpretations are possible and application in empirical analysis becomes arbitrary. This evokes further questions about the conceptual nature of resilience. The notion requires specific views of ecological and social systems as evolving systems with unforeseeable changes, disturbance-prone, vulnerable, with limited systemic reaction capacities, and with potential regime shifts as a consequence of disturbance.

Adger et al. (2005: 1036) use an abstract definition of resilience to make the concept applicable to different kinds of systems. But the abstraction still bears the meaning of ecological resilience. Translating the concept from ecosystem to social system components implies normative assumptions when structures, functions and states of an ecosystem are used to assess the functioning of coupled systems. Such normative views, only insufficiently supported by the general idea of social systems being dependent on ecosystems, are also found in some areas of economics and ecological economics when resilience is understood as ecological resilience, attributing to economic systems a resonance capacity that can enlarge ecological disturbances. In economic resilience, as discussed by Briguglio et al. (2008), ecological forms of resilience are less apparent in the index for economic resilience, which includes the factors of macroeconomic stability, microeconomic market efficiency, good governance and social development – these can be seen as social system components without close connection to ecosystem changes. The index measures parts of the components of sustainable development, and the discussion does not add much to the broader debate about sustainable development, except that more attention is given to conditions of instability.

Linked with the ecological resilience concept and the model of the adaptive cycle is the analysis of long-term development of urban and regional economies from an evolutionary perspective by Simmie and Martin (2010). Additional knowledge of resilience of economic systems is generated through an extended analysis of instability that is not easily translated into policy and management strategies. Pettit (2000) draws attention to a further problem in analysing resilience in social and economic systems, "the empty black box", related to the absence of an evolutionary mechanism in social systems like the one that underlies functional explanations in biology and ecology (Box 3.4).

Box 3.4 Non-linear system dynamics in social-ecological systems (SES)

The analysis of complex interacting systems in nature and society to reveal the society–nature interaction is complemented in resilience research through the elaboration of concepts for the non-linear dynamics in SES. Complex systems or SES are examples of systems in non-linear development and non-equilibrium states. The change from equilibrium thinking and predictability to non-equilibrium thinking with disruptive change and insecurity (Scoones 1999, Lansing 2003: 192ff) is motivated by system complexity. Non-linear system dynamics with more open, contingent, non-predictable development and change are difficult to model conceptually.

In large, global and complex SES interactions cannot be analysed in all their causal and interaction components; modelling simplifies their complexity. In ecological research, as also in resilience research and sustainability science, the complexity is modelled mainly from the complexity of ecosystems, whereas the societal complexity is underestimated, which is to some degree masked by the abstract terminology. In SES the coupling of social and ecological components happens in manifold forms, degrees, scopes and levels of abstraction. The coupled systems are exposed to heterogeneous social, cultural, political and economic disturbances and crises that require different approaches to cope with risks and uncertainty, some of which return in the resilience debate under the notion of robustness. Differentiating between robustness and resilience seems so far to be the main idea in the resilience discourse to deal with the difficulty of human nature, accounted for in terms of consciousness, intentionality, rationality, reflexivity and anticipation. It marks the beginning of a more critical reconceptualisation of SES, adopting the idea of different system types and forms of coupling. Prior ecological and social research gives a series of descriptive notions for coupling, for example, in material, energetic, informational and symbolic forms, with co-evolutionary, synergetic, parasitic, functional and dysfunctional, stabilising and destabilising, exploitative and redistributive, synthetic, adaptive and non-adaptive components and effects. Social systems and ecosystems may be conceived as closely coupled or with loose coupling, following the historical development trajectories of societal systems and their socio-ecological regimes.

The core idea of non-linear system dynamics is found in resilience thinking and in neighbouring fields such as sustainability science, in earlier systems analysis, management and operations research. Non-linear processes of development and change have been discussed in theories of society, with many conceptual models for development – cyclic, repetitive, reproductive, differentiating, disruptive, casual, non-directed, evolutionary, revolutionary and combinations of these at different temporal and spatial scales. Other ideas about system dynamics can be found with the unfolding of ecology in the 20th century, in the direction from linear to non-linear change – from older ideas of long-term change models as "succession" and evolution towards a final stage of climax, stability or equilibrium, to multi-linear, differentiating, disruptive changes, punctuated equilibriums, chaotic processes, disturbances and system transformation. All of these processes mark complex time phenomena that are insufficiently understood as the complexity of multiple couplings of temporal, spatial and social structures. In resilience research the model of the adaptive cycle has taken up some of these ideas of ruptures, disturbances and catastrophes, but it is still a simple and idealised ecological model of systemic change. Its cyclic model of temporal structures is not sufficient for other forms of non-linearity and more complex temporality in societal systems with non-deterministic, open and long-term trajectories of evolutionary change.

Sources: mentioned in the text

Limits of resilience research from a social-ecological perspective. With the adoption of a perspective of non-linear system dynamics there are attempts to get rid of the problem of whether social and ecological systems show different evolutionary or development properties. Gallopín summarises the argument as: although there may be "essential differences in behavior and structure between social and ecological systems" this is irrelevant to resilience, as the use of the concept

> only requires the assumption that the state space of the system considered contains more than one basin of attraction. This is a natural assumption for all kinds of non-linear dynamical systems (although the applicability of the concept of dynamical systems to social systems might not be acceptable to some social scientists).
>
> (Gallopín 2006: 299)

The argument follows the functional reductionism of resilience and systems thinking, for which social systems are difficult cases. Questions about differences between system types, between intentional and reflexive action and non-intentional behaviour are unanswered – the differences are not simply denied, but declared to be irrelevant to resilience research. Gallopín's assumption that interdisciplinary communication and concept transfer can be achieved by formulating abstract ecological and social scientific concepts that are compatible seems inefficient for dealing with the complexity of SES. It would be necessary to study the differences of types, properties and scales of social and ecological system components in differentiated resilience analyses of human social systems, biological organisms and ecosystems. Working with different approaches in interdisciplinary resilience research promises better results than a single abstract framework modelled from ecosystem dynamics with the main ideas of panarchy and adaptive cycle (Gunderson and Holling 2002).

Panarchy is used to describe the interaction between different levels of a hierarchy of nested ecological or social-ecological systems in which adaptive cycles are used as conceptual models for processes in subsequent phases of exploitation, conservation, release or creative destruction and reorganisation. The idealised model of the adaptive cycle does not seem to capture all development processes in ecosystems or in coupled SES. The model is sometimes called a metaphor (e.g., Gotts 2007), underlining its non-explanatory quality and arbitrary assumptions, reducing the cognitive aspiration to a trial-and-error process – in some cases the model works, in others not. The review of ecological modelling practices by Schmolke et al. (2010) uncovers deficits of ecological modelling too, but does not look for other forms of modelling or different strategies of theory construction and knowledge about social systems.

The change in ecology from a simpler resilience model linked with multistable states in ecosystems to a more complex model of nested cycles of adaptive change in SES (Young et al. 2006: 304) also shows more clearly the limits of modelling the development in SES according to such a cyclical model. It does not change the interpretation of resilience significantly; it remains a functional, non-historical and non-social term to describe processes in SES, with the difficulty already mentioned that the ecological resilience concept is difficult to apply to social and organisational systems where the reflexive action capacity of humans is a core component, which do not simply follow a logic of functional adaptation like that of “mindless systems”. The adaptive cycle model seems speculative and misleading when applied in the analysis of dynamics of societal and economic systems, a conceptual transfer from ecology to economics that reveals some of the risks of concept transfer without taking into account the different epistemic and knowledge context of the two disciplines. A less disputed assertion about the changing patterns of resilience may be that resilience of SES has become more important with the development of societies towards more complex systems in which they have exchanged external for internal complexity (Young et al. 2006: 306). The discussion of global social and environmental change as interacting processes by these authors results in the conclusion that globalisation may increase the capacity of social systems to transform and develop resilience while simultaneously undermining the transformation and resilience of biophysical systems (ibid.: 312), thus confirming contradicting forms of resilience.

For complex and large-scale societal systems and SES it is theoretically and methodologically difficult to define the thresholds for collapse and identify all factors contributing to collapse in historical processes. Although depletion of the resource base and overshoot of carrying capacity play an important role in environmental history and historical ecology to explain the fall of empires, civilisations or societies, explanations suffer from social, ecological and physical reductionism. Historical examples of isolated societies on small islands seem inadequate to account for the resilience or collapse of large-scale territorial SES, empires or states. A characteristic difficulty is that of dealing with the complexity and changes of carrying capacity in modern and globalised societies. Ecosystems can develop resilience against disturbance in their ecological environment. Human societies need to cope with more kinds of internal and external disturbances. Many of these are risk-related phenomena not covered in the discourse about ecological resilience. Ecological disturbances and climate change provide the dominant examples of problems confronting societies. Only in abstract terms of "disturbance" can similarities be seen between tsunamis and hurricanes, depletion of natural resources and environmental pollution, global financial crises and economic losses of firms, political terrorism and religious fundamentalism, psychic traumas and racial or ethnic discrimination, violation of human rights and political authoritarianism, criminality and corruption, child abuse and domestic violence, economic poverty and social exclusion, health risks and epidemic diseases. To see them as similar with a vague notion of disturbance does not yet provide possibilities for coping with the various disturbances.

Societal systems analysis is insufficient in resilience research with regard to the complexity-enlarging factors mentioned – history, culture, consciousness, rationality, reflexivity, purposive action, collective learning and formal organisation, distribution of resources, unequal access to resources, unequal exchange and power relations – that are analysed in critical theories of the modern economic world system. In the adaptive cycle model as a "heuristic model, generated from the observation of ecosystem dynamics" (Folke 2006: 258), agency and social actors, history and culture, consciousness and reflexivity are neglected. Resilience research draws attention to and can help to describe dynamic interactions of social and ecosystems at several temporal and spatial scales, as in the panarchy model of "adaptive renewal cycles" (ibid.), but it is doubtful whether it can deal with the complexity that is brought by human action into the interacting systems or the heterogeneous time processes in the development of SES, including overlaying and interacting linear, cyclic, subjective and social structures of time. There is a trend towards more complex temporal structures, from engineering resilience to social ecological resilience, in the consecutive forms of constancy – persistence – transformability (ibid.: 259) that ends with the contingent factors of learning and innovation. Folke sees advances in research on social-ecological resilience (ibid.: 263), discussed further in Folke et al. (2010), directed towards social ecology. However, the concept and perspective of transformation remain abstract, with ideas derived from ecosystem research that do not take into account the complexity of societal systems.

Conclusions. Resilience research is trapped in reductions of cognitive aspirations, terminological problems with the analysis of complex SES, levelling of social and ecological systems analysis under a functionalist terminology, and vague ideas of adaptive management and governance. The ecological terminology has caused critical debates on the political ideas supported by resilience research (Reid 2012), but the interpretation by Reid that resilience research supports neoliberal views of sustainable development (ibid.: 74ff) remains controversial. Ecological resilience research tends to reduce sustainability to the adaptation of social systems to ecosystems and to coping with turbulence. The research on global environmental change and disasters (Centre for Research on the Epidemiology of Disasters: www.cred.be/) shows that the numbers of disasters and people affected by them have grown exponentially in the second half of the 20th century. This justifies vulnerability and resilience research, although it does not replace sustainability research that has adopted global system perspectives. Connecting the analyses of vulnerability and resilience (and their adaptation perspective) with the global resource use analyses of social ecology and the long-term transformation perspective of global sustainability research may be a way to deal with the terminological and methodological problems of resilience research that became apparent in studies of complex SES.

Interdisciplinary integration of ecological research

Sustainability science

Sustainability science (Kates et al. 2001) is based on the idea that the attainment of sustainability from local to global levels requires a specific form of research and combination of scientific and local knowledge. The specific form of interdisciplinary research involves studying the interaction between societal systems and ecosystems, as in social ecology. Sustainability science is based more on natural-scientific thinking, concepts and research to model nature–society interaction than on social-scientific knowledge and concepts. As the programmatic name of the approach is sustainability, it should also be discussed how the broad and vague idea of sustainable development is elaborated. A guiding idea is to specify sustainability beyond the Brundtland report notion of "intergenerational solidarity" as a more specific process encompassing a series of social system and ecosystem changes that require supporting strategies for "transformation management" in terms of scientific and local knowledge, of specific forms of resource management and of solving connected problems of distribution and redistribution of resources at local, national and global levels. A multi-scale and global perspective is guiding sustainability science, as specified in the "syndrome approach" (Schellnhuber et al. 1997).

When sustainability science was developed for studying dynamic interactions between nature and society it was presented by Kates et al. (2001) as an epistemological reflection and critique of academic science:

> sustainability science must be created through processes of co-production in which scholars and stakeholders interact to define important questions, relevant evidence, and convincing forms of argument. The pertinent actions are not ordered linearly in the familiar sequence for scientific inquiry, where action lies outside the research domain. Rather, these are combined in entangled patterns relating to the problem to be tackled and the practical constraints of inquiry.
>
> (ibid.: 2)

With such ideas sustainability science appears as part of the broader discourse of transdisciplinarity and "mode 2" (Nowotny et al. 2001), where new forms of knowledge production and application are sought to deal with complex problems. The key ideas of "global systems perspective", "cooperation perspective", "trustworthy knowledge and judgement that is scientifically sound and roots in social understanding" develop from earlier debates in ecology about science communication and bridging science and society (Odum 1997), meaning bridging natural scientific research and societal practices of knowledge use. The idea of an interdisciplinary "new ecology" (Scoones 1999) is somewhat different, and includes social scientific knowledge:

> "new ecological thinking, with its focus on non-equilibrium, dynamics, spatial and temporal variation, complexity, and uncertainty . . . " [has resulted in the following] "First is the concern with spatial and temporal dynamics developed in detailed and situated analyses of 'people in places' . . . Second is the growing understanding of the environment as both the product of and the setting for human interactions . . . Third is the appreciation of complexity and uncertainty in social-ecological systems and, with this, the recognition that prediction, management, and control are unlikely, if not impossible."
>
> (ibid.: 479)

Beyond the methodological profile, with a focus on qualitative and case study-based research, the guiding ideas of sustainability science are seen by Jäger (2009: 9f) as

- "achieving economic stability without growth of consumption", through "green jobs", "lighter" consumption, "new landscape culture", "redesigning settlement" and
- a new approach to policy through dialogue, joint learning from experience, implementation through cooperation and participation.

In this description the approach takes up ideas discussed elsewhere in scientific and political environmental discourses about dematerialisation and "limits to growth". Normativity and urgency of problems to be studied and solved have been highlighted, as in the description of "postnormal science" by Funtowicz and Ravetz (1993).

Discussion. The interaction of society and nature in sustainability science is not theoretically framed and analysed as in social ecology; the problem diagnoses seem less precise and consistent. Ziegler and Ott (2011), in a critical review of sustainability science, discuss its restrictions through conceptual and methodological choices in finding

> joint ways in which natural and social scientists can improve the understanding of environment-society relations. Typical tools for such attempts are scenario techniques that depend on information and causal mechanisms from natural and social sciences. Another example might be coupled models that shed light on the interaction between human and natural systems.
>
> (ibid.: 35)

The analysis of nature–society interaction in sustainability science follows an ecological-economic perspective of the economy as a subset of the biosphere and of important natural resources as non-substitutive (ibid.: 40), a variant of the new ecological paradigm (Catton and Dunlap 1978). Sustainability science shares with resilience research the theoretical construction of society in the vague concept of social-ecological system, an insufficient theoretical reconstruction of societal complexity, and a conservative view of society that neglects power relations, conflicts and the North–South cleavage between poor and rich, extractive and processing economies.

Social-ecological systems

The notion of social-ecological systems (SES) implies a major change of perspective in ecological research and a critique of earlier disciplinary research (Berkes et al. 2003). This critique is formulated in the hypothesis that the separation of social and ecological systems is wrong and misleads the analysis of society and nature. Social and ecological systems are "in reality" connected. Without more exactly describing different forms and degrees of coupling and interaction between social and ecological systems, this assumption levels in the last analysis to the biological argument that humans are part of nature, as is also society. However, the idea of SES is also the critical idea of interdisciplinary integration of natural and social scientific knowledge. Decoupling of society from nature underlies the discourse and process of modernity and modernisation, and is deeply rooted in scientific specialisation and in everyday social life and practices. Social systems differ, culturally and according to their functional or other specialisation; this contributes to masking their coupling with ecosystems, which can take many forms and degrees, functional and dysfunctional variants.

The coupling of SES is easier to understand in systems where natural resources are extracted, produced and processed, in agriculture, forestry, fishery and horticulture, in food production and in parts of industrial processing of natural resources. The use of natural resources shows a material coupling of nature and society in these SES, although not always perceived as such by the actors. But these systems also include culturally specific knowledge, differing practices and symbolic meanings; they are materially and symbolically coupled systems. Social systems that are more specialised in symbolic activities, cultural or scientific systems may less be seen as coupled (at least less materially coupled) with ecosystems through natural resource use. The general idea of coupling through resource use practices does not allow an identification of problems in the interaction of social and ecological systems that need to be solved through sustainable development. The historically specified notion of "colonisation of nature" in social ecology seems to capture the forms and qualities of coupling of social systems and ecosystems better than the amorphous notion of SES. Complex coupling across multiple scales and through global resource flows is studied more systematically in social ecology.

The differentiation and the analytical quality of social scientific concepts that reveal the system nature of modern societal and economic systems tend to be lost in SES analysis. The notion of SES for the analysis of use practices in an ecological perspective, conceiving social systems as systems interdependent on organisms, levels significant differences between social systems from different historical epochs, cultures and modes of production from a functional perspective, influenced by natural scientific research and thinking, which tends to simplify the notion of social systems in different ways to adjust them to ecosystems. Theoretical implications of different social system types are ignored; the notion of social system is subjected to a mode of abstraction that can be applied to living systems and organisms.

Also, Ostrom tends to reduce the construction of SES to one that can be achieved with a simplified theoretical understanding of social systems, one that relates mainly to systems for natural resource use with simple coupling that can be described without elaborate theoretical concepts of society which are not sufficiently described as multi-level systems:

> Given rapid changes in large-scale human and biophysical processes – carbon emissions, population increase and migrations, overharvesting and pollution leading to loss of species – scientists are worried that many of the social-ecological systems existing today may collapse by the end of the 21st century. . . . . More important than simply worrying, however, is the development of a strong diagnostic method for analyzing the diversity of processes and the multiplicity of potential social and biophysical solutions that are needed to cope effectively with these varied processes. Past efforts to impose simple solutions to these complex problems have frequently led to worse outcomes than the problems addressed. Our need today is building a strong interdisciplinary science of complex, multilevel systems that will enable over time a matching of potential solutions to a careful diagnosis of specific problems embedded in a social-ecological context.
>
> (Ostrom 2007a: 1)

A more advanced idea of coupling and interaction of SES from ecological research comes with the connectivity hypothesis, which makes use of insights and knowledge on globalisation and global environmental change to formulate the idea of a significant historical change in the relations between nature and society and in nature and society themselves in the industrial epoch with a geological concept, that of the anthropocene. Opposed to prior thinking in terms of detachment of society from nature during modernity, this theory diagnoses a deepening coupling in the sense of strong modification of ecosystems through societal practices that result in a growing instability and non-sustainability of global social and ecological systems. This idea paves the way for a more critical understanding of societal and ecological change that cannot be ignored in social or in ecological research. The theory of the anthropocene does not even try to formulate another theoretical concept of society to express the changes observed, but dares to formulate a theory of society directly in natural scientific terms. This seems more consequent and theoretically promising than the vague notion of SES, and is also historically specified, although in an unusual way, by coupling the timescales of geological and societal processes. Also, the critical voices in the SES discourse tend to formulate more theoretically critical ideas of coupled SES that do not ignore the internal dynamics of societal systems:

> The linkages between biophysical systems and social systems have grown to the point where we routinely speak of human dominated ecosystems and realize the critical need to understand the dynamics of socio-ecological systems (SESs). Simultaneously, social and economic

> globalization has led to increased flows of goods, resources, people, and information and ideas across greater distances with interactions operating at various scales from local to global. Thus, biophysical systems need to be seen as interacting with social and economic systems, while social processes like globalization need to be seen as being coupled to the dynamics and constraints imposed by biophysical systems.
>
> (Young et al. 2006: 314)

At more concrete levels of empirical analysis where questions of sustainable resource management are taken up, the idea of SES and coupled systems unfolds more critically under the question of how to design, measure and assess systems of sustainable resource use and management at different levels. A preliminary answer highlights that management

> will be effective only if resources are matched with governance structures and management techniques. A governance structure using a technique on one resource might succeed, whereas the same governance organization using the same technique might fail miserably when applied to another resource. For example, tradable environmental allowances have worked well in controlling air pollution . . . , but such programs (e.g., ITQs) have generally not done well in managing fisheries because they have motivated fishermen to high grade (discard all fish except the most desirable) . . . , have led to a concentration in control by a small elite . . . ., and in many cases have not conserved the fish stocks.
>
> (Acheson 2006: 129)

Discussion. While the results from comparative empirical research on resource management are useful in developing critical SES analysis, a weakness of the approach practised so far is shown in two points:

1. The SES analysis is in an undeveloped state after the recent start of work with the concept of coupled social and ecological systems. There are hardly any theoretical elaborations of SES, and the combination of the two terms of social and ecological systems has not stimulated more critical reflection about the forms and problems of coupling, or studying coupling in more specific historical and culture or society-bound forms.
2. Rather, in certain forms of SES analysis, the differentiated analysis of social system components in the society–nature interaction is annihilated, as, for example, in Folke's assumption that with the combination of the terms separate studies of social and ecological systems have become useless or superfluous.

In parts of the new SES discourse, as also in resilience research and sustainability science, a naturalistic reductionism prevails that annihilates the advances and growth of knowledge that social sciences have achieved since the mid-19th century, after their cognitive and epistemic emancipation from the natural sciences, which were still showing their influence in early sociology, in social physics (Quetelet) and evolutionary sociology (Spencer). The new forms of SES analysis, sustainability science and resilience research mask the deficits of societal systems analysis through a new terminology and the idea of coupling of social and ecological systems. The possibility is not excluded that similar differentiations are made in SES as in social ecology between societal systems and practices, colonies, societal relations with nature, societal metabolism and nature. A critical, theory-based interpretation of SES would require the analysis of different forms of coupling. Also, the traditional social-scientific theories that reintroduced the idea of a joint terminology of social and biological or ecological systems, functionalism and systems theory in the social sciences that was influential during large parts of the 20th century (Parsons, Luhmann) maintained a critical understanding that the distinction between an action frame of reference and a biological (or behavioural) frame of reference (Parsons) was an epistemic breakthrough in understanding the functioning and reproduction of society and social systems with specific sociocultural forms of evolution. Although theoretical integration of social system and ecosystem analysis is possible, to annihilate the knowledge about differences between the two system types with a terminological stroke of the pen seems too high a price for the desirable integration of knowledge.

More elaborate and theoretically reflected variants of SES that include more systematically integrated knowledge from social and natural scientific research develop with social ecology. In social ecology the critical reflections about the limits of the resilience concept for social systems that are tentatively formulated by Janssen (2006) and others mentioned above can also be taken up.

Towards a science of global environmental change – discussion and conclusions

The discourses of natural-scientific origin discussed in this chapter did not contribute significantly to a critical reformulation of the concepts of nature and society and nature–society interaction, but followed the dominant functionalist tradition by reducing historically connoted theoretical concepts through abstract terms as social systems or ecosystems. Functionalist theories in the social sciences are not necessarily reductionist theories, as the tradition of sociological functionalism (Merton, Parsons, Luhmann) has shown. In the new interdisciplinary approaches of resilience research, sustainability science and social-ecological system analysis, functionalist thinking tends to omit more in-depth and theoretically guided analysis of societal systems with the insinuation that such analysis is superfluous, that all that is important for analysing society–nature interaction is given with the notion of complex adapting systems.

More than through theoretical structuring and framing, the cognitive interest in exploring human resource use was driven by the controversies about population growth and natural resource use limits to which answers were sought in ecosystem and SES research – for example, in the elaboration of the "limits to growth" hypothesis in a more specific formulation of "planetary boundaries" of human resource (Rockström et al. 2009). This shows some advances in the long controversy about natural limits, as well as an effort to make scientific knowledge applicable to societal practices of natural resource management, environmental policy and resource use in life-world contexts. But knowledge transfer and application, such as in the ways Moran has explicitly asked for, through commitment of researchers and participation of resource users in ecological research, is still not advanced; in these processes more resistance against adaptation to global environmental change and policies of sustainable development can be expected. The debates of transdisciplinarity, participative research and stakeholder involvement obscure the knowledge transfer that really happens; the results of such new forms of cooperation in knowledge production in terms of approaching solutions for sustainable resource management remain unclear. Progress towards the aims programmatically formulated in sustainability science is slow. Participation, genuine cooperation and knowledge integration are difficult to achieve, and it is still unclear how transitions to sustainability can happen. One of the problems is that the research reviewed in this chapter can be used for different strategies of reasoning in scientific and in political discourses about environmental problems. The ecological research is not connected to social ecology and its discourse order, although it is close to it and influences its research. More is required to make the approaches of ecosystem research and SES part of social ecology. They need to be integrated by social ecologists themselves in the discourse of social ecology and in their research through critical and theoretical knowledge synthesis. This requires participants in the ecological discourse to become reflexive and to discuss aims, limits and strengths of ecological research epistemologically and theoretically. The processes of "becoming reflexive" can be followed in several steps:

1. Epistemic reflection of the discursive knowledge culture in scientific disciplines, similarly to Gouldner's theory of a "culture of critical discourse", helps to adapt research practices to new requirements of knowledge use in society. The function of such a discourse (Fischer-Kowalski 2008) is to find new societal rules and mechanisms of regulation to cope with new problems that confront society, such as the current problems of global environmental change. While the prior debate was looking more to the protagonists and representatives of the discourse culture – for

example, the professional and knowledge elites of intellectuals, scientists, scientifically trained professionals, journalists and artists – the social ecology debate requires answers to the questions of knowledge components relevant to an interdisciplinary analysis of global SES and resource flows.

2. Reviewing and assessing the discourses concerned with the global environmental crisis (Mühlhäusler and Peace 2006: 457) that intensified during the past decades shows limited advances. Most environmental discourses are, according to the authors, about local environmental concerns; only a few of the discourses are trying to globalise the environmental themes (ibid.: 471). With the development of the discourses participants become aware of the language they use and how it specifies themes selectively. However, it is not always clear how far these processes of awareness-building have contributed to improving the knowledge and the managerial practice for ecosystem management.
3. Reflecting the ecological discourses from an explicit theoretical perspective, such as that of interaction between society and nature or societal metabolism, is the final step in becoming reflexive. This has, except in social ecology, happened to a limited degree: in physical resource theory, for example, and in attempts to formulate a theory of societal resource use on the basis of natural scientific knowledge, the theory of the anthropocene.

The anthropocene debate reacts to the "great acceleration" in the 20th century (Costanza et al. 2007): the increase in human population, economic activity, resource use, transport, communication and science-based technology that is presently happening in the industrialised parts of the world and is delayed in other parts of the world. The "engine" of acceleration

> is an interlinked system that consists of population increase, rising consumption, abundant cheap energy, and liberalizing political economies. Globalization, especially an exploding knowledge base and rapidly expanding connectivity and information flow, thus acts as a strong accelerator of the system. The environmental effects of the great acceleration can be identified at global scales: changing atmospheric chemistry and climate, degrading many ecosystem services (e.g. provision of freshwater, biological diversity), and homogenizing the biotic fabric of the planet.
>
> Toward the end of the 20th century, there were signs that the Great Acceleration could not continue in its present form without increasing the risk of crossing major thresholds and triggering abrupt changes worldwide. Transitions to new energy systems will be required. There is a growing disparity between the wealthy and the poor, and, through modern communication, a growing awareness by the poor of this gap, leading to heightened material aspirations globally, a potentially explosive situation.

> Many of the ecosystem services upon which human well-being depends are depleted or degrading, with possible rapid changes when thresholds are crossed. The climate may be more sensitive to increases in CO_2 and may have more inertia than earlier thought, raising concerns of abrupt and irreversible changes in the planetary environment as a whole.
>
> (Costanza et al. 2007: 225)

The diagnosis of social and environmental problems of industrial production is critical in these reflections that connect social scientific and natural scientific knowledge and research results. It is still somewhat insufficient, less critical and systematic for the societal components than for the ecological. The Holocene is the postglacial geological epoch of the past 10 000–12 000 years during which the acceleration phenomena in human societies happened, first with agriculture, later with industrialisation.

> Humankind has now inhabited or visited all places on Earth . . . Vernadsky . . . recognized the increasing power of humankind in the environment with the following excerpt " . . . the direction in which the processes of evolution must proceed, namely towards increasing consciousness and thought, and forms having greater and greater influence on their surroundings." He, . . . P. Teilhard de Chardin and E. Le Roy in 1924 coined the term "noosphere," the world of thought, knowledge society, to mark the growing role played by humankind's brainpower and technological talents in shaping its own future and environment. A few years ago the term "Anthropocene" has been introduced . . . for the current geological epoch to emphasize the central role of humankind in geology and ecology. The impact of current human activities is projected to last over very long periods. For example, because of past and future anthropogenic emissions of CO_2, climate may depart significantly from natural behaviour over the next 50 000 years.
>
> (Steffen et al. 2007: 615)

Global environmental change is described by the anthropocene authors in terms of its effects on human societies and the environment. But it is a long way from there to sustainability, requiring another "great transformation" of human societies, as social ecology is trying to show with its societal system analyses. This great transformation and its requirements in terms of necessary changes of societal metabolism and metabolic regimes of resource use are underestimated in the theory of the anthropocene, as in the ecological research discussed in this chapter. The reasons for that underestimation can be seen in the missing analysis of societal systems, in theory and research that are not systematically analysing industrial systems and their accelerating resource use.

4

Thematic Profiles of Social Ecology – The Research on Resource Flows and the Physical Economy in a Global Context

The emerging science of social ecology is discussed in this and the following chapter with two of its main research themes and results, (a) global resource flow and (b) land use related to human consumption of biomass and food, before the emerging theoretical framework, including societal relations to nature and societal metabolism, is reviewed (Chapter 6). In the following description of the analysis of societal metabolism, the social ecology of human resource use is reviewed with two guiding questions:

1. How is the controversy about the tragedy of the commons as one focusing on limits of human resource use solved in social ecology?
2. What does the idea of social metabolism and metabolic regimes imply for the empirical study of global resource flows in social ecology?

A framing controversy about human resource use – the tragedy of the commons

The controversies about human use of natural resources (discussed in Chapter 3) influence the subjects and discourses in the following review of physical resource flows in the global economy. A specific controversy marks the beginning of the research discussed here, the neo-Malthusian debate of the tragedy of the commons (Hardin 1968) and its theoretical model of causes and solutions to environmental problems and overuse of resources. Although not explicitly an economic theory, it is structured through an economic reasoning in which assumptions about the economic behaviour of man are connected with assumptions about property rights in natural resources, resulting in the core argument: rational actors who follow their individual interests in using a common resource will finally, without intention, destroy the natural resource base through overuse, unless they are restricted in their resource use through the institutionalisation of property rights, private or state property. In this summarising formulation of Hardin's ideas, the construction of a tragedy of resource use is controversial for several reasons, which bifurcate into two lines of a critical debate:

– One debate is about a problematic interpretation of commons as jointly used resources with doubtful assumptions that are not supported by historical knowledge and observations of how resource use dilemmas have been solved.
– Another debate is about the question of what kind of regulatory institutions are required to prevent overuse of limited natural resources and ruin of the environment.

The first controversy is about the deficits of Hardin's theory and concepts and is not of interest here. It has been easily found that Hardin understood commons inadequately as "open access" resources that are free for all and that the underlying economic theory of resource users as rational actors is the source of many distorted observations and errors of interpretation (McCay and Acheson 1987). The second controversy is the core controversy centring on the question of appropriate institutions for natural resource use. Its framing through the concept and institutions of property creates the decisive argument that resource use problems can be solved through the institutionalisation of (private) property rights. This argument also limits the insights that can be obtained from an analysis of resource use problems as property problems, excluding much more significant knowledge about human resource use and management problems that are not dependent on property forms. The typology of four basic property systems (open access, common property, state property and private property) forms the theoretical backbone of the model and seems to account for its selectivity and weaknesses in accounting for the resource use problems found, a weakness which is connected with the economic thinking that guides the model. A second weakness of Hardin's analysis shows in the simple assumptions about human behaviour, to some degree also inherited from economics in the construction of "economic man" as selfish and individually rational, but also influenced by philosophical speculations about the biological nature of humans. From the participants in the commons discourse – McCay arguing on fisheries' commons, Ostrom arguing on different forms of local commons, Martinez-Alier arguing on the question of privatising common land – Hardin's assumptions about property rights and solutions to the tragedy of overuse have been rejected. Their arguments show the full dimensions of the controversy. Whereas McCay and Ostrom argued with empirical and historical examples against Hardin's diagnosis, referring to many cooperative solutions found in common pool resource management, Martinez-Alier's critical point was that the tragedy is not so much one of commons but of enclosures, not of common property but of private property that results in overuse and destruction of the resource base. This last argument is based on theoretical knowledge about the modern economic world system which is not included in Hardin's model, or in the empirically based critique by McCay and Ostrom.

After the transformation of the controversy into one about adequate property regimes for natural resource use that help to avoid overshoot and collapse, it still remains controversial whether a discussion of property rights is sufficient to find solutions. Already the argument (McCay) for differentiating between the more abstract notion of property forms and the more concrete idea of resource management forms that comprise the operational rules for resource use and the control of practices of users makes a significant difference to Hardin's assumptions about property rights. With the introduction of the term "resource management systems" additional to property rights in resources, more of the practical problems with resource use can be shown. Resource use problems are, in the final analysis, not determined by property rights or the form of property. Each form of property can, in unforeseeable ways, generate positive or negative effects for the environment, so that the answers are dependent on empirical research and local case studies. In the course of research about the use of common property and of common pool resources, it has, furthermore, become a critical question whether local commons problems and their solutions can be used for analogous reasoning in the case of global commons, of the oceans, the air and the atmosphere, the global forests, the climate, the energy resources, biodiversity.

The debate about the tragedy of the commons is still influencing controversies and research today. Not all the important components of a physical economy or of the organisation of human use of natural resources are discussed in the classical variants of this discourse, but the following problems are:

– *resource availability problems*: the natural resources necessary for the satisfaction of human needs are available as finite resources (non-renewable and most renewable resources too; whether there are unlimited resources is a controversial question) and forms of resource scarcity are the problems to be dealt with;
– *resource maintenance problems*: how the stock of natural resources can be maintained for continuous use over generations (how can overexploitation and degradation or pollution be avoided?); the ecological problem formulation of avoiding "overshoot and collapse" has been translated into the economic formula "maintenance of the natural capital stock", a theoretical argument that is not always as easily operationalised as the paradigmatic case of maintaining the natural capital of a forest shows (where the operationalisation is: limiting the annual harvest of wood to the quantity that is added through the growth in one year);

– *resource distribution problems*: how natural resources can be distributed between all users to satisfy everyone's needs; this implies, for many natural resources which are not found equally distributed in all terrestrial and marine ecosystems, a redistribution between users at spatial (local, global) and temporal (generational, intergenerational) levels which cannot easily be discussed in the framework of property rights.

It seems impossible to formulate these basic problems in non-controversial and general form. Different paradigms, assumptions about human nature, theories and disciplines make the problems seen in human use of natural resources become controversial. The only way to deal with the controversial arguments seems to be to lay open and discuss the assumptions, interpretations and conclusions of the authors who participate in the commons debate, starting from their knowledge base. Questions of valuation are part of all three problem formulations above. The availability of resources, like knowledge about them, changes historically. Productivity and yields can change through human manipulation of resources, as happens continually in the development of agricultural production practices. Human resource use practices change depending on knowledge and culture. Human needs are variable, culturally transformed and interpreted. The biological minimum of resources needed for individual survival is exceeded in all historical societies. With improving knowledge about availability and substitutability of resources, the interpretation of needs also changes. Such difficulties are apparent in the present debate about planetary boundaries for human resource use. There it is obvious that the question of resource limits is not only about scientific knowledge of the resources, but much more about political and practical problems in finding solutions to limits of specific resources on which modern societies are dependent. The debate about "peak oil" shows that this main energy resource for industrial societies has finally become deadlocked in the question of oil reserves known and not yet known.

A further difficulty in the discussion of physical limits results from the heterogeneity in type, quantity and quality of natural resources for human use that prevents simplifications and generalisations such as those in Hardin's model. General and global limits of human resource use came to be discussed in more concrete empirical terms only after Hardin's analysis: first in the global modelling of resource use in the "limits to growth" debate that followed similar assumptions to Hardin's neo-Malthusian thinking, then in the 1980s and 1990s through intensified research on local commons and common pool resource use problems, and in the past decade through investigation of global resource flows more in social-ecological research or through the recent debate over planetary boundaries of resource use. Hardin's diagnosis of a tragedy is derived from specific resources, finally reduced to land use problems that show the intellectual heritage of the Malthusian debate from old theories in political economy. Hardin's reasoning evokes a series of critical questions: whether resources and users are studied at local or global levels; whether historical or present cases are studied; whether and how resource use problems differ between cultures; which resources, in what quantity and quality, are to be included in the definition of human or basic needs; which forms of property rights are found historically and how specific forms of property are used in social reality and practice, by different owners; are the broad types of common, state and private property that are discussed in the commons debate homogeneous forms or is, for example, the intensively discussed form of private property one with manifold historical and social variants? With such questions one approaches the empty core of the ambiguous controversy that continues without convincing answers to the question of whether one type of property rights can help to avoid overuse of resources. The controversy is in large part one in which the opponents miss each other's points, talking in different languages, with different terms and assumptions. In a tentative summary of the debate of the commons the following arguments summarised in Box 4.1 have been compiled.

Box 4.1 Tragedy of the commons

For many years, the story about the tragedy of the commons has been told as a tale of uncoordinated exploitation by a group of resource users. This analysis was initially developed by Gordon . . . in his classic on the tragedy of the commons, in his discussion of common lands and animal grazing. It was then generally adopted by many other analysts of the overexploitation problem, often times in relation to fishing boats and fisheries. . . . Within this framework the problem of resource overexploitation comes down to a failure of horizontal contracting, i.e. some failure to contract and coordinate between users of a common natural resource . . . . We argue here that the horizontal facet is a small part of an overarching problem, which is the failure of the responsible state to institute incentives for resource management. In short, over-exploitation in a commons situation should be viewed more as a governance problem rather than a coordination problem. The problem with the traditional explanation is that it fails to explain why such conditions inhere in regard to certain resources, and not in regard to others, under the control of the same state. All terrestrial resources fall within some state's jurisdiction but not all are subject to the same level or lack of care and management. It is not apparent why the idea of imperfect property rights or management is a useful concept to apply when the same owner-state capably regulates some

> resources (e.g. tin mines and tea plantations) while failing in regard to others (e.g. wildlife and forests). Given this, it is probably better to view a given management regime as the consequence of societal choice, rather than the cause of collective failures. More fundamental forces are determining the owner-state's decision concerning which management regime to apply to a given resource at a given time.
>
> (Swanson 2007: 112)

Swanson does not seem to approach the dissolution of the controversial questions by answering them clearly. Rather, he opens a new round of the debate by connecting it to the present debates about global and environmental governance. The arguments are reminiscent of that presented by Mol when transforming the theory of ecological modernisation into one of global flows, and, in so doing, limiting the problems of global flow analysis to a problem of governance of flows without analysing flows quantitatively as in social ecology. In Swanson's variant an even more conventional form of governance is taken up with the argument of state jurisdiction for governmental regulations than in Mol's theory, in which state-centred governance is critically reflected.

Source: mentioned in the text

The formulation of commons problems is impossible without theoretical and valuing assumptions. Hardin's variant, in which commons are (mis)interpreted as resources with open access or no property, continues to argue along the lines of the classical foundations of the Malthusian view of "natural limits", without explicitly formulating the basic assumptions. The main problem is not the historical example of overgrazing on common land in a medieval village that serves to illustrate the problem, but the global problems of overuse of resources and potential collapse of the global economy today, which is seen by Hardin as a consequence of the exponential growth of the global population in the 20th century. It is part of the "doomsday prophecies" re-emerging in ecology in the 1960s and 1970s, including also the "population bomb" debate of Ehrlich and others. After the classical discourse of the tragedy of the commons in human ecology, there followed differentiations and variations of the problem formulation, mainly in ecology and economics. The influential variants can be found in:

1. physical resource use theories, including the thermodynamic paradigm of ecological economics (Georgescu-Roegen 1986) and the renewed Malthusian discourse about global limits to growth,

2. political economy and political ecology, including the theory of energy resource use as limiting factor ("Promethean revolutions" using the notion of Georgescu-Roegen 1986: 15), the theory of unequal ecological exchange, and the connecting theory of ecological distribution conflicts in ecological economics and political ecology (Martinez-Alier 1995).

With the concretisation and practical application of knowledge from the theories above developed an intensive debate on ecological indicators and the measurement of limits of human resource use. Conceptual models such as the ecological footprint, and in social ecology more advanced and empirically based indicators for global materials and energy flow accounting (MEFA) and human appropriation of primary net production (HANPP), are discussed below. The MEFA can also be used to verify the assumptions of unequal ecological exchange theory and the theory of societal metabolism. Of special interest is the analysis of perverse ecological effects (rebound effect), which cannot be simply explained by the contradictory or complex nature of humans, but involves institutional structures of modern economic systems.

With the questions of measuring human resource use and its natural limits, one approaches further questions about the transfer of knowledge and results from research to societal practices of resource management or political programmes for sustainable development. With that come further controversial debates about dematerialisation, decoupling and degrowth. In the sequence of dematerialisation of production, decoupling of growth and resource use, and degrowth (or setting absolute limits of materials and energy use in economic production and consumption), the ideas show a "radicalisation" in terms of an ecological critique of the capitalist economy. Dematerialisation has already been discussed (Chapter 2) as insufficient to support environmental sustainability. The more critical ideas of decoupling and degrowth are closely connected with social ecology. Like other ideas about natural limits to economic growth, these are not new but reinterpretations of older ideas that have long been found in political economy – for example, the idea of the "steady state" economy. With this concept it is assumed that no growth of population and resource use is a precondition to avoid the collapse of SES. Haberl et al. (2004: 208) discuss the magic triangle of decoupling as delinking economic growth from material and energy flows (increasing efficiency), delinking material and energy flows from social welfare (increasing sufficiency) and delinking social welfare from economic growth (increasing equity). How such strategies of delinking can be practised in the institutional structures of the modern economic world system is far from clear. With the recent degrowth debate the discussion has been taken up again through a new social movement, whereas scientific debates on degrowth are still limited.

Indicators and concrete suggestions on how to limit resource use to maintain ecosystem functions in the long run have been used in global environmental assessments such as the Millennium Ecosystem Assessment from 2005, or in the global scenario debate about sustainable development. These forms of applied research and assessment close the circle of scientific and policy discourses about sustainable development. As far as the debate has progressed today and is included in the social ecology discourse, its critical arguments are the following, taken up in this chapter:

– *the perspective of global sustainability*: The idea of national or spatially limited solutions, of "sustainability islands", is abandoned with arguments for the necessity of societal system transformation or another "great transformation" to solve the resource use problems that are in the last analysis dependent on global resource flows and unequal exchange (arguing against "rich country illusion" effects).
– *the systematic analysis of natural resource flows in the global physical economy*: This provides arguments against the assumption of Mol, who saw the quantitative analysis of deterritorialised and hybrid global flows as impossible.
– *the reconnection of scientific, policy-related and social movement discourses*: This happens through new debates, paradigmatically the transdisciplinary knowledge and issue-linking in the recent degrowth movement.

As a consequence of these points of discussion a further one needs to be taken up: the adoption of new policy and management models for natural resource use that develop more complex ideas about sustainability, for example, in the adaptive governance debate (Chapter 8).

Analysis of global resource flows – the emerging paradigm of societal metabolism

In a programmatic résumé the biophysical economy approach is described by social-ecological authors as follows:

> Ecological economics, in contrast to, for example, environmental economics, treats the environment not as an adjunct to socio-economic activities, nor as a medium through which some social activities harm or benefit others. Instead, ecosystems are conceptualised as the fundamental entities within which socio-economic systems are embedded. Thus, environmental problems can be seen in terms of shortfalls in the capacity of economic and ecological systems to function in conjunction with one another.... In the context of ecological economics, a "biophysical approach" emerged..., dealing with the question of natural resources contributing to economic growth. In contrast to the approach

> of ecological economists, the mainstream view is that energy and other natural resources should be regarded as economic intermediates, as consequences of industrial activity rather than as factors of production. Commonly, long-term economic growth is dealt with as an issue of technological and social innovation, driven by thrusts of human inventiveness .... This perspective is challenged by authors like Robert U. Ayres, who treat the economy as an evolutionary materials processing system; an adequate description of this system must include materials and energy flows as well as money flows .... These flows and conversion processes are governed by the laws of thermodynamics.
>
> (Fischer-Kowalski et al. 2003: 4f)

This general reasoning needs to be broken down into more specific theoretical and methodological forms of global resource flow analysis to operationalise the core concept of societal metabolism in social ecology. Societal metabolism is understood here as the flow of energy and matter between nature and society in human natural resource use processes in the subsequent phases of extraction, processing, distribution, consumption of resources and deposition of residues or reuse and recycling for material resources. The four variants of global resource flow analyses include two resulting from physical resource use theories – (1) the renewed Malthusian discourse about global limits to growth, population growth and resource limits (Meadows et al. 1972), (2) the thermodynamic paradigm of ecological economics (Georgescu-Roegen 1986) – and two resulting from discourses in political economy and political ecology – (3) the theory and analysis of unequal ecological exchange, following from older variants of critical theory or political economy and (4) the theory of energy system development through "Promethean revolutions". Related theories include that of ecological distribution conflicts in ecological economics and political ecology (Martinez-Alier 1995).

All these theories and analyses emerged outside the academic mainstream of science and research, as heterodox and critical discourses motivated not only by scientific interests, but also by practical and social movement discourses. Although research is partly carried out in disciplinary frameworks, it seems important to understand the physical economy from an interdisciplinary perspective of the material, energetic and informational interactions between society and nature. The dominant theme of the debate is limits to economic growth connected to limits of population growth and limits to natural resource use. As the natural resources on the earth are limited – even renewable resources can be overused, for example, through the interruption and manipulation of geophysical cycles, which has already happened with the global water cycle – the idea being put forward now in the follow-up to the limits to growth debate is that of planetary boundaries that mark the final boundaries for a safe operating space in human resource use (Rockström et al. 2009). The archetype of a scientific debate that connects economic processes and natural resource use in an ecological perspective was the physiocratic discourse in political economy in the 17th century, when the question of natural limits to human resource use appeared as one of the limits of land and its productivity, the echo of these ideas still being heard in Malthusian thinking. The physiocratic principles were formulated long before the path-breaking ideas in the classical political economy of the 18th century, articulating the industrial revolution in theoretical form. In the new environmental discourse in critical economics in the 20th century the paradigm of agriculture returns, broadened into an extensive theory of physical resources. In more recent debates in environmental economics this agricultural paradigm was, for example, taken up in ecological economics (Georgescu-Roegen 1986).

In an ecological analysis of economic systems a critical question is that of the reference model or paradigm for the societal organisation of economic systems. There are not many historical forms of socio-metabolic regimes or modes of production found in human history. When we look for historical examples and alternatives of organising large-scale societal production systems, it is soon obvious that the two important ones are agricultural or industrial metabolic regimes, both of them enduring into modern times. It is no big surprise that, in the ecological discourse in science and politics, preference is given to agricultural production, which includes working with and managing ecosystems and is more important than industry for the satisfaction of basic human needs in terms of food production. Historically, agriculture has been based on renewable resources, to a large degree on solar energy and use of organic material for biomass production; it has organised systematic recycling of organic matter; before technical modernisation, agriculture came much closer to ecologically sustainable ratios of EROI (energy return of input) than modern, industrialised, high-technology, high-energy input agriculture. All these seem to be arguments in favour of agriculture as a theoretical paradigm for organising the societal economy sustainably, according to ecological principles. However, that does not yet answer the practical questions of how modern economic systems under conditions of globalisation can be restructured and whether agricultural production can become an economic system model, taking as a given that global sustainability cannot mean returning to the social and economic structures of agricultural societies before industrialisation.

Agricultural production was modernised in the 20th century, at first in Western countries according to industrial mass production principles, and thereafter through the genetic manipulation of plants and animals in the form of a scientifically managed industrialised food production. The genetic modification of organisms is indicative of the modernisation coming in the 21st century, in which farmers as autonomous producers are threatened with disappearance. But it still seems difficult to imagine further transformation of modernised agriculture. How agriculture and food production can become sustainable; whether there are environment-friendly forms of genetic modification of plants and animals that are compatible with the idea of ecological sustainability; whether industrialised food production can be partially converted into new forms of peasant production; whether it is necessary to invent in the course of transition towards sustainability a completely new, presently unknown socio-ecological system of food production; all these questions are presently hard to answer in the sustainability discourse. Taking such questions into account, it seems necessary to discuss the transition to sustainability in more depth and more concretely than with a general theoretical idea or with "technical fix" ideas and ecological modernisation.

In the economic discourse the discussion of ecological models for the sustainable reorganisation of economic systems has left some intellectual tracks, mainly in ecological economics. When the question of limits to resource use is discussed in conventional resource economics in academic science, its interdisciplinary knowledge sources are truncated to fit the cognitive interests of mainstream economics. Slade (2009) shows in an exemplary way this truncation as subjecting resource use analysis to economic modelling.

> A survey of Hotelling's . . . model of resource extraction and tests of that theory is particularly appropriate, as Hotelling's model has dominated the economics of exhaustible resources for many decades. Not only was Hotelling the first to derive the implications of finite reserves for the evolution of prices and consumption under an optimal plan, but he also showed that competitive markets will achieve the planner's solution. This rosy picture is, of course, a special case of the first theorem of welfare economics, which states that competitive markets are Pareto efficient. . . . One could therefore conclude that, because the market will solve the resource extraction problem, we should forget about it. Unfortunately, this is not the case. Indeed, many aspects of real-world markets, such as imperfect competition, non-neutral taxation, and the absence of property rights, can lead to severe intertemporal distortions. Although most of those complications were not considered by Hotelling, his model can easily be altered to assess many interesting and realistic features of fuel and nonfuel mineral markets.
>
> (Slade 2009: 240)

Although the imperfection of markets is critically discussed in this summarising argument, other forms of markets or alternatives to a market system for resource allocation seem rather irrelevant to an economic analysis. They also seem practically irrelevant, as no alternatives to the globalising market systems are apparent. The necessary corrections of market failures seem to require traditional forms of governmental regulation and planning. For an ecological analysis of the physical economy, such a perspective is of limited interest. It does not take into account the rationale of an interdisciplinary perspective in which the physical and biological reality of natural resources counts more than the monetary analysis of resources and produced goods, the value of use more than the exchange value. This double nature of the economic process as physical production and economic value production is an old theme in the economic debate, often traced back to the Aristotelian terminology of "*oikonomia*" as physical economy and "*chrematistike*" as monetary economy, in which these two meanings of economy have remained until the present ecological discourse. There they are taken up again, for instance in the interpretation of ecology as the science of "nature's economy" (Worster) and economics as the "dismal science" of scarcity and growth in the neo-Malthusian discourse.

The statistical figures about changes in global resource use during the 20th century support the impression that the end of economic growth is coming closer. But still no societal decisions have been made about how to prepare for a no-growth economy through a managed transition to global sustainability. Catastrophic forms of achieving degrowth and global sustainability cannot be excluded, although not necessarily in the global dimensions of the neo-Malthusian "limits to growth" prognoses. The transformation of the global economy is now split into two contrasting trends:

– While the economic globalisation process is still driven by ideas of developing the economic growth mechanism, in whatever form (deregulation, ecological modernisation, third-sector economy, information-based economy),
– it is the reality of global environmental change with climate change, biodiversity loss and land use change that enforces an economic conversion, driving the transition process towards global sustainability not for short-term requirements of adaptation, but for the long-term requirements of maintaining the global resource base for use by future generations.

The 20th century has been described by environmental historians as the unprecedented intensification of natural resource use, summarised as "there has never been anything like the 20th century" (McNeill 2000, p. 3). The 21st century is, following the ecological and social-ecological discourse, to become the century of transition to a new societal metabolism. The search for potential transition paths happens in scientific discourses with the analyses of global limits to growth and global resource flows.

The global systems analysis of "limits to growth"

The possibility of continued exponential economic and population growth has become a main theme of the ecological discourse since the 1970s. The

"Club of Rome" reports, beginning with the "Limits to Growth" (Meadows et al. 1972), discuss economic growth in unclear and changing ways. After the first report, with its neo-Malthusian view of resource scarcity and its later updates, other ideas are put forward in later reports, especially the controversial idea of "sustainable growth". That idea attempts to bypass the hot topic of limiting growth, saving and redistribution of resources in the search for a system-immanent way to approach sustainability through dematerialisation of production in much higher degrees, as in the practice of dematerialisation in economic production (Weizsäcker et al. 1997). Also, the Brundtland report "Our Common Future" in 1987 left the possibilities of global sustainable development unclear, not touching on questions of limiting growth, but only seeking arguments that growth is still possible, even essential for countries of the global South, although sustainable growth should take account of limited availability of natural resources. This vague reasoning could be understood as supporting arguments similar to dematerialisation.

The limits of the dematerialisation idea (Chapter 2) for supporting sustainable resource use have become apparent in the critical points that were also seen by the proponents of sustainable growth: continued growth annihilates the ecological gains of dematerialisation, and perverse effects (rebound effect) that are shaped by the market system and its institutions make dematerialisation in economic production a stimulus for consumers to use more resources, thus supporting growth, instead of limiting or reducing global levels of resource use. Two critical questions remain, though in the meantime they have been more intensively discussed and the first answers are available:

– Can the global economy be transformed into a steady state economy without growth?
– Can resource-intensive economies in Western countries be maintained under the auspices of global sustainable development?

The argument favoured by ecologists and ecological economists, that only a steady state economy with no economic or population growth can maintain the natural capital in the long run, over generations, seemed unrealistic or utopian – until recently. Growing doubts about growth-driven resource use and consumption (e.g., Stiglitz et al. 2009) bring Mills' (1856: 326) old question back into the present ecological discourse: "*When the progress ceases, in what condition are we to expect that it will leave mankind?*"

The first global systems analysis of "limits to growth" was to become not only a founding document of the emerging environmental movements, but also one rejected by the political institutions, the academic establishment, and both Marxist and non-Marxist theoreticians. Its main result, a model-based prognosis of a collapse of the global economy because of overuse of resources and pollution towards the end of the 21st century, did not meet with consensus, but evoked rejection as another variant of doomsday prophecies. It provoked more ideologically than scientifically motivated reaction in the form of a "desperate optimism", as in the futurology of Kahn, who tried, against the background of a rapidly deteriorating state of the global environment, to revitalise a variant of the 19th-century "dominant western worldview" – by prognosticating unlimited possibilities of economic development and resource use for mankind, arguing that finite resources are always substitutable by newly found or created ones. With this, some of the economic myths that Georgescu-Roegen criticised in economic theories for their neglect of physical and ecological realities of human resource use were repeated. It took more time and two updates of the report by Meadows et al. (1972), for it to be discussed more seriously, not only with more or less justified criticism of its inexactness or inadequateness in concepts and assumptions, which can be addressed as methodological problems of modelling, of data availability and of interpretation of key variables of complex systems. Today it seems more difficult to reject the reports with the simple argument that they follow neo-Malthusian and naturalistic premises of population growth and limited resources. Final limits of economic growth and resource use are becoming known and visible, in spite of changing carrying capacity of ecosystems and continued scientific and technological development. It is less contested today than in the 1970s, when the global environmental discourse was about to begin, that there are ecological and social limits to growth.

The growth concept of the report is undifferentiated, conflating growth in all forms of physical (of more and more use of physical resources, matter and energy in production and consumption processes), biological (of plants, animals, species) or economic (in terms of monetary value, income and richness of individuals and countries) growth. But it is not difficult to develop more differentiated growth concepts. It is more difficult to find out how this analysis connects with that of ecological Marxism, which uses thermodynamic theory to interpret limits of economic development, such as ecological economics (see below). The concepts of growth and exponential growth are viewed critically in the report mandated by the Club of Rome and in the ecological discourse with the generalised argument that exponential growth in the long run is not possible because it "eats up" the available natural resources. Mathematical reasoning shows this logically, and knowledge from biological and ecological processes of growth provides some evidence – insufficient arguments, as they do not touch upon societal and scientific development and the complicated questions of interaction of society and nature discussed in social ecology. In Marxist political economy the phenomena of growth are analysed with several critical concepts, interpreting the effects of what appears statistically in the measurement of growth in monetary terms: the social inequalities that are concealed by market-based economic growth, but that continue to exist within countries or in the global North–South divide. It seems that the different critical analyses of growth in systems dynamics, ecological economics and ecological Marxism can be combined in a critical analysis of the system boundaries of capitalist development which includes knowledge from the social and natural sciences. The older social-scientific hypothesis of self-destruction of a disembedded capitalist market economy (Polanyi 1944, already including in the argument social and environmental destruction), the more recent one of Hirsch (1976) of social limits to growth and industrialisation as a "positional good" from which only few countries can profit in terms of social welfare, and O'Connor's hypothesis of a second, ecological, contradiction in the capitalist system mobilise interdisciplinary knowledge for the diagnosis of limits to growth.

The "limits to growth" reports continued a discussion which dates back to the classical controversy between Malthus and Marx in political economy as one between resource limits and how to overcome these by drastically limiting population growth (the Malthusian argument) or by developing the productive forces in new economic transformations and energetic or "Promethean revolutions" (the counter-argument). The older controversy was not yet structured in ecological terms. The theme of ecological limits to growth came to unfold in this controversy in rather incoherent and contradictory forms for as long as it was encapsulated in economic theories, concepts and arguments that do not sufficiently use ecological and other natural-scientific knowledge about limits to resource use. Such interdisciplinary combination of knowledge in theoretical or empirical forms, using different concepts, epistemologies and methodologies, remains difficult and contested today. To reconstruct the controversies about resource use simply as two contradicting perspectives of ecology, an imperial ecology of domination and an emancipatory ecology of liberation (Worster), does not help to solve the controversy, but rather falls back into a simplified reasoning of pre-analytical visions that motivate scientific theories. Worldviews, paradigms or pre-analytical visions do not explain all the incoherence and ambivalences in the resource use debates. It seems to have become a dead end in the ecological discourse to identify the normative assumptions of scientific and political thinking as those of two contrasting paradigms, formulated in the recent human ecological discourse by Catton and Dunlap as the human exceptionalism paradigm (HEP) and the new ecological paradigm (NEP). The controversy requires new knowledge and data from different disciplines to advance towards answers about social and natural limits to economic growth and resource use.

Malthusian arguments have not been much more refined in the neo-Malthusian discourse, which is still expressed in crude terms of population growth and resource use that do not take sufficient account of societal system complexity. Reducing the social reality of globalised capitalism to these two countervailing trends remains an oversimplification which is masked by another simplification, the diagnosis of a "full world" formulated by ecological economists. The material reality that the "Limits to Growth" report describes is one of exponential growth of resource use, population, waste production, environmental disruption and ecosystem change throughout the 20th century. These are significant changes that need to be analysed for the capitalist world system. The simple idea of an overpopulated or "full world", something that Marx could only hypothetically assume for a far distant future, a situation for which he saw the Malthusian analysis as more adequate, has historically happened much faster than could have been foreseen. However, it is still not necessary to accept the naturalistic (neo-)Malthusian argument of "population explosion" as a reason for rapid environmental degradation and overuse of resources or pollution of the environment. This argument translates easily into the doubtful reasoning that the large numbers of the poor in the global South are destroying the environment. The unequal consumption of resources determined by income levels and the institutional transformation of economic systems with the consequence of a North–South division into rich, resource-intensive and consumptive economies and poor, extractive and resource-exporting economies should be taken into account in the "limits of growth" debate. With the interdisciplinary development of ecology, the argument of a mutual exclusion of the biological and the social scientific frameworks and explanation is more difficult to maintain. The question has become one of how to combine both frameworks in convincing forms to develop stronger theoretical arguments for a possible reintegration of nature and society.

Ecology and social ecology can, with their analyses of global environmental change and human resource use practices, fill the knowledge gaps that the separate scientific disciplines left in their attempts to produce universal, complete and exclusive explanations on the basis of specialised, disciplinary knowledge. The simple, not exclusively Marxist, argument that the capitalist growth mechanism and the systemic nature of the capitalist world system produce environmental destruction as a non-economic by-product has not been consequently followed up, except in the critical political-economic theories of the treadmills of production and destruction, the theory of unequal exchange and world system theory. The masking arguments for growth to overcome poverty – pollution of the environment as the price to be paid to become modern, overuse of resources and overpopulation as facts to be accepted temporarily until technological solutions have been found – seem to reuse older theories and arguments. This happened again in ecological modernisation theory, shifting unsolved problems to the future and closing the analysis to interdisciplinary knowledge. With social ecology a further step is taken to break the vicious circle of knowledge production. The arguments include the theoretical and empirical ones that are discussed in the following parts of the chapter.

The neo-Malthusian discourse shows some value-laden, speculative arguments about the solution of human resource use problems through drastic limitations or reductions of human population: "Soylent Green" visions of an overpopulated earth. Such arguments reappear in the abstract formulations of ecological economists, a "full earth" and a "steady state economy", that hide a number of extreme ideas. The concept of a steady state economy, renewed by Daly in ecological economics, implies that two "*basic physical magnitudes are to be held constant: the population of human bodies and the population of artifacts (stock of physical wealth)*" (Daly 1977: 16). To hold constant the natural capital requires a policy of redistribution of resources to satisfy the needs of all humans and a policy of global birth control. How such a birth control policy should be practised is open for speculation, where an authoritarian biology seems to misuse its knowledge. Schwartzman (2008: 47ff) summarises and criticises some of the provocative ecological visions: that the carrying capacity of the earth is now exceeded; that the human population level is no longer sustainable; that the global population needs to be cut back in sustainable retreat (Lovelock), reduced to pre-industrial levels (Rifkin); that the largest part of the human population should be eliminated in a genocide by use of airborne Ebola (Mims). Apocalyptic visions and speculations about population figures are not the final word of ecology. An alternative use of ecological knowledge is to analyse the limits to human resource use in more depth to find solutions in terms of changing production and consumption forms and renewals of energy systems and their composition of energy sources. This requires dealing with the theoretical debates about energy and resource limits in further theories: thermodynamic theory and critical theories of unequal exchange.

The thermodynamic paradigm of ecological economics

A physical analysis – in energy terms – of economic processes did not start with the thermodynamic theory of Georgescu-Roegen, which is conceived as the beginning of modern ecological economics. In the economic discourse a debate is found about the Podolinsky controversy in the 1880s. Podolinsky discussed his suggestion to reformulate the Marxist theory of capitalist economy in terms of the thermodynamic theory to show the potential of more efficient energy conversion, deposition and use in economic processes. Also, he used the model of agricultural production to formulate his arguments. The discussion of an energy-efficient and energy-intensive modern economy in which human labour is seen as capable of accumulating energy seems to be no longer of interest today. Nevertheless, controversy about its interpretation continues today between ecological Marxists (Foster and Burkett 2000; their interpretation of an ecologically broadened Marxist theory is convincingly criticised by Gehrig 2011) and ecological economists (Martinez-Alier 1995). The combination of value-theoretical economic and thermodynamic arguments in a physical and political-economic analysis of labour remains a problematic attempt, not only for the Marxist critique of political economy. Another theoretical idea seems required, other than a direct combination of economic and physical terms or a translation of the terms from one discipline into another. Interdisciplinary ecology and social ecology can learn that shortcuts of theory combination and transfer, as in theoretical social-ecological systems concepts, may be wrong or useless when a critical reflection of the different subject and validity spheres of specialised theories is neglected. Gehrig (2011: 635) also formulated this argument against more sophisticated trials of a thermodynamic Marxism by Altvater. There may be a more successful interdisciplinary connection if theories and concepts do not level different validity criteria to achieve a joint theory, but work with different and only loosely connected theories.

The Podolinsky controversy illustrates attempts to combine physical and economic theory, as was later done in modern ecological economics by Georgescu-Roegen. The parallels in the interdisciplinary dialogue of physics and economics seem striking and indicative of the difficulties in achieving a theoretical synthesis. By analogy with the example of agricultural production applied to demonstrate the ecological interaction of economy with nature in the framework of modern ecological economics, the thermodynamic theory identified energy as the key resource of modern economies, although with different connotations: in Podolinsky's physical interpretation of economic processes it is the utopian idea of socialism as an energy-accumulating, not wasting, system; in Georgescu-Roegen's interpretation the anti-utopian model of living and producing within the limits of the thermodynamic laws.

The aim of all attempts to formulate a physical economy is to analyse the economic processes both in economic terms of value production and in physical terms of material production. Within such abstract formulations a variety of integration attempts are possible that differ in modes and degrees of coupling concepts and knowledge from economics and physics. Also, the concept of scarcity adds to the difficulties of formulating limits of natural resource use, contrary to the impression given by the concept. In the sociological debate about scarcity two variants can be found, summarised by Stanley (1968: 858f): "scarcities rooted in nature" and scarcity "not as facts of nature but . . . acted upon cultural definitions of situations". A further discussion of scarcity would be required, including historical and comparative analysis of societies, to make clear the consequences of institutionalisation of scarcity, which, according to Tijmes and Luijf (1995: 328), have become obvious only in modern and affluent societies (for further critical discussion of value theory, see Burkett 2003). A close coupling of physical and economic concepts is found in thermodynamic theories of economy in ecological economics and ecological Marxism. A loose coupling with less ambitious – and less ambiguous – cognitive interests is found in social ecology, where the theoretical integration is less strict and is not based on a highly specific physical theory of thermodynamics. The utility of this way of thinking is not ignored insofar as it helps to argue for resource protection and to criticise environmental damage through societal action, as Fischer-Kowalski (in Fischer-Kowalski et al. 1997: 20) argues. However, with regard to the thermodynamic theory as a framework for social ecology, Fischer-Kowalski's arguments are cautious, since she avoids stating directly why the theory is not chosen in social ecology: the entropy theory is highly abstract and cannot be plausibly used in the ecological discourse to discuss limits; it may even be deterring; moreover, a translation of the abstract physical theory of order into socio-economic concepts is hardly possible (ibid.). In this latter argument the core point for a rejection of the thermodynamic theory becomes evident, as happens with the widespread arguments against the use of the thermodynamic concepts for economic analyses as summarised by Gehrig: instead of theoretical integration and explanation, which Georgescu-Roegen is seeking, the use of thermodynamic concepts for economic processes remains nothing but metaphoric use of concepts for heuristic purposes, analogies, and in the political discourse, for a moral interpretation of economy in ecological terms (Gehrig 2011: 640f).

Georgescu-Roegen's view of the economy as a thermodynamic process has mainly been criticised for his modification of the entropy term to make it compatible with social-scientific reasoning about the value of use of economic products; in so doing he broadens the entropy analysis to include, in contrast to the physical theory, not only energy but materials too (Gehrig 2011: 636). The second main critique is connected with the formulation of a "fourth law" of thermodynamics with doubtful assumptions about the interaction of energy and matter, the interpretation of the earth as a closed system and his "conflation of isolated and closed systems" (Schwartzman 2008: 45, with further sources). The thermodynamic laws in physics have been formulated for closed systems, not for open systems, which are far from a thermodynamic balance. To apply the thermodynamic laws to the analysis of economic processes, Georgescu-Roegen interprets the earth in complicated formulations as a "practically closed" system, similarly to other thermodynamic economists who take the earth to be a materially closed and energetically open system, exchanging only energy with the cosmic environment (Altvater 1992, similar Binswanger). Or they argue in contradictory ways, such as Söllner (Fischer-Kowalski in Fischer-Kowalski et al. 1997: 19, Schwartzman 2008: 50ff, Gehrig 2011: 636f).

For social ecology, two points have become important in its process of learning from earlier economic attempts to develop an interdisciplinary theory of resource use based on the nature–society connection.

1. The abstract physical terms of energy, entropy and order in the thermodynamic laws cannot be integrated with similar concepts used for social systems; to make, for example, the thermodynamic notion of order and

that of social order compatible requires doubtful modifications of the concepts.
2. Instead of applying a specific physical theory, such as that of thermodynamics, which is in continuous debate and interpretation in physics, it seems more promising to analyse the different energy sources and forms of energy conversion to concretely identify the limits of their availability and use (e.g., Hall and Klitgaard 2011). This can be done in the empirical forms of MEFA as practised in social ecology and in more theoretical terms such as that of energy systems as coupled social and technical systems (Debeir et al. 1986).

Social ecology cannot avoid controversial debates by renouncing thermodynamic theory (its basic concept of societal metabolism also remains controversial), but it easily creates communicable empirical energy analyses. This perspective of developing improved methods for empirical analysis of materials and energy flows – which may still be controversial on methodological grounds of operationally defining energy that can be measured in different forms – also seems to show ways out of the dilemma of formulating a dogmatic theory of entropy driven by interest in showing the limits of human use of natural resources. For this reason Schwartzman (2008: 45) credited Georgescu-Roegen with a "useful error"; the latter's cognitive interest in showing the limits of materials use and recycling is valuable but could also be realised without a fallacious fourth law of thermodynamics. The limits of available energy are not imposed by the "*simple absolutes of the laws of thermodynamics but by the complex of difficulties associated with its extraction*" (Hughes 2000: 61). Cottrell's detailed discussion of the relations between energy, social change and economic development ended with the conclusion, still useful for the present discussion of future sustainable energy systems: "Any attempt to deal with such a complex of variables as is involved in predicting the course of civilization must be to some degree a failure." He assumes "whole areas of ignorance whose exploration might increase the accuracy of our thinking about the future development of human society. If it does succeed in providing a framework for research of a kind that will reduce our error, it will be justified ..." (Cottrell 1955: 311).

As the controversies about the reformulation of the modern capitalist economy in energy terms, from Podolinsky to Georgescu-Roegen and ecological Marxism, show, these problems cannot easily be exposed in the framework of a physical energy theory which has disengaged itself from the analysis of the systemic constitution of the global economy. The fact that the thermodynamic laws are also valid for economic processes does not mean that these can be reduced to physical processes. If one accepts the assumption that physical and societal theories are both required to discuss the energy future of modern society but cannot be integrated in one joint theoretical system, the controversy does not impede the study of societal energy systems.

Unequal ecological exchange and ecological distribution conflicts

Both theories taken up here have been discussed (in Chapter 2) in the context of environmental sociology, to which one of them, that of unequal ecological exchange, belongs. The theory of ecological distribution conflicts has been elaborated in the interdisciplinary context of ecological economics and political ecology, which has consequences for theoretical reasoning and terminology: viewed sociologically, the theory is inexact, with regard to the characteristics of social actors in conflict with other actors, and the phenomenology of the conflicts described from an ecological perspective of resource extraction, distribution and pollution or waste. However, this inexactness is not relevant in an interdisciplinary analysis of societal metabolism, where the ecological logic counts more. The theory of ecologically unequal exchange formulated by Rice (2007, 2009) and other authors is based on the analysis of global resource flows in the international trade of natural resources. Its main arguments can be summarised as follows (Table 4.1).

The theory of Rice can without difficulty be combined with that of ecological distribution conflicts by Martinez-Alier. The two theories are complementary in the sense that the theory of unequal exchange describes the systemic reality of the modern world system, which results in manifold resource use conflicts described in Martinez-Alier's theory from the perspective of social action as the clash of the lifeworlds of the global poor and the global rich, or as the "environmentalism of the poor" (Martinez-Alier 2002) and the "environmentalism of the rich". Complementary theories are useful in a social-ecological perspective thanks to cognitive synergies they create in the analysis of global societal metabolism. The results of unequal exchange analysis summarised by Rice (Table 4.1) need to be translated into the political discourse, in strategies for sustainable development that take up the critical message of unequal exchange in strategies for transforming the global economy. One of the forms in which contrasting requirements of transformation become apparent is represented by ecological distribution conflicts between the global North and South, conflicts that need to be taken up and solved in the sustainability discourse, as the second component of system transformation apparent in the degrowth debate.

Energy system development through "Promethean revolutions"

"Promethean revolution" is the term used by Georgescu-Roegen (1986: 15ff, Altvater 1992: 82ff) to analyse the changes in energy systems that were connected with the transition from one societal mode of production to a new one in human history. The first Promethean revolution, controlled use of fire by humans, made possible the transition to agriculture, and the second revolution, the combination of thermic energy and water in the production

Table 4.1 Ecologically unequal exchange

The theory of Rice in summary form:

1. *Asymmetric resource flow from extractive economies ("least developed countries", LDCs) to productive economies (industrial countries)*: the latter accumulate wealth and appropriate large parts of global resources, especially of energy resources. Consumption of forest products, for example, is highest in core countries of the world system, but deforestation is highest in periphery countries where the consumption of forest products in the country is low – core countries can afford to protect their forests.
2. *Core countries use greater proportions of global sink capacities*: for example, global warming is primarily a consequence of CO_2 emission by industrial core countries – however, globalisation and late industrialisation in some big countries, such as China, have changed the emission data during the past decade.
3. *The better protection/conservation of resources and nature in industrial countries* may not be an indicator of their higher ecological rationality but of their ability to shift negative consequences of resource consumption and degradation to countries in the periphery.
4. Many core industrial countries have ecological footprints beyond their national natural capital stock, through high population density and/or high consumption rates. They use natural capital elsewhere, in the periphery (the "Netherlands fallacy": Rice 2007: 63).
5. *The environmental situation in a country*, positive or negative, is not only a consequence of domestic factors but depends on its relations with other countries – these relations are structured through the world system.
6. *The "rich-country illusion effect"*: "By importing natural resources and exporting sink capacity demand and environmental costs inhabitants of core countries can mistakenly perceive their lifestyles as sustainable, as their consumption rates are not highly linked to domestic environmental conditions . . . Conversely the rich-country-illusion effect implies that LDCs are to blame for failure to sustain their domestic natural capital" (Rice 2007: 63). All examples and trends indicate "asymmetrical sustainable development": "Core countries . . . attain high consumption rates of natural resources and maintain their domestic environmental assets at the expense of countries more marginally situated within the world-system. Core countries, therefore, appear sustainable while simultaneously making true broad-based sustainable development increasingly problematic." (p. 65f)

Source: Rice (2007)

of steam, is one of the inventions that made industrialisation possible. The transition to new energy regimes from hunting and gathering to agriculture and industry included productivity gains, more energy "harvested" for use in the economy, more intensive use of resources and more wealth in economic terms. The new combination of energy sources and conversion techniques can be seen as the triggering event for a transition to a new socio-metabolic regime. The industrial regime based on fossil energy sources is independent of the net primary production of biomass in ecosystems and, through transport of energy resources, more spatially independent of natural ecosystems, allowing, for example, concentration of industrial production in cities. While the historical changes can be described easily, the consequences of changing energy systems and the separation of ecological and economic productivity in modernity are more complicated. The separation indicates a societal system structure that cannot be understood without political economic analysis of its socio-metabolic and accumulation regime. The transformation of energy systems in human history has been analysed systematically by Debeir et al. (1986) with the concept of energy system, as a social and technical system.

> Although highly promising for its transdisciplinary, holistic approach to energy history – interlacing social with ecological dynamics through a political economy explanation – the methodology of complexity theory adopted by Debeir et al. has not been widely followed.... Nevertheless, the concept of 'energy system' was essential to early [energy history works on the industrial revolution] which tended to follow a 'resource scarcity' or 'energy and materials flows' approach...; some of these studies also started to give attention to environmental and social costs of the urban/industrial way of life, such as entropy, pollution, public health, resource exhaustion.
>
> (Barca 2011: 1312)

The analysis of historical energy systems and discussion of potential future energy systems by Debeir et al. (1986) can be seen as part of the "opening debate" for the new social ecology, in which the simpler term of energy systems is replaced by a more complex and theoretically derived concept and typology of socio-ecological or metabolic regimes. Empirical energy flow analyses for the global economy have advanced within the MEFA framework of social ecology, although not all methodological questions about energy measurement have been solved (see below). The advances in theoretical and empirical analyses of material and energy flows mark, however, the interdisciplinary research required for the discussion of societal transformation to sustainability (Haberl et al. 2011) that go beyond the limited debates of "governance transformation" found in ecological modernisation theory and in the present debates about global environmental governance. The analysis of energy components of socio-metabolic regimes seems to become a core theme in the scientific and political discourse about sustainable development when the alternatives for transformation paths are formulated in the preliminary terms that are found in the present ecological debates as strategies of dematerialisation or degrowth (see below). The theoretical contours of the concept of socio-metabolic regimes and its use for societal transformation theory are discussed further in the reconstruction of the integrated framework of social ecology (Chapter 6). The concept of Promethean revolutions is not yet an elaborate theory and needs to be developed further from the preliminary meaning it was given by Georgescu-Roegen (1986) to analyse the leaps in energy use during the historical transitions to new modes of production. The critical capacity of the theoretical concept depends on its ability to help formulate another energy system transformation, one that interrupts the trend towards a global high energy society. The analyses of this conversion process are not advanced, circulating around the basic idea found in the sustainability discourse, the vague idea of reducing the "throughput growth" in the economic world system (Altvater 1992: 82).

Not all of the various ways of theoretical thinking about limits to resource use have influenced the societal metabolism perspective unfolding in social ecology. There is more scepticism among social ecologists about the neo-Malthusian and the thermodynamic theories than about the unequal exchange and energy system analyses which support the empirical analyses of global resource flows. The interdisciplinary analysis of limits of human resource use in social ecology is more complex than that exposed in the earlier debates; it uses different components for knowledge integration and synthesis, theories and theoretical concepts, conceptual models, various methods for empirical analysis of resource flows, and attempts to translate the analysis of results into new discussions about another "great transformation" towards global sustainability. This interdisciplinary accounting for nature–society interaction is working with several perspectives, in an open, pluri-theoretical framework without the theoretical or methodological reductionism that came up with several trials to "shortcut" theory integration, as in the thermodynamic theories of economics or in ecological Marxism. The chances for future theoretical synthesis are gradually coming closer. The social-ecological discourse has arrived at this stage of preliminary consolidation of its ideas. The empirical components of societal metabolism analysis are now discussed in terms of important indicators and models.

Analysis of global resource flows – indicators and models

Widespread indicators for analysis of human resource use and global resource flows are the ecological footprint and the framework for material and energy flow accounting (MEFA), in which three concepts have been integrated, material flow accounting, energy flow accounting and human appropriation of net primary production of ecosystems. The ecological footprint analysis is not discussed further, only the more advanced indicators for the analysis of societal metabolism. MEFA traces socio-economic materials and energy flows, assessing changes in relevant patterns and processes in ecosystems related to these flows. The analysis links socio-economic processes to biophysical stocks and flows, and these to ecosystem processes.

> Obviously, material and energy flows related to economic activities ... do not comprise society–nature interactions in their entirety. One important aspect that cannot adequately be grasped by the socio-economic metabolism approach is land use – one of the most important socio-economic driving forces of Global Change .... Land use can be conceptualized as "colonization of terrestrial ecosystems" ... and as such can be included into the MEFA framework. This approach analyses land-use related changes in ecosystem patterns and processes by comparing ecosystem patterns and processes that would be expected without human intervention with those observable today. An example for this approach is the calculation of the "human appropriation of net primary production," or "HANPP".
>
> (Haberl et al. 2004a: 204)

Within the MEFA framework and its analysis are connected three forms of resource use analysis required to operationalise the theoretical concepts of societal metabolism and colonisation of nature. These comprise the industrial throughput of resources in the global economy as well as in other economic sectors, especially the land use relevant to the analysis of agricultural resource use. HANPP is a critical indicator for the colonisation of terrestrial ecosystems, measuring the difference between net primary production of potential vegetation and that part of net primary production that remains in the ecosystem after human "harvest" and use of resources (see Chapter 5). Its relevance to the discussion of socio-ecological strategies for transformation to global sustainability needs to be discussed in the context of a transformation of the industrial agri-food system.

The first three components of resource accounting – MFA, MEFA and HANPP – developed and discussed in social ecology do not cover all methods and measurements required for the operationalisation of the theoretical concepts. Haberl et al. (2004) have pointed to further developments: expressing socio-economic metabolism not in terms of materials, but as carbon flow, would increase its usefulness for important applications in the ecological discourse, and further accounting tools can be developed. The authors summarise the use of the framework as follows:

> The MEFA framework can be applied on many spatial scales. It allows for long-term historical studies and it has the potential to support the analysis of scenarios.... In particular, we have offered two MEFA-based assessments: a reduction in the yearly flows of renewable resources can be interpreted as progress towards sustainability, and reductions in outflows (emissions, wastes) are also such a progress. Both interpretations are based on long-term considerations and on the overall assumptions of the MEFA framework, or the concept of a social metabolism at large.... One challenge to the MEFA framework is the difficulty in calculating or

> estimating plausible "sustainability thresholds" for many of the observed processes. This task might be beyond the scope of scientific analysis and has to be accomplished by international negotiations such as those conducted at the UNFCCC conferences. The strength of the MEFA framework, however, is its ability to deal with questions such as decoupling of economic growth, social well-being and material/energy flows and thus to provide answers to the direction of a given change: An assessment whether this particular change moves society towards or away from sustainability.
>
> (Haberl et al. 2004a: 210)

The connections indicated between material and energy flow accounting, land use analyses and applications of the HANPP are illustrated in the discussion of food production and land use changes (Chapter 5).

Changing controversies – from dematerialisation to degrowth

The earlier debates about dematerialisation and limits to growth in the ecological discourses in science and politics in the second half of the 20th century have, through their deficits, stimulated the search for new ideas, knowledge and methods to broaden the "limits to growth" debate from the perspective of transitions to sustainability. This critical debate is also taken up in social ecology (Fischer-Kowalski et al. 1997: 208ff, Haberl et al. 2004) to connect the analysis of societal metabolism with the political discourses about sustainable development that are based on different premises of saving resources, de-intensification of industrial resource use and sharing of resources. The "background controversy" is between developing the industrial systems, through their ecological regulation and "taming", and another great transformation of socio-metabolic regimes which implies a new "Promethean revolution" of energy systems, but for the first time in human history the transformation is not aimed at further intensification and concentration of materials and energy in the economic system and production. The industrial system that is with its energy and material use discounting the global future, using a socio-metabolic opportunity structure that has existed historically only for a short time (Fischer-Kowalski et al. 1997: 208), cannot be extended into a global industrial system for future generations. To prepare the alternative idea of a "great transformation" the debate between dematerialisation and degrowth can be summarised as follows (Bruckmeier and Tovey 2010).

In the social theory discourse, arguments can be found that modernisation and globalisation are creating a social world structured around non-material flows of information rather than around flows of material resources (Mol and Spaargaren 2005). It was widely assumed in economics and other discourses that dematerialisation would help in setting national economies in industrial countries on sustainable paths of development. But the dematerialisation term carries heterogeneous meanings and is often ambiguous with respect to the data used to support its occurrence. The dominant interpretation of dematerialisation, as reduction of materials and energy in production and consumption, fails to connect with sustainable development through insufficient analysis of social and economic systems and of social relations around natural resource use, globally and at local levels. A question that evokes controversies is: what are the effects of the processes of dematerialisation that are undoubtedly happening in economic production? Within modernisation thinking, advances in information and communication technologies have been treated as making human dependence on nature less and less important to social change and its interpretation, following the argument that society and human resource use can be successfully delinked, although no detailed discussion of delinking is found.

This mainstream view can be confronted by more critical and interdisciplinary theories and analyses of the modern economic world system, in which changing societal relations to nature are seen as necessary to achieve global sustainability. The two contrasting lines of reasoning include: (a) technological innovation, economic and ecological modernisation as ways to develop the industrial system, and (b) changing the economic structures, social institutions and social practices of resource use that support unequal exchange between the global North and South as a transformation of the industrial system. These contrasting views evoke the question of whether scarcity supports economic growth and technological innovation in attempts to detach society further from nature, or whether it is an argument against growth and for reconnecting society and nature. Major obstacles to resolving the debate are ambiguities in the concept of dematerialisation itself. The different meanings and ambiguities can be summarised as follows.

Sun and Meristo (1999), analysing energy saving and decarbonisation in OECD countries between 1960 and 1995, summarised the definitions used in the dematerialisation debate from the early 1990s, differentiating between dematerialisation, immaterialisation and decarbonisation. They found a variety of definitions in physical terms, but most of these converge on decrease in the intensity of material and energy use or pollution (ibid.: 276). More recent debates have focused on quantitative dimensions of dematerialisation of production in an ecological context – for example, the "factor 4" and "factor 10" debates (see Weizsäcker et al. 1997), or the eco-efficiency and dematerialisation debates (Dobers and Wolf 1999). A more critical and historically specified analysis of long-term and cyclical changes of use of materials under the term "transmaterialization" is given by Labys (2004). All these analyses are still guided by physical indicators of materials use. Debates about immaterialisation of consumption are more concerned with value changes, such as changing individual preferences towards consuming immaterial goods such as sociability, intellectual and ethical satisfaction, democratic participation and so on. Such aspects, discussed since Inglehart's hypothesis of a silent value revolution in Western countries in the 1970s, have received less attention in the economic and ecological debates about dematerialisation.

In public policy and debate, dematerialisation is understood primarily as technological innovation and change for an environment-friendly society, driven by agents of change such as engineers and designers of lean and clean products and services. Such discourses, although they helped to uncover a series of factors supporting dematerialisation (e.g., environmental pressures and certain technological changes) and impeding factors (e.g., physical, safety and technological limits, consumer preferences), generally avoid asking how technical change is linked to societal development. Often technical change is simply understood as directing social change, encouraging illusions about how society can develop or solve environmental problems. A significant reinterpretation and theoretical transformation happens when dematerialisation is translated from technical improvements into social strategies for sustainable development, as with the debate about delinking of economic growth and resource use (Fischer-Kowalski et al. 1997: 214ff, Haberl et al. 2004). If efficiency, sufficiency and equity were to be realised simultaneously, through complex strategies of managed social change, economic growth could finally vanish as a driving factor for development and an institutional mechanism for modern economic systems.

In most variants of the economic and ecological debates dematerialisation is understood in natural-scientific terms, as reduction of physical throughput of materials and energy. With sociological debates about ecological modernisation and the knowledge society dematerialisation appears in broader and more diffuse ideas about knowledge and information, rather than physical resource use, as drivers of economic growth. A series of critical questions arising from the review of the dematerialisation debate can be summarised as follows.

Is dematerialisation more than the continuing improvement of technical efficiency in economic production, with its side effects of qualitative changes in the composition of materials and quantitative reduction of material throughput? Does dematerialisation allow for the production of more products and goods with the same material and energy input, thus supporting mass consumption and economic growth? Or is it a mechanism for encouraging more environmentally friendly styles of life and consumption? Does dematerialisation imply the continuation of growth-based production and private consumption only in certain (Western) national economies, or globally? What are the limits of technical efficiency improvements for different types of materials and especially energy? How are so-called hidden flows (WWI 2004: 10f, i.e., flows that are not found in the final products exchanged) taken into account in dematerialisation? How is dematerialisation linked to reduction in the use of toxic materials? How is information related to materials use – is the information technology that has spread throughout modern economies an indicator of less material and energy-intensive forms of resource use?

Further questions come with measurement. What kind of data, statistics or indicators can be used to measure dematerialisation – monetary and/or physical? How are the difficulties of measuring energy use (e.g., primary, final, upstream, embodied energy) in dematerialisation processes solved? How is dematerialisation linked to the forms and quantities of waste production, emissions and pollution of the environment (supposing that these are not linear connections) – should it be measured in terms of reductions in emission, such as carbon dioxide emissions (decarbonisation), or in terms of reduced throughput of energy and matter in the production process, or with other indicators? Transmaterialisation, finally, describes "the characteristic behavior of material markets over time by focusing on a series of natural replacement cycles in industrial development. As needs of economic society change, industries continually replace old materials by newer, technologically more advanced materials" (Labys 2004: 6). This historically specified empirical analysis of dematerialisation phenomena probably best describes the reality of dematerialisation processes as innovation and replacement cycles of materials use through industrial development that can in social-ecological analysis be studied for their connections to changing metabolic regimes during industrialisation which mark transitions such as that from the classical industrial coal regime to the oil regime in the 20th century.

There are also sources of confusion about the idea of dematerialisation at more theoretical levels – resulting from the definitions of matter, materials, materiality and materialism in the natural and social sciences and in philosophy. The abstract and theoretical terms materiality and materialism are affecting the more concrete notions of dematerialisation. In large parts of the ecological discourse, in science and in politics, a simple division is made between material reality as analysed and measured in the natural sciences and social or symbolic reality as analysed in the social sciences, as the socioculturally formed practices of communication and language use. Such ontological divisions of reality are based on dualisms (such as that of nature and culture) that are at the same time strongly criticised in ecological thinking. Older interdisciplinary theories, such as classical Marxist and critical theory, achieved under the traditional philosophical notion of materialism more complex understandings of the nature of nature and society and their interactions than the simple division between materiality in the physical sense (of matter and energy) and non-material symbolic sociocultural reality. Their critical point, with which the present socio-ecological discourse connects, is that of multiple connections between physical, historical and social elements in the notion of materiality. This theoretical perspective can be developed further in the theoretical discourse of nature–society interaction in social ecology (see chapters 6 and 7).

Degrowth as a critical term to articulate the requirements of a transformation to sustainability in line with the prior debates in ecological economics is not yet discussed systematically in the social ecological discourse. In future it will become more important for the analysis of societal metabolism than the simpler dematerialisation arguments. The theme of degrowth has arrived at the social-ecological discourse agenda with the bits and pieces found in the recent ecological discourse (e.g., the new degrowth movement, the debate about planetary boundaries of human resource use). The theoretical analysis of how to achieve a non-growing economy needs to be connected with other components of a transformation to global sustainability and a new societal metabolism, as in the Millennium Ecosystem Assessment reports from 2005, or in the report about global agriculture (IAASTD 2009, see Chapter 5), in more systematic analyses of limits to human resource use that take into account societal structures as well as ecosystem functions.

Conclusions

From the themes discussed in this chapter – the physical economy of the modern world system in the perspective of physical, ecological and economic limits to human resource use – the contours of a more systematic social-ecological analysis become apparent as analyses of societal metabolism with the components of socio-metabolic regimes, great societal transformations of the past (agricultural and industrial revolution) and future transformations under the auspices of global sustainability. The question of what the idea of social metabolism and resource use regimes implies has been answered from different perspectives, of which three have been taken up in this chapter (the fourth will be covered in Chapter 8):

1. *the systematic analysis of natural resource flows in the global physical economy based on the concept of MEFA*: This provides arguments against the assumption of Mol, who saw the quantitative analysis of deterritorialised and hybrid global flows as impossible.
2. *the perspective of global sustainability*: The idea of national or spatially limited solutions, of "sustainability islands", is seen as unrealistic with regard to the globalised economy of the modern world system, which requires transition to sustainability to be discussed as a global problem, as the necessity for societal system transformation or another "great transformation" to solve the resource use problems that are dependent on global resource flows and unequal exchange.
3. *the reconnection of scientific, policy-related and social movement discourses*: This is happening through recent debates, paradigmatically as transdisciplinary knowledge and issue-linking, for which the recent degrowth

movement is an example as a network of different ecological movements in science and politics.

4. *the adoption of new policy and management models for natural resource use*: The new policy-related discourses that take up some of the social-ecological ideas are those of adaptive governance and global governance.

In all these themes of social-ecological analysis and in the broader ecological discourse with which it connects, the core component of a critical analysis to understand the global limits of resource use is that of material and energy flows in the analysis of the physical economy. This analysis bears the critical messages of the interdisciplinary discourses in social and political ecology and ecological economics.

5

Thematic Profiles of Social Ecology – The Research on Human Land Use, Food and Biomass Production in European and Global Contexts

The interdisciplinary perspective of social ecology for the critical analysis of global resource flows and the interaction of nature and society structures and directs the analysis of agriculture, food production and land use in specific ways. The use of MEFA and HANPP indicators results in conclusions about the physical limits of human resource use that cannot be made with monetary analyses of resource flows in economics. The conclusions are also specific in their application to assess sustainable development; they do not confirm the simple assumptions in neo-Malthusian studies that population growth always implies growth of resource use that exceeds the carrying capacity of ecosystems. With the development of the social-ecological indicators the carrying capacity concept needs to be differentiated (Rees 1996; see below) and seen in relation to the other indicators – there is no longer a single and simple ecological criterion for measuring the limits of human resource use.

The cognitive interests of social ecology differ significantly from a sector-specific economic analysis in which agricultural production is analysed in a market and modernisation perspective. Agricultural economics has dominated agricultural policies, for example, in the European Union, with programmatic formulas for the development of agriculture as integration of agriculture into the national economies and markets. The normative premises of this perspective of mainstream economics include the view that technical and organisational modernisation of agriculture is an economic necessity and the consequence of modern scientific knowledge for agricultural production; its negative social and environmental consequences need to be accepted and can to some degree be compensated. Also, a sociological perspective of supporting a farmer-based agriculture with arguments derived from the sociological knowledge about socially and culturally integrated rural communities is not fully compatible with a social-ecological perspective. This sociological analysis is critical of the normativity of mainstream economics and is to some degree compatible with the interests in environmentally sound and sustainable agriculture, but it cannot assess the environmental consequences of agricultural resource use, for which MEFA and HANPP analyses seem important (although not sufficient). The theoretical concepts of colonisation of nature and societal metabolism that frame these analyses make the interdisciplinary study of agriculture and food production in social ecology unique. The way towards such an interdisciplinary and critical research perspective is – as for the other themes analysed in the preceding chapters – paved with controversies about the nature of agriculture and food production, classical ones like the Malthusian debate of resource scarcity, and more recent ones like the controversy about the use of agricultural land for bioenergy production.

A framing controversy: land use, food production, hunger and misery

The relations between land use, food production, resource distribution and the existence of misery and hunger throughout human history have given rise to continuing scientific controversies. The Malthusian question of population growth and resource use limits was renewed by Hardin (1968) as the tragedy of the commons (see Chapter 4). The empirical resource use studies of common pool resource research (see Chapter 2) have already brought significant modifications to the Malthusian arguments, showing further factors and variables that influence the outcomes of joint resource use and do not privilege a specific form of property rights as sustainable. The empirical research helped to clarify the deficits and misleading assumptions in the Malthusian theory, both in its classical form and in its renewed form as a theory of global resource limits. This had already been seen in the original controversy between Malthus and Marx, and it happened again in the controversy following Hardin's model of the tragedy of the commons. The questions arise: Why did the empirical data gained and the attempts at rational solution based on positive knowledge not work well, and not help to finally solve the controversy? Why do the old cleavages still continue today, with much more and better knowledge of global resource use and its limits? This controversy appears to be continuous; it cannot be answered once and for all, but suggests only preliminary answers that invite further counterarguments. Interpreting the controversy in this way may appear to give it the status of a big philosophical controversy, but it may only be shallow, maintained through differing worldviews, paradigms, ideologies and prejudices that are supported by selective use of empirical data and knowledge.

A partial clarification of the reasoning about overpopulation has today been introduced into the controversy by formulating clearer premises, for example, with regard to the assumptions of a "full world" and global resource use limits that give the neo-Malthusian thinking more precise contours. With this new framing a controversial question arises: When is it possible to speak about a full world, and how (if at all) can the notion be quantified in terms of human population figures and specified resource limits? It seems that scientific knowledge contributes more to answering these questions, with the construction and calculation of indicators and indices such as that of the carrying capacity of ecosystems, ecological footprints, material and energy flow accounting, human appropriation of net primary production, and the various sustainability indicators and indices. The indicators again evoke controversial discussions about their constructions, definitions and assumptions or their competing nature. But better-informed guesses are possible today about population growth and natural limits. Some of the old controversy seems to survive for other reasons, channelled either by political motives or by the specialised and limited disciplinary knowledge and perspectives from which the opponents argue. Since its early times the controversy has centred around biological and social-scientific knowledge; knowledge hegemony, a power question, emerged in the scientific discourse. As a controversy about scientific knowledge its opposing parties were interested scientists, and to a lesser degree concerned political actors. Cases when a Malthusian reasoning was taken up for the sake of politics and the solution of specific resource crises seem to be of interest in understanding the ideological nature of the reasoning. The analysis of historical hunger catastrophes from the point of view of the Malthusian hypotheses may identify political interests, ethical positions, and moral values underlying the problem construction. Such a practice test of Malthusian thinking was, for example, the management of the great famine in Ireland in the 1840s by the British government. The remarkable point about that catastrophe is that even today the controversy among scientists is not yet settled as to whether it is to be seen as a consequence of British government policy; for example, food exports from Ireland were not stopped even during the worst years of hunger. Today the neo-Malthusianism uses the idea of the steady state economy with zero growth of population and resource use to formulate a solution to the global resource crisis. This includes a policy of redistribution of resources that can hardly be imagined in any other way but an equal distribution between all people, and a policy of birth control to bring population growth to zero. The latter, an even more controversial theme, becomes practically interesting when ecologists calculate "sustainable" levels for the global population. At this point knowledge, valuation and guesswork become blended and widely different figures seem to be defensible, varying between the more than nine billion persons expected to form the global population peak after the mid-21st century (for these, with a fair distribution, sufficient food would still be available) and a pre-industrial population level of fewer than one billion, as some ecologists assume as a maximum. The lower figure evokes extreme suggestions for methods of population reduction, including some that can be taken as provocative – for example, to annihilate the largest part of the human population by airborne viruses (see Chapter 4). Progress might be made in scientific debates if they could turn away from abstract models, speculation about figures or genocide ideas, and analyse more socially relevant and real catastrophes stemming from present-day political and economic decisions about land use, food and bioenergy production.

The apocalyptic visions of an overpopulated earth with hunger and poverty that motivate the thinking in neo-Malthusianism and, to some degree, in ecological economics did not influence the research in rural sociology (discussed in Chapter 2), which included critical views of rural development under the impact of industrialisation and urbanisation. The questions of population growth that dominated Malthusian thinking were not the focus of rural sociology, although its themes included the nexus between hunger and modernisation of agriculture. Malthusian thinking evoked controversies not because it addressed poverty, which has existed constantly in modern times, but because of the way it explains the problem and its solution through limitation of population growth. Sociological research into land use and food production, with its context-specific knowledge, stands closer to the historical and social realities of food shortages, hunger and unequal distribution of resources than the abstract and decontextualised models and theories from the "dismal sciences" of economics and ecology.

It took a long time before the argument spread in ecology that carrying capacity – the maximum number of animals and plants that an ecosystem can feed – does not apply to humans in the same form as it does to animals, as Rees (1996) suggested in a critical discussion of the carrying capacity concept, where he referred to the increasing consumption levels in the course of human history through the development of trade and technology. Rees describes the situation for humans in such a way that answers come less from biological or ecological knowledge than from sociological, economic or anthropological research. The concept of carrying capacity needs to be modified for humans as a consequence of the socially determined variations in human resource use. Human consumption of resources is not biologically determined, varies widely in history, within and across countries, cultures and social groups, and is influenced by agricultural productivity, which has varied greatly in the course of human history. Along with intensification and modernisation of agriculture, the quantity of land required for food production for the given population is reduced, although not to the degree which appears in national statistics (which does not include the land used outside a country for imported animal food and other inputs of modern agriculture). The Malthusian question of how many people on the earth can be fed cannot be answered from a maximum human population level, but rather from a maximum level of human consumption of natural resources, as Rees (1996) suggested. Taking into account this complexity of a varying consumption level, the limits of human resource use cannot be defined as a simple global indicator, but through attempting to measure limits to growth with a variety of indicators as done today in ecology, for example, in the form of planetary boundaries of human resource use, or through indicators such as MEFA and HANPP. When final limits cannot (yet) be formulated scientifically, "ceilings" can be negotiated, for example in policies for sustainable development.

To make sense of the notion "overpopulated earth", different phenomena and reasons for "overpopulation" need to be described. Only one of them, a biological population growth in absolute numbers of humans, returns in (neo-)Malthusian arguments. Two basic forms of overpopulation that can be analytically differentiated include (1) overpopulation as a biological phenomenon (absolute or relative), meaning that too many people have to live on the natural resources available in a limited area. But to interpret and specify the limits of resources further descriptions are required that include (2) forms of overpopulation with predominantly economic, social or cultural reasons to be identified in historically specific studies of population–production relations. The practical difficulty is that both forms, biological and social, are always combined in complicated variations. A reduction to a biological phenomenon of rapid population growth is also misleading with regard to the present phenomena of exponential growth of the global population. Boserup (1965) has studied relations between population growth and food production in agricultural, not industrial, societies, and showed different dynamics that interact with each other, a dynamic of population growth and one of technological improvements to increase agricultural yields.

The question of historical and cultural variation of human resource use and consumption levels comes up in social ecology in another way as the polemically simplified "population bomb" reasoning (Ehrlich and Ehrlich 1968): in the comparison of historical modes of production that shows how far human consumption in historical phases of societal development went beyond the biological minimum of food required for survival (e.g., Fischer-Kowalski et al. 1997, Krausmann and Fischer-Kowalski 2010). Consumption levels depended on the societal organisation of resource use and production in a society that allowed individual, lifestyle, wealth and group-specific variation of consumption levels only in the limits of the socio-metabolic regime that determined the dimensions of surplus production. The average levels of per capita use of materials and energy have shown considerable intensification of resource use in the long development of human societies (Fischer-Kowalski et al. 1997: 30). To understand this historical trend in long-term societal development is one part of the knowledge problem with limits of resources for human use – the explanation is directed away from population numbers towards limits determined by socio-metabolic regimes that include complicated combinations of population growth and material and energy use (see Chapter 6). The other part of the knowledge problem is that of finding possible ways to a more sustainable global socio-metabolic regime in future.

Controversies about agriculture and food production in a global context

With its specific theoretical concepts and methods of resource use analysis, social ecology has shown that it can produce ecological knowledge required for the assessment of limits of land and resource use in more exact, systematic, historically and socially specified measurement. The crude indicators suggested in ecology (carrying capacity) and in the Malthusian reasoning (global figures of population growth and resource use) can gradually be replaced by a better-informed assessment of natural resource consumption. With social-ecological research about global resource flows the patterns of unequal resource consumption can be shown and conditions for a global transition to sustainability can be formulated that allow criticism of the distorting picture of national strategies for sustainable development that produce "rich country illusion effects" (Rice 2007). The debate on the green economy in the "Rio+ 20" process has brought all that is required for formulating renewed strategies for sustainable development of the second generation that can help to overcome the dead end at which the global sustainability discourse has arrived (see Chapter 8).

The policy discourse about sustainable development and limits to growth takes up information from the scientific discourses selectively, from specialised research and different disciplines that compete with each other. The selectivity has been discussed (in Chapter 3) as one that neglects social scientific and interdisciplinary knowledge, showing a traditional understanding of environmental research and science. For a renewal of the sustainability discourse a broader knowledge base is required as a focus on global change and a global sustainability perspective. For social ecology, seeking its way into the discourse, it seems necessary to become part of its renewal. Older controversies about weak or strong sustainability, ecological modernisation or environmental democracy can be bypassed without denying their utility in the continued search for improved solutions. The reframing of the discourse, shifting from local or national to globally coordinated and integrated strategies, is supported by the global governance debate and the search for solutions to global environmental problems. The socio-ecological discussion of socio-metabolic regime changes offers a possibility to enter the sustainability discourse with the theme of renewable energy sources and a discussion of renewing energy regimes that are part of the great transformation towards global sustainability (Haberl et al. 2011).

The discussion of agriculture, food production and land use is of increasing significance in the sustainability discourse. In the first decade of the 21st century global food production has quickly became a controversial theme in science and policy: food prices have changed rapidly and repeatedly in a short time and the agricultural world market is in turbulence. Several problems and development trends are intersecting – climate change, sustainable development, industrialisation of food production and global land use changes. The question of population growth remains in the background of these debates. A political controversy about alternatives of agriculture and food production started with three policy documents in which the scientific arguments for conditions and limits of food production were reviewed. The discussion is framed in three paradigms of agricultural policy and development (Bruckmeier and Tovey 2008):

1. The changes observed in agricultural development in Western countries are summarised in a review of conceptual models for policies in the OECD (2006) report as a shift towards a "new rural paradigm" in global agriculture. The document focuses on a governance shift through which a more critical view of policy processes and power structures comes to be seen. Built on a sweeping analysis of socio-economic trends in member countries, the new paradigm is identified from new regional approaches to rural policy in several countries, European and non-European; from that in turn are derived some governance strategies for cross-sectoral, place or area-based and integrated approaches to rural policy. The paradigm – by its nature as a paradigm – is neither exact nor specified. It can be interpreted as offering guiding principles for creating new legitimacy for funding of rural development after the old agriculture and subsidy-based top-down policies have been variously criticised as inefficient, incoherent or giving rise to unwanted effects. The new rural paradigm includes elements of a conceptual model, guiding ideas and examples from case studies supporting these framing ideas.
2. This paradigm shift is elaborated more clearly in the report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) about world agriculture (2009), which is less dominated by the interests of the countries in the Organization for Economic Co-operation and Development (OECD). In this new report knowledge problems and practices of knowledge use for agriculture were analysed more critically.
3. In contrast, in the development report of the World Bank (2007) the thinking about agriculture and rural development remains conventional, using a development paradigm which has long been criticised for its narrow focus on development as economic growth and a market-dependent process.

These three reports cover the spectrum of positions in science and policy on global agriculture and rural development. They are influenced by broader debates about sustainability and global environmental change, but these are not in the foreground. The IAASTD report on global agriculture is the most elaborate in terms of scientific reasoning and assessment; it has been produced by a large number of scientists and rural experts from many countries and with different political interests. Scientifically there is wide consensus about problems to address in future rural development, but it was not possible to translate scientific into political consensus in the IAASTD report. Interest conflicts between powerful actors prevented the report from becoming a document of global consensus as, for example, the Brundtland report about sustainable development was 20 years before. In the IAASTD case the agro-food industry withdrew from the work. Their dominant interest was in working with genetic modification of organisms. Moderate criticism of genetic manipulation of material for food production and a discussion of whether it can solve the problems of feeding a growing global population was enough for their representatives to withdraw from the cooperation.

In the IAASTD report, analysis turns away from productivist and fossil energy-based agriculture in order to better address the needs of local populations, the requirements of feeding the global population, and producing in environmentally sound forms. This matches the objectives of most ecological research (discussed in chapters 3 and 4). It is also critical of neoliberal assumptions which concentrate on world markets, monocultural production, substitution of man by machines and chemicals and the modernisation of agriculture – without completely rejecting these, but being more aware of their negative and unintended effects that need to be dealt with. The report could be seen as offering perspectives and knowledge from social-scientific debates, for example, about systemic risks as discussed in the sociological risk discourse; these ideas, however, have not explicitly guided the diagnoses and analyses presented.

Not all the ideas in the IAASTD report are new and original; it is primarily a summary of observed trends and developments. But for the first time an encompassing and more critical picture is used in a global assessment of land use strategies and rural development. Compared with the two other reports, this has a much broader perspective, taking into account eight topics that affect agriculture and rural development: bioenergy, biotechnology, climate change, human health, natural resource management, trade and markets, traditional and local knowledge and community-based innovation, and women in agriculture. With regard to these topics, the other two reports have to some extent hidden agendas, which become apparent through issues discussed in this report. The report gives a clearer picture of environmental damages from modern agriculture and of how problems are interconnected: reducing poverty requires enhancing rural livelihoods, achieving food security and environmental sustainability, supporting human health and nutrition, and achieving equity. Finally the report gives a clearer picture of priorities for action: improving social welfare in the countryside; empowering marginalised stakeholders to maintain diversified, locally adapted agriculture and culture; maintaining the natural resource base; and collaboration in knowledge production and knowledge integration.

In contrast to the hidden agenda of the other two reports, the IAASTD does not strongly argue for genetic modification of organisms or biotechnology as a significant strategy to combat hunger and support rural development. Although it may offer potential benefits, the report doubts whether biotechnology directly contributes to combatting poverty, supporting poor rural producers and smallholders, or is in the interest of consumers. The report does not simply argue for continuation of specialised research but asks for new, interdisciplinary, cooperative and knowledge-sharing approaches in research. In that regard it is part of the broader development of interdisciplinary and transdisciplinary knowledge production that includes social ecology. A research agenda can be derived from the IAASTD, including six areas of important and hitherto neglected research (Bongert and Albrecht 2008: 287ff): (1) agricultural plants, (2) production techniques, (3) biological diversity, (4) locally adapted, environment-friendly land use, (5) social, economic and political context of agriculture, (6) health and nutrition. While the first three areas do include more conventional themes of agricultural research, the last three are of more critical and interdisciplinary character and come closer to research in interdisciplinary ecology, social ecology and ecological economics. Comparing the IAASTD report with the other two reports regarding the knowledge they use, it can be concluded:

1. The World Bank report does not address questions of local knowledge or the subjective capacities and interests of its target group of the rural poor, nor does it argue for opportunities to strengthen their influence and participation in development-related decisions. The practical knowledge of small rural producers is seen as irrelevant for the development process. The report offers the same ideas and development perspectives that characterised modernisation processes and market-driven development earlier. Its knowledge excludes, or rather prevents, critical questions about development within science and technology used for the further industrialisation of agriculture and food.
2. The OECD report struggles with a core problem for rural sustainable development policies and discourses: How to produce, use, manage, share and redistribute natural resources from rural areas? But in the report knowledge is not sought to answer the questions of sharing and redistributing resources. No coherent analysis is found in the formulation of the new rural paradigm, but it is assumed that countervailing trends in agricultural development can be reconciled. Sustainable development, realised in policy terms through the significance given to places

or territories and to natural resource bases, is assumed to be compatible with the requirements of economic globalisation and deregulation. The shift from sectoral to spatial policies opens up managerial processes to divergent and contradictory influences, as older policy processes and practices do not vanish with the new model, but continue to operate in combination with the new trends.

3. The IAASTD report addresses a variety of knowledge questions in an encompassing analysis that takes more account of problems and negative effects or failure of prior modernisation, development and economic growth. It is the most critical of the three reports with regard to policy processes but also to scientific knowledge production and application. However, it is still a report with scientific expert knowledge and expert-dominated assessment, although the notion of the expert has become pluralised and democratised here. Its sectoral perspective on agriculture is also open to multifunctional and trans-sectoral views, but not to the extent of being open without preconditions to the inclusion of local knowledge from rural producers in the assessment of knowledge and technologies for rural development.

Looking at the three reports in terms of the knowledge – not policy – paradigms found within them raises further questions regarding their worldviews, their methodologies, and the role of empirical knowledge and the ethical premises of research as well as of knowledge use (Bennett and Elman 2007: 456f). Without analysing the knowledge components more deeply, some important aspects are summarised. All three reports see global reality as complex and incomprehensible in totality; they do not make efforts to analyse processes adequately in causal terms and the linkages between development processes, limiting the governance of such complexity to partial, obvious problems and effects. Simplification or complexity reduction is sought with modelling or other knowledge production strategies and methods. In this regard the reports reflect the ideas of transformation of governance that have been discussed in the discourse of ecological modernisation and have been interpreted (in Chapter 2) as an indicator of the insecurity in science about the knowledge science can produce to solve the complex problems under discussion in the ecological discourse. None of the reports seems interested in taking up the further discussion of science, knowledge production and policy intervention in one of the discourses of sustainability science, adaptive management, ecosystem approaches in resource management, global governance or socio-ecological research.

The normative features of all three reports in terms of views of humans, society and nature are compatible, to different degrees, with conventional anthropocentric views of nature and the human exceptionalism paradigm (Catton and Dunlap 1978) that can be translated into the European mainstream model of sustainable development as ecological modernisation, with the IAASTD assessment being most critical of this, but not offering a definite alternative. The reports stretch across a spectrum of positions in the scientific and political debates about the future of agriculture, but their epistemological presuppositions and theoretical ideas are not explicit. The ethical premises of the reports and the implications of these for research, knowledge use and politics (normative and axiomatic questions of justification and application of knowledge, e.g., research ethics) need to be sought out and critically discussed. All three reports show the dominance of conventional scientific knowledge and empirical data from disciplinary science and approaches which frame most policy advice – mainstream economics, policy analysis and evaluation research. This raises ethical questions of a different kind. Ethical issues do not arise only when knowledge is applied, through new technologies or products, in ways which affect individuals or consumers, or limit their options. This is the point at which ethical considerations are usually recognised, but such a reduced form of ethical reflection does not prevent risky decisions, nor does it address ethical issues in relation to research and knowledge production. As the IAASTD report shows, there is no consensus on the value of the knowledge production which underlies genetic modification of food. This may be a controversial example, for which the arguments and positions in science and in political discourses are still developing and changing, not yet definite. But what seems more relevant for all three reports and the discourses supporting them is the limited advancement towards a critical interdisciplinary research and knowledge production for rural development. From that, a gap between scientific and policy discourses about rural and sustainable development becomes apparent that cannot be ignored in future debates.

The interests of dominant power coalitions, as identified in science studies, of universities, governmental institutions and private economic firms ("triple helix") are apparent in rural development and in the agro-food system. The three reports relate differently to the interests of the agro-industrial complex without directly discussing these. To change these powerful knowledge coalitions and the long-enduring representation of specific scientific knowledge as a privileged form of knowledge that does not need to enter into discussion with other knowledge forms seems to take much more time than policy processes and cannot yet be included in them. Whether the longer time horizons presently found in the global scenario debate on sustainable development scenarios where land use changes and food production are important themes are sufficient to transform global power relations is not yet clear. In the social ecology discourse the combination of several forms of analysis makes new views of rural development possible, but tracing their realisation is still difficult. The process advancing from

– the preparatory analyses in the conventional policy documents and assessments discussed above, to

– the social-ecological analyses of global resource flows in connection with global environmental change analyses (land use changes and changing forms of food production), to
– the knowledge transfer, for example, in frameworks of global sustainability scenarios that are taken up in the policy discourses, is slow, with no breakthrough in societal practices towards a new socio-metabolic regime (Chapter 8).

A more critical assessment of food production takes into account the limiting factors for transformation processes towards sustainability found from analyses of energy systems and unequal exchange. Arguments from these perspectives show the dominant options for policies of technical modernisation of agriculture and support for urbanisation – with the consequence of large parts of rural populations leaving the countryside – as socially and environmentally unsustainable.

Indicators and models for the analysis of global resource flows – land use and food production

Conceptual models and indicators of societal metabolism have been developed to a large degree outside the new social-ecological discourse, but have been critically assessed and integrated in the common framework of MEFA, where the advantages and limits of various attempts to measure resource use became apparent – of ecological footprints, material and energy flow analyses, HANPP and sustainability indices. The MEFA framework (shown in Table 5.1) does not show the practical difficulties of translating the concepts into methodologically refined procedures, where a series of problems arises with the operational definition of concepts and the standardisation of statistical data for the purposes of MEFA (see Chapter 4). The methodological problems will not be discussed further here (see Haberl 2006), where the interest is in discussing how results of MEFA and HANPP affect the broader debates about sustainability: How do these frameworks support the development of a social-ecological theory of a transformation of societal relations to nature towards more sustainable socio-metabolic regimes? (Fischer-Kowalski and Haberl 1998, Haberl et al. 2004a, 2011, Haberl 2006a).

A first hindrance on the way to formulating new strategies for sustainable development based on more recent interdisciplinary research into global resource flows has nothing to do with the limitations of the MEFA methodology, but causes manifold problems in translating conclusions from MEFA into governance models for sustainable development: the paradoxical effects that have been discussed in economics as the "Jevons paradox" or in the recent debate as the "rebound effect" countervail the simple assumptions of consuming less, saving energy and materials, reducing the material and

Table 5.1 Conceptual framework – material and energy flow accounting (MEFA)

The MEFA, based on a conceptual model in which the economy is embedded in nature, is accounting flows of resources (a) in quantities of withdrawals/extraction of resources (abroad and domestic), (b) additions to domestic resource stocks and (c) output (export of resources, wastes and emissions). Cyclic processes of resource flows in SES (from nature to society and back to nature) are logically included in MEFA, but the ecological processes of reduction/absorption in ecosystems are not shown in the model. The MEFA includes (for a national economy) the following components:

1. Input of resources (raw materials, energy resources)
   - 1.1 Imports (including the material and energy resources imported and the imported hidden flows, e.g., residues of mining that do not enter into the economic process and are not accounted for in the economic system)
   - 1.2 Domestic extraction of resources (including material and energy resources and domestic hidden flows)
2. Use of resources in economic processes – processing/production and consumption. Addition to socio-economic resource stocks that include in an ecological perspective the living resources (humans and domesticated animals) and the artefacts (buildings, technical infrastructure)
3. Output of resource use processes
   - 3.1 Exports of resources
   - 3.2 Residues (in form of wastes, emissions)
   - 3.3 Deliberate discharge

Source: own compilation; Haberl et al. (2004a) and Haberl (2006b)

energetic throughput in industrial production, and improving eco-efficiency that guide most practical ideas found in the sustainability discourse.

The “rebound effect” or “Jevons paradox” can be seen as a variant of non-anticipated consequences of social action, a classical idea in the sociological discourse. Non-intended consequences of improved technical efficiency of energy delivery are generated through the capitalist market mechanism, whereby more efficient forms of resource use in terms of efficiency of material and energy use stimulate economic growth that results in more energy and materials use, annihilating the efforts towards improved efficiency or savings by some producing firms or consuming households (Sorell and Dimitropoulos 2008). What the rebound effect shows, and what Jevons had found out long before in the 19th century, is that forms and consequences of natural resource use are more complex than they appear from the perspective of individual consumption processes and their changes under the influence of environmental awareness or efforts to achieve sustainable production and consumption. The ecologically enlightened consumers who reduce consumption of energy and material resources contribute to environmental improvements should become aware that the unwanted consequence of their action is economically similar to reducing prices to stimulate more consumption. This does not make the MEFA and HANPP useless or the "additions and withdrawals" perspective superfluous, as Mol and Spaargaren (2005) argued in a kind of "sceptical environmentalism" attitude, referring to the regional limitations of the perspective. The studies of the physical economy also cannot be devalued with a similar critique to that formulated by Moran against certain approaches in ecological anthropology: their "calorific obsession". The counting of material and energy quantities in terms of calories or other measures of human resource use is probably useful in finding out limits of consumption. It is not comparable with the often ironically discussed "ideology of tons" in Soviet industrialisation in the first half of the 20th century. If there are natural and social limits to growth they should finally be found out and become measurable. That may be as controversial and as difficult as the economic value discussion that is in a dead end with the multiple analytical differentiations of the value concept. But improved knowledge can be expected from continuing research, and arguments against physical measurement of human resource use cannot be built on methodological problems or problems of operationalisation. Methodological critique demands continued improvements of methods before the idea of measurement of limits is – too quickly – given up.

The development, discussion and critique of indicators for material and energy use are documented in the social-ecological discourse for the indicators referred to here (Haberl et al. 2004a, 2004b, 2004c, 2009). In a comparison of ecological footprints and HANPP, Haberl et al. (2004b; see Box 5.1) conclude that they are complementary. The ecological footprint allows the human dependence on the availability of bio-productive land to be measured, showing that overuse of that land depletes the natural capital. The HANPP can measure the human domination of ecosystems, high levels of HANPP indicating potential risk to biodiversity (Haberl et al. 2004b: 281). Also, regarding the methodological difficulties in approaching a global HANPP, the first solutions to measure imported and exported HANPP have been found (embodied HANPP: see Box 5.1).

Box 5.1 Ecological indicators for land use – ecological footprint (EF) and human appropriation of net primary production (HANPP)

EF measures exclusivity of use, while HANPP measures intensity of use, making them complementary metrics. EF is an efficient tool to evaluate overshoot and communicate the results to a broad audience. It calculates the amount of bioproductive area needed exclusively to sustain the activities of a defined human population, and it provides an aggregate figure of the human draw on

> nature. It also serves to document ecological distribution conflicts. HANPP assesses the extent of "human domination", or the "intensity of socio-economic colonization" of a given terrestrial ecosystem or region, but it includes a more limited subset of resources than EF. EF and HANPP focus on different aspects of a society's draw on ecosystems. While EF includes trade to appraise a society's appropriation of biocapacity domestically and abroad, HANPP has thus far concentrated on domestic impacts. Aggregate HANPP related to a society's imports and exports could, in principle, be assessed, but such appraisals would be quite demanding and could still only be based on country-averages for different traded products. This would introduce inaccuracies. EF differentiates between domestic extraction and import . . . , but insufficient data exist to link each consumption item to its spatially explicit origin . . . . The biocapacity component of EF accounts can, however, be spatially mapped. HANPP can be used for spatially explicit analyses and is therefore able to relate a society's metabolism to land use and its effects on ecosystem functioning. It is thus a promising approach for linking analytical tools such as material flow analysis (MFA) or approaches such as industrial ecology to landscape ecology or biogeophysical analyses of environmental change.
>
> (Haberl et al. 2004b: 286)

Embodied HANPP:

> In our rapidly globalizing world economy activities in one region have increasingly important effects on ecological, economic or social processes elsewhere, an effect which we here denote as "teleconnections" between different regions. Biomass trade, one of the causes behind such teleconnections, is currently growing exponentially. Integrated analyses of changes in the global land system are high on the agenda of sustainability science, but a methodological framework for a consistent allocation of environmental burdens related to the consumption and production of biomass between regions has not been put forth to date. The concept of the "embodied human appropriation of net primary production" (abbreviated "embodied HANPP" or "eHANPP") allows for the assessment of the "upstream" effects on ecosystem energetics associated with a particular level of biomass consumption or with a given biomass-based product. This concept is based on HANPP and its two components: (1) productivity changes resulting from land conversion (ΔNPPLC), and (2) harvest of biomass in ecosystems (NPPh). HANPP, defined

Box 5.1 (Continued)

as the sum of ΔNPPLC and NPPh in any given territory, is indicative of the intensity with which humans use the land for their purposes. eHANPP is defined as the NPP appropriated in the course of biomass production, encompassing losses along the production chain as well as productivity changes induced through land conversion or harvest. By making the pressure exerted on ecosystems associated with imports and exports visible, eHANPP allows for the analysis of teleconnections between producing and consuming regions. This article puts forward the eHANPP concept, illustrates its utility for integrated socioecological landchange research based on top-down data on global HANPP and biomass consumption, and discusses the possibilities and challenges.

(Haberl et al. 2009:119)

Source: mentioned in the text

The social-ecological indicators discussed above do not directly measure the environmental consequences of food production and consumption, although all of them touch on it to a more or less detailed degree. The ecological footprint can, for example, be calculated for different food products, and the biomass flows in MEFA or the land use intensity in HANPP can be connected to food production and consumption. But all of them show only certain aspects of food security, a traditional component of environmental security that changes significantly when it is redefined from national to global food security. The global food security discussion takes place under the influence of the financial crises in the globalising economy that significantly affect the world market for food products. Rapid changes of food prices and problems related to global climate change may in future affect agricultural production more significantly. Rising global temperatures bring the risk of reducing the productivity and yields of most agricultural plants produced today, and the changing of climate zones makes conditions of food production more difficult, as is the expected long-term consequence of climate change, with negative consequences dominating over positive ones.

Changing controversies – from rural sustainable development to global food security and sovereignty

Rural development in European countries was dominated by EU policies, oriented from the beginning of common agricultural policy in the 1960s until the end of the 1980s towards modernisation of agriculture in the member countries in terms of productivity, taking advantage of a supranational system that could generate and concentrate resources for that project more quickly and to a degree beyond the capacities of nation states. Agriculture and rural development became a dominant sector of EU policy. As this process was managed and mitigated through the traditional interest groups and agricultural corporatism, the long-term social and ecological consequences of that enforced technical and economic modernisation remained unclear both to those who formulated the ideas politically and to the peasants who followed them. When modernised agriculture became a producer of large surpluses but also a polluter of the environment, the first critical debates and reform ideas came up in the policy discourse. But the modernisation process included other problematic effects that were less addressed in the policy process: the number of rural producers was reducing dramatically, their autonomy undermined, their knowledge devalued, themselves becoming dependent on larger chains of production, processing and distribution of food products that have been described with such neutralising terms as mentioned above, integrating agriculture into national economies and markets. It became obvious that the non-anticipated consequence of agricultural modernisation is “the end of peasants”, as was earlier formulated by French ruralists (Mendras 1967).

The changes in EU policies that first appeared in the late 1980s, interpreted first as post-productivist agriculture and strengthening endogenous rural development, marked the beginning of changing rules for a more encompassing public, a plurality of actors, interests and systems, most clearly expressed in the evolution of linking agricultural development to environmental quality, integrated rural development and sustainable rural development. This example of moving “from government to governance”, as the EU’s white book diagnosed the changes of broadening legitimacy, covers rather than uncovers the underlying logic of economic globalisation. Rural development was discussed in Europe from the early 1990s with the following main ideas under the influence of the emerging sustainability discourse:

1. The “beyond modernisation” debate (van der Ploeg and van Dijk 1995) or the discourse about “endogenous and exogenous development” signalled the introduction of the sustainability theme under the auspices of a crisis of the dominant modernisation paradigm. From this debate remained the concept of endogenous development. In the context of the larger debate about sustainable rural development, this became a first attempt to formulate another model for rural development that grasps the local reality and a perspective for long-term development. The idea of endogenous development is reconciled with the socio-ecological research about common pool resources in the idea of mobilising local actors with their knowledge and capacities. But, for reasons that will not be followed

further here, it has not become the dominant model for sustainable rural development. Already in the debates of the mid-1990s the critical conclusion was formulated to go beyond the exogenous–endogenous dichotomy of rural development.

2. Ecological modernisation (Chapter 2) advanced quickly to a mainstream idea and guiding policy concept for a development path towards sustainability, although the idea remained a multifaceted one (Buttel 2000). In contrast to the endogenous development concept, it was explicitly formulated for the sustainability discourse, as a political strategy of reform and adaptation that made it easy for governmental institutions to adopt in national environmental policies. Ecological modernisation is not a specifically rural development concept. Driven by the interests of the industrial sector, it was only later widened to include consumers and rural development aspects. An attempt to formulate the framework of ecological modernisation for the purposes of rural development was made by Frouws and Mol (1997). The theoretical reflection of ecological modernisation was guided by the idea that this concept and sustainable development form two conceptual frameworks underlying environmental policy-making in industrialised countries (Berger et al. 2001). This industrial development perspective takes into account the history and situation of the European countries that were approaching the end of industrialisation, some already developing strategies for post-industrial development. The attempts to keep the advantages and welfare gains of modernisation and industrialisation during economic globalisation seem to be less and less realistic the longer globalisation endures.
3. Since 2000, historically specified models for rural development have been discussed for the purpose of grasping the changing nature of European rural development more systematically, using historically specified conceptual models. Marsden (2003) presented a sequence of three models guiding policies and rural development processes: the agro-industrial model, the post-productivist model and the rural development model, which can be seen as the most recent and most unclear, but with this one the idea of sustainable development breaks through. The changes in rural development under way with the guiding idea of sustainable rural development can be understood as differentiation. The agro-industrial model represents the out-phasing debate of the post-war rural modernisation thinking with priority on increasing food production that has reached a crisis with the discussion about environmental impacts of agriculture since the late 1970s. For Marsden the agro-industrial model is of importance not mainly because of its content but because of its negative consequences. Although agriculture is in focus here and rural space defined as agricultural space, it contributes to the marginalisation of agriculture through decreasing value of primary production with its capital intensity and increasing quantities of production, and it raises concerns

about food quality and the environmental effects of modern agriculture. The post-productivist model covers a new phase of European rural development since the 1990s and has been commented on as the "new orthodoxy" (Evans et al. 2002). Marsden (2003: 93) describes the post-productivist model as following another logic of marginalisation and centralisation of rural space and people: marginalising the agricultural productive sphere and food supply chains, where the farm appears as a "dirty and criminal place", whereas nature and the agricultural landscape become a preferred good for the consumer, because of its attractiveness and aesthetic value – the consumer perspective dominates agriculture. This model is influenced by the parallel sustainable development discourse and is now confronted with a new, not yet elaborated model of rural development with some vague and guiding ideas of what European rural development might be in future, when answers to the requirements of sustainable development have to be found more consequently than in the post-productivist model, which did not help to solve the problems resulting from agro-industrial production with its shift towards consumers' perspectives and environmentalism. The new model for rural development has agro-ecology as a focus and ecological modernisation as a wider framework and is suggested as an evaluation paradigm for rural sustainability.

The three conceptual models do not totally reflect the changes in the rural development processes, only those of guiding ideas, organising principles of agricultural and food production, and common trends in (European) rural development. The models are formulated with the help of knowledge from certain countries or cases and therefore they are never free of particularities. There are problems in applying the models in all European countries, especially in Southern and Eastern Europe. They can be applied when they are modified or seen as grasping part of the problems. With all three models agriculture is in view, although in the last one from a perspective of diversified rural economy in which agriculture needs to find its future roles. It is this last model which adopts a more holistic view of rural development as this is unfolding in the concept of rural livelihood, one of the components of the model. The models can be understood as ideal types that coexist and are combined in different forms in the rural development process, in different countries, in manifold variations and combinations. All of them, and the following model of multifunctional agriculture, can be connected with or interpreted as part of the broader sustainability discourse which is up to now the framing discourse in the policies of the EU and the member countries.

4. Another integrative idea about development of rural areas after the end of productivism came with the debate about agricultural development that has been going on in policy and science under the heading of

> "multifunctional agriculture". This discourse, current in rural sociology since the 1990s, experienced rapid political success after 2000, when the term became a guiding concept for the reform of European common agricultural policy. It opened the debate of delinking agriculture from food production. The discussion about multifunctional agriculture, in the practice of agricultural and rural development linked with the agri-environmental policy programmes from the EU policy reforms since 1992, can be read today as mapping of different national discourses about the future of agriculture in search of new roles beyond food production, but also as a step-by-step retrieval of societal functions and services of agriculture that have been lost during modernisation and specialisation. That connects with the objectives of sustainable rural development, where agricultural producers are also seen as stewards of the rural landscape and the natural resources.

Simultaneously with the scientific discourses, and mixed with these, political discussions about sustainable development can be identified through which the transfer of the concept of sustainable development became the mainstream idea in public policy programmes for rural development (see Table 5.2).

What can be seen in the European scientific and political discourses about sustainable rural development is how the guiding idea of sustainable development was incorporated and reinterpreted in a series of different conceptual models. All of them were thought as political models, compatible with the basic idea that is now implemented in most national policies and strategies of European countries: an industry- and technology-oriented view of sustainable development, driven by innovation policies, although the political rhetoric of regional differentiation, participation of stakeholders and local management approaches is not missing from that discourse. As far as ecological modernisation has been reformulated in ecological terms (with the more recent contribution of Mol and Spaargaren 2005), it is approaching the perspectives of research on common pool resources, in which such local and participatory management thinking has developed (Chapter 3). However, the dominant political strategies of ecological modernisation still echo older ideas. The European countries that started early with policies of ecological modernisation of the national economies include the Netherlands, Germany, Sweden and Norway, and, outside Europe, Japan (Baxter 1999: 201). Ecological modernisation there follows an industrial logic in which agriculture and rural economy are only minor parts of national economies, as they appear in the sectoral view of the economy, not with regard to the natural resource base. The new ideas of multifunctional agriculture and of bioenergy production on agricultural land can still fit into the ecological modernisation perspective, but it should be asked whether this elastic theory that has gone through

Table 5.2 European policy discourses on agriculture and rural development

1. The Cork Declaration in 1996 highlighting a consensus between governmental and non-governmental actors in European rural policies about the paradigm of integrated rural development was a major step towards the idea of sustainable rural development, although not necessarily synonymous with it. The importance of non-governmental actors, decentralisation and regionalisation of resource management, participation of stakeholders, rural diversity, multi-functionality and integration of rural development were elaborated in this declaration.
2. Adoption of the "ecological modernisation" debate in the policy processes at national levels happened, for example, with the ecological debates about reduction of material and energy use in production ("factor 4/factor 10"), with the measurement of ecological footprints, and with studies that tried to specify national transition processes towards sustainability in such reports as "Sustainable Netherlands" or "Sustainable Germany".
3. Adoption of the idea of multifunctional agriculture in the rural policy processes happened with the "Agenda 2000" reforms in the EU's rural development policies, in which integrated rural development came to be a guiding idea. The multi-functionality debate was not only a European one; it included all countries in the OECD. It remained for a certain time the concept with which the EU tried to formulate its rural policies under the auspices of the gradual opening of agricultural markets. The multi-functionality discourse can today be understood as rediscovering an agriculture in the specific industrial country context of going "beyond modernisation" with functions and services that it had formerly possessed, before agricultural modernisation, that also match the multiple functions that small-scale agricultural livelihood systems still have in many parts of the world.
4. The European environmental movements participated in the scientific as well as the political discourses about sustainable development. Their specific ideas can, for example, be found in methodologies and strategies such as the ecological footprint measurement, or in their contributions to a "new governance" debate in the broader discussion of global governance (Brand et al. 2000).

Source: own compilation; mentioned in the text

continued reinterpretation can be reinterpreted any further. The shifts in the sustainability discourse from national to global levels may change the diagnosis of environmental problems significantly. The sociological analysis of global flows (Mol and Spaargaren 2005) does not include a detailed analysis of flows, as is done in the theory of unequal exchange and in social ecology as MEFA.

There have not been many trials by rural sociologists to adopt or apply the conceptual model of ecological modernisation for research about rural development. It is obvious from Marsden's (2003) analysis that he tries to use what he calls theory of ecological modernisation as a framework to interpret rural sustainable development. However, the close coupling of ecological modernisation to rural development and the limited perspective of reflecting the rural development dynamics from the agro-food industry seem to create more problems than allowing the elaboration of his third conceptual model with the guiding idea of ecological modernisation. To loosen the theoretical grip and to reinterpret rural development strategies in search for alternatives and new frameworks that are no longer overburdened with the conceptual models from the early sustainability discourse seems helpful. Models for future agriculture are not sufficiently elaborated and still show the influence of older societal development models, as do the agro-industrial and the post-productivist models.

Beyond ecological modernisation. The emergence of the scientific debates about actor network theory and social capital and the public and political debates about governance and ethics of resource use show some of the changes that open social-ecological perspectives for the analysis of rural development. Rural networks play an important role in this search for alternative futures. Murdoch (1998) has formulated a preliminary typology of rural networks based on the purpose or goal of network-building – that of networks of innovation, standardisation and "between innovation and standardisation". It does not yet show a social-ecological perspective, but helps to identify a new discourse dynamic in rural development. The question of the changing nature of network-building can be analysed along the changing nature of social networks that are discussed as social capital and building of trust for cooperation. The beginning of critical networks of innovation in the policy process for rural development was marked by worldwide protests of farmers against the neoliberal policies that characterised economic globalisation.

> From the mid-1980s to the mid-1990s, farmers' protests at GATT (General Agreement on Tariffs and Trade) meetings galvanized a growing international movement critical of the lack of democratic accountability of supra-national institutions, of the terms under which agriculture was included in free-trade agreements, and of how neoliberal policies and industrial farming threatened rural livelihoods, human health, genetic diversity, and the resource base.
>
> (Edelman 2001: 304)

The ethics of rural networks are not governed by homogeneous interests and goals but reflect the pluralisation and differentiation processes in social and economic changes in rural areas. If one counts as the relevant social networks those of the producers and inhabitants who make their livelihood in rural areas and from their resources, there is still no homogeneity of interests and values given, although diversity of interest is limited. The ethics required for collective action of different actors and groups are not only ethics of social networking or social ethics, but include the broader problems of resources and natural resource use, equity as well as sufficiency. That ethic includes the maintenance of the rural resource base and cultural landscapes through the sustainability process. It starts with questions about the user groups claiming the use of rural resources: the rural producers as the first users, the urban consumers as the last users, the environmental movements and nature protectionists as those interested in maintaining "living" rural areas, the economic producers and enterprises, and the scientists and researchers who have acquired a knowledge production monopoly also with regard to rural development.

New ideas in thinking about agriculture and rural development have come with the discussion of global food production and food security within an agro-industrial organisation of food production and under the premises of global climate change. Knowledge questions, interdisciplinary knowledge integration and synthesis play an important role in both critical debates about the future of food production. Knowledge questions and knowledge integration seem to have been neglected in the prior sustainability discourse. The knowledge transfer practices in strategies for sustainable development (also in ecological modernisation) often followed older ideas of "research and development" or "science and technology". Such ideas are becoming outdated with the discourses about interdisciplinarity and transdisciplinarity and the newer discussion about governance and cooperation in the sustainability debates. There are no sustainable technologies that work in all rural and social contexts, as one can conclude from the empirically based critique of "panacea" solutions to resource management problems in common pool resource research. Technologies, even when designed as general solutions, are applied in specific contexts, for specific interests, by specific users with specific knowledge, and all these factors decide the success or failure of development technologies.

From the epistemic discourses of knowledge production and use, more specific ideas can be developed on how to frame and manage knowledge from the perspective of rural sustainability. Some of these models are found in recent literature about sustainable development and resource management, as procedures to deal with different knowledge forms in a specified context of sustainability; for example, the "epistemological bridges" model (sustainable development as a discursive platform concept to maintain a debate between concerned actors, not as a homogeneous guiding idea), the knowledge integration model of transdisciplinarity, the "collaboration and social learning" model of sustainability science, the idea of social-ecological systems from ecological and resilience research, and the ideas about sustainable resource management that resulted from common pool resource research (see Chapter 2).

The newer ideas can be seen as having learned from the older practices of production and application of scientific knowledge. These new ideas support communication and learning processes when actors in rural development, resource managers and scientists cooperate. This shows both strengths and limitations. Most of these conceptual models for cognitive processes and knowledge management build on the premise of cooperation as a promising way to solve the problems to be dealt with in sustainable development and natural resource management. In doing so they often neglect the problems that block cooperation, that is, problems of inequality, social exclusion, power differences, conflicts and incompatible interests that have to be dealt with as part of sustainable development processes, not separately. It is under such conditions of inequalities, ownership and power differences that the interdisciplinary and transdisciplinary strategies of knowledge use need to be practised. Improved collaboration and integration processes are, in European as in other countries, barely established, not yet elaborated methodologically, but they keep expectations alive in the governance debate that improved forms of transdisciplinary knowledge integration will be found that will be capable of dealing with environmental problems.

The discussion of agriculture and rural development (so far from a sustainability perspective) is not yet systematically connected with the social-ecological discourse, although important frameworks and methods from social ecology have been discussed in this chapter. In contrast to sociological and other disciplinary analyses of rural development, the social-ecological analysis is much more complex, as shown in an exemplary way by Krausmann and Fischer-Kowalski (2010), where the conceptual frameworks of societal relations to nature and societal metabolism are used to frame and interpret agricultural production in a historical and comparative analysis of earlier agricultural and industrial societies. The historical differences of agricultural production can be described with regard to environmental effects of agriculture and agricultural metabolism. To the environmental problems that agriculture created in all historical societies (deforestation and loss of fertile soils) new problems are added in industrial societies (large-scale and monocultural agricultural systems where agrochemicals pollute soils and groundwater). According to its role in the socio-metabolic and the energy system, agriculture has, through the industrial transformation, changed from a source of energy used in society to an energy sink. With its dependence on fossil energy sources, industrialised agricultural production requires more energy input than the energetic value of the food produced (ibid.: 19).

A first scenario-based study from social-ecological authors (Erb et al. 2009a) shows perspectives for global food production and security that go beyond the present debates on sustainable development. In scenario analyses such as those used in this study, as in the global scenarios of the Millennium Ecosystem Assessment from 2005, other perspectives are opened in the limits to growth debate, beyond the attempts to formulate planetary boundaries of human resource use (Box 5.2).

Box 5.2 Socio-ecological scenario "eating the planet"

> The surging demands of a growing and increasingly affluent world population are confronting the natural world with mounting pressures. Human use of the earth's land for agriculture, forestry or infrastructure is degrading the ability of many ecosystems to deliver vital services to humanity. While modern agricultural technologies have resulted in rapid increases in yields and efficiencies, they have also caused significant and widespread negative environmental effects. . . . one of humanity's grand challenges: assessing how we can feed and fuel the world sustainably, fairly and humanely in the future. . . . we develop a biomass-balance model that calculates the balance between global biomass demand (food and fibre) and global biomass supply from cropland and grazing land for 11 world regions, 11 food categories, seven food crop types and two livestock categories as well as a global bioenergy potential from cropland and grazing areas. Forestry is beyond the scope of this study. We evaluate the possible effect of climate change on yields using a coupled plant growth and water balance model (LPJmL) to calculate the effect of climate change on cropland yields, thereby modelling both the inclusion and exclusion of the poorly understood CO_2 fertilization effect.
>
> (Erb et al. 2009a: 8)

Assumptions:

> We develop a consistent set of assumptions to analyze the situation in the year 2050. We use the United Nations medium population forecast (9.16 billion in 2050) to project global demand for infrastructure areas and to calculate total food demand. We use FAO projections of world agriculture in 2050 as a crop intensification scenario, where crop yields are forecast to grow by 54% on average and cropland area grows by 9%. This is compared with two other crop production scenarios: "wholly organic" crop production and an "intermediate" crop yield scenario, reflecting a mix of farming systems that create a mean yield between the "FAO intensive" and "organic" crop systems. We assess four different diets, ranging from a "western high meat" diet – high calorie (3,171 kcal/cap/day), rich in animal protein (44% of protein intake) – to a nutritionally sufficient "fair less meat" diet with 2,800 kcal/cap/d, sufficient protein and fat and low in animal protein. We assume three different livestock rearing systems ("intensive", "humane" (free range),

Box 5.2 (Continued)

> and "organic"). We assess two estimates of land use for cropland expansion (+9%, +19%). This results in 72 scenarios, each of which is classified as "feasible" if calculated cropland demand is 95% or less of the cropland available in 2050, "probably feasible" if cropland demand differs from available cropland by less than 5% and "unfeasible" if cropland demand exceeds available cropland by 5% or more.
>
> (Erb et al. 2009a: 8)

Results:

> Results suggest that feeding the world with organic crops and an organic livestock system is probably feasible. This would require a growth in global cropland area by approximately 20% and the adoption of a diet with on average 2,800 kcal/cap/day and 20% of protein from animal sources. While this diet is nutritionally sufficient, a high degree of equality in food distribution would be required to avoid malnutrition. The "western high meat" diet outlined above is also probably feasible but providing so much food would require a cropland expansion of 20%, "FAO intensive" yields and "intensive" livestock production.....
>
> We find that the potential for producing primary (mostly solid) biomass for bioenergy production in 2050 ranges from 58 to 161 EJ/yr. The bioenergy potential depends strongly on the choice of diet: it is lowest in the case of the richest diet and highest in the case of the "fair less meat" diet. Climate change could have a positive or a negative impact on the global food and bioenergy system: In the absence of a CO_2 fertilization effect, climate change could have a significant negative impact on food and bioenergy provision, whereas the effect could also be strongly positive if the CO_2 fertilization effect is fully taken into account.
>
> (Erb et al. 2009a: 8)

Source: mentioned in the text

The discussions about long-term perspectives of land use (Haberl et al. 2001), global energy metabolism (Haberl 2006a) and food production in the scoping study by Erb et al. (2009a) mark the beginning of research and discussion in social ecology that is not just trying to quantify food production and food security problems, guided by the only assumption that a growing global population needs more food. It opens a much more complex view of the future problems of food production. Two arguments seem important from a sustainability perspective:

1. Industrialisation changed agricultural metabolism dramatically through the energy input into agricultural production that made agriculture independent of biomass production in the area itself:

   > Many other changes in socio-economic material and energy flows – e.g., the surge in the use of metals, the development of greater spatial reach in transportation and trade – were only made possible through an increased appropriation and use of energy. This process of change in the phases of industrialization fundamentally changed the role of agriculture and forestry in regional and national economies: in agrarian societies these sectors were almost the sole source of energy, offering nutritional energy for humans and livestock, firewood etc.
   >
   > (Haberl et al. 2001: 2)

2. The dimensions of human appropriation of global terrestrial net productivity of ecosystems have also changed dramatically (regional appropriation of biomass in the course of industrialisation shows, however, more complex patterns of change):

   > Whereas the energy input of agricultural societies prior to the advent of industrial societies 200-300 years ago did not exceed 5% of global terrestrial net primary productivity (NPP), humanity's energy input currently amounts to about 30% of global terrestrial NPP and is likely to surpass 50% in about 2050. This shows that the sheer magnitude of human-induced flows is historically unprecedented and poses at least two closely interrelated sustainability challenges: (1) a reduction of energy available to ecosystem processes that can be assessed using the concept of "human appropriation of net primary productivity' and (2) the changes in the global carbon cycle resulting from land-use change and fossil-energy combustion.
   >
   > (Haberl 2006a: 87)

To interpret the consequences of changes in land use and energy metabolism, more theoretical analysis is required to show the interactions between industrial production, material and energy flows, land use and human consumption of natural resources, as in the analyses of the global metabolic rift in the nutrient cycle (see, e.g., Clark and York 2012: 27ff). Not only intensification and industrialisation of agriculture itself, but also the consequences of global trade of natural resources and the phenomenon of global "land grabbing", need to be analysed. Global food security becomes an extremely multifaceted and contradictory phenomenon in this system context of nature–society interaction. Potential alternative ways to achieve food security should be investigated further, and in doing so the debate on food security needs to change. Beyond the quantitative dimensions of global food production, questions about the quality of food production and about the control of food production through local producers and consumers, connected with the critical term of "food sovereignty", become more important. The term "food sovereignty" is used by some social movements to discuss critically the technocratic and power-based debate on food security by the dominant political and economic actors. The debate of "food safety or sovereignty" marks potential future conflicts and controversies in the global governance and sustainability policies, coming, for example, with the political renewal of the sustainability discourse through the "green economy" discussion and with the economic valuation of nature for purposes of biodiversity maintenance, as in the TEEB concept ("The Economics of Ecosystems and Biodiversity"; see Chapter 8).

Conclusions

It has been argued in this chapter that the combination of several forms of resource use analysis in social ecology makes possible new views of rural development and food production. But the realisation of alternative paths towards sustainable resource use and production in a global perspective still seems difficult. The process is slow in advances from

- the preparatory analyses, the conventional policy documents and assessments, to
- the social-ecological analyses of global resource flows in connection with global environmental change analyses (land use changes and changing forms of food production), to
- the knowledge transfer, for example, in frameworks of global sustainability scenarios that are taken up in the policy discourses. No breakthrough in the societal practices towards a new socio-metabolic regime has become apparent yet.

A more critical assessment of food production takes into account the limiting factors for transformation processes towards sustainability found from analyses of global resource flows, unequal exchange and energy systems. Global scenarios (see above) show different possibilities for the solution of agricultural production problems in future, but it should not be forgotten that nationally and regionally different approaches are also required.

These include other solutions than that in European countries, where finally the rural population stops producing and migrates to the cities. In many countries, including newly industrialising countries such as China, another future needs to be sought for the rural areas and the rural population than urbanisation.

6
Thematic Profiles of Social Ecology – Knowledge Synthesis in a Theory of Interaction of Society and Nature

Social ecology is an interdisciplinary discourse system with open boundaries. A plurality of theories and analytical frameworks can be applied and connected in varying forms for the study of different aspects in the broad theme of interaction of society and nature. For social ecology this theme cannot remain one of an unstructured variety of ideas and concepts from empirical studies, documenting historical cases and the cultural variation of ideas, as, for example, in the history of ideas by Pojman (2006), which summarises the theories of human nature throughout the history of science. Theoretical knowledge synthesis in social ecology is an attempt to integrate the pre-theoretical concepts of society, man and nature in a historically specified core theory. This theory allows the interaction between society and nature to be studied and explained for different historical forms of societies with conceptual models as socio-metabolic regimes.

Theoretical discourses in earlier theories of society and nature

Human and cultural ecology and philosophical anthropology (discussed in Chapter 1) paved the way for the new social ecology, but ended without sufficiently addressing natural resource use from a global perspective. In social ecology the renewal of this cognitive programme is justified with the argument that earlier interdisciplinary approaches lost their significance, their critical capacity and the practical capacity to guide environmental research and environmental movements. The unfinished discussion in human ecology of interrelations between man, nature and society is started in the social-ecological discourse with other, relational concepts of societal metabolism, colonisation of nature and societal relations to nature. In sociology the difference between static “substantialist” and “relational” theories with “dynamic, continuous, and processual terms” (Emirbayer 1997: 281) has been discussed epistemologically, from a limited disciplinary perspective and for the discussion of traditional sociological themes. The interdisciplinary study of relations between man, nature and society in human ecology did not proceed towards a "relational theory", but ended in a plurality of approaches (or theoretical synthesis was renounced). For social ecology the contradictory trinity of man, society and nature is no longer a theory-generating framework, but a heuristic scheme that helps to organise the theoretical reflection and the critical evaluation of the earlier thinking about nature and society. Interdisciplinarity is still the common denominator, but in the new social ecology the decoding of interactions between nature and society is sought with more theoretically and historically precise concepts, which transform the static terms of society, nature and man to dynamic terms.

In cultural anthropology the contradictory trinity of man, nature and society has been reformulated as a loose conceptual framework for interdisciplinary research on the human condition that reconnects knowledge from the separated social and biological sciences. Anthropology has, according to Keesing (1976: 15), the "ability to see humans both as biological organisms and creatures of culture, to see the cultural and the biological as interacting and complementary, and to see humans in ecosystems as well as social systems, which gives anthropologists a broad evolutionary perspective on the human condition". This argument shows at once the strengths and weaknesses of cultural anthropological research. It aims at a comparative analysis of the historical and present cultures of local societies. A unifying concept for all cultures in history tends to reduce societal complexity into descriptions of social structures and divisions of labour that do not show the growing complexity of societal systems in the course of history. The development of large-scale societal systems, empires or world systems indicates this complexity beyond the quantitative dimensions of population or territorial size. Reducing the differences between societies to those which exist between small and large-scale societies (e.g., Bodley 1994) is widespread in ecology and human ecology and in the ecological discourse at large, where the normative ideal of a society is seen as a small-scale local society. Large-scale societies appear from this ecological perspective as less stable compared with local societies. Steward, being aware of problems in applying a simple conceptual framework to different systems of society, assumes that his culture core concept can be applied to local historical societies with simple social organisation as well as to complex and industrial societies. The adaptive function of culture – adapting humans to nature – is described by Steward with some components of subsistence technology and production or resource use – for example, division of labour, size, structure and persistence of local groups, distribution of human groups in space, rules for residence regulating number of people in settlements and their cooperative organisation of production (Steward 1955, Keesing 1976: 207f).

Two problems remain when applying the culture core framework in a theory of modern society and its interaction with nature: that of blending the material and the symbolic forms of culture without theoretical structuring, and that of accounting insufficiently for the systemic quality of modern society as a global system (the modern economic world system). Whereas Steward oscillates epistemologically between mentalist and materialist interpretations of the human condition, cultural ecology later tended towards cultural materialism, with the conclusion that symbolic culture – for example, religious beliefs and customs – has only a peripheral role in adaptation to the local environment (Keesing 1976: 208). This materialist accounting was rejected by Keesing with the argument (ibid.) that, for the sake of thorough scientific analysis, both possibilities must be kept open to answers from empirical research. Also, symbolic systems may unfold adaptive capacity through their influence on human behaviour. The use of a culture concept for analysing the global system components of modern capitalism opens again the epistemological controversy about dualism (of "mentalism" or "materialism") and monism (e.g., "cultural contextualism"), in analysing societal systems. These questions give rise to continued discussion in theories of society and societal interaction with nature and their epistemological basis in dualisms such as objectivist or constructivist approaches or in monist approaches in which nature and culture are seen as closely connected or merged. In the world system theory the culture concept becomes a description of cultural practices that cross-national boundaries with such concepts as ethnicity, race, gender, class and nation.

The bequest of cultural anthropology to social ecology is this controversy about the culture concept with its materialist, mentalist or contextualist variants (Descola and Pálsson 1996). What tends to be neglected in all these approaches is that each uses the ecological and functionalist argument of symbolic or material culture as a mechanism adapting humans to their natural environment or mediating the interaction between humans and the natural environment. This common interest of human and cultural ecology has only in exceptional cases resulted in attempts to elaborate a composite theory of the capitalist system in which a macroscopic system analysis and a microscopic cultural analysis are specified to combine a complex theory of modern society, such as a world system theory, with the analysis of social resource use practices, where local cultures and cultural transformation come into view. The problem with such a theory is not a methodological one of combining analyses of global and local social systems, but that of a historically specified theory of modern capitalism that does in theoretical elaboration what multi-scale social-ecological system analysis does in empirical forms by analysing the interplay of symbolic culture, material technologies and social resource use practices at various spatial levels: the significance of culture changes in mentalist, materialist or contextualist interpretations of natural resource use. Whether a global system of economic production and exchange can be described as a cultural system remains controversial, for example, for the modern world system as economic unity with political and cultural multiplicity. To reconstruct modern capitalism as a complex and global cultural system, as in the culturalist approach of Sahlins (in which all explanation results from the interpretation of the system as the universal spreading of Western culture), does not grasp many of its macro-systemic, structural, material and biophysical qualities. The limits of analysing modern capitalism with the culture concept are seen in the neglect of such complex system structures as the mode of production, where material and symbolic flows interact and need to be systematically analysed with the help of a theory of society–nature interaction. Modern and historical societies are based on further systemic mechanisms, symbolic and material components in varying composition in a system of nature–society interaction that includes resource use regimes and further components of socio-metabolic regimes (see below). In classical theories of modern capitalism the systemic mechanisms have been called "material factors" by Marx and "bureaucratic organisation of production" by Weber.

In recent variants of cultural anthropological analyses of nature and society, in semiotic and contextualist approaches, the materialist and functionalist reductionism is criticised (Hornborg in Descola and Pálsson 1996: 47) in attempts to formulate a non-dualistic or contextualist paradigm by reducing materialist or mentalist approaches (such as Bateson's "ecology of mind") into monist approaches and by arguing that former distinctions between nature and culture or society are no longer adequate (ibid.: 57). Constructions of nature in the natural sciences that provided the basis for objectivist, materialist and functionalist approaches are now interpreted as specific cultural codes and languages for the construction of nature. The construction of nature in high-energy physics is characterised by

> a particular organizational structure and distinctive kinds of talk or habitus: "the physics way" as physicists tend to say. It is only in a second instance that the establishment of nature as a meaningful sign gains importance on a general level. It does so by processes of translation, whereby specific localized versions gain global importance. These processes also serve specific ends, in that they play an important role with respect to what is called "scientific leadership," producing a ranking of nations (cultures) based on evolutionary and linear conceptions of time.
>
> (Nothnagel,in: Descola and Pálsson: 257)

Universalist analyses of global systems operate with such languages and with the global spreading of specific local cultures and codes, which explains some components of the universalist thinking in natural sciences and brings into view power relations in science, but the controversies surrounding nature and society constructions do not end with this argument.

Cultural anthropology, especially cultural ecology, hosts controversies about the nature of society and its interactions with nature through resource use. Social ecology has not developed in direct response to these controversies, but by seeking its theoretical core concepts outside the discourses of human and cultural ecology or philosophical anthropology. Both concepts, the notion of societal relations with nature and that of societal metabolism, originate from older debates in political economy and critical theory of society in which they represented marginal themes that are not fully elaborated in these theories.

Critical theory: societal relations to nature

"Societal relations to nature" is a formulation used in Marxist and critical theory of the Frankfurt School to characterise the interactions between man and nature as mediated by societal system structures. Humans organise their interaction with nature only within a society, where they act in cooperation, concert or competition and conflict with other individuals. Individuals are socialised, learning to live and act within the systemic, structural and institutional constraints that society and nature together exercise upon the social actors. This perspective developed from the Aristotelian view of humans as social beings living in social communities with other humans and ecological communities with other species. For a long time the epistemological controversies about human nature or the human condition continued to be about concepts, paradigms and epistemological positions that continue in modern social sciences; for example, that of methodological individualism or methodological holism in sociology and economics. With Marxist materialism, such dualisms or older dualisms such as the philosophical positions of materialism and idealism were replaced by integrated concepts that connected both poles of symbolic and material reality. The escape from epistemological dualisms seems to have become possible with the transformation of philosophical and ontological thinking into social and empirical sciences. Marx's theory is part of a materialist tradition of the kind that Schmidt (1961) called non-ontological materialism. It needs to be completed through an epistemological reflection about the social constructivism and postmodernism debates. A non-ontological materialism grapples with the notion of "societal relations to nature" material-energetic aspects analysed by Marx with the concept of metabolism and symbolic aspects that show the culturally specific reflections about man and nature throughout history – in religious, philosophical, scientific or everyday forms. The integration of material and symbolic realms becomes a key question in theoretical synthesis and in contextualised concepts as the socio-ecological notion of "colonisation of nature".

The analysis of interaction between society, man and nature by Marx varies with the unfolding of his theory, developing from an abstract philosophical discussion in the early writings towards an analysis with positive knowledge in his later work. In the early writings the interaction between man and nature was already understood as being mediated by societal practices in historically specific forms, organised as modes of production. A specific idea of this interaction is found in the "*Grundrisse*" manuscript. It is not the unity of living and active humans with the natural, inorganic conditions of their life and their metabolism with nature that should be explained as result of a historical process, but the separation between the inorganic conditions of life and the active life of humans in society – as a separation that develops in historically varying forms and ends in modern society in the distinction between wage labour and capital (Marx 1974: 389). The difference between nature and society is not of ontological quality or one of the dualisms of nature and culture that are criticised today in the ecological discourse. In contrast to non-historical views of "naturally given" differences between nature and culture that do not change during human history, in the Marxist tradition the separation of man from nature was understood in historically varying forms analysed with the ideology concept. The separation is seen as coming into existence historically, varying between modes of production or societies, having reached an extreme form in modern capitalism, and potentially disappearing again in the future in a reconciliation of society and nature that was not discussed further in this theory. This historical diagnosis of the human condition has far-reaching consequences for the theory of nature–society interaction – not as naturalism or ontological materialism or realism, but, as the name of the theory indicates, a "historical materialism", which describes the mediation between man and nature in varying forms of interaction between nature and man including the labour process (Schmidt 1961: 10ff).

Societal relations to nature that codify humans' historically specific interaction with nature in different historical epochs and societies are discussed in Marxist theory in two aspects: material-energetic (through societal metabolism) and symbolic (through culturally varying interpretations of nature and man–nature relations in different spheres of thinking from the philosophy of nature or philosophical anthropology to the everyday views of world, nature, man). With the established specialisation of knowledge and the differentiation between natural sciences and humanities or social sciences, the prevailing epistemic culture is to separate symbolic and material aspects or to analyse only one of them from specialised and narrowed disciplinary perspectives. The cognitive interests in Marxist and critical theory aim at reconstructing the interaction and mediation of material and symbolic relations. In the reconstruction of this interaction it is explained why the impression of separation has emerged when it is alternatively possible to diagnose an ever-closer connection between man, society and nature in modern industrial society, or one of the joint transformations as articulated in the ecological and socio-ecological discourse. Labour plays a significant role in the mediation of human interaction with nature, as analysed in the Marxist critique of political economy. Further theoretical concepts have unfolded to analyse this interaction between social humans and nature: (a) the theorem of dependence of human social life and thinking about nature and society from the regulation of biological and socio-economic reproduction; both forms of reproduction are connected in (b) the socially structured division of labour and (c) the appropriation of nature through labour and subsistence. These components of theoretical cognition refer to relations of domination in historically specific forms: domination of humans over humans and domination of humans over nature. The forms of domination in modern capitalism are rooted in the mode of production, and differentiate into economically (exploitation) and politically structured power relations (authority) that are reconstructed as structural, institutional and functional forms of dependence. The reification and veiling of power relations in capitalist commodity production and exchange processes are the core problems in analysing the structures and the development trajectories of this economic system. Domination remains veiled in the forms of formal equity and equal rights that structure social contract relations in bourgeois society, whereas social inequality exists in specific class structures. The "split reality" becomes possible through the functional differentiation of a political sphere with democratic and citizen rights and an economic sphere where exploitation of human labour and nature continue.

Reconstruction of the mechanisms of such "contradicting unification" of modern society was the cognitive interest of classical Marxism and the Frankfurt School, and especially in the Frankfurt School for analysing the forms of cultural veiling of domination that changed in late capitalism. The societal relations to nature that are structured through historically changing constellations of domination and exploitation resulting from the modes of production and use of natural resources have not been systematically analysed in the older theories. Relations to nature gained more significance in Horkheimer's and Adorno's "Dialectic of enlightenment". Nature remained a general social-philosophical concept that appears in the sociological theory only in abstract form and as a kind of "negative dialectic": nature is the other of society, excluded and edged out, but never analysed with regard to the interaction of society and nature and its social and ecological consequences as is done today in environmental discourse and in ecological Marxism.

The review of older critical theory cannot be interrupted at this point where the genesis of the core concept of social ecology and societal relations to nature is summarised. To understand the new form of theoretical analysis in social ecology for decoding societal relations to nature, the consequences of this theoretical term within a critical theory of modern capitalism should be discussed. At this point another cryptic, metaphorical formulation comes into the theoretical discourse: that of society as "second nature" (see Box 6.1).

Box 6.1 Society as "second nature"

The hypothesis of society as "second nature" (using a concept with many meanings, not finally cleared in the critical theory discourse: Beilharz (2003)) can be used to characterise the compulsion that capitalist society applies to organise economic production through the abstract principles of "value production" (producing monetary values that direct all economic interaction of labour and capital). The use value of goods is in this economic system only a physical substrate of the monetary value, without significance for the economic system as market and exchange mechanism.

From the (shortened) description of value forms the argument can be developed: modern society becomes, through its separation from nature that is inscribed in economic value production, a form of reification, a second nature for humans (which cannot be explained by Western culture, and not sufficiently by Weber's hypothesis of rationalisation and disenchantment of the world). The term "second nature" has different meanings: sometimes it means society as appearing in artefacts, buildings, infrastructure, products of human labour and the technologies used to transform nature. Society as second nature implies that elements of nature–society interaction are compounded as in Steward's notion of the culture core, but in a theoretically more complicated version that cannot be formulated within the conceptual framework of cultural ecology.

The "second nature" quality of society, technology, mode of production and mode of distribution of resources is articulated in different forms in what is referred to in the Marxist and critical theory tradition as reification and alienation in modern society (covering the part of critical normativity in these theory programmes). These analyses evoke controversies and misunderstandings in which the lack of nature in Marxist analysis has been criticised as a lack of cultural specificity that appears in the use value of products. The critical component in Marxist theory, however, is missed in the critiques: in capitalist society the relations between humans and the relations between humans and nature are out of the control of humans themselves, exercised through the system mechanism of capital that directs labour and resource use in forms that destabilise society and nature. To regain agency or capacity to transform a societal system and to regulate its interaction with nature requires more ideas, knowledge and critical analysis than the environmental movements in recent decades were able to offer. Individual attempts at reconciliation with nature by means of changing ways of life and consumption are not in vain,

Box 6.1 (Continued)

but those attempts are not sufficient to transform the reified societal relations of society as a second nature. At this point of connecting the individual and society (Dickens 1998) the social-ecological analysis of possibilities of regulation and transformation of societal relations to nature to find new forms of a societal synthesis with nature begins.

Source: own compilation

The "second nature" quality of society gains importance in the discussion of how the interaction of society with nature is perceived in traditional theory, as in the social and natural sciences that analyse such interaction without being able to decode its complicated forms as "societal relations to nature." The social origins of the distortions, separations and deformations in nature–society interaction remain unclear to a large degree in the ecological discourse. It seems that the deficits and limits of social-ecological agency appear in policy and science as a curtailment of cognitive processes and interests, and as a lack of success in changing society and modern consumption cultures in environmental action, although a growing consensus is found for the necessity of such changes. These deficits stimulate in social ecology new attempts to analyse the "roadblocks" towards sustainability, starting from the unfulfilled expectations of environmentalism. At the point of reflecting the complex interaction of society and nature, Horkheimer's formulation gives preliminary guidelines for further analysis with the following epistemological reflection. The facts we perceive are predetermined by society in double form: through the historical quality of the perceived object and the historical quality of the perceiving subject or organ. From this point forward, new interdisciplinary reflection of knowledge generation is required for a critical theory of nature and society that does not fall apart into irreconcilable objectivist-realist and subjectivist-constructivist epistemologies. The concept of metabolism helps to decode the "historical quality" of the perceived and the perceiving.

Biology and ecology: metabolism

The term "societal metabolism" has long been understood as a metaphor for the analysis of society–nature relations. It borrows from the biological analysis of chemical processes of composition and decomposition that occur in organisms through the exchange of materials and energy between organism and environment. The natural-scientific origin of the notion of metabolism is not important for interdisciplinary analyses of nature–society interaction. Rather, it is the effort to give this notion a specific meaning that makes it applicable to the analysis of material and energy flows between society and nature in economic production and in resource consumption processes. Although in ecological and environmental research the metabolism concept has been used in several variants of social metabolism, for example, industrial and urban metabolism, the concept of societal metabolism remains a contested one. In the social-ecological discourse societal metabolism has been critically discussed and clarified in its historical development with contributions from biology and ecology, sociology and social anthropology, social geography and industrial metabolism (Fischer-Kowalski 2003) and in its theoretical contours (Fischer-Kowalski et al. 1997, Fischer-Kowalski and Haberl 1998). This has shown that the biological concept of metabolism was early on transferred into social-scientific analyses of natural resource use. In the political economy of Marx, two concepts borrowed from the natural sciences have been used in the analysis of economic resource use processes: the concept of metabolism and that of a metabolic rift which characterises the modern agriculture of that time (Foster 1999). The interdisciplinary concept of societal metabolism has a long history, summarised in Box 6.2.

Box 6.2 The development of the notion of "societal metabolism"

A historical review of the use of the metabolism concept in relation to social processes and societal interaction with nature shows that the idea is widespread in interdisciplinary, economic and ecological analysis of human resource use. Although the concept oscillates between metaphorical formulation and theoretically specified meanings, its persistence indicates the need for a theoretical concept to comprise nature–society interaction, as summarised by Giampetro et al. (2000):

Origins: The notion of "metabolism of society" initially referred to the flows and cycles of materials in nature as influenced by the actions of human society: the carbon cycle, the water cycle, and the nitrogen and phosphorus cycle. Work by agricultural chemists such as Liebig and Boussingault was important for the development of the idea of material metabolism. Moleschott proposed for it the word "Stoffwechsel". In the last decades of the 19th century, the study of the flows of energy within human society was also included within the notion of "social metabolism", so that now this expression refers to the analysis of both material and energy flows. The connection between cycles of agricultural nutrients and agrarian structures was pointed out by Liebig and echoed by Marx in *Kapital*, when he wrote that dispersed settlements and small rural properties were more conducive to recycling nutrients than large farms exporting crops to large

Box 6.2 (Continued)

cities. Remaining in the historical roots of modern discussion, we can note here a debate on the increase of carbon concentration in the atmosphere. The discussion about the inability of "carbon sinks" to absorb carbon released by the combustion of coal was in full swing by the 1890s, when Arrhenius wrote his well-known papers on the enhanced greenhouse effect. The view of the human economy as a flow of energy was first proposed by Podolinsky around 1880. He stated that the energy productivity of agricultural labour should be higher than the efficiency of the conversion of food into work, in order for an agricultural economy to be viable.

Recent debates: Another crucial concept, the distinction between the endosomatic and the exosomatic uses of energy – which Georgescu-Roegen clearly introduced, building on an insight from Lotka ... – is a crucial insight in today's work on "social metabolism".... It was Schrödinger ... who systematically investigated the foundations of life (biological metabolism) in terms of entropy disposal ... Schrödinger reached the right conclusion that disposing of thermal entropy is a necessary condition for living systems to continue living. Schrödinger's idea did not seem to attract other physicists' attention until a Japanese physicist, M. Sugita ... focused on the importance of Schrödinger's theory on life. In 1970s Tsuchida ... created a theory that explains the global mechanism of thermal entropy disposal .... Another crucial scientific concept linked to societal metabolism, and strictly related to the idea of entropy disposal, is that of "dissipative systems", a class of systems mainly investigated by Prigogine's school .... Human societies belong to the class of self-organizing dissipative systems and this implies that their structures and functions are stabilized by a continuous inflow of inputs (energy and matter) taken from the environment and a continuous flow of outputs (wastes) dumped into the environment. This translates into two crucial characteristics: (1) these systems are "becoming systems" (they are co-evolving in time with their context); (2) their organization is based on the existence of hierarchical levels.

Source: Giampetro et al. (2000: 99–101)

The history of the metabolism debate shows the unfolding of interdisciplinary analysis of material and energy flows between society and nature. Although the metabolism concept remains a contested concept, it is required for theoretically conceptualising the flows that cannot be sufficiently conceptualised with more concrete notions such as natural resources or information flows. Like the other basic notion of social ecology, societal relations with nature, metabolism is characterised through its use in critical, interdisciplinary and heterodox thinking in political economy and in political and social ecology. Whether the concept will become a more widely accepted term in environmental research and disciplinary sciences remains to be seen.

A composite theory of societal interaction with nature

The debate on dematerialisation of production and consumption (Chapter 2) showed unresolved questions about the possibilities to achieve sustainable resource use regimes. How to connect empirical knowledge on material and energy flows with theoretical analyses of the interaction between society and nature? The concept of societal relations to nature is used in German socio-ecological research in two variants: as a framing concept for the theoretical analysis of society–nature interaction at different spatial scales (Becker et al. 2011) and in a more specific sense as "basic societal relations to nature" that guide individual and societal reproduction simultaneously, and connect the theoretical framework with empirical studies of lifeworld and needs-related research (work and production food consumption, sexual reproduction and further basic needs; Jahn 2005: 32), and this research with research into global resource flows. Global resource flows and unequal exchange are analysed as components of societal metabolism. The statistical information about flows may not be sufficient, as the analysis requires further data about toxicity of resources, the measurement of pollution beyond CO_2 emissions, and more detailed analyses of the environmental and social consequences of resource use for specific ecosystems and social systems. Confronted with the complexity of global problems and systems, such analyses have been performed only in fragmented forms and in preliminary attempts such as the global Millennium Ecosystem Assessment, which demonstrates the methodological difficulties in synthesising knowledge for global social-ecological studies. In a critical analysis of nature–society interaction from local to global scales it should be possible to include not only the hard facts of material interaction in terms of land use, material and energy flow accounting, but also the soft facts of symbolic interaction accounted for in terms of heterogeneous and varying worldviews, value orientations, ideas and knowledge, which guide environmental and resource use behaviour in different lifestyles and consumption styles.

Ecological modernisation theory turns to knowledge as a means to solve environmental problems, assuming that knowledge of nature is a product of scientific research, and natural sciences produce accurate descriptions of environmental problems. More recent developments in ecological modernisation theory (Mol and Spaargaren 2005, Mol 2008, Mol et al. 2009) take a sophisticated approach in analysing global and information flows, and understanding how societies are managing their resource base. Information flows are a core process characterising present society as an information or knowledge society, although neither term indicates the specific form of societal interaction with nature or environmental problems. With these terms the meaning of dematerialisation seems to disappear in physical terms, albeit not through a theoretical reflection of material and immaterial flows, but through an idea of immateriality of information or knowledge. More use of information and knowledge does not necessarily mean dematerialisation of society in economic production and consumption. Knowledge remains an inexact concept with regard to the material implications of resource use. Whether the information flows that occur in the knowledge, information or network society with internet-based communication indicate a progressing dematerialisation of production, consumption and resource use is doubtful. Empirical observations and available knowledge could also justify the view that in present global society dematerialisation is limited, whereas the dominant trend is exponential growth of materials and energy use. Furthermore, theoretical reflection on the knowledge of nature and its social structuring is required to capture society–nature interactions, and reflection of the difficulties in analysing this interplay.

Meta-theory: societal relations to nature

Problems in diagnosing the global crisis of society–nature interactions. The implicit assumption of most variants of ecological thinking and criticism of modern society is that during the 20th century and with the completion of the modernisation project in Western societies (in its economic, technological, political and sociocultural facets) there unfolded a hitherto unprecedented global environmental crisis. This environmental crisis was analysed in the 1960s and 1970s from predominantly naturalistic perspectives; for example, following the North American naturalism of Leopold and Carson, in the Malthusian perspectives of the "limits to growth" debate initiated by the Club of Rome, in the related "doomsday prophecies" and in the "population bomb" discussion in ecology (Ehrlich and Ehrlich 1968). Common elements of that critical ecological thinking are: (a) a selective analysis of ecological problems, such as human resource use or population development, and their destructive consequences; (b) a neglect of social-scientific knowledge about modern society in the use of biological and ecological knowledge to study the consequences of human resource use; (c) a primarily ethical motivation combined with specific normative thinking about nature.

Many debates in the international environmental discourse since the 1970s illustrate this diagnosis of a lack of critically reflected knowledge about society – for example, the debate about "post-material values" (Inglehart

1977), the deep ecology discourse, the ideas about a loss of ecological thinking and worldview in Western societies, and popular-scientific spiritualist ideas such as the "Tao of physics". Also, most natural-scientific environmental research did not try to understand the nature of modern society that was causing problems for nature. The natural-scientific theory of society under the term "anthropocene" is a recent exception. In most variants of the environmental discourse society was reduced or fragmented into one of its components or phenomena taken in isolation and made the root cause of the problems, be it technology, worldviews, lifestyles, or lack of spirituality or ethics. Or society became abstractly conceived of in spatial dimensions as small-scale or large-scale systems, or as a malfunctioning machine or as an order that produced destructive effects. Critically analysing the reification of social systems and structures for the purposes of dismissing it was not successful, although most of the critical arguments grasp aspects of human alienation from nature. To draw the "veil of ignorance" from modern society requires continued cognitive efforts. Examples of deconstructing the complex institutional and systemic nature of modern capitalism are mainly from older critical theories, including Marxist theory, critical theory of the Frankfurt School, and institutional economics, especially Polanyi's (1944) analysis of dis-embedded markets. More recent debates about new scientific or social realities have suffered from a neglect of societal system complexity – for example, the cybernetic thinking of Vester, the ecology of the mind of Bateson, and chaos theory for the dynamics of complex systems. An implicit, hardly articulated assumption with such theories was that of a changing social reality in one or another form of the "silent revolutions" that have been diagnosed in recent decades in science and politics.

The neglect of social-scientific knowledge in the ecological discourse persisted, supported by intuitive and evident construction of environmental problems. Environmental pollution and global environmental change seem to require natural-scientific knowledge for their diagnosis as well as for their solution, and the natural sciences seem to provide objective knowledge which needed to be transferred into political action and decision-making to work with the solutions. Ecosystems research seems to point out directly what is necessary to reduce environmental pollution and degradation and to strengthen environment-friendly production and lifestyles. Through changes in individual consciousness of producers and consumers, environmental changes seemed possible, supported by ethical awareness-building, enlightenment and education more than through knowledge from social sciences. Sociological knowledge could, it is supposed, contribute little to understanding and solving the environmental crisis in late modernity. It helped to describe environmental awareness of social groups, forms of political organisation in movements and parties, and the approaches in environmental policy. The time for biologists and ecologists seemed to have arrived, as they were credited with the capacity from their knowledge to tell the politicians directly what to do. What the North American pioneers of naturalism did in their seminal works about environmental problems was to combine natural scientific knowledge with corresponding ethics of the land or of the sea, and to give a cognitive model of how to approach the environmental crisis.

The deficits of the ecological discourse seem to mark a misplaced confrontation in knowledge fights with the hegemony question "which knowledge counts?" Interdisciplinarity seems to be one of the ways out of the confrontation, integrating knowledge without ignoring knowledge boundaries and disciplinary knowledge cultures, but combining several perspectives, concepts, theories and methodologies. Interdisciplinary knowledge justifies the reformulation of the global environmental situation in social ecology as a crisis in the systemic and institutional constitution of modern capitalism articulated in the interaction with nature.

Developing a theory of global interaction of society and nature. A further step in knowledge synthesis for the purpose of creating knowledge to solve global environmental and resource use problems requires the elaboration of three components of a composite theory of nature and society: societal relations to nature, societal metabolism and transformation of society. The methodology of material and energy flow accounting grounds the analysis empirically, but for conceptual framing a more theoretical analysis is required. The combination of the three relational concepts for analysing the resource use in a given society may seem at first glance to be nothing more than an attempt to take into account more factors and variables in a complex reality. However, through theoretical analysis the "black box" of complexity should be explained by showing the historically specific complexity of society–nature interaction in a systematic theoretical analysis. With the analysis of material and energy flows between society and nature in distinct modes of production, social ecology realises its cognitive interest in reconstructing societal agency for solving environmental problems and for seeking ways towards sustainability in a global context.

So far only rudiments for such analysis of global systems exist – the tradition of ecological Marxism that has grown out of Marx's early use of the social metabolism concept and analysis of a metabolic rift in modern capitalism (Foster 1999, Foster and Burkett 2000, Swyngedouw 2006); the variants of critical theory that influence social ecology through the notion of societal relations to nature; World System Theory; and the present amalgamations of ecological economics, political ecology, critical environmental history and world system analysis. From such sources a more elaborate analysis of material and symbolic social ecological relations in the global economy and society that are informed by the metabolic profiles found in MEFA studies of national economies may finally become possible. The final synthesis is guided by the concept of societal relations to nature. The symbolic and material relations that direct resource use have only exceptionally been analysed

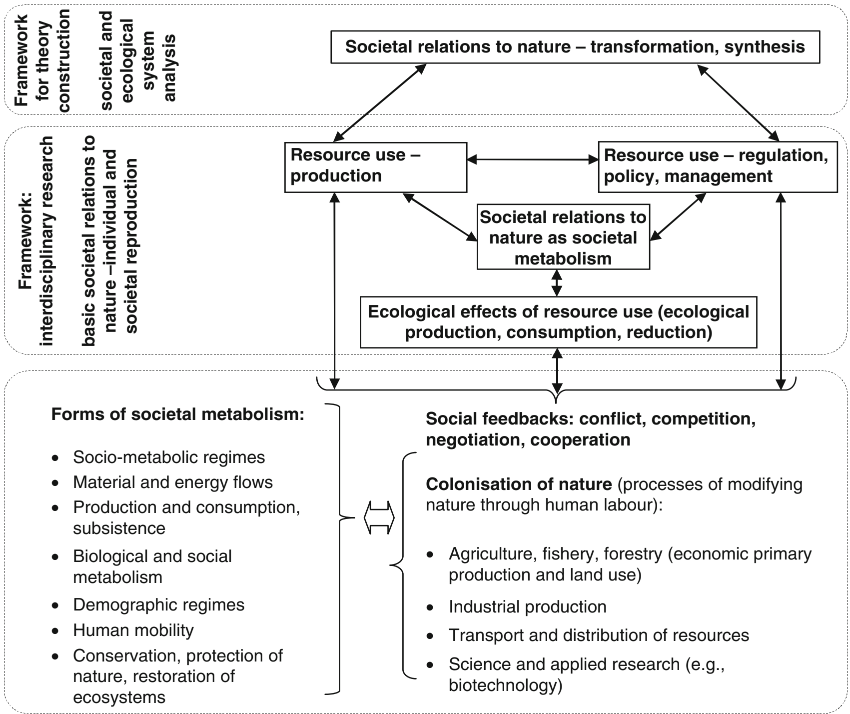

Figure 6.1 Conceptual framework for a composite social-ecological theory
Source: own compilation from social-ecological concepts and frameworks

in the newer environmental discourse – for example, in the socio-ecological theory of Moscovici (1982), who goes beyond the fragmented sociological argument that nature is socialised or internalised in society. Moscovici's diagnosis evokes critique when he writes about a reconciliation of humans and nature in the 21st century, but this may be inadequate. It was not part of the later debates about sustainability, climate change and resilience that successively showed more difficulties in achieving such reconciliation (Figure 6.1).

How could the emerging social-ecological theory of societal interaction with nature contribute to an improved and more critical analysis of problems of sustainable development? After elaboration of the theoretical framework, the answer from social ecology includes two elements. (1) Transition paths to sustainability need to be found from spatially and temporally specified analyses by connecting dematerialisation and further strategies for ecological transformation of the globalising economy with more systematic analysis of the present socio-ecological regimes. (2) The conceptual components of the composite theory allow an identification of the limits of the splintered sustainability discourse. The sustainability discourse is preoccupied with value conflicts and cultural and institutional change, but it does not sufficiently touch the core questions of resource use practices and redistribution of resources that initially motivated and drove the discourse. To make the debate about resource use and distribution conflicts more critical and concrete, a theoretically and empirically based diagnosis of the problems that have to be dealt with in global sustainable development is required, and somewhat more so than the abstract formulas of intragenerational and intergenerational equity in resource use. Preliminary elements of such a diagnosis have been formulated in the socio-ecological discourse through a critical discussion of naturalistic, idealistic or technocratic diagnoses of an environmental crisis (Becker et al. 1992: 171f, Becker and Brand 1996: 121ff, Becker and Jahn 1999).

1. What is in crisis is not nature or the environment, but the historically varying socially shaped relationships between man and nature: the societal forms of material and symbolic interaction between man and nature in late modern capitalism, called "societal relations to nature", which result in modifications of ecosystems. These relations include science that can no longer show clear ways to solve the crisis; its differing interpretations and assessments of the problems, loss of authority, and implicit value stances can contribute to a worsening of the crisis.
2. Societal agency to regulate and transform societal relations to nature needs to be enlarged – it cannot be limited to communication about nature in society and policy programmes, but needs to encompass all material and non-material components of a society–nature interaction in political, economic and social practice. The global crisis includes social, economic and ecological components that cannot be isolated from each other (this is – in a nutshell – the answer to the question of the policy relevance of social ecology; see Chapter 8).

"Societal relations to nature" becomes in social ecology a broad concept with more meanings than in the older variants of critical theory. In the research practice of the Institute for Social-ecological Research (ISOE) Frankfurt (Becker and Jahn 2003, 2006, Jahn 2005) it is the framing concept for all social-ecological research, used for developing the research programme of social ecology theoretically. A specific variant for empirical research is described as basic societal relations to nature (see above). In the Austrian social ecology the term is less important for the theoretical elaboration of the research programme, more used as the overarching concept for the analysis of societal metabolism and colonisation of nature (Krausmann and Fischer-Kowalski 2010: 1). In both institutional contexts the concept of societal relations to nature includes materially regulated and culturally symbolised relations.

What the concept of societal relations to nature adds to earlier critical analyses of environmental problems and preconditions for sustainability can be summarised as follows. The material and symbolic interaction between man and nature is no longer separated into physical and sociocultural components; both can be integrated in the agency term and become part of the search for new forms of synthesis of society and nature. Scientific knowledge practices are included in the critical analysis of the societal interaction with nature. Science, and the more specific forms of environmental research aiming to understand and solve environmental problems, can also prevent their solution. The privilege of science as true knowledge production is challenged here. The larger programme of theoretical analysis that ends with a theory of societal transformation includes a series of steps of critical analysis to reconnect knowledge practices in science, politics, and economy and in culturally shaped social lifeworlds. Critical analysis of knowledge generation and use is a domain of the metatheoretical analysis of societal relations, whereas the core theory of societal metabolism includes theoretical components of analysis (e.g., colonisation of nature, socio-ecological regimes) as well as empirical analyses of global resource use and flows (e.g., MEFA, HANPP) of the ecological distribution conflicts resulting from that and their resolution, and of social-ecological resilience to cope with the natural hazards and disasters that accompany sustainable development under the auspices of global environmental change.

> Sustainability (or unsustainability) is an attribute of a "social-ecological system." A social-ecological system emerges through the interaction of a society with its natural environment. Some have defined social-ecological system as an ecosystem "that does explicitly include humans or, more specifically, the social system" (Berkes and Folke . . .). This formulation, however, could be misleading because it implies that society can be seen simply as a subsystem of the ecosystem. Such a view is inappropriate because society cannot be reduced to its biophysical aspects. Although societies are essentially dependent on material and energy, they have emergent properties that cannot be fully understood by analysing the biophysical structures sustaining them. Thus, society in its entirety cannot be regarded as a subsystem of an ecosystem. This is expressed in the sociological principle to regard the social as a reality "sui generis." On the other hand humanities and the social sciences tend to conceptualise society and underestimate the relevance of biophysical aspects, or even neglect them altogether (e.g. Luhmann . . .). For sustainability research, however, neither the naturalistic view of ecology nor the culturalistic perspective of the social sciences and humanities will suffice.
>
> (Haberl et al. 2003: 3)

The preconditions for sustainability are not specified in this summarising formulation. Social ecology needs theoretically reflected and valued ideas of what sustainability is about and what it prevents. It can be assumed that sustainability is finally achieved through combinations of many strategies of change that sum up to a transformation of societal and economic systems: individual awareness-building – in practice not an individual change, rather a form of collective learning; changing of life and consumption styles towards sufficiency; institutional changes in political and economic systems towards more de-centralised and localised systems; more sophisticated strategies of environmental policy and resource management (adaptive management, etc.); empowerment of local actors and social groups; building of civil society at local, national and global levels; changes of socio-ecological and metabolic regimes with new forms of materials and energy use; restructuring the global flows of materials and energy to reduce unequal exchange; de-commodification or de-commercialisation of natural resource use; social practices of environmental justice; use of available scientific and local knowledge to strengthen agency and capacity of many non-governmental actors; a rethinking of society in ecological terms; and the following of ecological imperatives, such as carrying capacity. These ideas may support, directly or indirectly, decoupling and degrowth. They arose from the ecological discourse in science and policy during the past decades, many of them preliminary and tentative ideas and attempts in search of solutions to the perceived environmental problems, hardly elaborated in theoretical forms. From sociology the idea is important that these changes are societal and not individual in nature, requiring more than personal ethics and changes in everyday life and consumption. This can also be formulated as follows: the way towards individual changes of life and consumption styles, towards sufficiency, is through the transformation of the economic and societal systems that govern individual behaviour.

It seems that economic and ecological modernisation, technological innovation and dematerialisation in terms of reducing material and energy flows in the "greening of capitalism" describe the limited changes that can be managed from within the globalised capitalist economy, without its transformation into another not-yet-known future system: a new socio-ecological regime that requires for its realisation a third "Promethean revolution" (after the agricultural and industrial transformation of social-ecological systems). An improved analysis of the global economic and societal systems is required in social ecology and world system analysis. In such analysis the transformation of the industrial socio-ecological regime with its core component of materials use and energy systems would not be the only system components to change on the way towards global sustainability. But the last variant of this metabolic regime, the oil regime, can be seen as the starting point for systematically transforming societal relations to nature, including a variety of basic and sub-regimes, important among which is the accumulation regime linked with the metabolic regime as two basic regimes, both linked with more specific and limited components: global politico-economic governance, power and conflict relations; economic property rights and resource management regimes; or sociocultural knowledge regimes for symbolic mediation and interpretation of material relations to nature, to mention some main components of societal relations to nature.

Core theory: societal metabolism and colonisation of nature

Societal metabolism. Societal metabolism has become in social ecology a concept that describes with positive knowledge and empirical data processes that are otherwise not systematically analysed and understood. Its successive transformation into empirical analyses of natural resource use proceeds along the steps of colonisation of nature, socio-ecological or metabolic regimes, and analyses of material and energy flows and of the human appropriation of biomass. The basic definition of societal metabolism is discussed by Fischer-Kowalski, meaning that societies organise material and energy flows through the extraction of raw materials, the processing to food and other (e.g., industrial) products, and in these processes humans produce emissions and waste (Fischer-Kowalski et al. 1997: 4). The concept gains a clear theoretical meaning when its relation to biological metabolism is elaborated. This happens in the following steps (ibid.: 4ff; see also Krausmann and Fischer-Kowalski 2010):

1. For human societies the biological metabolism of humans defined in terms of their biological needs to survive, measured in terms of energy and biomass intake in calories or joules, is a precondition that connects with further forms of metabolism.
2. Beyond the human organic metabolism, humans use much more materials and energy that are transformed into products for clothing and shelter (dwelling), energy transformation necessary for providing food and shelter (fire or other forms of thermic energy for cooking and heating or cooling), for mobility and transport, for work and communication. These components define the basic societal metabolism.
3. The basic societal metabolism can be much larger than the minimum defined through the biological needs of all humans, and this results from the socially organised process of maintaining and reproducing a given society or form of production. The basic societal metabolism becomes much larger in nomadic and agricultural modes of production when the production and use of biomass are increased through modification of ecosystems and animal husbandry, and through plant and animal production. The agricultural modification of ecosystems and animals is the first and historically important form of creating an extended societal metabolism through the colonisation of nature for the purpose of changing the reproduction rates of renewable resources and achieving higher

yields. The second form of extended societal metabolism that intensifies human use of natural resources is through the use of resources in the form of modification of material cycles in the biosphere (e.g., the water cycle) and use of non-renewable resources, including metals and fossil energy resources, as they are characteristic of industrial production.

As soon as the three forms of biological, basic and extended societal metabolism are interlinked with each other in theoretical terms and subsequently in empirical analyses of resource use, the concept of societal metabolism makes sense in more than metaphorical use and analogy. It becomes the core concept for conceiving and measuring human use of natural resources and identifying the different problems that come with resource use and environmental destruction in human societies. It is evident that conceptualising and analysing societal metabolism require the use and combination of concepts from natural sciences, physics, biology, ecology, chemistry, and especially from social sciences, cultural anthropology, sociology and economics. Although the basic description of the process and its components (as summarised above) is rather simple, the analysis causes conceptual and methodological difficulties. Many of these difficulties can – and are – solved in the theoretical and empirical analyses in social ecology. But two forms of controversies remain. (1) To transfer, combine and modify concepts from different disciplines, especially "long distance transfer" across the boundaries of natural and social sciences, was and is sacrilegious in the tradition of academic science with disciplinary specialisation. Interdisciplinary research and concept transfer of this kind will remain controversial and give rise to knowledge conflicts that are mainly normative and worldview or paradigm-based. (2) The concept transfer and the operationalisation of theoretical concepts for the analysis of societal metabolism are confronted with the problem that established concepts – for example, that of energy and the energy-related laws of thermodynamics – are not clear, but are continually discussed in the disciplines in which they have been formulated. The use of these concepts in interdisciplinary science, as, for example, the laws of thermodynamics in ecological economics, evokes critical debates about their "correct" interpretation and use, as, for example, the controversy around Georgescu-Roegen's interpretations of thermodynamics in resource use analysis showed (Schwartzman 2008, with the summarising comment that Georgescu-Roegen conflates isolated and closed systems in the so-called fourth law of thermodynamics – he neglects the potential of harvesting a larger part of the solar energy flux to the earth: ibid.: 45, 48, 52). Some of these controversies can be cleared up through scientific discussion and critique that requires applying concepts that are clearly defined, methodologically correct and coherent. The important part of the controversies cannot, however, be settled in this way, as they involve competing interpretations and use of terms that result from competing theories or paradigms. The only hope is future clarification of concepts.

Colonisation of nature. The concept of colonisation of nature was introduced in social ecology to complement theoretically the concept of societal metabolism, which was not seen as sufficient to characterise the interactions between society and nature. These interactions need to be conceptualised for society and nature, and it seems evident that the material and energetic processes of exchange between social systems and ecosystems do not comprise the dimensions of active influence, of modification or of agency that society exercises. Colonisation of nature is the appropriation of parts of nature through society in the form of colonies and of nature modified to suffice human needs. The process is easiest to understand within the context of agricultural colonisation – historically seen as the paradigmatic case of colonisation of nature. The social-ecological concept of colonisation of nature includes the modification of biotopes or landscapes, of organisms (in animal husbandry), of cells (in cloning) and of biological macromolecules (in genetic modification of organisms). It includes all modifications of physical and biological resources in agriculture, industry and science (Haberl and Zangerl-Weisz in Fischer-Kowalski et al. 1997: 133). The historical analysis of agricultural changes in the transformation of nature and a theoretical classification of agricultural systems from a social-ecological perspective is an important component of social ecology (Lauk 2005).

The theoretical term of colonisation of nature takes up in the component of the colony some of the semantics of the more abstract term of hybrids that has spread in environmental sociology and actor network theory (see Chapter 2), but in other forms and analytical perspectives, and not only as mixes of symbolic and material flows that are formulated without analysing the particularities of flows in physical, biological, economic and social terms. Colonisation of nature is consciously constructed from a traditional term that existed in similar meanings in science and everyday life, and the forms of generalisation and theoretical abstraction that happen with the specific term to keep a historical memory of the meanings and changes in the human modification of nature. Thus the concept of colonisation of nature, along with theoretical reconstruction, seeks historical understanding of changing societal practices of resource use.

Socio-metabolic regimes. The regimes are described in social ecology, for example by Fischer-Kowalski et al. (2012), with (1) a “metabolic profile” (system of energy and materials use that is measured per capita of human population); (2) a specific pattern of use and change of nature/environment: land use, resource exploitation, pollution, effects for biological evolution (colonisation of nature); (3) a specific resource management system with the help of infrastructures (transport and communication systems) and specific technologies (agricultural, industrial production); (4) specific economic and political/governance institutions (market order, national/international political systems); (5) a specific pattern of demographic reproduction, structuring of human life, time and labour/employment structure; and (6) positive and/or negative feedback is possible between the different components of a regime (its socio-economic system and its natural environment).

Socio-ecological regimes have been described along these dimensions in macroscopic analyses of large societal formations in human history. The modes of production that appear from an ecological perspective are hunting, agriculture and industry. Such regimes include managed and non-managed components, for which non-management is a conscious decision in society. Socio-metabolic regimes are results of social action in given historical situations, but as wholes they are not designed, planned or managed. Managing the societal relations with nature in more specific systems of socio-metabolic regimes evokes the question: How (far) can the regimes be managed or regulated? In social-ecological research there needs to be a detailed investigation into how material and symbolic processes are connected in transforming human production, distribution and consumption practices through knowledge and power-based communication and symbolic interpretation. This research is directed against a dominant thinking in ecology that uses the arguments of knowledge limits, human ignorance and limited societal agency. Analysis of nature–society relations in their historically specific and changing forms is required before one is able to identify the boundaries of human action and resource use and the forms of societal agency that can be improved. Knowledge, as capacity to transform nature, is a socially productive force; shifts in natural resource use by societies lead to transformations in knowledge, in ownership, in power and in their combination as productive forces. Long before social ecology developed there was the idea that nature and society co-produce one another in continued, complex interactions that do not exclude contradictions, contrasting practices and worldviews, as Marx and later critical theorists, or anthropological theorists (e.g., Moscovici), have shown in theoretical and empirical analyses. Critical social-ecological theory needs to develop the arguments for a theory of societal transformation towards global sustainability that includes society and nature, the globalising economy and the problems of global environmental change.

Historically situated theory of societal transformation

Preliminary ideas about the transition to sustainability have been formulated in recent socio-ecological discourse, for example, by Haberl et al. (2011), Fischer-Kowalski et al. (2012). These ideas show that social ecology is working towards societal transformation that does not easily translate into established concepts of policy research such as decisions and programmes, their implementation and evaluation, policy cycles, policy instruments and political regimes. Theoretical and other difficulties in formulating criteria for societal transformation towards sustainability that can be translated into policy-relevant categories remain (see Chapter 8).

Transition to sustainability from modern industrial society is, according to social-ecological analyses, a process for which no knowledge is available and for which the study of past historical societies and modes of production does not provide models. The paradox of sustainability from this perspective is that of inventing a new societal metabolism without knowing how to do it – it looms as a third "great transition", which, like the prior two transitions in human history, the transition to agricultural societies and the transition to industrial society, is not to become a short, simple and planned process, as appears in large parts of the political discourse and in policy programmes for sustainable development. Rejecting many of the prior debates about sustainable development as insufficient ideas does not mean confirming Malthusian and doomsday prophecies of a catastrophic collapse of the global economy during the 21st century that reduces complex socio-ecological processes to quantity of population growth and resource use. Historical analyses of socio-metabolic regimes of different societies or modes of production show that the sustainability problems need to be specified differently for each form of society. With the critical analyses of global resource flows in environmental sociology, the social-ecological analyses of sustainability problems in industrial society share the conclusion that transitions are not possible by the single-handed efforts of local communities or national governments, but rather on a global scale. What the policies of sustainable development in industrial countries have brought about, often unintentionally as a consequence of de-industrialisation and shifting industrial production in the course of deregulation to newly industrialising countries, is not to be called sustainable development but rather "rich country illusion effects" (Rice 2007) of externalisation of negative environmental effects and cost-shifting.

One of the important consequences of reanalysing environmental problems in terms of societal relations to nature and societal metabolism is that such externalisation phenomena can be criticised. When nature and human society interact and modify each other's spheres in historically changing forms and degrees, it should be possible to formulate, with the help of scientific knowledge, ideas about the long-term trajectories and possibilities of the "co-evolution" of society and nature. The conditions for the transformation of societal systems and the formulation of transformation paths are only discussed to a limited degree in the ecological discourse – as changing ways of life and consumption, recycling materials, reducing waste and emissions, and dematerialisation of production by reducing energy and matter ("factor 4-" or "factor10" reductions) in the tradition of ecological modernisation. It has easily been found that savings of materials and energy with gains for the environment have been "eaten up" by continuing exponential growth, growing pollution, late industrialisation and growing resource use in other countries and economies. The early industrialising, rich countries of the West used their accumulated wealth and political, economic and scientific power to support or enforce "clean technologies" in certain areas of economic production without significantly reducing the total material and energy flows in their economies, protecting the environment and saving resources only in their own countries, but without reducing resource imports from other countries, or by occupying land in other countries for food production, exporting waste and toxic material to other countries, as practically all Western countries do with the help of their positional advantages in the global economy, which support their joint interests in the international institutions. The picture of the globalising economy and the competition between branches, national economies, regions and cities is certainly more differentiated and complicated than that. But to deny the effective consequences of long-term positional advantages – industrialisation as a positional good in Hirsch's (1976) term – that favour unequal distribution of gains and burdens from economic and resource use processes, and the unequal exchange, would be to self-block the critical capacity of environmental movements and science. Although global environmental movements can help to foster the critical North–South debate, it seems that large parts of the Western environmental movements recede to local and small-scale solutions with the direct dialogue and participation of local resource users and citizens under the notion of "reconstructing civil society" or widening "ecological citizenship". Global problems other than climate change and biodiversity reduction – for example, shifting ecological burdens, environmental inequality and injustice, unwillingness of global resource sharing and redistribution – seem to be much less perceived and critically discussed in public and politics. The "environmentalism of the poor" (Martinez-Alier 2002) and the concomitant debate about ecological distribution conflicts have opened more critical perspectives that were finally taken up by the global degrowth movement (Chapter 8).

On the way towards a theory of transformation of SES that "would involve the relevant internal dynamics of the SESs, including aspects such as local stability, resilience, structural stability, and self-organization . . . , the various forms of interaction of the system with its environment (including both threats and opportunities), and the kind of resulting deleterious or beneficial transformation of the system" become part of global change research (Gallopín 2006: 302). This is in a nutshell the theoretical perspective that resilience research is seeking, but that social ecology delivers. Gallopín's formulations stick to the perspective of functional systems analysis and its abstract terms. The arguments for such abstraction are of the impossibility of controlling and manipulating variables or of replication and experimenting in "real world situations of coupled social-ecological systems", so that a general theory needs to be developed from "principles" in ecology, economics and political science and through the comparative analysis of many cases (Walker et al. 2006). In social ecology another theoretical discourse about nature and society opens for a discussion of resilience as a contested term. The introduction of the SES perspective brought about a more interdisciplinary and social science-based debate about constituents and determinants of interacting society and nature in which the concept of resilience was differentiated from that of robustness as a component of human-designed systems (Anderies et al. 2004), and further analysed in a network perspective for SES (Janssen 2006, Janssen and Anderies 2007). The more controversial debate begins when SES is integrated into the theoretical frameworks of social ecology with the analysis of metabolic processes and flow of energy and matter between social and ecological systems (Becker and Jahn 2006, Fischer-Kowalski and Haberl 2007), and unequal exchange (Rice 2007, 2009).

In the ecological resilience and the sustainability science debate the interaction of social systems and ecosystems is reflected in abstract terms and exemplary empirical analysis and case studies that selectively adopt social-scientific terms and maintain a distance from more elaborate theoretical terms in social sciences and social ecology that do not easily connect with the ecological terminology. The discussion in systems ecology about "ecology and society" relations, taken up in more recent debates (Bradshaw and Bekoff 2001), shows the insecurity in using the "society" term, which is often downsized to meanings of practice, resource management, politics and decision-making. The resilience discourse, with some efforts to find connections to theories of global society as world system theory, has not yet advanced to more interdisciplinary, critical and theoretical discourse of the nature/society interaction. Also Gotts (2007) transfers the ecological terminology of the adaptive cycle and panarchy to social-scientific analysis. The ecologically rooted resilience discourse tends towards naturalistic reductionism and reification of social systems in terms of ecosystems. To connect resilience and critical socio-ecological discourses is not just concept transfer. The concepts used in both discourses imply heterogeneous views of nature, society and problems. To make such differences apparent, more elaborate theories of nature–society interaction are required than those presently found in the resilience discourse.

The critical theoretical debates in social ecology developed outside resilience research, and the attempts to connect the discourses remain cautious (Haberl et al. 2006, Brand and Jax 2007, Gotts 2007) as they deal mainly with conceptual definitions and reflections, and showing the differences of perspectives. This indicates a difficulty for the ecologically dominated resilience discourse to develop into a clearly interdisciplinary and theoretical discourse, with Brand and Jax (2007) as a paradigmatic example. The limits of the ecological resilience discourse are furthermore indicated in the epistemic debates about knowledge synthesis in ecology (Miller et al. 2008, Carpenter et al. 2009, Gunderson and Folke 2009a), which end at the point where the "natural limits" of ecology seem to be, not going beyond a discussion of resource use and environmental problems manifesting in ecosystems. The prototype of such "theoretical enclosures" is the formula of epistemological pluralism that was inaugurated in the aftermath of the postmodernism debates, a compromising interdisciplinarity in ecology, in which the nature of the systems or interactions is not studied in depth and the practical limits of cooperation in research teams prevent more theoretical reflection and knowledge synthesis because of multiple ways of knowing, differing compositions of research teams, and complicated negotiations between knowledge-bearers (Miller et al. 2008). The limited interdisciplinarity in resilience theory as discussed by these authors seems to be marked by the exclusion of more critical reflections about nature–society interaction that touch questions of power and authority relations, resource flows and redistribution of resources in the globalising economy and world system: these are paradigmatically visible in Brand and Jax's (2007) account of the resilience terminology, in which the connections to sustainable development appear as purely normative issues, or, consequently, as left to a practical solution outside research in knowledge application and resource management. In the discussion of the science–policy interface in ecosystem or resource management these questions reappear as problems of dysfunctional interfaces where blocking of information, selective filtering of information and what Popper called "immunization against empirical refutation" happen (Cartledge et al. 2008). The ideas about nature–society interaction in the resilience discourse seem to be less coherent, but rather fragmented, and characterised by specific empirical knowledge and epistemological pluralism that does not take up theoretical reflection other than in the Ostromian tradition of empirically grounded theoretical concepts that show "a world of possibility instead of necessity" (Ostrom 1998: 16).

The discussion of the resilience concept by Brand and Jax (2007) results in broadening the concept from a descriptive ecological term into a more general and abstract one for the analysis of complex systems. Resilience as part of a terminology of general systems analysis is adapted for application in different disciplines, research areas and contexts of research and by way of successive specification and differentiation of an abstract notion, a way of ex-post interpretation and contingent applications. However, it remains part of a universalistic system framework and terminology that is specified as a de-contextualised concept from a top-down perspective. Whether it is to be understood as part of a universalistic general theory in the tradition of general systems theory and similar universalistic theoretical approaches like traditional grand system theories in the social sciences (Parsons, Luhmann), or as part of other, epistemic frameworks or paradigms, is not yet clear.

It seems that the resilience concept can be applied in different disciplines and research contexts only because of its abstract and de-contextualised meaning, which is specified by way of application. It is a concept of the kind demanded by Ostrom in her critique of general theoretical concepts and panaceas: only empirical research can create and verify concepts that guide further research, but the universalistic form of general theories, concepts and laws or the epistemic quality of necessity will never be reached.

Continuing controversies – the differences of society and nature

Becker (2006) has argued from a social-ecological perspective against the dissolution of the differences between nature and society in an abstract holistic thinking that reacts to critical analyses of culture/nature dualisms, as, for example, found in the Potsdam Manifesto from 2005: "We have to learn to think in a new way." Becker does not criticise the intentions of holistic thinking or the necessity for critical reflection on such traditional dualisms as nature and culture or nature and society. But, with regard to modern society and the global environmental problems, he criticises the conceptual dissolution of society and nature in a new ecological holism that operates with assumptions found in widespread forms of the new ecological paradigm, such as society imbedded in nature, or with the new conceptual constructions of social-ecological systems that, without further reviews of social-scientific knowledge, see a mistaken analytical separation of society and nature in scientific analysis that is to be corrected by the new term. However, to annihilate the historically existing differentiation between nature and society that can be empirically traced in the components of socio-ecological regimes and modes of production (especially for industrial society) seems to be a dramatic neglect of knowledge and a simplification of societal analysis to forms that are not sufficient for the analysis of modern societies and global systems – which can only be justified as philosophical, ethical and normative ideas about the "good society". It is doubtful whether the ecological discourse can work with such simplifications, which show a neglect of social-scientific knowledge, now once again confirmed for scientific participants in the discourse.

Throughout the chapters of this book the guiding question has been to formulate the global environmental crisis in theoretical terms and informed by empirical knowledge. That it is a crisis in the societal relations to nature, in which knowledge is lacking concerning the regulation of this interaction, has been almost exclusively formulated in the social-ecological discourse. Large parts of the scientific and political environmental discourses rely upon simple and doubtful interpretations, as once again shown in the Potsdam Manifesto. To see the crisis as one of human thinking that can be solved by way of moral reflection and ethical discourse is, with its lack of analysing power relations, societal systems and conflicts, more a way of extending the finding of solutions than investigating them with the help of interdisciplinary knowledge as in social ecology.

Conclusions

Three points in the theoretical reconstruction of social ecology seem to mark further unclear or controversial points from which a more systematic discussion about the future development of social ecology can be taken up.

1. The manifold and heterogeneous *concepts of nature and culture* found in the history of Western culture and science, not yet taking into account other cultures, support the assumption that nature, culture and society cannot be dealt with once and for all by definition and scientific research. Simply replacing the notion of nature by that of ecosystems and that of society by social systems avoids discussion of the problems of conceptualising a complex reality that becomes apparent in these multi-semantic concepts that developed historically and are still widespread in modern science (which is even building on these concepts in its disciplinary organisation). All of them can be seen as open concepts that need to be reflected upon and developed continuously, with changing knowledge and problems, and learning from the changes instead of only rejecting earlier variants and asserting each time a new concept or theory is formulated that it is a progress. To see nature as a philosophical concept and ecosystem that frames positive knowledge and empirical research in natural sciences and ecology is in some ways meaningful, but not a solution to the conceptual problems for environmental research on natural resource use and global environmental problems. The concepts of nature and society have been reflected on in different chapters, and the reasons why they have not been replaced in social ecology by other terms have become evident – they keep, through their history and continued reflection in the context of specific theories, a memory of the differentiation between the two spheres that is critically reflected in social ecology. In modern societies society and nature appear as different spheres that are connected through “colonies” in a specific theoretical sense of colonisation of nature. The only term that is not systematically reflected in social-ecological theory and synthesis is that of culture (discussed further in Chapter 7).

2. Older controversies in the Marxist discourse about *value production* and productivity of labour and nature are not followed further today in the ecological discourse. In the discourse of ecological economics that refers to some aspects of the Marxist discourse, the interaction between labour and

nature is only reformulated in shortcut notions such as that of joint productivity. In the political discourse large parts of the ecological critique of commodity production only relate to the use value of products by criticising the production of "useless" goods for human consumption or of wasting of matter and energy through modern industrial production systems. Necessary as such criticism is, and one of the strong points of ecological criticism of modern capitalism, it cannot help identify the sources of such waste of resources, overproduction, conspicuous consumption or production of positional goods, unless in doubtful assumptions about human nature, value orientations of consumers and modern urban lifestyles that need to be changed or "ecologically corrected" by means of education, awareness-building and enlightenment of individuals. That an abstract subject is active in environmental and resource degradation, which is not a human subject but an artefact, a subject composed of capital, supporting property rights and market structures, seems to be either "theoretical metaphysics" or irrelevant to most participants in environmental movements, and for most scientific participants in the ecological discourse, as it reminds them of outdated speculative thinking. It seems to show such metaphors of ignorance as the "invisible hand" trying to understand the coordination function of markets or the "ruse of reason" working as a non-intended consequence of human action in finally generating a rational society. The theoretical analysis of value production and nature's role in it is not superfluous in the ecological discourse. The debate about valorisation of nature that is continuing in ecology and social ecology requires this problem to be clarified further.

The otherwise blocked debate about commodification and its significance for an ecological critique of modern capitalism has continued in the environmental discourse during the past decades concerning the "valorisation of nature", as a follow-up to earlier debates about primitive accumulation, privatisation of common resources, and subjection of nature under capital production as happens within economic globalisation; for example, with the clearing of tropical rainforests and with the patenting of living and genetic resources for purposes of commercial exploitation through private, agricultural or pharmaceutical companies. Although the main critique of this is still in the highly moral and value-loaded terms of colonial-style "robbing economy" ("*Raubwirtschaft*") and "biopiracy", there is now an enforced discussion about economic valuation of ecosystems that requires a more theoretically and empirically elaborate critique. Such a critique requires a discussion of the concept of scarcity and the economic dogma of "natural scarcity of resources" as, for example, in neoclassical economics. Instead of assuming an eternal and natural scarcity of resources in relation to human needs or desires, it would be required to differentiate between various forms and functions of scarcity – a biological or ecological scarcity that relates to the carrying capacity of ecosystems as a limit of resource use and growth of species; a physical scarcity concept that is developed through the quantity and quality of energy and material resources on earth for human resource use; and an economic scarcity concept that is not simply natural but a consequence of institutional mechanisms that constitute the modern capitalist market economy and its monetary valuation and pricing mechanisms. Each of these scarcity concepts could be differentiated further and specified to debunk scarcity myths that misguide the critical discussion of "limits to growth" for the global economy.

3. The *revaluation of space and of nature as socially appropriated nature* remains an unfinished discussion. With the remark that the innermost secret of capitalist economy is the economy of time, Marx has formulated – and to some degree analysed – the transition from extensive to intensive forms of exploitation linked to space and time and their socio-economic transformation in the capitalist mode of production. Historically seen, the extensive phase of exploitation was that of pre-industrial European capitalism in the 16th–18th centuries, when the creation of wealth, accumulation and exploitation were linked to spatial expansion or domestication of space through the formation of a capitalist periphery in European colonialism. This phase was coming to an end during industrialisation in most European countries in the 19th century, when there were no more territories to conquer and colonise. Instead of following only a new logic of exploitation as domestication of time, new capitalism is not spaceless or de-territorialised, and space is not vanishing as a constitutive moment of production. Space also has not vanished with the information society or through the use of modern information technology. The social transformation of space and spatial division of labour in late capitalism is a theme in Lefèbvre's "phenomenological Marxism", in which the production of space is analysed historically in the different modes of production in human history (Lefèbvre 1991). A classification of societal production of space in historically different forms includes the analogous space, the cosmological space and the symbolic space, which has been supplemented by Grönlund in the concepts of absolute space, sacred space, historical space, abstract space (as the capitalist space with simultaneous dynamics of homogenisation and fragmentation) and the perspective space (Lefèbvre 1972: 12f; for Elden's later systematisation see ibid.: 27ff). Space in such historically differentiated forms is not necessarily linked to nature or the environment in physical terms, which is important in analysing environmental problems in ecological Marxism. The social transformation of spatial relations as connected with the generation and the solution of environmental problems is hardly a clarified question in the ecological discourse arising, for example, in "radical geography", in which the continuous rescaling of modes of regulation in global governance is seen as a new mechanism of domination.

The idea that space and place are socially transformed and structured, not only categories from the natural sciences or physics, found its way into sociology and geography, for example, after the long phenomenological and philosophical debates about the subjectivity of time and space, but without significant consequences for the predominant naturalistic thinking in the ecological discourse. The consequence is more that of an unclear doubling of knowledge – natural-scientific categories now have social-scientific counterparts, which can be called social constructions of nature, space, place and time and need to be studied in parallel, or by dividing the knowledge about nature into a "material" and a "symbolic" or social part, the interaction of both forms being understood no further than that there can be mixtures or "hybrids." The less abstract and more traditional notion of colonisation used in social ecology to describe historically distinct forms of transformation of nature through human resource use seems to be more useful for the intentions of the ecological discourse and to identify transformation paths to sustainability because it includes more concrete analysis of the dominant forms of hybridity. The essential diagnosis of environmental problems and environmental crisis is still founded on natural-scientific knowledge, naturalist and realist epistemologies and paradigms that direct problem formulation. It seems to have become an important role for social-ecological research to work with the clarification of the theoretical concepts and diagnoses for further research about global environmental change.

7
Social Ecology – A Science in Development

Social ecology exposes the possibilities and the limits of interdisciplinary knowledge production through its development and the way in which it learns and organises interdisciplinary knowledge production in a paradigmatic way. Interdisciplinarity in general has raised the awareness of problems with knowledge production and application. Social ecology as interdisciplinary discourse is especially required when the boundaries of social and natural scientific disciplines are transgressed. Natural and social-scientific knowledge cannot easily be projected in a continuum of integrated knowledge and a continuum of interlocking spheres. This became apparent again in the controversy about the Potsdam Manifesto (mentioned in Chapter 6).

The interdisciplinary heritage of philosophy of nature, critical theory and environmental sociology

The new social ecology has developed as an interdisciplinary science of nature–society interaction in the border region between the epistemic cultures of the natural and the social sciences (Becker and Jahn 2006: 22). Interdisciplinarity was a characteristic feature of the earlier approaches of critical theory, human ecology and environmental sociology, but not in this explicit form of a science of societal relations to nature that implies studying the difference between nature and society, not dissolving it. Interdisciplinary knowledge production and integration requires more systematic reflection on the different kinds of knowledge to use and criteria for the concepts, theories and research results that should be used in environmental research as the main part of the work in social ecology. Some, but not much, of that reflection can be done with classifications of knowledge. Typologies of knowledge are general and abstract, and only of limited use for knowledge synthesis. The typologies include the normative forms and components of (scientific) knowledge that need to be dealt with in interdisciplinary discussion. Ott (1992: 208f) summarises some typologies of knowledge, following Scheler, who differentiates between knowledge for disposition, for orientation and for salvation. A similar differentiation was later formulated by Wolter as thematic knowledge of a specific subject area, of disposition, orientation and wisdom. Habermas, who replaced the variant of salvation by that of emancipation, describes the differing cognitive interests in knowledge use as validity claims connected with knowledge – the claims of being understandable (with regard to lingual expression), of claiming truth (of statements), of normative validity (using norms correctly) and of honesty (of intentions). In doing so he brings back into science an ethical reflection of knowledge which is connected with the tradition of critical theory in sociology, but has in similar ways characterised the trajectories of interdisciplinary research on society and nature in human ecology, critical environmental sociology and social ecology. It implies a threefold perspective of

- interdisciplinarity (integrating special knowledge from different disciplines or subject areas),
- critical reflection of knowledge used (identifying and assessing knowledge types and their validity claims) and
- guidance through the notions of process and relations in understanding nature, man and society (these knowledge domains are not seen as isolated but as dependent on each other).

The components of "process and interaction" connect human and social ecology to other philosophical discourses. As Gare (2002) has shown, process philosophy includes more than this revival of a notion and opens the reception of a neglected holistic tradition represented by the older philosophy of nature from the 17th century (Spinoza) to the 19th century (Humboldt), in which the idea of humans as becoming beings, developing and changing with human culture and society, unfolded until it was later interrupted by evolutionary biology with its lack of interest in the sociocultural evolution of man. This holistic tradition has a special history connected with the end of the philosophical epoch that Virchow and other scientists stated in the 19th century. At the very moment the holistic science of nature culminated in Humboldt's grand synthesis of knowledge about the cosmos, it began to be outcompeted in the practice of natural sciences by the simultaneously unfolding evolutionary biology of Darwin, which is more connected with the epistemological ideas of positivism and evolutionary thinking than with interdisciplinary holism. Although Darwin documented his reverence for holistic and process thinking by mentioning, for example, Goethe among the predecessors of the theory of evolution, there was no further interaction between the two traditions of Humboldtian and Darwinian science. The analysis of human nature and development beyond the proof of the evolutionary genesis of *Homo sapiens* is not of much interest for evolutionary theory. The sober philosophy demanded in Marx's criticism of metaphysics seems to have developed into a poor philosophy, with philosophical reflection replaced by formal logics and epistemological philosophy of science, which, according to an arrogant statement by Quine (1966), is philosophy enough. The awareness of the historical and process character of knowledge is vanishing from the dominant epistemologies in the 20th century. Social ecology is as well connected to the heritage of a holistic tradition (which reached it through the human ecological discourse) as it is critical of that tradition when it results in an ecological naturalism that ends the analysis with the conclusion that society is embedded in nature.

The project of philosophical anthropology is not systematically discussed in social ecology, but it was of interest in the discussion of the forerunners of social ecology (in Chapter 1) because it maintained an interdisciplinary knowledge culture that shows a more historically aware form of knowledge integration in working with the constituent concepts of man, nature and society than the more recent ecological thinking in which interdisciplinarity starts in theoretical terms with the notion of social-ecological systems. Philosophical anthropology keeps alive the idea that a theory of interaction between society and nature requires a theory of the human condition which develops from knowledge about the biological and cultural evolution of man. In that sense it represents a tradition of interdisciplinary thinking that reached environmental sociology through human ecology. In the newly developing environmental sociology of the 1970s Catton and Dunlap discussed interdisciplinary knowledge integration in a limited form of connecting sociological and physical data in sociological analysis, later as assimilating sociology into ecology. To incorporate a specialised subject area into another one by way of reducing disciplinary specialisation is an exceptional idea – historical examples of dissolution of established disciplines and "de-specialisation" are rare. Other, epistemologically ambitious attempts to integrate natural and social sciences, for example, in the sense of a social science of nature (Böhme and Schramm 1985), were also not taken up in the broader interdisciplinary discourses about knowledge synthesis. Also, the disciplinary integration of economics and physics under the umbrella of the theory of thermodynamics remains controversial, as has been discussed (in Chapter 4). The crossing of boundaries between the natural and social sciences and cognitive integration of their knowledge is methodologically difficult; that is the main experience in social ecology (Becker and Jahn 2006: 29ff). Such knowledge integration meets strong resistance, although it is necessary in environmental research. Attempts to create unified disciplines in more or less ambitious forms and to overcome the historical divisions between social and natural sciences and humanities have been rejected or ignored in disciplinary as well as in interdisciplinary knowledge discourses. The reasons are manifold, and they leave doubts about the development of interdisciplinary environmental research which cannot be overcome through single concepts, theories or methods but require continuous work in an open and continually developing network of connected concepts and methods, which is typical of social ecology. The example of energy problems of modern societies shows that interdisciplinarity can hardly be achieved with a single theory, but should integrate knowledge from different disciplines. Thermodynamic theory is a part of explaining the maladaptation of societies to nature. But the theoretical answer of physics to natural limits of resource use is not sufficient to understand the natural and social consequences of energy use. The critical point becomes more the societal choice of energy sources than the physical laws, which are a limited help in the search for new energy sources and the development of energy systems in society.

After such experiences, the question in social ecology is more that of finding out which spheres of specialised knowledge need to be connected to answer questions about global resource use problems. Connecting biological and sociological knowledge rather than physical and economic knowledge allowed some progress of knowledge integration for the theory of nature–society interaction. Furthermore, the limits of functional differentiation and specialisation of science became apparent. With the organisational limits of knowledge production in disciplines dominating the academic research culture, the principles of funding research to solve environmental problems also reached a crisis. Difficulties of coordination, integration and governance of the functional subsystems of policy, economy and science appeared, as well as new research problems such as global climate change and new ideas such as sustainable development that require interdisciplinary knowledge integration (Becker et al. 1992).

The combination of theories is a means to interdisciplinary knowledge integration for the analysis of interacting social and ecological systems, but for social ecology it is also the reinterpretation of older concepts, theories and frameworks that appear in the guiding terms of colonisation of nature, societal metabolism and societal relations to nature. The reinterpretation also brought some experience with the transfer of concepts between natural and social sciences. Ecological concepts are connected to a biological cognitive programme. To introduce them in the analysis of societal phenomena implies as the first step analogical reasoning or introduction of new metaphors without achieving further explanation. Societal metabolism became a powerful metaphor for the interaction of society and nature that was gradually transformed into a theoretical concept with the help of more differentiated conceptual frameworks such as socio-metabolic regimes, and could in this way also be connected with empirical research that helped to describe resource use problems better, for example, by showing the non-intended consequences of resource use, the patterns of unequal exchange and distribution of natural resources. Integration of the culture concept in social-ecological research is more difficult. Neither economic nor sociocultural transformations of the interactions between humans and nature can be reconstructed in biological terms. To reduce culture to functional mechanisms to mediate between biological organisms and their environment is in its reductionist form a selective explanation of cultural processes. These processes are multifunctional, not only relating to the interaction of humans and the environment, but more to interactions between humans that are to a large degree not connected with natural resource use. Maladaptation to the environment through cultural mechanisms is more a problem to be studied in environmental research for modern societies than successful adaptation. Ecological concepts becoming social ones results, in the worst case, in natural-scientific determinism in the social sciences. In the best case, similarities and complementarity of knowledge spheres can be identified and knowledge gaps can be closed. The idea of an epistemological continuum of natural and social sciences beyond the positivist tradition (e.g., Böhme and Schramm 1985) seems to follow similar cognitive interests as in social ecology, but requires a methodologically careful knowledge integration for which methods are still today hardly elaborated – a deficit with which social ecology has to struggle continuously.

Conceptual integration: social-ecological systems as unit of analysis

The interdisciplinary concept of SES (Glaser et al. 2012), which has been developing during the last decade in ecological research, was formulated in an effort to attain a knowledge synthesis, but it has quickly shown its limits; too many epistemological questions about the integration of disciplinary and specialised knowledge were not clarified in that conceptual operation. Using the concept is not problematic in social ecology; however, the assumptions with which it has been formulated in ecology, namely that the separation between social and ecological systems was wrong, are not meaningful for analytical purposes of research. The idea that the concept can help to articulate consists in an ecological perspective of social and ecological systems forming a unit. Whether the concept can become a common one for social and natural sciences depends on its interpretation. Arguing that humans are part of ecosystems and simultaneously of social systems (an inexact formulation) is not controversial; however, the assumption that society and nature operate through integrated social and ecological systems appears as a controversial view of modern societies. To connect sociological and ecological analysis or to reconstruct the interaction between nature and society in terms of societal systems is more complicated than assumed in the notion of SES. Social ecologists have argued critically against this form of holism and its normative implications – Becker in the critique of the Potsdam Manifesto and Haberl et al. with the differentiation of theoretical concepts for the analysis of society and nature. In both arguments the point is that society is not simply a subsystem of nature and it cannot be reduced to its biophysical aspects. Social ecology followed different procedures that showed more success in framing interdisciplinary knowledge areas, with a theoretical structuring in more historically contextualised notions (Chapter 6).

The empirical research on SES focuses on resource use problems, disturbing events, conflicts and catastrophes, by supporting a view of global sustainable development as a conflicting process close to catastrophe, which implies resilience or coping with disasters, a capacity to be developed by communities and societies. Urry (2007, 2008) reflects such functionalist reductionism in a discussion of two extreme alternatives for a planetary future which may be the consequence of societal adaptation to climate change: either a Hobbesian "dystopic barbarism", which would eliminate many democratic political, social and economic practices, or a "dystopic digital Orwellianism" of self and society in which almost nobody is left outside the "digital panopticon" and there is "no movement without digital tracing and tracking" (Urry 2007: 276). But the reflections indicate new problems beyond the critique of social adaptation to climate change. It can be asked how these metaphorical formulations translate into a more concrete critique of adaptation measures – if they remain a warning against all adaptation they converge with the arguments of sceptical environmentalism. The formulations of potential futures leave the impression that it is difficult to formulate the critique of political and societal development in more exact scientific terms.

The complexity of SES supports the view formulated by Lash (2003) that complex systems do not reproduce but change. This again provides some difficulties in analysing the functioning of coupled SES. It seems impossible to describe both social and ecological components without accounting for the differences in the reproduction of social and ecological systems. Sustainable development becomes a matter of "balancing at the abyss". Its main requirement is not for technological innovations of the kind encouraged by ecological modernisation and a new environmental thinking or ethics of sustainable consumption. Technological innovations, as they are presently used to sustain economic growth, are attempts to extend the ecological limits of production temporarily. New environmental thinking and behaviour, including critique of the modern market economy's ecologically dysfunctional effects, seem to result in the building of local society "islands" where self-exclusion and self-isolation from mainstream society are seen as a path towards a solution, which in contradictory ways is also happening now with national strategies of sustainable development that support the illusion of national solutions to global problems. In contrast, it seems more important to focus on analysing the possibilities for structural changes of economic and societal systems and socio-ecological regimes as long-term relations to allow global sustainable development, global sharing and redistribution of resources; to mitigate ecological scarcity globally; to find ways into a "post-mass consumption" society (Chapter 8).

The debate about physical dematerialisation (reviewed in Chapter 2) has long found support from many different sides because of its simplicity – in contrast to many earlier technological solutions, it seems to have the virtue of no negative external effects for nature and society. In recent years this discussion has lost significance as a strategy for sustainable development. Such dematerialisation is an incomplete process; however strong the institutional and civil society support may be, sustainability requires further changes. Further processes of a non-technological character are required, such as the Polanyian idea of de-commodification of fictitious commodities – natural resources as land, human resources as labour, and also money, so that it becomes a means of payment again and not a capital resource (Adaman et al. 2003: 371). Knowledge and people are important in this process in other ways than discussed in theories of knowledge and information society: as knowledgeable actors with practical knowledge, as in their capacities as decision-making citizens (Adaman et al. 2003: 371; see also Ostrom 1998), and as constituents of enlarged societal agency to cope with environmental problems.

Leaving the technocratic variants of regulating the interface of society and nature in favour of a social project of changing societal relations to nature implies that another socio-metabolic regime is not just a measurable process of quantitative changes, reduction of material and energy throughput in production and consumption, but a more complex process: dematerialisation in physical terms is only the beginning of a process of collective learning, of finding pathways towards global sustainability as mentioned above, through manifold combinations of knowledge practices, technological improvements, social and institutional change strategies and specified scientific research. Already at the level of physical materiality dematerialisation includes changes in material and energy use, and furthermore in toxicity of materials and residuals, in waste production and in ecosystem functions and services through extraction and absorption of residuals.

Such changes are structured in manifold ways by societal relations – modes of production, distribution and consumption of resources, or cultural, political and economic structuring of resource use. This again raises the question: how (far) can the complex symbolic and material societal relations to nature be managed, influenced, changed? The voluntarism prevailing in the political sustainability discourse makes it rare to ask about systemic and structural blocks to achieving sustainability. It seems necessary to provide room for consciousness and developing agency as well as taking system structures and social and geo-bio-physical materiality into account. This implies that natural limits to growth and human resource use cannot be simply read off from physical and ecological research, but require interdisciplinary knowledge synthesis. They do not appear as static, definite, unchangeable in the sense of eternal laws of nature, and are calculable only insofar as empirical knowledge is available about the limits, and this knowledge is continuously changing.

Regulating societal relations to nature by increasing social-ecological agency has been a topic of socio-ecological debate, but in this debate the limits of social ecology also become apparent. Regulation and transformation of societal relations to nature are aspirations for which natural and social scientific knowledge are not available and will not be made available with social ecology, a situation that has been reflected as that of post-normal science or the paradox of inventing a new form of societal metabolism without knowing how to do it. The critical analysis of the contingent interaction of individual, nature and society and connecting material and symbolic social relations and processes is part of the search for solutions that obviously require transformation of production, distribution and consumption practices through knowledge-based and power-based communication and social action. The way of thinking in ecology that underlines the limits of knowledge to argue for limiting human action and accepting human ignorance is not sufficient for that purpose. Without doubts about the limits of human knowledge, the principal question is how to make use of the knowledge available at a given time. The analysis of nature–society relations in their historically specific and changing forms is required before one can answer this question and identify the boundaries of human knowledge, action and resource use. Ecological and sociological thinking both struggle here with the complexity of systems and problems, and search for creative ways to deal with it. Urry appears to have found a way to be applied to a knowledge society framework: to reduce everything to fundamental laws of nature is no longer meaningful; instead he argues for a focus on the study of "emergent complexity" (Urry 2007: 27). What researchers actually encounter is not nature as an emergent complexity but objects – materials, machines and so on, as part of infrastructures or socio-technical systems. The reduction of nature to things, objects and resources implies physical reductionism without ecological and social relations. Also Urry (2008), with his material-bound analysis of the socio-material organisation of transport and travel, seems to stop with a sociological cognitive programme where it would be necessary to analyse the interaction of nature and society in more complex forms as discussed (in Chapter 6) for social ecology. There are significant difficulties in using a sociological framework for these purposes, where the dominant perspective is still concerned with how humans modify or change nature as a socialisation of nature, not how ecosystems react to human interventions.

Knowledge society is a vague notion in the sociological and political discourses, where a more or less hidden understanding of societal development prevails as a shift from the use of physical power to the use of intellectual power, which is seen as increasingly able to function as a driving force for changing society. This seems insufficient from a social ecological perspective, where changes of societies need to be analysed also in terms of material and energetic changes – for example, as shifts from muscle energy to fossil fuel energy (Huber 2009). Critical analyses of social forms of energy use as limiting factors of societal development throughout human history and up to the present time are rare in sociology and social ecology. In such analyses knowledge is perceived as the power to transform nature (Huber 2009), not only as a limiting factor, but as a socially productive force. Shifts in natural resource use by societies can be triggered by manifold events, and lead to transformations in knowledge, technologies and ownership forms, and the combination of these as productive forces. To view these forces as productive, not excluding the possibility that they can be misused in destructive ways, seems to make the abstract notion of power–knowledge interaction more concrete. It seems desirable in social ecology to gain back some of the lost societal theories to analyse interaction between society and nature – as attempted by Moscovici, for example. The argument of knowledge as a productive force that changes in the historically situated practices of human resource use developed by Marx, in critical theory, by Moscovici, and in the present socio-ecological discourse, opens for an analysis of nature and society as co-evolving and co-producing one another in continued, complex and temporarily contradictory interactions. Such an analysis is formulated in rudimentary form in the theory of the anthropocene (Steffen et al. 2007); it would help to analyse the global interaction between society and nature in a more theoretically concrete way.

Neglected themes in social ecology

Social ecology as an interdisciplinary science cannot integrate the total spectrum of sociological, economic or ecological research. The fields of empirical research that developed in the German and Austrian variants of social ecology are not fully coherent with the theoretical contours of social ecology – they show casualties, contingencies and temporal exceptions in the programmatic profiles. Certain themes that have been reviewed in the preceding chapters are not fully accounted for in the social-ecological resource and debate – especially themes related to the mediating of nature–society interaction through cultural and power relations and through the anthropological theme of analysis of human nature that intersects with the culture theme. The focus on the interaction of nature and society has furthermore created some distance to work with a renewal of theory of society after the end of the "grand theory" tradition in sociology, its critical (Habermas 1981) or traditional (Luhmann 1984) variants. This discourse of theory of society has not ended with the post-modernism debate critically seen in social ecology as "postmodern culturalism" (Becker and Jahn 2006: 20); this merely interrupted it for a time.

From the beginning, social ecology has concentrated on theoretical notions necessary to reconstruct the interaction between society and nature from historical perspectives: those of societal metabolism and colonisation of nature, under the broad framing term of societal relations to nature. It has not followed the intentions of a new theory of society, nor has it cleared the complicated relations between the terms of society and culture. These themes and questions cannot be ignored in the further development of social ecology. Why the theories of culture, of society and of man and nature are important for social ecology is discussed in the following sections.

Culture, agency and knowledge practices

In social ecology the notions of societal action, agency as capacity to change society, and culturally framed knowledge practices that support the change of societal system structures are not sufficiently elaborated, either theoretically or for use in empirical research. The connections between culture, knowledge and agency are discussed in cultural-anthropological research but need to be reformulated for social-ecological research where cultural practices of resource use and environmental historical studies about societal changes have been carried out. In historical analyses the concept of cultural evolution is introduced to explain changing interactions between society and nature (Fischer-Kowalski et al. 1997: 37ff), but more in exceptional studies, for historical cultures and societies, with a vague functional interpretation of culture as "recursive communication" (ibid.: 43). This is not yet an elaboration of the notion of culture to be used in the theoretical framework of social ecology. The social-ecological studies of transformations of socio-metabolic regimes pay less attention to cultural factors and practices and more to changes in material and energy flows (Fischer-Kowalski et al. 2003, Fischer-Kowalski and Haberl 2007); also in epistemological discussions of SES cultural factors are hardly reflected (e.g., Haberl et al. 2006, Becker 2012). The cultural framing and regulation of natural resource use and the processes called in social-ecological terminology "colonisation of nature" bring several denotations of the culture concept to affect the historical analyses of human modification of nature. But there is still no theoretical framework or systematic and comparative observations of cultural practices to be found in resource use. Exemplary analyses of the interaction between symbolic culture and SES (Wildenberg 2005) do not remove the theoretical deficit of analysing the roles of cultural values and processes in natural resource use; they do not answer this question for the level of global resource use analysis either, but it remains at the local level of case studies, as in common pool resource research.

The culture concept and discourse can be taken up in different ways, starting from the sources of social ecology discussed in earlier chapters:

– The culture and agency debates in sociology and cultural anthropology: How to connect these with ecological and natural-scientific analyses of environmental and resource use problems?

- The culturally mediated knowledge practices in local resource use: How are these to be integrated or transferred from human and cultural ecological studies of resource use into the common pool resource studies where cooperation, knowledge-sharing and power issues have been the focus?
- The results of studying societal resource use practices with different concepts and forms of cultural analysis (e.g., a conventional view of culture as consensus and value-based concert of action; the dichotomy of thin and thick culture; the analysis of culture in world system theory where the economic unity of the world system is seen as contrasting with a multiplicity of cultures operating within that economic system).
- The self-observation of social-ecological research practices: How does an interdisciplinary culture of knowledge production and application develop that works in transdisciplinary form with different – scientific, managerial and local – knowledge cultures that interact with each other and should be integrated?

These questions require a review of the manifold culture concepts and how these can be applied in social-ecological research into natural resource use practices. The multi-semantic culture concept and that of society create continuing confusion in ecological research through their normative interpretation. In the resilience discourse the concept of culture, as well as that of society, has been taken up (Gunderson and Folke 2009) in a debate that shows the difficulties of applying social scientific concepts in ecological research, for example, when culture is seen to represent a "social pathology" undermining resilience through the power-based hierarchical structuring of state-based societies, so that a way out is sought through the adaptive capacity "inherent in the social, i.e., cooperative, nature of society" (Tyson 2009: 1). That the terms "culture" and "society" are both used here in fragmented, extremely simplified and valuing denotations is the least critical comment that can be made. The construction of a contradiction between culture and society becomes misleading as long as no historically concrete cultures and societies are analysed and referred to. Case studies would show more and differing relations between culture and society. This quotation also shows major weaknesses of the view of society in resilience thinking: power structures are excluded or neglected (in this case ascribed in a doubtful way to cultural processes), and human society is conceptually modelled from the term of community that implies cooperative social interaction, but nothing of the complex system qualities of modern societies.

Culture, in its variety of meanings, has denotations that are important to explain and measure resilience in ecosystems and can be related to natural resource use and to ecosystems. The meanings include the controversial attribution of "cultural services" to ecosystems, and furthermore that an ecosystem has a kind of memory that it can use as a mechanism for adaptation, development and learning in differentiating between system states and striving for stable, normal or preferred states in reaction to changes inside and outside the system. Culture, from that functionalist perspective, is a mechanism to enhance agency and the capacity of development of ecosystems (beyond the simpler notion of adaptation that describes more a mechanical than a cybernetic mechanism). What do memory and learning as components of transformational capacities imply in such reductionist applications? The non-somatic brain components of ecosystems should be explained without attributing to ecosystems in doubtful ways the quality of living systems or organisms, as has been done in several variants of ecology, as well as in the resilience debate. Older concepts of biosphere and noosphere by Vernadsky stated a "cosmic brain" function which appeared as a kind of Hegelian mind ("*Weltgeist*") in the noosphere idea, and the more elaborate "Gaia" hypothesis (Lovelock) also followed a similar reasoning.

If the culture concept could be separated from that of an actor, organism or living system to explain agency and development capacities in another way, societal agency, sociocultural evolution and changing forms of nature–society interaction could be analysed without using analogies to living systems. The roles of culture in coupled SES cannot be sufficiently described with the basic ecological meaning of culture as non-genetic adaptation. Cultural anthropology has during its history provided a series of conceptual and methodological components to develop the notion of culture (Box 7.1). Such approaches to anthropological studies of culture, different as they are, do not primarily use the individual person-related capacities of using symbols, language and symbolic communication and learning in interpreting the idea of culture.

Box 7.1 Terminology – concepts of culture

In cultural anthropology (systematic description: Budin 2003):

- culture as super-organic phenomena (Kroebers' distinction of culture from biological mechanisms, similar to Weiss),
- material and artefact components of culture,
- the collective capacities of human groups effective through institutions as cultural wholes (referring to a universal notion of culture that expresses a common property of humans: White),
- the ecological traditions of anthropology (cultural ecology, cultural materialism and the combination of local cultural studies with global power and resource exploitation in the modern capitalist world system and its history: Wolf),

Box 7.1 (Continued)

– the structuralist and materialist notions of culture that are used to describe socio-ecological practices of resource use as patterned not by common belief systems but by modes and relations of production that dominate in a society. These direct the ways of consumption and lifestyles more from a societal than from a cultural system (e.g., in the British tradition of cultural studies, using among other interdisciplinary perspectives that of political economy).

In the policy discourse:

WWI (2004, 2010) – from WWI report "Transforming Cultures – From Consumerism to Sustainability" (WWI 2010: 2):

"Like a tsunami, consumerism has engulfed human cultures and Earth's ecosystems. This cultural system encourages people to define their happiness and success through how much they consume. But on a finite planet, this system is maladaptive and threatens to cause significant disruptions to Earth's climate and ecosystems, and subsequently to human civilization. If, on the other hand, we channel this wave, intentionally transforming our cultures to center on sustainability, we will not only prevent catastrophe, but may usher in an era of sustainability – one that allows all people to thrive while protecting, even restoring, Earth."

The project "Transforming Cultures" of the World Watch Institute aims at shifting consumer cultures into cultures of sustainability through a transformation of core institutions shaping society – the media, educational services, business, governments, traditions and social movements.

For a more systematic analysis of the development of mass consumption and consumer culture see Dauvergne (2008).

Source: mentioned in the text

The culture concept has been reviewed critically several times in anthropology with the question of whether to retain it or leave it. Hannertz (1993) did this some time ago to capture the different and shifting emphases of the term. His discussion captures the varieties of the term in a cognitive landscape that is mapped theoretically with such terms as the universal, the collective, the unique, the diversity and the plasticity of human nature and human-designed systems. It can be assumed that the comparison of the multiple meanings of culture (e.g., Budin 2003) can help in developing a conceptual framework in social ecology to study nature–society interaction:

not by making varying meanings coherent or reducing their common qualities to still more abstract concepts, but rather by showing the utility of working with different variants of the terms.

The culture, agency and knowledge concepts as related to the regulation and transformation of social-ecological relations are not discussed in detail or connected in social ecology. The older debate in cultural ecology, including Steward's concept of a culture core, follows a functional analysis of the mediation between a local society and its natural environment that has already shown its limits. The discussions in Wolf (1982) and in world system theory give other ideas and examples for ecological analyses of culture. For Wolf a macroscopic analysis of system structures of capitalism requires as complementary analysis a microscopic, local and time-bound analysis of the modern world system that shows how the system works in historical reality under different geographical and cultural circumstances: culture and the differences between local cultures do not simply vanish or become melted into a "global western culture" during modernisation and globalisation – they communicate, are in conflict, are modified and to certain degrees blended. A question that comes up repeatedly in the world system analysis, but also in the MEFA and unequal exchange analyses, is: How do cultural factors support or hinder the unfolding of systemic structures of the world system and modern capitalism? How can cultural rules and institutions be used to transform the system, for example, in strategies for sustainable development? In environmental sociology Yearley (2009) has recently renewed studies of the cultures of environmentalism in three thematic perspectives of movement culture, public policy and knowledge cultures. His empirical studies take up the problems of globalisation and sustainability. Although the studies turn away from theoretical debates, they deliver input for the discussion of environmental governance (Chapter 8). Discussion of sociological and anthropological culture studies in social ecology is a possible way of developing the interdisciplinary framework for the study of nature–society interaction that can help to balance the functionalist knowledge cultures of natural scientific ecology. For social ecology the interest is not in a unified and coherent theory of culture or in explaining modern capitalism as a universal cultural system. Such theories exist in sociology and cultural anthropology, for example, that of Sahlins. To work with a plurality of terms, beyond such abstract meanings of culture as recursive communication, with other questions than traditional comparative studies, would support new research in dealing with the systemic limits of regulation and transformation. Studies of the transformation of cultures in the process of globalisation, through mass media, global information flows and technical communication processes, are already established research, using theories such as Castells' theory of the network society. But they do not answer the question of societal agency; rather, they give up on this question under the impression of complexity of changes perceived. If social ecology is to develop more specific studies of culture that fit with its cognitive interests and conceptual frameworks, it should start from this point, where the disciplinary theories give up. Instead of renouncing research and accepting limits of knowledge, social ecology tries to reduce the limits of knowledge through research – but this requires further improvements of the conceptual frameworks to include the themes of culture and environment.

Theory of society

Social ecology is, according to its definition and research programme, a science of interaction between society and nature, not a renewal of theory of society, although prior theories of society influenced its development. The motives of the elaboration of social ecology include achieving better understanding of society by addressing themes of society–nature interactions that are insufficiently dealt with in the sociological, economic and anthropological theoretical discourses about society. It seems, however, that further questions of theory of society cannot be continually neglected in social ecology by leaving them to other thematically specialised research. In the interaction between nature and society the theoretical clarification of both abstract and multi-semantic concepts is continually required (in sociology: Urry 2000: 7ff, 200ff) to avoid misleading discussions of culture and society concepts as in the resilience debate. To refer to the sociological discourse, where the analytical utility of the notion of society has sometimes been doubted, replaced, for example, by that of social systems from a functional perspective, is not an answer either. The late grand theories of society by Habermas and Luhmann and the sociological theory of ecological modernisation do not offer starting points for taking up the discussion of theory of society again from a social-ecological perspective. The grand theories show their weaknesses in the analysis of the interaction of society and nature – it disappears from the sociological construction and analysis of society and appears in epiphenomenal themes only. In Habermas' theory (1981), interaction between society and nature appears in the discussion of the role of new social movements and in some points of instrumental rationality that represent the relicts of a theory of human labour and exploitation of nature. In the general theory of social systems by Luhmann (1984), it is reduced to environmental communication between social actors, with the main argument that environmental problems fall "between the stools" in a functionally differentiated society where none of the subsystems of policy, economy or science is able to react adequately to environmental problems; all are specialised for other functions of cognition and action. The ecological modernisation discourse has been discussed intensively (Chapter 2) in its deficits as a theory of nature–society interaction. The risk society theory by Beck and that of reflexive modernisation by Giddens have not been discussed further in this book, but they have been discussed sufficiently in sociology to show their limits for the analysis of the interaction between society and nature – connected in both theories to the guiding term of reflexive modernisation that limits the analysis of societal relations with nature to a sociological study of how the interaction is perceived and reflected by social actors, including scientists.

A new social-ecological debate about the development of modern society can be taken up from other discourses that continue with the discussion and elaboration of a theory of society that includes societal interaction with nature. These discourses include the critical theoretical tradition of political economy of globalised capitalism, to which social ecology relates and from which it simultaneously keeps its distance. Several variants of political economic theories presently in progress include the world system theory (Wallerstein 2004), O'Connors' (1998) theory of the second contradiction of capitalism, Schnaibergs' (1980) "treadmill of production" theory, some variants of ecological Marxism (Foster, Altvater), and the policy and regulation-centred critical discourse without a distinctive theoretical name that appears in "neo-variants", for example, as the discussion of neo-Poulantzanian approaches (Görg et al.; see Box 7.2). The reconnection of these theories with the analysis of nature–society interaction in social ecology does not seem easy. In the ecological Marxism of Foster a renewal of capitalism theory happens with a dogmatic closure, as shown, for example, in the repeated discussion of the theory of a metabolic rift as classical foundation of environmental sociology (Foster 1999; see Box 7.2), which does not inspire interdisciplinary and inter-theoretical research.

Box 7.2 Ecological Marxism

1. The classical debate – "metabolic rift":

> Marx was very much concerned with the asymmetric exchange of nutrients and other material resources between town and countryside in 19th-century Europe, which among other things resulted in the impoverishment of rural soils and the accumulation of garbage and sewage in urban areas. The deterioration of European soils prompted capitalist entrepreneurs to exploit phosphates in Oceania and deposits of guano along the west coast of South America, and to develop artificial fertilizers requiring significant inputs of energy. Marx's crucial observation can today be extended to the metabolism of the entire world-system …, some parts of which are ecologically impoverished while other parts are smothered with garbage, air and water pollution, and other forms of material overload …. The pattern is quite simple, if not self-obvious. When too much biomass, nutrients,

Box 7.2 (Continued)

> water, or other natural resources are removed, the result is loss of biodiversity, topsoil, fish stocks, or other vital assets ... Conversely, when too much matter and energy use is concentrated in an area, it may suffer from smog, acidification, eutrophication, accumulation of heavy metals, and problems with the disposal of solid waste (see McNeill...). In fact, even the global logic of carbon dioxide emissions and climate change can be understood within this theoretical framework.
>
> (Hornborg 2009: 247)

2. The present debate: A more adequate summary of the inherent weaknesses of the ecological thinking of Marx and Engels was given by Görg (1999: 60): a basic weakness of their theorising about nature and society is that they, although starting from the societal reconstruction of external nature, do not critically reflect and discuss the question of "eternal laws of nature", which also finally results in an ambivalent concept of nature as in a reduction of the concept of social emancipation to one of technical control of nature as far as knowledge of laws of nature allows, but there is no critical analysis of the influence of science and technology on the interaction of society and nature and its regulation, as Görg underlines. Such criticism brings Marxian ecological analysis of society, in the context of the debate of domination of man over nature, close to the Baconian tradition of human emancipation from nature.

There are several variants of a theory of ecological Marxism, but such a theory is not identical with the criticism of capitalist society and relations of production and a solution of environmental problems does not necessarily follow from the changing of these social structures (ibid.). The societal relations to nature in cognitive or symbolic forms, as well as in technical and practical forms, need to be analysed separately. However, from where to take knowledge and what role natural sciences play is an open question.

With the points of critique formulated by Görg (similar to that of Becker and Brand 1996: 118ff), a currently significant controversy about the interpretation of ecological Marxism is touched that can, in a somewhat simplified formulation, be seen as lying between an "objectivist" and structuralist or orthodox ecological Marxism (e.g., Altvater) and a "critical intersubjective", socio-centric interpretation (Becker, Brand, Görg et al.). The latter is developing by discussion of Marxist theory into "neo-variants", taking parts of prior debates about theory of the state and theory of regulation to create a theoretical framework for analysing globalisation processes with a focus on internationalisation of the state (Hirsch et al. 2001, Hirsch 2002), with labels such as combining "neo-Gramscian" and "neo-Poulantzanian" approaches (Brand 2004). The former is focusing on social classes in international political economy, the latter on the renewed discussion of the structures and functions of the state. It is obvious that in this controversy, which is reminiscent of previous controversial debates in Marxist discourse, the role and understanding of laws of nature, especially of physical laws (thermodynamics), is a decisive point. Altvater's position is similar to that of the founding figure of ecological economics, Georgescu-Roegen, who has reclaimed this reintroduction of thermodynamics in the analysis of economics (mainly arguing with regard to agriculture). This has meanwhile been criticised as a positivist variant of theory construction (Gehrig 2011).

Sources: mentioned in the text

The theory of the metabolic rift is not sufficient for developing social-ecological theory of nature–society interaction with knowledge from critical political economy. How should ecological criticism of political economy be further developed today? Not in textual exegesis, by reading and rereading Marx. But other theories in the political economy tradition mentioned above also do not invite further interdisciplinary research. Also, the political-economic approaches of O'Connor and Schnaiberg have made their points in theoretical arguments that do not open for new investigation of nature–society relations. From Lipietz' (2000) critical reflection of political ecology one may conclude that his accounting for what he calls the "Marxist-Polanyian" framework in O'Connor's (1998) discussion of ecological Marxism is a way to continue interdisciplinary work, but Lipietz himself is sceptical about such a discussion. The possibility of debates with world system theory that have to some degree happened in social ecology, or with the "neo-variants" discussed above, remains as a further option in social ecology. The latter are closer to the core question of social ecology, of regulating the interface of society and nature. A difficulty that cannot be discussed in theoretical or epistemological terms is the practical one that the complex social-scientific theories cannot be easily communicated between social and natural scientists. The schism of ecological interdisciplinarity in resilience research or sustainability science (both under-theorise societal complexity) and the sociological interdisciplinarity (that overburdens the discussion of societal relations with nature with complicated theoretical reflections) is obvious in environmental research. Social ecologists can decide to accept the challenge to work with the renewing of a theory of society or regress to the limitation of aspiration levels for the analysis of society–nature interaction to the fragments that are already found in the social-ecological discourse, the new "middle range" theories of ecologically unequal exchange and ecological distribution conflicts.

Walker (2005) presents some useful ideas for interdisciplinary analysis of nature–society relations, arguing mainly from the neglect of a Weberian tradition in environmental sociology. Without sharing his diagnosis or accepting the introduction of Weber's sociology to upgrade environmental sociology, which sounds somewhat traditionalistic, his criticism of the narrow definition of the field of environmental sociology and the methodological limits of the discipline is inspiring. He calls for an interdisciplinary opening, for an improved conceptual construction of the human–environment relationship as a "proactive two-way interaction" and a more specific theoretical classification of environmental problems to be analysed. Walker also looks for connections to cultural anthropology, and, beyond that, especially interdisciplinary ecological research into environmental sociology, which is so far poorly connected and dispersed across the fields of natural resource management research. His reference to anthropology evokes the question of how this interdisciplinary knowledge can be used in the social-ecological discourse.

Man and nature – philosophical and cultural anthropology

At the beginning of the Enlightenment, Pascal took the role of the sphinx in formulating the unsolved task of anthropology. "Man is to himself the most prodigious object of nature; because he cannot conceive what body is, and still less, what mind is, and less than any other thing how a body can be united with a mind. That is the climax of his difficulties, and yet that is his own being" (Pascal 1991: 72). Looking back, he seems to have written a comment before the events, before the Enlightenment that did not solve the puzzle, but tried different answers about man and nature from the perspectives of rationalism and empiricism, anthropocentrism and holism, dualism and monism. Pascal's and Descartes' dualism of body and mind can be followed later on in biology and sociology; both disciplines took up both themes, reduced to their respective disciplinary cognitive interests. The theory of the mind was taken up in biology with brain research, in sociology in interactive constructions of the human mind, such as in the classical variant of Mead with a dialogical concept of the mind developing from the ego–alter dyad of intrapersonal communication in which society is already present in the learned capacities of thinking, communicating and socially interacting. Philosophical anthropology, not necessarily philosophical in nature, but more a synthetic interdiscipline of knowledge about human development, inherited and continued the tradition of a theory of human nature and development that does not reduce humans to their biological quality as organisms, but interprets their societal nature. Although the concept of society is not the focus of this analysis of the human condition, it systematically reflects the views of humans in modernity and indirectly approaches a historical and critical view of modern societies that oscillates in its normative and evaluative ideas between a conservative view of social order and a critical view of modern society similar to critical theory. The ecologically relevant message of philosophical anthropology for the social-ecological discourse about nature–society interaction can be sought in developing the older notions of human nature as that of a social being, of a rational being and of one that interacts with nature in culturally mediated forms. These say more about the nature of society and its relations with nature than the philosophical anthropological discourse may intend to say. The societal origin of man, based on the communication and cooperation between humans as a sociological explanation, has to some degree also been discussed in the classical foundations of sociological theory (e.g., Mead; see above). The fact that there is no uncontested view of man may have been one of the reasons why modern philosophical anthropology was met with scepticism from its beginning. Horkheimer denied the possibility of anthropology with the argument that there are too many differences between humans to allow a meaningful general anthropological theory, reproducing with other intentions in the name of critical theory an idea widespread in Anglo-Saxon cultural anthropology in which the term "cultural" indicates a study of differences between humans, not of their joint and general traits, which may be found through cultural comparison but are met with scepticism.

The interactive or dialogical interpretation of human nature in the concept of a total human subject that includes all social relations in family, state, economy, culture and society has been articulated repeatedly. This "social being" hypothesis was summarised by Feuerbach (1842: 35) at an important point of anthropology's development as "The essence of man is found in the community, in the unity of man with man." The thinking in terms of a general philosophical theory of man does not imply uniformity and coherence of philosophical anthropology, but rather an open and controversial discourse, as appeared in human ecology. Man can as well be interpreted through a dominant relation to society (e.g., Durkheim, Mead, Parsons), to biologically represented nature (e.g., Gehlen) and to a supra-individual human capacity of mind or consciousness (e.g., Scheler, Sartre).

At this point there is controversy over the interpretation of Darwin's theory of evolution: whether it represents an anthropocentric or a biocentric perspective in the interpretation of humans. Crist (1996) has summarised the arguments for an anthropomorphism in Darwin's thinking which is not only metaphoric but "reflects his understanding of evolutionary continuity, which includes behavioural and mental continuity between humans and animals" (ibid.: 33). With that emerges the question of whether evolutionary thinking is contrary to essentialism when it "emphasizes the seminal significance of inconstancies, gradations, and continuities" (ibid.: 43), which is answered with "yes" by Crist and many evolutionary biologists – a doubtful answer which purports a too simple and ready idea of essentialism. The existence of variations and evolutionary changes of man is not yet a proof of absence of constants and essences.

This and the other problem to be dealt with critically in anthropology – that man exists historically only in culturally, socially and historically specific forms that need to be reflected as time- and culture-specific self-interpretations of man – make it difficult to identify the general nature of man in biological and cultural terms. Specialised research in different disciplines and approaches created competing, not complementary, knowledge about humans, organised in different worldviews, paradigms and theories. Biologically and culturally, man is no longer seen as being of a constant and unchanging nature. The biological and the cultural natures of man are both in evolution, although evolutionary changes may happen over such a long duration that they appear as relative constancy of the nature of man.

Biogenetic and socio-genetic synthesis. The conclusion from the discussion of philosophical anthropology (in Chapter 1) is summed up in the complementary hypotheses of a biogenetic and a socio-genetic synthesis of knowledge about human development. In its simplest form, the problem taken up in philosophical anthropology can be described as that of integrating biological and sociocultural components in such a way that they explain each other (Gehlen 1961: 12). The connection between biological weakness and cultural strength is given with the argument that sociocultural capacities compensate the biological deficits of man. While the basic argument is simple, the different forms, processes and causes for such compensation are more difficult to trace, and they result in contradictory diagnoses of the human condition, the problems and the development potential of man. Moscovici's work connects the discourse of philosophical anthropology to the present ecological discourse with the hypothesis of socio-genesis of human development, one that reconnects nature and society conceptually as a "unity in differences". His analysis ends by showing society as a form of nature in different stages of evolution, of social processes as extension and mediation of natural processes (Moscovici 1982: 500). The idea of an extended concept of nature that encompasses society is not easily interpreted, and makes Moscovici's theory open to critique. However, it does not need to be interpreted as a simple idea of embeddedness of society in nature. It can be seen as closer to social-ecological ideas – that the historical development and change of societal relations to nature is structured through human modification of nature that can be analysed as colonisation of nature and as societal metabolism. Moscovici denies a passive and one-sided dependence of man on nature, an idea that is deeply rooted in ecological and biological thinking and adopted by some authors from philosophical anthropology (especially Gehlen), by ethologists, sociobiologists, evolutionary psychologists and parts of ecological movements. A joint and doubtful consequence of such reductionist variants of anthropology is to interpret humans through their early evolutionary stages and an archaic heritage of aggression, implicitly following the hypothesis of constancy in human behaviour programmes that resemble animal behaviour programmes, directly or indirectly neglecting the possibility of modifications of humans and of their relations towards nature through biological and sociocultural evolution. In contrast to such biological views, Moscovici reformulated ideas connecting back to a critical theory of man, society and nature in the unfinished project of a critical theory of society of the Frankfurt School. It seems that the big syntheses of Moscovici and his predecessors in philosophical anthropology took up the relevant theoretical and empirical knowledge for studying nature–society interaction. Since these authors there has been little substantial progress in the discourse of an interdisciplinary science of humans. It is open now for social ecology to continue the interrupted discourse.

How to adopt philosophical anthropology and philosophy of nature in social ecology. Anthropological knowledge was marginal in the development of new social ecology, as confirmed by Becker and Jahn (2003) for the research at ISOE, which became a point of controversy between the more empirically oriented and the more philosophically oriented variants of social ecology (Hosang et al. 2005). Social ecology, like human ecology before it, has no exclusive knowledge and no scientifically privileged view of humans, but combines knowledge from different sources, thus underlining the possibilities of pluralistic approaches in interdisciplinary reconstructions of the relations between humans, society and nature. These cannot evolve into a unified theory, but remain a patchwork of ideas brought together for the currently available research and loosely connected through the guiding notions of societal metabolism and societal relations with nature. The inclusion of philosophical knowledge in an ecological research context is more complicated. However, the lack of philosophical reflection in ecological and other natural or social-scientific research cannot simply be compensated by positive knowledge. In the synthesis of knowledge, philosophical thinking about man, nature and society returns, not to replace positive knowledge in the role that it had prior to the development of modern social and natural sciences, but to guide knowledge synthesis that requires more than integration of data and concepts. It is a way of developing knowledge synthesis beyond such normative integrators as worldviews and paradigms in empirical sciences that have dominated the epistemological debates in the late 20th century. Worldviews give free rein to trivialising the interpretations and reflections about humans, nature and society to normative assumptions as, for example, constructed for human ecology and environmental sociology by Catton and Dunlap.

The ways of using philosophical knowledge for the synthesis of ecological knowledge about man and nature can progress in several steps. The relational and interactive nature of humans can be elaborated in a synthesis of knowledge about man–society relations and about man–nature relations. The synthesis ends in a "patchwork" theory in which the situation of man in social-ecological systems is analysed with the knowledge from many disciplines and framed in rehabilitated philosophical concepts of man and nature. In spite of the difficulties of knowledge integration, the concepts of man, society and nature have survived until today, with their generic quality and abstractness, after many epistemological and methodological attempts to get rid of them. The three terms keep open the memory for the requirements of knowledge synthesis to counteract the specialisation and splintering of empirical research. The relational concepts of social ecology offer one possibility of theory-guided knowledge synthesis.

Against the dissolution of the concepts of man and nature. The complex of notions to analyse the human condition that evolved during modernity – man, individual, person, subject, mind, body, reason and rationality – has gone through deconstructive epistemological reflections in the 20th century, with some of the concepts repudiated or severely criticised. The differentiation of empirical knowledge about humans through the disciplinary specialisation of research in the modern disciplines of biology, ecology, sociology and anthropology, from which most empirical knowledge about the human condition is gathered, developed late in the academic specialisation in the 19th and 20th centuries. For this empirical research the detachment from philosophy was characteristic, leaving the role of reflection of concepts to an epistemology with reduced cognitive aspirations in which questions of interdisciplinary synthesis of knowledge have been neglected. The continuing discourses of philosophy of nature and society have shown the constructivist character of the concepts of nature and society that influence natural sciences and ecology without renouncing the general terms of "man" and "nature". The dialogical, interactive, embodied and embedded constructions of man and nature that existed in holistic philosophies of nature have been reactivated with parts of critical interdisciplinary research in human and cultural ecology.

The dissolution of the philosophical idea of humans was countered during the 20th century, for example, by philosophical anthropology. The idea of studying, in the name of interdisciplinary and holistic thinking, the integration between humans and nature seems to represent the critical reaction to specialisation and the development of biological and natural scientific research. The decoding of the human genome and deciphering of the human brain seem to indicate further progress in the deconstruction of man as subject, allowing the human to be seen in a new variant of a mechanical view, as an information processing machine. The growth of empirical knowledge evokes further questions about practical usefulness or necessity of the knowledge, its utility in solving environmental problems, its ethical justification and its social and ecological consequences, which have not been reflected epistemologically. A critical view of the compilation of empirical knowledge in biology and anthropology raises questions as to why different views of humans and nature have developed and whether it is possible today to formulate a coherent view of humans that allows integration of splintered knowledge from this research. The scientific process must not end in dismissing the idea of the human subject, but can be understood as a continuing search for another subjectivity, of relational views of humans, in which human evolution is seen as part of the evolution of society and nature. What has become apparent with the analysis of human-related worldviews in human ecology is not the vanishing of subjectivity and agency of man, but its changes in the form of revival of anti-dualist and relational thinking of the interaction between humans, society and nature. Relational thinking with an interactive and dialogical view of man and nature was represented in the discourse of modernity in the philosophy of nature, giving rise to Romanticism as critique of Enlightenment and modernity. In Novalis' reflections of human interaction with nature through breathing, eating and drinking (Vietta 1995: 132ff), this interactive view of human dependence on nature was reflected and paradigmatically unfolded in a philosophy of the human subject in which the interactive nature of subjectivity is not derived from the cultural specificity of humans as unfolding in society, but from humans in community with nature. Ecology, without connection to the philosophical tradition, takes up similar ideas of humans as part of an ecological community.

Rediscovering and reclaiming the human subject – relational thinking. The dissolution of the human subject which Lyotard saw as a result of modernity seems a dissolution of the idea of the individual or person as a coherent human subject – in the tradition called subject philosophy with its isolated perception of man facing both nature and society. The implicit assumptions about the constitution of subjectivity can be criticised. The concept, implying the intersubjective, interactive and socialisation-oriented views of man resulting from the social sciences, shows ways towards a critical conception of the human subject that can be elaborated in interdisciplinary research. The abstraction of an individual and isolated subject as model of man unfolded in new forms in the 19th and 20th centuries, in contrast to the ideas of human community with nature. In the end, an old idea of a heroic consciousness and never-changing identity of a subject, with never-changing forms and criteria of thinking, should be given up (Schneider 1998: 29f). Ideas about an interactive, dynamic, dialogical and communicative subjectivity claim that the individual becomes subject through cultural interaction with an internalised other. Such ideas need to be elaborated with regard to the capacity of human subjects to manage manifold and contradicting requirements in society and nature. The view of humans as "relational beings", in relations with other humans or society and in interaction with nature, develops in co-evolutionary views and with the formulation of "societal relations to nature". Relational thinking developed in different theories covering contrasting views and approaches. Examples of relational and holistic thinking about humans are given with the older sociologies of Durkheim, in which humans are seen as created culturally or through society, not biologically; the sociology of Parsons as a voluntary theory of action where humans are relational in culturally rooted value patterns; Mead's interactive sociology, and the synthetic theories building on these, such as the theory of communicative action by Habermas (1981). In biology and ecology relational thinking unfolds with ecology studying organism–environment relations, with Uexküll's subjective biology in which living beings, plants, animals or humans, are situated in a threefold lifeworld including the environment, other living beings and the world as it has evolved historically. The concepts of biosphere and noosphere (Vernadsky, Chardin, Lovelock) develop the idea of humans as part of a larger subjectivity of living nature, of which the individual being is only a dependent part, dependent on and interacting with other individuals, species, groups, societies, ecosystems and the uniquely structured and composed biosphere. Systematising the relational views, two points are important:

- The interaction between humans and nature as individual interaction can be described with the concepts used in subjective biology (Uexküll) and philosophical phenomenology – environment, coexisting environment, effective environment with which an individual interacts, lifeworld, and the connected concepts of perception, experience and interaction.
- The interaction of humans and nature as collective or social action can be identified from the analysis of human resource use and its cultural transformations – with concepts such as productive labour, mode of production, societal metabolism, culture core (Steward) and co-evolution (Norgaard).

Relationality of humans and interaction in social-ecological networks. The philosophical-anthropological syntheses of knowledge about humans developed from a critical reflection of the consequences of modernity. Different facets of humans discussed in philosophy and anthropology with knowledge from several disciplines do not synthesise into a coherent picture of humans in either its normative or its positive knowledge components. The understanding of humans as relational, being more than a "closed system" view of humans as biologically determined in their behaviour programme since the early phase of their evolution, is coded in the formulation of "becoming not being", unfolding in social system and ecosystem networks, in open systems. Open systems, paradigmatically the views of the organism and the ecosystem as boundary-maintaining systems in a continuous exchange and transformation of energy and matter, differ from the subject view of humans in philosophical tradition. They resemble a "patchwork" view of humans with differing, loosely connected, sometimes contradicting qualities and factors that change over time, thus contributing to the critique of the notion of subject in post-modernism. However, this seems too fast, meaning an interpretation of the subject idea as constant structure, not as a dynamic process with the capacities of integrating different and contradicting functions in relation to a differentiated environment, of "stability through change" or dynamic stability that are compatible with the open systems view. The subject and agency capacity of humans, as, for example, in the sociological reconstruction of humans through different and specialised roles that are maintained simultaneously, helped to prepare a relational view of humans. Rather than accepting the idea that human subjectivity has disappeared, it could be interpreted as developing through different stages of human alienation.

In an interdisciplinary and interacting system view of human–nature relations, a distinction can be found between the qualities of humans identified with scientific knowledge from different disciplines, the diagnosis of human superiority over other beings derived from normative classifications or hierarchies of forms of life, and the idea of human domination of nature. Making apparent the interaction between man and nature with the concept of culture cannot be seen as the final answer to the question of human nature, but as a step in the changing knowledge of humans that remains open for changes in the knowledge production processes, such as in the social–ecosystem interactions. It can be assumed that the complicated web of interactions between man, society and nature is never fully understood or solved in one formula. The interactions are complex and changing throughout human history; they cannot be explained with positive knowledge only, but require an interpretation of the human condition with the help of different theories and worldviews. The synthesis in an interdisciplinary theory of human evolution that combines biological, ecological, social and cultural properties of man in a historical and evolutionary perspective, through the long trajectory of human evolution, is an attempt to connect scientific knowledge – not in a concept of man, but in describing the whole history of "man as becoming". As recent variants show (Morin, Moscovici, Freese), this open evolutionary view of man, without confirming an eternal nature of humans in some "anthropological constants" of human behaviour, does not seem to confirm the biological notion of humans as *Homo sapiens* and does not satisfy the expectations set in that typological concept that tells all about humans. The emerging interdisciplinary picture of a manifold, multifaceted, continuously changing and developing being, born several times and in different forms during evolution, not a universal human remaining unchanged throughout the times, but a historical, cultural and social human with many variants, cultural "dresses and masks", can be maintained in human, cultural and social ecology. It is simplified again as soon as humans are interpreted only through long-term evolutionary constants of humans with knowledge from evolutionary theory in biology, sociobiology, and evolutionary psychology.

Human ecological reconstruction of man–society–nature interactions implies an interdisciplinary view without searching for a scientific discipline that provides the key and valid knowledge for a final understanding of man and nature. Still, in the 19th century, before the fragmentation of academic knowledge finally suspended such attempts, syntheses of knowledge about man, nature and culture were formulated in philosophy that criticised simplified ideas of understanding man, nature or society from the construction of a philosophical system with the help of some final or evident principles. The philosophical systems of Fichte and Schelling were criticised by Hegel as such simplifications (Siep 2000: 67). The conclusion from the critique about neglecting the historical variability of man and nature presumes that humans and nature can be reformulated in human ecology. Interdisciplinary interpretations of the human condition with regard to nature and society include a hermeneutic circle in constructing man–society–nature interaction. The circle dissolves when man is seen as part of society and of nature, society as part of man and nature, and nature as part of society and man. A synopsis of the views of man unfolding in a long process of research and reflection, through the history of philosophy and science, shows a detailed "map" of knowledge about man – with many components, many variants and many errors. The synthesis of knowledge about man should include historical knowledge and inquire about the significance, necessity and justification of the different pieces of knowledge about man found during history.

Conclusion: future trajectories of social ecology

The new social ecology today is a science in development, for which a review of its evolution up to now gives some ideas for its further progress. Social ecology develops in research about global environmental and social change and asks how modern societies can cope with it. It cannot embrace all environmental and resource use research, but it can discuss and react to ideas, topics, knowledge and critique of themes and theories touched upon in chapters 2–7. If these themes are abbreviated to shorthand formulas for the future development of social ecology, they include the following ideas:

1. The coming social ecology can be a science of global complexity of nature–society interaction, a science that takes up unsolved and contradicting issues that cannot be integrated in one coherent theory, but need

to be analysed in coherent ways: not in a closed theory but in a pluralistic theoretical framework for critical analysis of global resource use.
2. Empirical research into interrelations between global resource flows and local resource use can adopt the divided form of a global social-ecological system described in programmatic terms in world system theory as a symbiosis of an economic system that operates through multiple cultures and local differences in natural resource use.
3. A new critical theory of society can develop as part of the development of a critical analysis of societal relations with nature, influenced by natural scientific knowledge, translating the knowledge of the "natural history of society" into an improved theory of the anthropocene.

With the discussion of tentative future development of social ecology, epistemologically and methodologically unsolved questions appear which refer to the complexity turn and interdisciplinary trends in environmental research. These can continue to be dealt with as has been done up to now, without aiming at a new super-science or theory that would allow a synthesis of all knowledge relevant to global change and societal development. The progress of knowledge integration happens, rather, in the gradual unfolding of different fields of research and knowledge to be combined in slowly improving interdisciplinary knowledge production, integration and application. Social ecology is a pioneering form of that knowledge practice.

Expectations that analyses of interaction between society and nature or societal relations with nature will rapidly result in a consolidated theoretical concept do not seem to be justified – the notion of social-ecological systems gives the wrong impression. The diagnosis of ecological research, that society and nature are more closely interwoven and depend on each other in their further development, need not be doubted. As the social-ecological discourse has shown, the diagnosis does not justify a neglect of the differences between both spheres (Becker) in a naive holism of a new unity of society and nature. It is difficult to forecast how the changing couplings and interactions of social-ecological systems affect further evolution of nature and society. To use such terms as "hybrids" does not say much, nor does it say much that we can no longer speak about nature or society in specified meanings. Instead of expecting a new, unified and coherent concept of "socionature" or "society-nature", specialised research can be expected to continue in different directions. Questions remain as to how, under these conditions, a theory of nature–society can (and how the interaction between science and society will) develop. The risk of drifting away into conceptual speculations is always given; the big notions of nature and society help to keep the speculation alive. But not every abstract thought must be speculation. In discussing the complicated theme of societal relations with nature, it may be said at the preliminary end of the story: the difference between society and nature, both inhabited by humans, is retained in social ecology because it keeps open the possibility of understanding global environmental problems. These problems are problems of humans, and they need to be investigated through the societal practices of natural resource use that either generate these problems or help to resolve them through a transformation of the societal practices.

8
Social Ecology and Practice – The Policy Process and the Social-Ecological Discourse

The unfinished debate of environmental agency and governance

> Policy-makers in the twentieth century gained much experience in managing confined ecosystems, such as river basins, forests, or lakes. In the twenty-first century, they are faced with one of the largest political problems humankind has had to deal with: protecting the entire system earth, including most of its subsystems, and building stable institutions that guarantee a safe transition and a co-evolution of natural and social systems at planetary scale. I call this the challenge of earth system governance, as a new paradigm to describe this particular challenge of planetary coevolution of humans and nature.
>
> (Biermann 2011: 4)

Global environmental governance in the sense described by Biermann is confronted with two problems: protecting the ecological earth system and managing a transition to the planetary co-evolution of natural and social systems in the sense of global sustainable development. The global environmental and resource use problems that require response through political and social action appear as complex and unsolvable, no longer manageable as the new terms of adaptive management and adaptive governance signal: management when the era of management is over (Ludwig 2001). In analyses connecting the concepts of global governance and sustainable development as performed by Biermann, as "co-evolution of natural and social systems", no answers are available yet for transitions to global sustainability. The paradoxical situation in the sustainability discourse was formulated years ago in the debate of the Austrian social ecologists: global sustainability requires the invention of a new socio-metabolic regime, but we do not know how to build it. What we need to discover about a new socio-metabolic regime after industrial society has to be discovered during attempts to change societal practices of resource use. The scientific "trial and error" model of knowledge creation seems to have become a guiding idea for the future global policy process.

After 25 years of a global discourse on sustainable development, there are few results in terms of transition strategies. Also, the scientific discourse of transdisciplinarity showed the limits of science; in search of new ideas to transform society, it uses old models of deliberation like that of the "agora". Knowledge transfer and application, the relations between science and society, and the forms of cooperation in public policy again become themes of epistemological debates. Social ecology, with its complicated theoretical notion of societal practice, also does not show easy ways to the transfer and application of the knowledge it generated and synthesised. "Societal practice" refers to two big notions, society and nature, or, from a disciplinary perspective, to the ecological earth system and the economic world system. These two systems interact through human resource use practices which are organised in many institutions, by cooperation of many actors, in multi-scale processes. Knowledge from social-ecological research (about global resource flows and their consequences) and the theoretical criteria for knowledge application (societal action, practice and agency, boundary systems and epistemic systems) are not easily translated into models and strategies for practice. The social subject that is expected to be able to realise the transformation to sustainability is a complex global subject with many institutions and actors, no longer a social class, a social movement or a government, as was formerly the case in societies organised as nation states. The new term of "cosmopolitanism" that has entered the sociological discourse indicates the search for new epistemic and social subjects that meet the requirements of global governance.

The purpose of this chapter is to review the fragmented discussion of knowledge transfer, sharing and application in social ecology and sustainability debates and to come to preliminary conclusions in terms of agency for the great transformation to global sustainability that social ecology supports with its knowledge. New models for scientific communication unfolding with the ideas of adaptive governance, multi-scale governance and global governance are still abstract ideas about principles or requirements of societal transformation, more described for ecological systems than for social systems. Ideas about the social components of new management and governance strategies are few, as the following summary shows.

A debate about learning from failures of prior environmental research, from policy and management failures has developed in recent years. Questions of how to improve communication, knowledge transfer and knowledge sharing between various actors become more and more important when the aims of problem-solving are maintained (e.g., Acheson 2006, Ostrom 2007a, 2009). The ineffectiveness of panaceas, general and standardised solutions of resource management problems is widely accepted, but more fine-tuned, locally adapted, multi-scale approaches required in future to deal with global problems in concerted action are difficult to elaborate. Another critical debate, about the doubtful effectiveness of technical solutions to environmental problems, also remains without clear results. In social ecology, reflecting both problems of panaceas and technical fixes, new communication and cooperation models for global environmental governance develop slowly, as the epistemological debate about "frontier research" shows with the idea of lifting the barrier between basic and applied research (Becker and Jahn 2006, Jahn et al. undated). This discussion is only a first step to address the manifold problems of communication and knowledge transfer for global environmental governance. The conceptual differentiation between societal problems, discourses and practice in the model of Becker and Jahn (2006) is methodologically useful, as the rationality of transforming problems through discourses and practices in solution-generating knowledge production, but it has not yet dealt with the communication barriers or the forms of joint learning. How to deal with the many competing forms and sources of knowledge that can be applied in global environmental governance is not sufficiently discussed in social ecology and is not clarified in the transdisciplinarity discourse. Methodologically, the processes of transferring scientific knowledge can no longer be described in simple, pragmatic rules of effective communication through complexity reduction and model construction. Communication and application of scientific knowledge are becoming more complicated, as the transdisciplinary and participatory research practices that characterise parts of environmental research today show. Decision-makers are exposed to the same problems as the researchers, who need to reflect the methods of knowledge production, synthesis and the limits of knowledge. There is no more safe knowledge that can be applied for decision-making, and no longer a clear division of labour between research and decision-making; policy and decision-making have become the same puzzle-solving activity as research. The interaction between science and society has become a continuous process of discursive research and knowledge management, and the idea that circulates in all knowledge application debates is a simple one: cooperation between researchers and practitioners. What the epistemological debates of transdisciplinarity, post-normal science and sustainability science mainly show when dealing with the situation of global complexity is the new insecurity of environmental science when participatory research, cooperation and knowledge-sharing are introduced – the means of communication, not yet of problem-solving.

In the policy-related discussions about social-scientific research, knowledge application problems and practices are part of the debate about the internationalisation of the state and multi-level governance (Robinson 2001, mainly formulating questions). Brand et al. (2007: 218ff) identify three sets of ideas in this unfinished part of the global governance debate:

- Neo-Gramscian approaches in international political economy focus, from a civil society perspective, on social classes as important actors in international governance, reducing states to passive institutions transmitting only international requirements to national policies ("outside-in" perspective, criticised by Panitch, ibid.: 219).
- In the post-modern theory of empires (Hardt and Negri), political and economic institutions are melting together to form a new international order for regulating capital relations as a whole. The empirical analysis of the regulatory practices of governmental institutions and their changes is neglected in this theory; only radical critique of the globalising system remains.
- In Anglo-American radical geography (Brenner et al.), the vanishing privileged level of organisation of policy and economy is discussed. For a long time this privileged level was that of the national state; a continuous scale-shifting or reshuffling and reorganisation of spatial scales is observed, as Swyngedouw formulates it (ibid.: 220); the rescaling appears as a mechanism of control.

Each of these approaches highlights certain structuring mechanisms in a theoretical perspective, but neglects others. The difficulties in going beyond former ideas about social subjects of societal transformation are apparent in the neo-Gramscian approaches, the lack of empirical knowledge about regulation and governance – in the theory of empires, and the lack of ideas about multi-scale action – in radical geography, where the ecological multi-scale governance problems are simply reformulated into shifting international power relations and coalitions. Spatial differentiations of policy and governance processes are reflected in these new approaches, but questions of the detailed functioning of international governance mechanisms remain unanswered. This allows the conclusion that research on the internationalisation of the state (Brand et al. 2007, Wissel 2011) has not yet advanced. From this debate on global governance it is difficult to draw conclusions for reorganising communication between scientists and political actors.

Empirical and pragmatic discussions of science and policy communication, reviewed by Jones (2009: 11), also do not show more advanced ideas, only some general process models to connect knowledge production and policy: the rationality model assuming the rationality of the policy process as driven and guided by knowledge; the model of pluralism and opportunism, in which policy is seen as involving pragmatic decisions in uncertainty, and knowledge flow and use depend on efforts of various actors; the politics and legitimisation model, in which the power–knowledge nexus is understood as knowledge reflecting and sustaining existing power structures and imbalances. The three models mirror important changes in science policy communication. The first model is outdated and unrealistic in its simplicity; the two others are critical reactions to the first, each grasping certain aspects of the communication process important in the global governance debate and for social-ecological themes of societal metabolism and global resource flows. From the third model the conclusion is drawn (by Autes 2007) that valid or legitimate knowledge is no longer assessed according to scientific standards, but politically negotiated. The interaction between science and policy is no longer a one-way knowledge transfer but a highly contingent process, subjected to power and valuation-based criteria of knowledge selection.

Spatial scales are often assumed as given in governance research, and the existing power mechanisms and hierarchies are not critically reflected with the focus on problem-solving (Wissel 2011: 134). In interdisciplinary environmental research like the common pool resource research of Ostrom et al., simpler approaches of multi-level governance appear as those formulated in critical international political economy. Ideas from international political economy are hardly used in the ecological discourse about resource management; the policy process is not theoretically reflected, which also shows the difficulties in connecting ecological and social-scientific knowledge. Among the tentative ideas taken from ecology is that of “policies as experiments”, motivated by the complexity of social-ecological systems, for example, in adaptive management, which has been the first crisis formula for knowledge transfer in environmental policy and management. Adaptive governance may become the second crisis formula, in which the uncertainty and unpredictability of ecosystem development restrict knowledge communication between science and society still further, underlining the open, discursive nature of this communication. Social ecological knowledge gives paradigmatic examples of these difficulties in transforming scientific learning into social – societal – learning.

Conclusions from the debates about environmental agency and global governance. The debates critically reflect problems with older policy and resource management strategies, but do not come to a consensus about new strategies for global environmental governance (first conclusion). The notion of global governance lacks theoretical foundation and becomes itself a communication problem when it is supposed to be used to specify the term of societal practice. The dispersed debates about improved practices of local resource management and international policy cooperation discussed in the past two decades in the political and scientific environmental discourse follow a rather simple common idea: communication between science and society is improved in the course of broadened local, multi-scale and global policy processes with governmental and civil society actors’ involvement. The idea has not significantly changed from the early discussion of co-management and participatory management to the recent discussion of adaptive management and governance. Debates about participation and cooperation have only slowly advanced to address the cooperation problems in terms of knowledge use practices – translation, application, evaluation and knowledge-sharing appearing with the manifold and competing forms of environmental research, interdisciplinary and other.

The second conclusion drawn from the deficits of global policy and governance debates is that the multi-scale action and communication problems identified are not derived from in-depth and exact diagnoses of the environmental crisis. This seems the critical point on which social ecologists insist: without an exact diagnosis of the environmental crisis, summarised as a crisis in societal relations with nature, no further advances in the formulation of strategies for global environmental governance and transition to sustainability can be expected. The knowledge problems of formulating such strategies are manifold – so far insufficient pooling of knowledge (even with transdisciplinary approaches), problems in communicating contradicting ideas and knowledge to the actors, complexity of international policy arenas that limit effective communication and cooperation, controversies about means of problem-solving and difficulties with intractable problems, inefficiency of earlier approaches to integrated and trans-sectoral resource management, and insufficient development of policy instruments for international cooperation have been identified. These interdependent problems cannot be solved separately or consecutively. To address them, two questions that require further discussion are taken up in the following final discussion of social ecology's development:

1. Which guiding discourses in environmental policy can be used for science–society communication to connect knowledge and action for the global problems analysed in social ecology? The discourse of sustainability and sustainable development seems to be the most inclusive in the science–policy communication interface, and social ecologists have argued in its favour more than for the more recent governance or resilience discourses. In the social ecological discussion no new vision of sustainable development has been added to the already overburdened debate; rather, criteria are sought for critically reviewing, assessing and improving the sustainability discourse, opening it for debates about the difficulties of a "great transformation" of society and of building new socio-metabolic regimes.
2. Which themes from the discussion in the preceding chapters (2–7) should be taken up as policy and practice-relevant issues from a social-ecological perspective? The "power over nature" theme connected with the debate of the anthropocene can be used to supplement and specify the sustainability discourse, and this power analysis connects with more concrete themes of lifeworld and policy. For both questions, of the sustainability and anthropocene debate, the sustainability paradox formulated in social ecology can be taken up: science and society together

> need to invent a sustainable societal metabolism without knowing how to do it (Haberl et al. 2001: 11), but a fundamental transformation shall happen within one generation to avoid more catastrophic forms of change (Fischer-Kowalski et al. 2012: 50).

Another policy process – global sustainability in social ecology

The interaction between science and society is a broad and complicated theme that needs to be taken up in the analysis of possibilities of solving complex global environmental and resource use problems. For this interaction some general models are discussed in sustainability science, for example, by Henry (2009) – the social learning model to understand complexity, to attenuate normative belief and value conflict, and to link knowledge with action. Social ecology performs policy-relevant research with its themes, but this does not result in a simple agenda for policy reform. What social-ecological research shows, rather, is the requirement to develop policies for global governance that carefully connect local, national and global action from multi-scale perspectives. This is not sufficiently shown by policy-guided research programmes, for example, the German programme of social-ecological research, which does not say much about communication problems in global governance. Furthermore, the German research programme has shown the expected difficulties in establishing new research competing with established environmental research. In the research of the ISOE, more local or regional governance problems are analysed in empirical studies. Also, in Austrian social-ecological research the methodological difficulties of global governance become apparent, as paradigmatically discussed for the HANPP indicator (Haberl et al. 2009) and to some degree for the multi-scale approach of long-term socio-ecological research (Haberl et al. 2006).

In the discussion of the policy relevance of social-ecological research the difficulties in finding answers to the knowledge communication problems are partially apparent, for example, in the methodological discussion of discourse analysis and policy analysis by researchers from the ISOE Institute in Frankfurt:

> ...we can distinguish problem-oriented discourse field analysis, as discussed here, from policy field analysis, as found mainly in political science, above all with respect to the object of analysis: a discourse field is not only characterized by the negotiations over societal and scientific views of problems taking place within in it but also by the fact that several policy fields and policies may be superimposed within the field.... A central concern of problem-oriented discourse field analysis is the extent to which the arguments, positions and evaluations found in a discourse gain access to the policymaking process.... With respect to discourse fields, the focus is on the reconstruction of evaluations of stocks of knowledge, as this takes place during negotiations at the beginning of a policymaking

> process. Here the focus is much more on the reconstruction and interpretation of societal ways of viewing problems (certain/uncertain knowledge) than on an analysis of concrete regulations such as the Convention on Biological Diversity or its national counterparts (national biodiversity strategies). What policy and discourse field analysis share is a certain dynamical way of viewing the emergence of problems and their handling, as well as a common actor-oriented procedural method.
>
> (Jahn and Lux 2010: 9f)

The discourse field analysis for the practice of social-ecological research shows a more reflective and critical view of the policy process in which the question of evaluation of knowledge for policy is taken up, reacting to the critical conclusion by Autes (2007; see above) that knowledge selection becomes itself a political process and is no longer guided by exclusively scientific criteria of validity. But this conclusion also shows where the reflections about knowledge and policy are stuck, creating more questions than answering them. The consequences of a global situation requiring new forms of science–society communication need to be discussed beyond specific methods applied to the social-ecological topic of global resource flows, and find answers to questions that environmental research is self-evidently expected to answer – how to solve complex problems practically, how to cooperate with many actors, how to achieve sustainability. The two guiding questions formulated above illustrate the difficulties in answering these more concrete questions. The vagueness of ideas as "adaptive governance" or "no panaceas" testifies that there are more symptoms of the difficulties than answers to global governance questions, as does the argument that the complexity and interaction of problems, scales and systems prevent policy-related answers.

The sustainability discourse has been renewed in recent years with a focus on global transition to sustainability, moving beyond debates and strategies for local and national sustainable development. In a globalising system sustainability cannot be attained as long as unequal global resource flows are not taken into account. A critical analysis of global resource flows, paradigmatically done in social ecology, shows that most national strategies in Western countries measure progress in sustainable development wrongly. They do not take sufficient account of the spatial problem shifting through economic globalisation, import of resources and export of pollution, waste and sink capacities – the phenomenon called by J. Rice "rich country illusion effect": protecting the environment in core countries of the world system but exporting negative external effects mainly to countries in the global South. In this debate another critical question emerges: Is cultural diversity a barrier or catalyst for global sustainable development? Questions of cultural institutions for sustainable development have not been sufficiently discussed in social ecology (see Chapter 7). The questions come up again in the discussion of transition processes to sustainability (Box 8.1).

Box 8.1 Transition towards sustainability

An exemplary analysis of the science–society interface for knowledge transfer in the social-ecological discourse addresses a specific perspective of transitions towards sustainability (Fischer-Kowalski and Rotmans 2009). The comparison of the social-ecological approach of socio-metabolic transformations and the Dutch transition management approach reveals similarities and complementarity:

> Sharing a similar understanding of sustainability transitions – namely as major transformational changes of system characteristics – and a background epistemology of complex systems, autopoeisis, and evolutionary mechanisms, they address the subject from different angles: one approach asks how transformative changes happen and what they look like, and the other approach tries to answer the question of how to bring them about. The Viennese approach is almost exclusively analytical and deals with a macro ("landscape") level of human history with a time scale of decades to centuries; the Dutch approach is based on intervention experiences and deals with a shorter time frame (decades) of micro–meso–macro levels of industrial societies. From both their respective angles, they contribute to some of the key questions of sustainability research, namely: how can a transformative change toward sustainability be distinguished from other types of social change? By which mechanisms can obstacles, path dependencies, and adverse interests be overcome? And what are the key persistent problems that call for such a transition?
>
> (Fischer-Kowalski and Rotmans 2009)

In the conclusions the similarities are summarised as follows:

> Both are systemic approaches conceiving of societies as complex systems in interaction with natural systems. Systemic change then encompasses changes in the patterns of interdependence of a broad range of variables. For the sociometabolic transitions approach, it is crucial that this also involves society–nature interactions and changes in natural systems. The transition management approach is more focused on social, economic, and cultural changes, changes that may imply a change in environmental

Box 8.1 (Continued)

> impacts. . . . Both approaches conceive of sustainability as a major deviation from current pathways, requiring substantial efforts on the part of society . . . use the notion of co-evolution, but in somewhat divergent ways . . . build upon a non-developmental paradigm: the evolution of social systems occurs in a non-directional manner; there is no hierarchically pre-established order of stages. The transition to states that may be considered more sustainable is by no means an automatically built-in turn of history. Nevertheless, the purpose of the analysis is furthering sustainable development, and finding pathways toward sustainability.
>
> (ibid.)

Source: mentioned in the text

The comparison of the two approaches of social ecology and Dutch transition research does not include a more detailed discussion of structures and power relations, or of the political and economic constraints that block the transition processes, but mainly questions of phases, multi-scale interaction and patterns in transition processes. The analysis does not deal with the problems of international policy and governance summarised above.

After discussing some examples of knowledge questions in governance and sustainability research with contributions from social ecology, a tentative answer to the question of another policy and governance emerging from social-ecological research includes three points beyond the general interpretation of the sustainability process as a great transformation towards a new global socio-metabolic regime.

First, as can be concluded from the discussion of problem-oriented discourse field analysis in ISOE (Jahn and Lux 2010), theoretical and methodological reasoning in social ecology indicates scepticism about many of the concrete ideas and strategies for policies that are derived from empirical policy and evaluation research. Such strategies do not systematically integrate theoretical and empirical analyses and do not bring into the policy discourse broader questions of societal agency and practice that cannot be answered in functional role definitions for the policy process (such as that of governmental and other political actors). Public policy, in local, national and global arenas, is only one component of societal practice; others include the arenas of action that are now to be connected to public policies and make them complex: civil society action, environmental research and research institutions, culturally structured lifeworld contexts of natural resource use practices in private households and in economic processes of production, distribution and consumption.

Second, in social ecology the ideas of co-evolution and "non-directional evolution" (see Box 8.1) are taken up from earlier discourses, but they do not yet say much about the organisation of policy and governance processes. They show more why a limited policy perspective does not meet the two theoretically important conditions for transition to global sustainability: society and nature interact as systems and change each other in that global interaction, and social systems evolve in non-directional forms, neither as politically dominated processes nor as ordered process of predefined development stages.

Third, the normative debates about sustainable development, in which positive knowledge of social and ecological systems is only material for visions and modelling, are not sufficient to discuss the problems of transforming social and ecological systems from co-evolutionary perspectives. With the visions and scenarios, necessary as they are as part of the process, transition to sustainability is again indirectly reduced to policy processes in which worldviews, visions and values of different actors are to be negotiated without sufficient attention to what can be discovered through social-ecological and environmental research about transforming societal and ecological systems. Rather than contributing to new visions of sustainable development and technological models for engineering societal transition, social ecology is confronted with the challenge of developing, from critical reviews of the discourses and development processes, other views and perspectives for societal transformation that include more than policy processes and political regulation. To broaden the perspective of transformation analyses, knowledge from human and social ecology and cultural anthropology can be more useful than empirical knowledge from comparative policy analysis.

Power over nature in the anthropocene

The discussion of human power over nature, much older than the recent debate of the anthropocene, blends problems of political, cultural and knowledge practices and normative questions of ethical and moral kinds. Before the power theme came to be a point in the ecological discourse it was taken up in the ethical debate on moral values guiding human action. This debate culminated long ago in Lewis' classical synthesis "The Abolition of Man" (1934), which still overshadows the ecological debate today. When the present environmental crisis is presented as a spiritual or moral crisis, as in the Potsdam Manifesto ("We have to learn to think in a new way") that was criticised by Becker (see Chapter 6), the crisis is again reduced to ethical and moral problems. To advance in this debate it seems necessary to set it in the context of knowledge from scientific analyses of human power over nature, with a more systematic discussion of the consequences and effects of modern science and technology for the interaction between society and nature. In the former ecological discourse, in the controversies about the tragedy of the commons and the limits to growth the interaction of society and nature was specified in terms of resource use practices implying power relations between humans, and between humans and nature. In the recent theory of the anthropocene, the human ability to modify ecosystems and their development is seen as a collective power factor, although the term "power" is not used in a specific sense in the theory. To deconstruct the power theme, it can be divided into several theoretical and empirical layers of analysis, in which the analysis of societal metabolism precedes the analyses of sociocultural change and transformation, and these precede the analyses of policy processes and regulations.

The ecological discourse is full of apocalyptic visions about the destructive power of man over nature. Through scientific knowledge, research and reflection the discussion of imagined and potential, real and normal catastrophes in modern society can be developed to become issues of more informed and reflected discourses, less appealing to normative views of man and nature, and moral reasoning, and more to empirical and theoretical knowledge about the human condition and societal development. Also in social ecology the need for philosophical–normative reflection about man and nature is great, as the debates reviewed (in Chapter 1) show. Rather than presenting a dogmatic debate about the choice of a specific worldview, theory, ethical, ontological or epistemological position, or the right combination of these components, social ecology should be kept open for various perspectives and changes which accompany new knowledge, and deal with controversial questions that cannot be solved by way of partial answers and positioning. The discussion of knowledge questions in human and social ecology showed, for example, the contradictory nature of the power–knowledge nexus. In ecological research the limits of science in understanding the complexity of social-ecological systems are discussed, but also the capacity of humans to modify nature to a significant degree with their knowledge. This contradictory interpretation of human nature and knowledge can be developed further, by making apparent the multifaceted and changing relations between human society and nature in human history. Knowledge from anthropological research, including philosophical and cultural anthropology, can be used as a first step of the formulation of long-term action strategies (Table 8.1).

The theme of human power over nature shows the influence of big themes of the past discussed throughout the epoch of modernity. The discussion of human power over nature is based on inexact diagnoses of the changes in nature–society interaction through modern natural sciences that started in the 16th century, paradigmatically in the discussion of natural sciences by Francis Bacon. The idea of freeing humans from the power that nature has

Table 8.1 Policy and resource management – application of anthropological research

The classical philosophical idea of Aristotle (in "Politics") about the nature of man still inspires anthropological and ethical debates: humans are social animals and society is something that precedes the individual – those who cannot participate in society are either beasts or gods.

1. *With empirical knowledge from the social and anthropological sciences, Aristotle's philosophical statement can be set in the historical context of modern society* – in the interdisciplinary discourses about man, society and nature in the 20th century in human, cultural and social ecology (reviewed in Chapter 1). The discussion of philosophical anthropology showed that society–nature interaction cannot be discussed without man–nature interaction, which is not separate, but part of the nature–society theme. For the new social ecology and for the application of its knowledge it seems important that this interdisciplinary anthropological debate has no final messages, no coherent view of man that connects knowledge from sociology, cultural anthropology and biology, but shows different perspectives that can be connected.
2. *The cultural evolution of man in society* that has been reviewed by Freese (1997a) as the historically changing human condition allows similar conclusions that no final anthropological synthesis is possible, synthesis being, rather, a continued recombination of concepts, theories, interpretations and empirical knowledge. The ideas of a human exceptionalism paradigm and a new ecological paradigm appear as contrasting worldviews, and do not sufficiently show how contradicting ideas about man, society and nature can be connected. More ideas than these normative constructions need to be taken up from the discussion of philosophical and cultural anthropology (summarised in Chapter 7) in social ecology.
3. *Man exists only in culturally, socially and historically specific forms*. These can be reflected as time and culture-specific self-interpretations of humans, but make it difficult to identify a general nature of humans in biological and cultural terms. Biologically and culturally, humans are no longer seen as having a constant and unchanging nature. The biological and cultural natures of humans are both in evolution, although evolutionary changes may take such a long time that the impression of "relative constancy" of human nature remains.
4. *Knowledge from philosophical and cultural anthropology* for a social-ecological synthesis of human–nature interaction can be used to reconstruct the "relational" and "interactive" nature of humans: for the formulation of a theory of societal relations to nature the hitherto separate knowledge about society–nature, human–society, human–nature and human–society relations can be combined, although not necessarily integrated in a "closed theory". The synthesis ends as a "patchwork" synthesis, in which the situation of humans in social-ecological networks is analysed with knowledge from many disciplines and framed in rehabilitated philosophical concepts of humans and nature. It can be assumed that the complicated web of interactions between humans, society and nature is never fully understood – because they are complex and change, and because the interactions cannot be explained with positive knowledge only, but require interpretation of the human condition with various theories.

Table 8.1 (Continued)

5. *For the application of social-ecological knowledge* it is not required to translate anthropological and philosophical research "point by point" into knowledge for resource management. Rather, the synopses and classifications of anthropological knowledge can be used to illustrate and discuss the difficulties met in the policy and resource management processes, in global governance and societal practices: as difficulties in finding sufficient and coherent knowledge, interpretive consensus, coordination and cooperation of actors over distance, taking into account political and cultural differences, dealing with differing ethical valuations, dealing with meta-decisions (when is a decision one by political actors, when is it one to be based on scientific knowledge), and further difficulties.
6. *Two points from the broader debates about humans and nature are directly relevant for policy and resource management practices*:

   – *Dealing with knowledge about humans*: not in a simple normative view of human nature, but distinguishing between (a) normative views of humans, (b) partial knowledge of humans from different scientific disciplines, (c) the diagnosis of human superiority over other beings derived from classifications of living beings, (d) the diagnosis of human domination of nature, a normative one, but not necessarily resulting from the hierarchical classifications of beings.
   – *Dealing with the power concept*: Human power over nature is more than the assumption of anthropocene theory of humans overwhelming the great powers of nature. The co-evolutionary perspective that has been developed and discussed in several parts of the ecological discourse (theoretically by Moscovici, empirically in the debates in ecological economics, in sustainable development and in the recent global governance discourse) offers possibilities of reformulating the power relations in nature–society interaction which cannot be dealt with by the great simplifications of "nature has power over humans" or "humans have power over nature".

Source: own compilation

over them through the knowledge science can provide was from the beginning a contradictory one, oscillating between the extremes of a Promethean view of humans controlling nature and a critical view of the role and use of science for the interests of powerful social, economic and political groups. In the present ecological discourse this critique of science has gained influence, for example, in the discussion of the change of biology from a science observing nature and classifying species to a science of controlling and modifying nature through genetic modification of organisms (Commoner 2002), and in the debate about the anthropocene, in which human knowledge and power are seen as overwhelming nature. To find successful strategies for global environmental governance in the transition to sustainability, the general analysis of human power over nature needs to be transferred into less generalised, more exact and historically specific analyses of the roles of knowledge and power in the regulation of societal relations with nature. This can be done, for example, with the guiding concept of co-evolutionary changes of nature and society towards sustainability.

In Moscovici's theory, in which the historical process spans nature and society, the idea of co-evolution was discussed before the ecological discourse unfolded, without the critical knowledge from recent environmental research. The recent sociological studies of the emerging complexity of nature–society relations by Urry (2003, 2005, 2007, 2008), aiming to make the global disorder analysable (Urry 2005: 249), show a much more complicated picture. Co-evolution dissolves into the analysis of complex interacting systems that shows similar results and ideas as ecosystem and resilience research in an abstract system-theoretical terminology. In Swyngedouw's policy-related analyses of "governance beyond the state" and of the "post-political condition" (2005, 2006, 2007, 2009) the critique is directed against the consensual style of environmental policies that has eliminated the culture of political disagreement. These analyses do not go far beyond the approaches in the global governance debate reviewed above (Brand et al. 2007). The development of empirically based global governance strategies requires more in-depth analyses of global policies. These policies started two decades ago with the formulation of "Agenda 21" and are today in crisis. Ways out are sought in the Rio+20 conference with a follow-up strategy for sustainable development called "green economy", in which clean technology ideas from ecological modernisation and sustainable growth are recycled. The coming controversies in the global environmental governance discourse are inscribed in this strategy, and social ecology is challenged to develop alternatives from critical analyses of the green economy discourse – beyond the minimal critique "if political, economical, and cultural constraints are not considered, green economy strategies will not be successful in their goals to end environmental degradation and reducing poverty" (Brand 2012: 28).

The power-over-nature question comes up again, closer to social-ecological research, with the analysis of energy regimes. A main problem in the sustainable development policies at national and global levels is the transformation of energy systems in the industrial socio-metabolic regimes – as the global figures evidence, this process is at the very beginning.

> Currently, fossil fuels (petroleum, natural gas, and coal) supply about 86 percent of world commercial energy needs. Oil makes up at least 40 percent of that total, while coal and natural gas each provide about 23 percent. Nuclear power and renewables supply about 7 percent each. Almost all of the renewable energy is hydro-power. Wind and solar energy currently make up less than 1 percent of our total energy use.
>
> (Cunningham and Cunningham 2007: 424)

The discussion of renewable energy sources has advanced in recent years, but unfolded an unexpected political dynamic. "Green economy" and the change of energy systems through biofuel production have become, within a short time, extremely controversial issues. The frontlines between those for or against a green economy, for or against biofuels as a means to develop more sustainable energy regimes are changing rather unexpectedly – the search for concrete solutions also splits the environmental movements. The consensual style of environmental policies criticised by Swyngedouw (above) seems to be followed by new global controversies and disagreement.

Transferring social-ecological knowledge for socio-ecological transformation of society – the grey box of adaptive governance

A review of the debate about governance and management in German social-ecological research (Voß and Bauknecht 2004) showed that no common ground is available for the conceptualisation of social-ecological transformations towards sustainability, but a series of conceptual models in search of transformation paths and the organisation of transformation in social and policy practices (meanwhile, with many projects carried out and hundreds of publications, the situation has become more complicated). No privileged social-ecological model has been found, but different views of problems with transformation have become apparent that need to be discussed further regarding their consequences for social-ecological research. The main ideas include the following (ibid.: 9f):

- transformation as an interplay of social, technical and ecological elements resulting from the idea of societal relations to nature or the co-evolutionary thinking and actor–network theory;
- in more policy and governance-oriented views and theories, formal and informal institutions, advocacy coalitions, patterns of interpretation and the various means by which actors become aware of sustainability problems describe the starting points for structuring social-ecological transformation;
- in the regional governance approach, changes of institutional and spatial structures of governance are seen as constituting the transformation process;
- in critical political economy approaches to regulating society–nature interaction, the transformation appears to develop from the analysis of globalised capitalism, its crises and the attempts to regulate the economic crises on which further and more far-reaching social-ecological transformation processes are to be built.

In the analysis of societal transformation towards sustainability and the knowledge transfer processes included, a plurality of theoretical and empirical approaches can be used in combination to frame the social-ecological analysis (Haberl et al. 2011, Fischer-Kowalski et al. 2012). The debate about regulating societal relations with nature in the transformation debate (Hummel and Kluge 2004) shows that the socio-ecological concept of regulation needs to be specified in a methodology for the analysis of social-ecological problems and for modelling of societal regulations. For developing such a methodology the authors propose to start from a perspective of a "cybernetic of second order" for complex, adaptive systems that are evolving and learning, in which reflection processes and positive and negative feedbacks are possible (ibid.: 49). These abstract conclusions approach those that have been formulated in simpler forms in ecological research and resulted in the ideas of adaptive management and adaptive governance. In the case of both ecological and social-ecological research, the abstract terms and the theoretical levels of debate indicate a lack of empirical research and knowledge about the regulation of social-ecological transformation processes. This lack of knowledge cannot be remedied by the discussion of adaptation strategies that have been formulated, for example, for climate change adaptation in a framework for decision-making (Climate Works Foundation et al. 2009): this framework has as its main components climate risk assessments and cost–benefit analyses to identify feasible measures in terms of infrastructural, technological, behavioural and financial solutions (ibid.: 10f). It is nothing more but a case study-based analysis of adaptation possibilities framed with concepts and methods from economics. The unresolved problems of how to address by way of regulation the processes of adaptation to ecosystem change from a short-term perspective, or transformation of socio-metabolic regimes from a long-term perspective, require joint learning and developing new approaches such as adaptive management and governance. Adaptive governance, as the new framing concept for the discourses of sustainability and climate change, requires a plurality of scales to be connected and adequate choices of scales when broadening the range of scales relevant to resource management. In ecology, scales are constructed as spatial and temporal scales to describe the dynamics of populations and ecosystems, but in resource management organisational complexity requires further scale matching, and not only by the rule "managing across the scales identified for ecosystems and populations"; it is necessary to identify scales in social systems, and these do not parallel that in ecosystems. Modelling of coupled social-ecological systems indicates other dilemmas of choice – most models are so far separate for ecosystems and social systems. Adaptive governance, as the unfolding debate shows, is blocked by some guiding ideas, including the following:

– the complexity of social and ecological processes restricts the capacity of policy and management processes – these can never reproduce the complexity found in the system processes;

- it is difficult or impossible to predict and model future states of resource management, policy, economy and society from the long-term perspective of several generations;
- the process of sustainable development blends with the short-term requirements of resilience, for which the notion of adaptation signals the requirements;
- knowledge from social scientific theories, such as that of the modern world system and its consequences of transitions to sustainability, is not used (showing the difficulties of communicating social scientific theories in the natural-scientific and policy discourses of sustainable development).

Social ecology and political practices – facets of global change

In social-ecological research on societal metabolism, the notion of "basic societal relations with nature" that are required for individual and societal reproduction (Jahn 2005: 32) guides the analysis of concrete forms of natural resource use in the lifeworld contexts of work and private life. The theme of (1) consumer movements and lifestyles, which has not been taken up in earlier chapters, is discussed below in more detail than the themes of (2) natural resource management as a policy issue and (3) policy and global governance as framing of societal agency. In the concluding discussion, the question is raised of how the different components of resource use analyses can be integrated into overarching strategies for sustainable development as great transformation.

1. *The consequences of global social and environmental change in the societal lifeworld – consumerism and lifestyle changes.* The topic of lifestyles and consumption, especially food consumption, has been studied in social ecology (at ISOE Frankfurt, e.g., Götz et al. 2011 and Hummel 2011; in Austrian social ecology, e.g., Lackner 2008, Erb et al. 2009a) in analyses that are part of the dominant social-ecological themes of material and energy flow or land use studies. Critical discussions of private consumption and lifestyles are part of the ecological discourse. The cultural critique of mass consumption adopts a perspective of social lifeworld analysis (see Box 8.2) developed in sociology and critically reflected in Habermas' (1981) synthetic theory of communicative action, one of the last grand theories before the theory crisis in the social sciences. His diagnosis of a "colonialisation" of the social lifeworld through the imperatives of political and economic systems in modern societies gives a theoretical account but not much practically applicable knowledge for critical discussion of lifestyles, consumption and environmental justice. The theory also does not account much more for new social movements, attributing to them the function of articulating the crisis of modern societies described in the metaphor of colonialisation. This notion

indicates a communicative distortion in the social reality of communicative action through the power and money-based interaction in modern societal systems, reformulating the classical theme of alienation in the language of sociological theory. Linkages can be developed from this theoretical analysis to the critical discourses of social and environmental movements; however, this has not been done in Habermas' sociology, or in the late critical theory discourse that has found new themes in philosophical debates about recognition and human rights. Not many critical and detailed analyses of mass consumption in connection to the environmental themes of global change can be found; there are some in recent environmental history and one by Dauvergne (2008). Addressing the environmental consequences of mass consumption in relation to global resource use and flow processes gives another, more critical picture of lifestyles and consumption than the theory of ecological modernisation. Dauvergne shows that consumers, consumption and Western lifestyles strongly influence the global crisis in societal relations to nature, that mass consumption organised in the patterns of unequal global resource flows is blocking solutions to many environmental and social problems. The role of consumers and consumer responsibility – whether they are locked into the economic system or can, through their responsible choices, help to transform the system – evoked a new controversial debate about consumer responsibility (Grunwald 2010, Bilharz et al. 2011).

Box 8.2 Mass consumption and lifestyles as themes of environmental movements

Questions of lifestyles and consumption are core themes of the new social movements, discussed as fundamental, value-loaded problems. The movements do not look for the empirical research and knowledge about human resource use or unequal access and distribution of resources that environmental sociology, ecological economics and social ecology can offer. The facts of overconsumption of resources in the early industrialised Western countries that profited from the positional good of industrialisation in terms of social welfare and mass consumption seemed evident without detailed data, not requiring more detailed empirical research. Critical and political consumerism is an ethical debate in which practical use is made of ideas and arguments from scientific discourses; for example, the de-commercialisation, de-fetishisation and dis-alienation debates that are taken up in the globally networked environmental and consumer movements – the "fair trade" movement, organic farming, degrowth and others.

Movements of private consumers, such as that linked with the name of Nader in the USA, have long been exceptional cases in Western countries. The economic role of consumers, individual persons or families with no further joint interests according to the ideological formula of "consumer sovereignty" seemed to qualify them as non-social actors with an egoistic economic rationality of welfare maximisation. In most European countries it was only together with or after the environmental movements that new consumer movements emerged and were organised, in the shape of strong political interest groups in different forms of ethical and environmentally conscious consumption – for health, environmental or solidarity reasons, as vegetarian movements, consumers of organically produced food, health food, locally produced food, or in the fair trade movements to support small producers in the Global South. National movements in organic farming, and fair trade as a global solidarity movement of middle-class consumers in the North and small producers in the South, have been the strongest and most quickly spreading and growing social movements in the past decades, supported by governments and governmental policies. Both movements have experienced the unwanted consequences of fast success, economic growth and growing social acceptance: political institutions and economic firms instrumentalised their ideas in dubious ways. Organic farming that is dependent on governmental funding, subsidies and political programs more than on independent social movements in the EU countries is discussed as critically as the involvement of large corporations and fast food chains in fair trade; both are criticised as "greenwashing".

Consumer movements trying to change market-based processes that operate through the price mechanism are acting in a difficult situation, trying to do something that appears paradoxical: to change the system of modern capitalism without institutional changes in the economic and political systems, only by individual decisions of consumers in the lifeworld sphere, through cultural and value changes and ethical debates. How behaviour changes – consuming less, environment-friendly consumption, practising voluntary simplicity – can endure and become successful in changing the systemic structures and mechanisms of capitalist markets is difficult to see when no further transformation strategies are discussed. Movements for simplicity and voluntary poverty in European history have existed in manifold forms, mainly as religious movements based on the Christian ideals of Saint Franciscus, but most of this ascetism implied a distancing from the social world and retreat into isolated religious lifeworlds, as is happening again today in some new social movements that are, for example, inspired by Buddhist philosophy.

Source: own compilation

Socialising discourses and changes of political and public cultures through other social movements, such as feminist movements for which "the private is political", or new constructions of the political through NGOs in terms of subpolitics (Beck) or existential politics (Giddens), were required to make apparent the complicated interaction of system and lifeworld spheres in modern societies. In Habermas' variant of a critical theory these spheres were separated in misleading ways, echoing the critique of mass consumption culture in earlier critical theory as colonialisation of the lifeworld through economic systems. From this theoretical diagnosis it is difficult to identify new ways of system transformation through social movements, the individual option to "emigrate" from society to esoteric movements not being an effective way of change. One way to effectively criticise mass consumption seems to be through consumer movements.

The consumer movements, under different themes and ideas, have joined the environmental movements in the most recent movement of degrowth with an idea that addresses the nature of systemic growth mechanisms as mechanisms for the "commodification of everything" in Wallerstein's formulation (see below). They have become strong movements, showing the possibilities of organised individualistic actors and interests, and also creating global trade networks and producer–consumer cooperatives, but they remain exposed to social and ecological dysfunctions of the market system which they try to change in soft or silent revolutions, in ethical discourses and in private changes of lifestyles. Organic food production and consumption as social movements aim at healthy food and de-fetishisation and dis-alienation of commodity and market structures, but they are part of the food commodity system. Although consciousness about these phenomena develops individually in terms of consciousness of market contradictions and market failures, it seems doubtful whether the change of market structures can be achieved by actors and production forms that depend on the functioning of the market-based agri-food system; the differences between a system transforming ethical consumption and a system supporting mass consumption are unclear. It is the logic of collective action of the new social and environmental movements to change economic system structures by organising individuals in their everyday life for specific purposes of protest, boycott and refusal through which agency should be created. The consumer movements succeeded in creating niche markets and ethical markets for limited numbers of consumers; however, whether these help to transform or to stabilise the capitalist world system is a controversial question. Other forms of social movements may be required than those that are only articulating the problems or symptoms without touching the system maintaining mechanisms of capital accumulation, growth and growing consumption. The system mechanisms to change are vaguely discussed in the Polanyian theory as re-embedding of markets and de-commodification of certain natural resources.

The distorting economic logic of scarcity of resources with the consequences of valorisation, commodification, privatisation and pricing of natural resources strengthens the globalising economic system, perpetuating growth, unequal exchange and overuse of natural resources. Also, parts of the social and environmental movements seem to have accepted the seemingly unchangeable institutional reality. The Economics of Ecosystems and Biodiversity (TEEB), a form of natural capital accounting for purposes of biodiversity maintenance, gives a recent example of the distorting economic valuation logic that becomes an instrument in the hands of powerful global players that can enforce the valorisation of biodiversity and build the structures of a green economy, which has become an extremely controversial issue with the Rio+20 conference preparation. In the agri-food sector the transformation of farmers into economic entrepreneurs was only the prelude to their successive expropriation in becoming dependent producers for the agro-industrial complex. The structures that are threatening and undermining the consumer movements' strategies for conscious consumption are the same multinational agro-industrial corporations that pretend to feed the world. Farmers and consumers are candidates for new social movements to combat the industrialisation of food production. The regulation of the power of multinational food corporations in the production sector (firms controlling through patents the markets for seeds, plant and animal species for farming) becomes important in addition to the organisation of consumer movements and raising awareness through campaigning, lobbying and education, and the practically relevant maintenance of buying power for consumers. But regulatory changes against the de-regulation trend seem to happen to a much lesser degree and with less success than the organic farming and political consumer movements.

The conclusion from the complicated situation of social and consumer movements in the food sector seems to be – more than for other forms of environment-related movements that had or have their successes in public policies and through collective action – that other, complementary forms of movements are required that address more directly the system mechanisms that prevent social and environmental sustainability through doubtful forms of mainstreaming. These movements need more knowledge about the system mechanisms than the first generation of environmental movements that could act with relatively simple system analyses of modern societies, often only with ethical critique. In the degrowth movements one can see the first forms of new, more system-critical movements that build transformative capacity, with more critical systems analyses of the globalising private economy, including the food industry, with combined knowledge from social-scientific and natural-scientific disciplines, and a differentiation of action strategies that include more actors as the social movement's activists. But the degrowth movement is still diffuse, with heterogeneous interests and aims, including illusionary and contradictory ideas for a transformation of the systems – not yet beyond the point of identifying the fragility of the system mechanism of economic growth. The agriculture and food sector requires such new movements that can work with critical interdisciplinary system analyses such as that of ecological economics. The present far-reaching changes in that sector are paradigmatic for a situation that creates new critical movements: the factual expropriation of independent agricultural producers; the specialisation and concentration in farming; the concentration of capital in the food processing industry; long distribution and transport chains and global markets; the new and powerful research and development structures such as agricultural, pharmaceutical and medical research with "triple helix" cooperation of governmental agencies, universities and private companies; the patenting of seeds and plant and animal products; the genetic modification of organisms; the emergence of new food safety problems through environmental damages, mass production and animal disease problems, and human or consumer health; the deregulation and weakening of governmental and legal control of food quality at national levels; the trade conflicts and power fights between global players at political and economic levels or to protect national and regional interests; the new forms of agricultural colonialism as "land grabbing" through governments and private firms in foreign countries.

2. *Natural resource use and management as policy issue*. From the discussion of consumer roles and movements it can be concluded that a critical question is how to account for the globalisation of economies in the modern world system and to transform the system analyses into action strategies for social movements. The modern world-system has been characterised as a historical social system of interdependent parts that form a bounded structure and operate according to distinct rules, or "a unit with a single division of labour and multiple cultural systems" (Wallerstein 1974: 390). The modern world-system as a world economy is larger than any state or country and the different parts of centre and periphery are linked economically, through market mechanisms (ibid.: 15). In this capitalist world economy accumulation of private capital, exploitation of human labour and natural resources are for the sake of "a system that operates on the primacy of the endless accumulation of capital via the eventual commodification of everything" (Wallerstein 1998: 10).

The global resource flows that determine the patterns of resource use in different parts of the world system are a paradigmatic case for political regulations that aim at the structural change of societal relations to nature which are called in social ecology "social-ecological transformations" (Becker and Jahn 2003) or transitions (Fischer-Kowalski et al 2012). However, the system structures of the global economy are not yet sufficiently discussed to be able to formulate regulatory mechanisms that support social-ecological transformations. The governance debate is too vague and diffuse, without theoretical guidance to be able to formulate effective strategies for system transformation. Social-ecological studies with their combination of theoretical and empirical analyses are candidates for providing knowledge for the formulation of governance mechanisms in the sense of transforming societal relations to nature. With all the empirical studies of consumption, regulation and governance carried out, especially in the ISOE institute, this discussion is not yet advanced and has not yet significantly influenced the broader governance debate. The paradigmatic debate on panaceas in common pool resource research illustrates this situation. Ostrom questions

> the presumption that scholars can make simple, predictive models of social–ecological systems (SESs) and deduce universal solutions, panaceas, to problems of overuse or destruction of resources. Moving beyond panaceas to develop cumulative capacities to diagnose the problems and potentialities of linked SESs requires serious study of complex, multivariable, nonlinear, cross-scale, and changing systems. Many variables have been identified by researchers as affecting the patterns of interactions and outcomes observed in empirical studies of SESs. A step toward developing a diagnostic method is taken by organizing these variables in a nested, multitier framework. The framework enables scholars to organize analyses of how attributes of (i) a resource system (e.g., fishery, lake, grazing area), (ii) the resource units generated by that system (e.g., fish, water, fodder), (iii) the users of that system, and (iv) the governance system jointly affect and are indirectly affected by interactions and resulting outcomes achieved at a particular time and place. The framework also enables us to organize how these attributes may affect and be affected by larger socioeconomic, political, and ecological settings in which they are embedded, as well as smaller ones.
>
> (Ostrom 2007a)

The multi-tier framework Ostrom is discussing here as a first step to approaching a complex situation of natural resource management may be a first step in the bottom-up perspective to generalise results from empirical case studies. It needs, however, to be complemented with further analyses that cannot be carried out in this inductive way: theoretical and empirical analyses of system structures of the global economy that direct or block the transformation of governance.

3. *Policy and global governance as framing of societal agency.* Conventional policy analysis – with empirical analysis, monitoring and evaluation of public policy programmes and policy instruments in established national and international policies – did not influence social ecology to a significant

degree. What social-ecological theory and research has to say about societal transformation towards sustainability needs to be communicated in policy terms, but not in these alone – it results from research guided by the terms of societal metabolism and colonisation of nature. These society–nature interactions refer to specific spheres of social action for the use of natural resources that require other mechanisms for socio-ecological transformation than those discussed in policy research and with the established forms of policy instruments that are tailored for governmental action and cooperation. The forms of knowledge use, knowledge practices and integration of different knowledge forms in societal practice, for example, have much more significance for social ecology than for the conventional forms of policy analysis.

Also, the broader governance ideas take up only part of the meaning that societal agency has in social ecology. Global governance, as summarised in the quotation by Biermann at the beginning of the chapter, is more a problem formulation and a guiding idea than an elaborate theory or methodology to address the complex problems that come up with climate change adaptation and global sustainability. It has been from the beginning limited to a policy-related debate that has not adopted much knowledge from environmental research in ecology or social ecology, as the formulations by Biermann already indicate when he addresses the problems in conventional management terminology of stability, guarantee and safety, which seem somewhat inadequate to address problems of global environmental change. In the article quoted, the author discusses only organisational solutions for the organisation of global governance in the framework of the Institutions of the United Nations – following the long debate about a United Nations Environmental Organisation, its form and responsibility. Without further discussion of the ideas from the environmental governance debate, the discussion tends to become a pure organisation debate in terms of decentralisation and centralisation, organisation of decision-making, participating actors and their rights. Necessary as this is, it cannot replace the discussion of the multi-level governance of interaction of social and ecological systems, of rescaling of decision-making, of integration and cooperation of institutions from local to global levels and from different policy and economic sectors. Global governance is a possible, but not an ideal, form of framing social-ecological knowledge for improving societal agency. The preferred formulations in socio-ecological theory are "societal" agency, practice and transformation, showing that policy in the historically given structures of national governments and government-dependent international institutions does not give an adequate framing of societal action; it is only a necessary component which cannot be bypassed. But social ecology, like other interdisciplinary research, has difficulties in developing the theoretical notions of societal agency, transformation or transition into more concrete terms of regulation, policy and governance. The recently unfolding research develops conceptual frameworks for societal transformation beyond industrial society (Fischer-Kowalski et al 2012), but still "it is extremely hard to say what this third transition should look like" (Haberl et al. 2011: 11).

Concluding discussion – sustainable development as great transformation. The discourse of sustainable development took up questions that seemed unanswerable with the available scientific knowledge. How far can the long-term consequences of human resource use be assessed? How can the changes of nature be assessed in terms of losses of nature values for future generations? What does sustainable development require in terms of changes in materials and energy use? What are the social, political, economic and cultural conditions that need to be fulfilled to allow sustainable development? (Sarkar 1993: 10). The assumption that intensification of environmental research is what is mainly required to find new knowledge for transitions to sustainability turned out to be misleading. Rather than knowledge problems, the transformation evokes problems in the sense that it is a way towards an unknown future that cannot be predicted, planned or modelled in management strategies but requires what has been formulated in the adaptive management debate: policies as experiments to find out from experience and from failures what works in the management of social-ecological systems. Also, answers from prior ecological research trying to find criteria for the stability of ecosystems are no longer useful – they cannot be translated into conditions for social stability and development. The questions of how to combine social-scientific and natural-scientific knowledge in analysing the problems of industrial systems (Becker et al. 1992: 434) are gradually being taken up in social ecology, and they have yielded so far the insufficient answer that a plurality of concepts, theories and approaches is required that cannot be integrated in a coherent theoretical framework.

In the recent discussion of transformation to sustainability, Haberl et al. (2011) argued for a fundamental change of society instead of implementation of technical fixes as in the eco-efficiency, dematerialisation and ecological modernisation perspectives, but the future socio-metabolic regime cannot be imagined or projected; it is only clear that it will be as different from industrial society as that is from earlier agrarian societies. The argument that it would also have been difficult to imagine the industrial society in the 16th century is used to understand the difficulty and argue against technological visions of a sustainable society. An important argument in reformulating the sustainability problem is to contextualise it historically and socially: the global transition is not simply one from industrial to post-industrial societies. The global societal reality is that two-thirds of the global population are in the transition from agrarian to industrial socio-metabolic regimes, and this causes the sustainability problems: the global industrialisation project cannot end – or can end only in such catastrophes as discussed in the discourse of "limits to growth" – and needs to be replaced by another socio-metabolic regime before the risky experiment ends in catastrophe. Looking at the concrete ideas of the socio-ecological authors for the transition process and its political guidance, the proposals are still more fragments of theoretical arguments, a patchwork of ideas in development that aim at something more than a simple transition management model:

> Socio-ecological tax reforms that can reduce the burden on labour use and increase the burden on resource use would most probably constitute an effective strategy to stimulate developments in this direction, not only for their immediately positive environmental impact through resultant price changes but also because they would send a strong communicative signal steering creativity and innovations in another direction.... The way in which we spend human lifetime is another element of possible strategies towards sustainability that is (still) overlooked today. Greater quality of life at the cost of lower material consumption could possibly be achieved through a reduction in working lifetime – an area of human life upon which political intervention can have an impact ... Finally, it is necessary to reflect upon societal institutions. The institutions of industrialized societies are nowadays based upon the concept of economic growth – without growth, industrialized societies fall into crisis .... Yet institutions are capable of change, however slowly this change may progress. Even if this is perhaps a vague hope – and certainly also a perspective that calls for a significant degree of radicalism in rethinking current social relations and the transformation they require – institutional change is a necessary part of the transition. Earth system governance research has helped to outline the challenges and the likely benefits that might be derived from such institutional change .... Twenty years after the proclamation of "sustainable development" (often understood as economic growth that would be ecologically sustainable), there are signs of a new doctrine or at least a new slogan in the rich countries, "sustainable de-growth", meaning economic de-growth that would be socially sustainable ... "Degrowth" needs to be operationalized. It is similar to our notion of a third transition in the socio-ecological regime of industrial economies, which we base on empirical data on global resource use (material and energy flows, land use).... fundamental and not only gradual changes in our interaction with natural systems are necessary for human survival. Social metabolism, that is, the amount of energy and matter used, has to decrease markedly, and land use has to be re-organized into a net energy producing system. While we have no clear vision of the make-up of the resulting society, we can infer from historical data how fundamentally different from the present pattern it would have to be as result of the third Great Transformation.
>
> (Haberl et al. 2011: 11)

Instead of a model for a future sustainable global society these reflections provide a preliminary answer to the question: How should the sustainability discourse be restructured to meet the requirements of a global transition to sustainability? If sustainability is perceived as a problem of global ecosystems and global environmental change, it requires searching at local and national levels of society for new ideas to global solutions: no "rich country illusion effects" (as today, e.g., in Europe), no externalisation of environmental burdens (e.g., through the relocation of polluting industries or toxic waste to the global South) from rich to poor countries. Finally, global sustainability is to be achieved as a no-growth economy. These premises leave many possibilities of modelling a future globally sustainable society as a multifaceted one: it can include many different forms of production (also industrial – but not as large-scale, dominant, polluting), many different cultures and lifestyles, also a higher level of global population than today – but new forms of resource distribution beyond the present market and growth-based mechanisms need to be found, or new forms of "redistributive economies". In environmental sociology the linkages between economic and ecological globalisation have been studied, for example, by Mol (2001). The more advanced analysis and discussion of Martens and Raza has not advanced further than repeating the points in the analyses of ecologically unequal exchange by Rice et al:

> Globalisation interacts with sustainable development at levels that make measurement difficult, e.g., trans-border environmental issues, cultural transformations and a so-called "global consciousness". For example, the data do not show us that the most globalised countries . . . have exported their pollution or that the costs of the goods and services they enjoy and contribute to their lifestyles are borne by people and environments in other parts of the world.
>
> (Martens and Raza 2010: 290)

Conclusions – models for the communication between science and policy

Whether there is another environmental science that can communicate more effectively with societal actors and change societal practices, a science for new social movements, was discussed a long time ago by Jamison (2001) under the headings of "greening of knowledge" and "cognitive praxis", but with unclear results. He aims at another form of environmental debate of environmental consciousness and action, seeing both phenomena as linked and structured through knowledge-related practices of social action ("cognitive praxis"). Regarding environmental movements, he argues for connecting individual and collective changes of behaviour through collective learning, developing knowledge-based social practices of social groups as forms of awareness–action linkages. The cognitive praxis of environmental movements is described by Jamison in three dimensions, with consciousness as part of all. Development of environmental awareness happens at different levels, in different contexts, in different actor groups, individually and collectively, including (1) a cosmological dimension with specific worldviews; (2) a technical dimension in the sense of connecting knowledge and "green" technologies; (3) an organisational dimension, collective learning sites of "citizen science" with organised processes of learning and knowledge use. This description of science–practice relations can be seen as a simple model of societal practice, not sufficient for social ecology, in which more specified knowledge is required to describe the state of interacting social and ecological systems. Jamison's analysis and his answers seem more concrete than Urry's abstract reflections about the societal knowledge situation, but they do not show further solutions in addition to those also taken up in the governance debate. Urry has remained in the theoretical diagnosis of the "complexity turn" with his reflections, as complexity approaches require

> a new "structure of feeling": one that combines system and process thinking . . . a sense of contingent openness and multiple futures, of the unpredictability of outcomes in time-space, of a charity towards objects and nature, of diverse and non-linear changes in relationships, households and persons across huge distances in time and space, of the systemic nature of processes, and of the growing hyper-complexity of organizations, products, technologies and socialities.
>
> (Urry 2005: 3)

The methods to analyse complex systems and problems still imply robust, simple, often model-based methods such as those in sustainability science and resilience research.

Scientific concepts and ideas such as these by Jamison and Urry have more often been communicated too early and in misguiding forms from ecological research to societal practice, the discourses in policy and of environmental movements, where they unfold their own "normative development" and are later criticised again by the scientists as non-scientific and non-serious ideas. The confusing debate about sustainable development since the Brundtland report in 1987 can give rise to such impressions. But such a critique of deficits in the communication between science and society still seems inadequate and inexact, as it does not describe the situation more exactly, identify communication problems and develop specific models for communication, as has been assumed above to be necessary for developing social ecology through knowledge transfer. Rather than failing communication, there seems more often to be a real deficit on both sides, on the part of both scientists and environmental actors: their inexact and unclear ideas about how science, society and policy can communicate and interact. A prominent example has been discussed in Chapter 6 with the controversy about a "mental crisis" as reason for the present environmental problems.

Ecology, as its transformation in an interdisciplinary science during the past decades has shown, requires more specific ideas, concepts, theories and methods to address the complexity of coupled social-ecological systems. Rather than articulating the complexity of both system components, it reduces that complexity, as, for example, in large parts of resilience research, to the complexity of ecosystems ecologists are acquainted with. Social ecology, as an advanced variant of ecology in terms of addressing complexity of social and ecosystems, works against such a reduction and simplification of scientific analysis as well as simplifications in communicating ideas to social actors and in the political discourse. Ecological research has so far said little on the societal transformation of nature through societal metabolism and natural resource use, and social ecology has started to fill that knowledge gap with its analyses of societal relations to nature, societal metabolism and colonisation of nature.

An early example for modelling the communication between science and society in the sustainability discourse was a multi-scale concept of sustainable development (Norgaard 1988: 619f) for the shift from a mechanical to a co-evolutionary perspective of systems development. Sustainable development appears from that perspective as a process of continuous improvement of knowledge and action, framed through the following processes:

1. The transition from competition and conflict to interdependence and cooperation that has started internationally, with the discussion of sustainable development, among other reasons, and supports this process.
2. Political and administrative systems, catalysed by contradictory processes of globalisation and environmental policies with new political actors, are developing towards compromise cultures.
3. The environmental policy process is open, requiring negotiations, discourses, and matching of different knowledge systems and cultures.
4. Improved knowledge and access to knowledge become key factors in the process of sustainable development.
5. The transition to sustainability is a difficult process; it does not mean the end of Western culture and science but reform and reorientation of both, including reducing power concentration and new forms of social order.

These ideas are not historically, culturally, spatially and temporarily specified strategies for sustainable development; they give only some general diagnoses and guiding ideas that need to be developed further. Most of Norgaard's ideas include normative assumptions about societal processes that require critical discussion, but he does not close the discussion through simple normative visions of a good society, or through adoption of a specific theory or approach. He assumes, although in somewhat abstract terms, that the different knowledge cultures of social and natural sciences are required in the process. The ecological and social components interact in more complicated forms than reproduced in the simple definition of three components of social, economic and environmental sustainability (which has become the mainstream version in the policy discourse).

Norgaard's ideas include a composite conceptual framework at different levels of abstraction. This framework can be imagined as a basic structuring of sustainability through ecological processes and requirements: maintaining functions and services of ecosystems that limit the social and economic perspectives and possibilities of development, formulated in a more elaborate form than the new ecological paradigm of society as part of nature. If that idea is to be made meaningful for sustainable development, it needs to take into account more historically exact descriptions of changing nature–society relations, which include, for modern societies, specifying how nature and society can interact in co-evolutionary processes, which institutions in society are to be maintained as core institutions (e.g., those organising the basic societal relations to nature) and which functions and services in ecosystems (e.g., supporting, provisioning, regulating and cultural services according to the framework of Millennium Ecosystem Assessment). The regulation of these processes requires multi-scale governance, including different temporal and spatial scales of social systems and ecosystems that limit each other's development. With the co-evolutionary model it seems possible to address the problems of global sustainability in the way Haberl et al. (2011) and Fischer-Kowalski et al. (2012) took up the ideas of Norgaard in the transition debate, which allows the following conclusions:

1. Industrial society cannot become global. To achieve global sustainability requires fundamental changes in the industrialised countries, their economic systems, and their high levels of consumption of imported resources and energy.
2. For the non-industrialised and late industrialising countries, alternatives to industrialisation and technology-driven modernisation are required for transitions to sustainability and ending the dependency state of extracting economies.
3. The common long-term strategy for system transformation of industrialised and non-industrialised countries is a transition to degrowth, the transformation of the capitalist system into an economically sustainable socio-metabolic regime.

4. To achieve all changes required for global sustainability complicated processes of changing communication and cooperation between science, society and policy should be envisaged. Instead of searching and accumulating scientific knowledge to organise the transformation, collective learning processes should be directed towards the use of different knowledge forms and cultures to develop new social, political and economic institutions.

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Index