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METHODS

Towards an understanding of long-term ecosystem dynamics by merging socio-economic and environmental research Criteria for long-term socio-ecological research sites selection

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A B S T R A C T

Human activity affects ecosystem functions through the disruption of pattern and rate of matter as well as energy flow through ecosystems. Extraction, transport and transformation of resources driven by societal and economic pressures change our landscape. These processes influence biodiversity, redefine the ecological state of ecosystems and impact both on society and the economy. Thus the inclusion of socio-economic dimensions into standard ecological research has been identified as a challenge in a new phase of development in Long-Term Ecological Research (LTER). Transformation from LTER to LTSER – Long-Term *Socio-Ecological* Research – raises questions about the comparability and compatibility of research, the need for indicators linking environmental and socio-economic processes as well as criteria for launching research sites that focus on interaction between society and nature. In this paper we propose criteria developed within *A Long-Term Biodiversity, Ecosystem and Awareness Research Network* (ALTER Net). These criteria are designed to support the process of transformation of traditional research sites, with the aim of broadening their scope to a socio-economic dimension. They may also be used for identifying and launching new sites — the LTSER-sites. We suggest that apart from criteria for selection of specific sites, the whole pool of different sites (the network database) is crucial for recognizing cross-scale processes, general socio-ecological and economic trends as well as resource management. Therefore the paper distinguishes between two sets of criteria: local “site criteria” and network “pool criteria”. They may be used both as a quality label for transition of traditional ecological sites and as a matrix for establishing and developing new research areas.

1. Introduction

In the past, the interaction of nature, society and the economy provided numerous benefits for human livelihoods. Nowadays mankind fears negative drawbacks, e.g. the depletion of resources and nature’s diminishing capacity to absorb and neutralize soil, air and water pollution. Moreover, during the last few decades human-related factors increasingly gained in

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strength equal to natural forces, marking a new stage in the earth's development, which may be described as the Anthropocene (Meybeck, 2001). Living in Anthropocene means that we have to deal with systems that emerge not only from an initial interplay of climate and geology, but also from more dynamic interactions of society and nature (Crutzen and Stoermer, 2000).

At local, regional and global levels, human activity affects ecosystem functions through the disruption of pattern, rate of matter and energy flow as well as modification of the ecosystem's structure. Extraction, transport and transformation of resources (driven by societal and economic pressures) change the landscape, influence biodiversity, redefine the ecological state of ecosystems and rate of delivering goods and services. This creates feedback impacting both on society and economy. Redman and others (2004) identified five core activities that drive the relationship between social and ecological systems: land use, land cover, production, consumption and disposal. On the one hand, these activities are embedded in social patterns and processes, such as demography, technology, institutions and culture. On the other hand, they deeply affect ecological processes, such as primary production, populations, and organic matter circulation. These core activities not only mediate between the social and ecological system, but they are themselves interrelated. For example, land can be used for production or disposal. Moreover, consumption of goods often presupposes their production and disposal after usage. Therefore this combination of factors must be considered as a step in the resource use process of social systems that secures the maintenance and reproduction of the system. Incorporating a socio-economic dimension that is based on these core activities into standard ecological research will ensure consistency of knowledge. This approach is also necessary for the completion of data reflecting the complexity and changing nature of the environment, in order to increase the power of scenarios and models to make predictions in the face of global change (e.g. climate change, globalization) and worldwide societal challenges (Millennium Development Goals; UNMP, 2005). What this implies is the development of an inter- and transdisciplinary approach, whereby knowledge, information and data sets are organized not with regard to a single discipline's interest, but with regard to the establishment of networks for collecting, analyzing and relating information and data to common spatial, temporal and organizational scales. The need also arises for transparent criteria to launch new research sites and to provide appropriate indicators. They should link environmental and socio-economic processes and promote a wider scope of classical ecological studies. One route to achieve this goal is to redefine existing Long-Term Ecological Research Sites (LTER) towards the establishment of Long-Term Socio-Ecological Research Sites (LTSER-sites).

By broadening the scope of research to socio-economic analyses, the present paper suggests criteria for selecting potential research sites that enable the development of ecologically effective, economically efficient and socially acceptable mitigation strategies. However, apart from the selection criteria for specific sites, we consider the whole pool of different sites (the network database) that is crucial for recognition of cross-scale processes, general socio-ecological and economic trends as well as resource management. Therefore this paper distinguishes between two sets of criteria: local "site criteria" and network "pool criteria". Each set is derived on the basis of the European Environment Agency (EEA) DPSIR framework (driving forces–pressures–state–impact–response framework) (EEA, 1999a,b).[1] Working within this framework we also propose a basic set of data, which should be acquired in parallel to ecological information, if the drivers, pressures and impacts on nature are to be identified with regard to dynamic society–nature interplay.

In the following Section 2 we elaborate upon the criteria with the aim of directing the process of transformation of Long-Term Ecological Research towards a more complex Long-Term Socio-Ecological approach. Subsection 2.1 introduces the site criteria and Subsection 2.2 the pool criteria. Section 3 summarizes and highlights some goals for future research activities.

2. Criteria for LTSER-site selection: The socio-economic viewpoint

Up to now a host of ecological, taxonomical, and environmental criteria have been applied to select the sites for ecological research. Since the international long-term ecological research network (ILTER) is dominated by natural scientists (mostly taxonomists and ecologists), criteria that reflect social behaviour and interaction between society and nature have so far been widely neglected. Below we present the efforts made within "A Long-Term Biodiversity, Ecosystem and Awareness Research Network" (ALTER Net; see http://www.alter-net.info) to foster compatibility of natural and social science research via the launching of new sites enabling the study of linked environmental and socio-economic processes.

2.1. *Site criteria and related data requirements*

Site criteria were developed for a better understanding of local sociological, political and economic processes, which directly or indirectly reshape ecosystem functions. They include: economic diversity, conservation relevant policy, local conflict, demography, land use and cover. These were suggested as a basic minimum set of data, which should be collected to describe major drivers of ecosystem change: economic and population growth, market changes, global trade etc., and related pressures: industrial and technological development, urbanization, water uptake, pollution etc. Additionally they were proposed as landmarks for ecological research sites, if they are to be instrumental in expanding the research scope. The term 'site' is used to describe the study area. In future, selected research sites may become models of how socio-economic and ecological research is integrated into a specific location and also deals with a specific set of problems. The criterion of the spatial extent of sites for selection is intentionally excluded from the list of criteria. Although this

[1] See Svarstad et al. (in press) for a discussion of shortcomings of the DPSIR model from a sociological point of view.

factor is important in ecological studies it does not seem relevant to include in a socio-economic analysis. The size of the socio-economic system is determined by other criteria, such as income and demography, whilst the number and characteristics of ecological units (ecosystems, river catchments) under consideration should be adjusted towards the aim and focus of the research.

2.1.1. *Criteria 1: Language*

Box I

> All data and relevant information should be available in the *English* language.

Environmental research is not only performed within a variety of disciplines, but also across a variety of nations. Therefore data, results, and case studies should be internationally understandable, transparent, and accessible to researchers from various disciplines and origins (especially if the site is to be entered into an international network). This is not a trivial requirement considering the diverse research traditions and the slow process of integration of European nations. Until today, most research is conducted in national languages. Therefore translations have to be commissioned in order to make the results available to a larger community. By setting the requirement of the data's availability in English, the following provisions are made: international accessibility of data; improved comparability (each researcher uses the same translation), and avoidance of time-consuming translation activities for individual researchers.

2.1.2. *Criteria 2: Economic diversity*

Box II

> *Income data* available for the primary, secondary, and tertiary sectors is to ensure internal linkages of local economy sectors. Sub-criteria are:
>
> - Intensification/de-intensification processes in the primary and secondary sectors
> - Changes in growth rate or capital/labour inputs in the secondary sector
> - Tourism as a crucial service of the tertiary sector.

The most prominent focus of socio-economic analysis is on people's activities, the underlying incentives and motives that stimulate behaviour. In order to make sure that a critical mass of people – and not only "two old men with a sheep and goat" – are present on the sites, the focus is not (!) on the criterion of spatial extent (as is usually the case for ecologists). Instead we call for measurable income stemming from the primary, secondary, and tertiary sectors.

In compliance with National Accounts regulation, *income* (GDP) should be defined according to three different points of view: firstly the source of income (e.g. production and transfers from the government); secondly the purposes of use (especially investment, savings and consumption); and thirdly the distribution among the relevant sectors (including a division between labour and capital income).[2]

The mix of economic sectors ensures that different types of economic activities are included. Activities that fall within the primary sector are for example: agriculture, forestry, fishery, hunting, gardening and other forms of extraction. The secondary sector includes all kinds of industries and manufacturing: the chemical industry, energy production, the construction sector etc. The tertiary sector includes services such as: transport, public administration, tourism and insurance. Activities within and across these sectors pose important dynamics that affect the status of biodiversity; e.g. land use changes are often driven by shifts from one economic sector to the other. Moreover cultural peculiarities are often reflected in the proportion of people working in each of the three sectors. Therefore it is expected that a broad range of biodiversity-relevant socio-economic impacts will be found at each selected site, if measurable income is proven within each of the main sectors of the economy.

One further *sub-criterion* was defined for each of the sectors:

a) In the primary sector, intensification or de-intensification processes should take place.
b) In the secondary sector, a change in growth rate or a change of capital/labour inputs should be observed.
c) In the tertiary sector, a tourist industry should exist.

Within the *primary sector* intensification and/or de-intensification processes, especially in agriculture, are identified to have major effects on levels of biodiversity (e.g., Tilman et al., 2005). Intensification/de-intensification should therefore be measured with reference to increasing or decreasing inputs [e.g., in Joules, tons, labour] per unit of land area over time. In the *secondary sector* – contrary to the case of agriculture – the intensity of land use cannot be measured directly. Here, it is useful to measure the industrial pressure by a change in growth rates and/or a change in the relation of labour and capital inputs. The relation of capital and labour additionally delivers important information regarding time use changes that may come up with further shifts e.g., in nature relevant leisure behaviour. In the *tertiary sector* it seems crucial to focus on the tourist industry since we simultaneously have to deal with short and long-term effects. Tourism, for example, increases the stress on ecosystems due to a temporary enlargement of the population size, but also by long-term decisions regarding land use and infrastructure (hotels and streets, for example, remain irrespective of the duration of the tourist season).

Of course, taking into account all three sectors of an economy calls for a certain size of selected site. However

[2] Moreover, dependent on the region where the site is located, it might be useful to collect data on the number of people growing their own vegetables and having their own life-stock (including data on the extent of these activities). This data helps to gather knowledge on the existence and the intensity of an informal economy which may have important impact on local and regional ecosystems as well.

from a socio-economic perspective, it is not the size of the site in terms of land area that is important, but rather the diversity of the social system within the site. Depending on the development of the countries the sites are situated in, the spatial dimension of the site that is necessary to exhibit this diversity can be very different. From a socio-economic point of view it was thus more enlightening to focus on income instead. This is all the more the case, since long-term observations of income variables allow conclusions to be drawn regarding the shape and relevance of the Environmental Kuznet Curve (e.g. Dasgupta et al., 2002; Grossman and Krueger, 1993).

The Environmental Kuznet Curve predicts a turning point regarding environmental quality degradation after economic growth (income per capita) reaches a certain peak. In relation to biodiversity issues, environmental quality can be understood in terms of habitat quality for example. Long-term observation of income data and the status of biodiversity consequently make it possible to test whether a relation between income and environmental quality holds at all in the biodiversity context. If so, further conclusions must be made about whether the site-specific Kuznet Curves are generally an inverted u-shape, what level of income is critical for the definition of a turning point, whether site-specific differences exist; and in which part of the curve the site under consideration is located.

2.1.3. *Criteria 3: Conservation relevant policy*

Box III

> Site-specific *policies* addressing biodiversity issues should be implemented and governmental or private investments in biodiversity conservation and improvement should be present. The possibility of *participation* by stakeholders from all three economic sectors (primary, secondary and tertiary sector) should be ensured.

In general, policy refers to social objectives formulated by a governing body and includes specific measures to attain these objectives (e.g. regulations, subsidies, incentives, etc.). Objectives and measures may have adverse side effects on the ecosystem, but are usually not studied with regard to their overall performance. To contribute to a holistic assessment site-specific policies have to be implemented, which address biodiversity issues; and government or private investments in biodiversity conservation have to be made. Here, we explicitly call for both elements: policies that impact on biodiversity *and* investments in nature conservation. The reason is that biodiversity-relevant policies are not necessarily aimed at biodiversity protection. To study the performance of government or private investments that relate directly but also policies that relate indirectly to biodiversity issues as well as to highlight the relationships between these policies, each type of policy must actually be present in the selected sites.

Special attention should be given to (a) questions concerning the dynamic efficiency and ecological effectiveness of policies and measures that are directly aimed at halting the loss of biodiversity and (b) the relation of policy implementation and innovations that are relevant for biodiversity conservation. This approach will provide an insight into whether and to what extent improvements regarding the status of biodiversity can be accelerated by policy measures. Moreover, it may also offer some hints as to whether the arrival of a turning point (as specified in the Environmental Kuznet Curve; see criterion 2, above) can be stimulated, and whether environmental improvements (e.g. by higher investments in nature conservation) positively feed back into the status of biodiversity.

Additionally it seems crucial for long-term socio-ecological research to address the question of the public's environmental education. Therefore participation by stakeholders from all three economic sectors (primary, secondary and tertiary sector) should be ensured. Sites showing this characteristic secure the involvement of interest groups for formulating site-specific policies. This in itself implies that information must be conveyed to the public. Thus, it is possible to study the impact of knowledge accumulation (e.g. by educational measures or scientific research) on the status of biodiversity. Moreover, this offers a basis for socio-economic research to contribute and improve its knowledge of social processes (e.g. the increase in conflicts) that cannot be studied if stakeholders are not aware of, and cannot influence biodiversity-related policy.

2.1.4. *Criteria 4: Local conflict*

Box IV

> Selected LTSER-sites should show *local conflicts* that have a potential effect on biodiversity (e.g. investments in new infrastructure versus investments in conservation). To understand and resolve dissent it is essential to gather information on the *socio-economic profile* of a community.

Local conflicts are often embedded in the socio-economic profile of the local population (age, sex ratio, employment etc.). However the socio-economic profile of a community within LTSER-sites cannot be specified by prescribing certain percentages of e.g. male and female inhabitants. We therefore refer to local conflicts (e.g. investments in infrastructure versus investments in conservation) that in many cases lead to social dilemmas.

A common characteristic of social dilemmas is a conflict between individually preferred action and socially (commonly) desired outcomes (e.g. Hardin, 1968; Platt, 1973; Dawes, 1980). This conflict may refer either to the local people of the selected area itself or arise between people (decision makers) from both inside and outside the sites. The conflicts may be due to goals formulated by outside agents (e.g. scientists) or a higher, hierarchical level of public administration. They do not necessarily have to be open. They may rather be potential or gradual conflicts of interests, such as: generational conflicts, conflicting goals of development, and conflicts for which there are established mechanisms for coping that are already built into the social system.

Analyzing local conflicts reveals people's attitudes, beliefs, culture, tradition and social needs. Conflicts are also reflections of lifestyle, well-being and priorities in time allocation. Local conflicts drive biodiversity change by jeopardizing conservation activities. They pose constraints for policy-makers aiming at implementing biodiversity improvement measures; and they affect cooperation and information exchange. Conflicts are observed when social needs and the requirements of the public clash with the goals of government/administration, and/or interest groups (i.e. partisan goals). Biodiversity, habitat, or land protection may, for example, lead to restrictions of people's activities and therefore be perceived as a handicap for local development. However the reverse situations can also occur. For example at Sebarna Lake in Bulgaria, dike constructions, land drainage, and intensive agriculture led to a deterioration of water quality and quantity in the lake, acceleration of sediment trapping and decline in biodiversity. Local initiatives demanding the improvement of the situation by dike removal were not allowed within the protected areas (Uzunov, 2003). Thus, conflicts often lead to unpredictable consequences that vary locally (e.g. Dietz, 2003; Ostrom et al., 1993).

It therefore seems necessary to study and compare conflicts with regard to variables, such as employment, education, gender, cultural diversity/continuity, grassroots initiatives and time use by inhabitants. Information on these variables will support an understanding of people's motivation and interest to identify and resolve social dilemmas as well as to forecast trends in local policy and economic development.

2.1.5. *Criteria 5: Demography*

Box V

> Data availability on long-term *demographic trends* (of at least 50 years) and the *demographic structure* of the site population with a focus on existence of *migration* or *mobility,* i.e. immigration into/emigration out of the site and/or movement of people within the site.

Demography is one of the crucial factors influencing land use types and intensity, transformation of land cover and urbanization processes. It also determines the resource extraction and consumption rate, waste production and pollution release. All changes to the landscape and ecosystem performance resulting from demographic processes are persistent. Moreover some of their consequences may be irreversible e.g., decline of wetlands in Europe due to agricultural expansion (Paludan et al., 2002) or decrease of water retention potential due to the combined effect of climate variability and land transformations (Lee et al., 2006). The outcome of irreversible environmental changes is the decline of ecosystem services imposing, for example, a switch in people's activities and land use mode. To analyze such issues, data on long-term demographic trends (of at least 50 years) and the demographic structure of the site population is indispensable.

The database should also include information on more dynamic, short-term demographic processes such as migration or mobility, i.e. immigration into/emigration out of the site or movement of people within the site (commuting). Commuting activities change the pressure on the ecological systems in a less consistent, but more dynamic way than other population factors. As a consequence it triggers adaptation processes in ecosystems, but gives them less time to adjust compared to a situation in which the number of people varies mainly according to the birth/death ratio. Migration and mobility processes thus generate an empirical setting for analyzing the presupposed link between the carrying capacity of ecosystems and ecosystem resilience (e.g. Seidl and Tisdell, 1999), which is independent of the actual birth/death rates. With regard to people's mobility — the database should differentiate between primary commuters (driven by local unemployment and commuting to cities where there is a call for labour) and secondary commuters who fled from cities to live in an environment that meets their criteria for a comfortable livelihood (which in some cases gives rise to commuter belts). A specification of the distance of travel as well as the frequency of the commute should give additional information on the local impact on biodiversity and ecosystem resilience.[3]

The extreme cases of rapid, intense, but short-term migrations refer to tourism. Areas favoured by tourists often suffer from natural resource depletion and environment degradation linked to people's behavioural patterns of high consumption rate and waste generation (Neto, 2003). The threat to ecosystem performance is also related to people's preferences, which are directed towards the most vulnerable, rare or unique ecosystems with limited adaptive capacity, e.g. islands or high-altitude areas (UN, 1999, 2001). Man's activities also increase the danger of weed spreading, trampling and pathogens (Kelly et al., 2003). On the other hand, tourism may also score some successes in improving environmental quality by triggering measures for conservation and improvement of local biodiversity.

Moreover the movement of people poses conditions expected during the process of demographic change in less developed regions of the world. In these regions, economic growth is often important for enhancing living standards, even if this is detrimental to environmental quality. In future we may have to answer biodiversity-relevant questions in regions where population is dense, but living conditions are improved (which also characterizes many big cities today). Of course, studying pressures on ecosystems during the tourist season may not simulate the expected ecological effects in developing countries. However, it allows us to gain knowledge about the functional coherences within social systems that have to cope with processes of (here, mobility-induced) population growth. This may also help to devise scenarios regarding the ecological impacts expected to emerge in the course of poverty-induced migrations worldwide.

[3] The authors wish to thank their anonymous referee for emphasis of this critical issue.

2.1.6. Criteria 6: Land use and cover

Box VI

> At each site, three different *land use/cover* types have to be found: (1) at least one natural/semi-natural land type; (2) at least two types of agricultural land use and (3) at least one urban or suburban land type. Moreover sites should provide *land use* and *land cover data* according to international classifications (e.g. Corine).

Land use has been identified as one of the most crucial drivers of biodiversity change (Redman et al., 2004; Haberl et al., 2004). Land use lies at the interface between socio-economic and ecological processes. Hence it reflects changes in economic and demographic structure and an interplay between all previously listed criteria — economic diversity, demography, conflicts and policy goals. Availability of land use and land cover data therefore facilitates a contribution towards a comprehensive picture of the state of the ecosystem and threats to its functions. Observing the links between drivers and landscape structure allows for improved advance knowledge of the possible changes in goods and services delivery, and leads to conclusions about the current and future economic performance of the area.

It is, for example, well known that increasing population and people's aspirations are the main drivers of deforestation, urbanization and infrastructure development. These processes are a threat to many regulatory and provisional ecosystem services (MASR, 2005). Conversely, a release of land use pressure imposed by society, such as land abandonment, does not necessarily lead to an improvement of environment quality. The cause of land abandonment may be national policy (China), economic transformation (Central and Eastern Europe) and relocation of agriculture and lifestyle changes (Western Europe). Land abandonment changes soil characteristics, e.g., decreases fertility (Genxu et al., 2004), bulk density (Liu et al., 2002), opens pathways for exotics invasion (Domènech et al., 2005) and causes a decline of native open-space species. Hence, contrary to public expectations, abandonment rarely enables recovery of original ecosystems and their services.

To observe the trends in land use changes, their ecological and socio-economic consequences and to identify and quantify the processes, the study area has to include different types of land use: natural and semi-natural, agricultural types that show different intensities of man's activities, and urban or suburban types.

Natural landscapes allow for identifying the basic matrix for geochemical and ecological processes. These are important from the viewpoint of ecosystem recovery, restoration and cultural services. Many of them, however, are excluded from management, as they are under protection (e.g. national parks). Urban areas provide information about extreme land transformations resulting from present and past societal goals and constraints. To a large extent, they generate income for local and regional communities and trigger land modification on sites that are in close proximity of one another. Long-term studies of these processes allow for insights into the costs and gains of industrialization and urbanization. Furthermore suburban and rural areas are places where the interplay between man and nature occurs in the most pronounced way. They are a space for the battle between conservation, utilization and exploitation approaches to nature.

The inclusion of both the aforementioned land use types and the different sectors of the economy (see Criteria 2, above) help in the development of bioregional management. According to Miller (1996), management falls into three categories: protection *against*, *through* and *despite use*. Within the first category land should be used for no other purposes than nature conservation (e.g. national parks). As regards the second category (protection through use) the idea is to protect biodiversity wherever it is found — in farmlands, utilized forests, fishing grounds; and not just within the boundaries of protected areas. This category calls for identification of incentive schemes that guarantee sustainable development of biodiversity with regard to individual decision-making processes. This is the most important option in the agricultural landscapes of Europe (WBGU, 2001) and is most prominently undertaken in suburban and rural areas. With respect to the last option (protection despite use) there is no need for management due to: a lack of risk to the ecological state, low risk only, or because economic activities are so profitable that policy intervention for the purpose of biodiversity conservation should not take place (e.g. in urban and suburban sites). Thus, inclusion of different land use types delivers a sound basis for elaborations on all three management options.

2.2. Pool criteria

Pool or network criteria were specified with regard to an interlinked group of sites, which can operate on the basis of data sharing. Such networks, like ILTER (International Long-Term Ecological Research Network), incorporating numerous sites across the world, enable description and comparison of processes, large samples, scenario building, and the identification of best practices adjusted for present and forecasted ecosystem conditions. It is therefore suggested that the network of sites should comprise either a number of contrasting sites (north–south, more, and less developed countries) or similar sites with regard to one, a few or many features. There are three criteria proposed in this set: (1) vulnerability of the economic system; (2) local trade relations; (3) differences in economic development.

2.2.1. Criteria 1: Vulnerability

Box VII

> In the pool of selected sites *vulnerability* due to biodiversity changes should be demonstrated. Also an obvious link (at least one, but ideally two for comparison) between ecosystem services and socio-economic development should be found, i.e. the dependency of economic sectors or populations on a limited number of species or ecological processes.

Questions referring to social vulnerability incurred by the co-evolution of natural and social systems are crucial in the face of global changes. Sustainable development will not be a realistic goal unless a social group and/or an economic sector vulnerable to loss of particular ecosystem services is identified and studied with regard to relevant policies. The loss of services, for example, can be caused by the combined effect of climate change, atmospheric composition, and land use with policy and type of resource use being superimposed onto this. Vulnerability can be perceived as both susceptibility and sensitivity to impact or as adaptive capacity to cope with the effect of disturbances (Mitchell et al., 1989; Turner et al., 2003; Metzger et al., 2005).

A strong relation between the local economy and ecosystem goods was shown in Newfoundland, where people's well-being was based on cod fishing. The decline of the fish stock caused by a harvesting method that pushed the fish population below a sustainable level resulted in the industry's collapse and high social costs (4 billion Canadian dollars for unemployment programmes alone) (Smith, 1996). A long-term interrelation of a similar type was analyzed by Luers et al. (2003). They looked at the vulnerability of the agricultural sector in Yaqui Valley, Mexico, with regard to climate change and the price of crops. They identified two critical factors – soil type and management level – defining the system's adaptive potential. The results showed that an average minimum temperature increase by 1 °C increases the vulnerability of the average farm by 10%. When considering prices, Luers et al. suggested that a 10% decrease in the price of crops raises the vulnerability of the average farm by 30%.

As set out by Mischung (1980), societies differ in their capabilities to adapt to environmental changes. In the pool of selected socio-ecological sites, the presence of vulnerable social systems as case studies for dependence on biodiversity is therefore required to enhance the knowledge of factors determining the adaptive capacities. A clear link (at least one determining factor, but ideally two for comparison) between ecosystem services and socio-economic development will enable the study of the dependence of economic sectors or populations on a limited number of species or ecosystem services. In this way, such a research endeavour can contribute to a development of relevant problem-solving approaches. It also gives valuable information on the links between ecosystem services and socio-economic development. Such an approach creates the possibility for analyzing the co-evolution of society, biodiversity, and management strategies.

2.2.2. *Criteria 2: Local trade relations*

Box VIII

Local trade relations focuses on the relation of total resources locally produced or extracted – either for local use or export from the site – to resources imported from outside the site. Sites should fall into three categories:

$0-15\%, 15-30\%, 30+\%$

These rates refer to the amount of *biomass* and *minerals* produced/extracted on site that are also consumed there, i.e.: exports and imports should be separately quantified.

In order to analyze the effects of trade relations on biodiversity, we are looking for a range of sites along the *subsistence–trade-integrated* range of economic performance: the lower the percentage range, the higher the dependency is on imports and vice versa. The question implicit to this criterion is whether a *closed* or *open* economy has beneficial or negative effects on biodiversity.

Trade may serve as a tool for solving environmental degradation problems but may also be the underlying cause of it. Imports and exports of hazardous waste, especially from developed to developing countries or countries in transition (e.g. the export of chemical waste) may serve as examples for hampering improvements in environmental quality by transferring inherent environmental problems to other places instead of solving the problems (e.g. Beck, 1986). Moreover, the worldwide trend to convert agricultural land to other uses in the course of development reduces both the quantity as well as the quality of this land use type. In consequence, national food security often depends on imports from other countries. This may induce negative side effects regarding the status of biodiversity in each of the involved countries: pressure to produce more food with lower quantities of agricultural land may foster the use of fertilizers, the import of genetically engineered food replacing traditional crops, and the use of technologies enhancing the attractiveness of uniform land use patterns (monoculture) that destroy habitat heterogeneity and are therefore detrimental to biodiversity protection.[4] At the same time, trade may improve the status of biodiversity through various channels, e.g. by a transfer of knowledge, the implementation of common governance strategies, and the transfer of environmentally-friendly technologies. For example, technology transfer has been applied between countries in order to achieve the goals of the Kyoto protocol designed to reduce greenhouse gas emissions (e.g., Endres and Ohl, 2005; Oberthür and Ott, 1999) and to govern a safe transfer of GMOs (genetically modified organisms) under the Cartagena Protocol (UNEP, 2003).

Thus in view of trade it is crucial to elaborate upon whether societies do well in biodiversity protection by taking conservation-friendly measures at home or by transferring biodiversity-related side effects of society's activities and consumption demands to foreign countries. Furthermore, different categories of sites representing various levels of economic *openness* enhance knowledge regarding region-specific, trade-related shifts in the use of renewable raw materials as well as between renewable and non renewable resources. These observations regarding the quality of trade networks provide a basis for sound recommendations of sustainable policy design, for example, whether or not there is the necessity of extending the idea of comparative land compensation (up until now applied on the national level only) to a policy of inter-regional land compensation (applied within the boundaries of e.g. Europe as a whole).

[4] These effects may to some extent be counterbalanced by converting forest areas into agricultural land. In any event, it changes the status of biodiversity.

2.2.3. Criteria 3: Economic development

Box IX

> Inclusion of two *differing types of economies* (in terms of income levels) in areas with similar resource endowments in each European region (North, Mediterranean, Central Europe, Western Europe).

Fulfilling this criterion helps explain the influence of income levels on the state of biodiversity either positively (higher investments in protection or restoration) or negatively (exploitation of resources or ignorance) under the condition of similar resource potentials. The inclusion of different economies in the pool of sites also allows for the study of similarities and differences regarding the Environmental Kuznet Curve (Section 2.1.2, above). Such curves have mainly been shown for emissions of pollutants but not for stocks of resources (e.g. Arrow et al., 1995). And it remains an open question as to whether poverty reduction (improvements in the quality of life related to economic growth and differing income levels) is a prerequisite for improvements in the ecological system or whether improvements instead depend on the abilities of a society to transform quantitative growth into qualitative development (e.g. Max-Neef, 1995).

Long-term research at different sites helps to clarify – for different spatial scales – whether, in general, threshold points exist beyond which societies care more about improvements in environmental quality (e.g. by setting up environmental legislation for the protection of the environment as soon as standards of living are sufficiently high) and, in the case of the thresholds' existence, which qualities they show along north–south and east–west gradients in Europe.

In essence, the question to be answered is whether environmental improvement or deterioration occurs in relation to ongoing economic growth. To answer this question the inclusion of different economic types with similar resource endowments in various regions helps to give an insight into regional differences: on the one hand relating to the link between the development of economic growth and income; and on the other hand, relating to the status of biodiversity and the development of resource stocks, ecosystems and ecosystem services. This knowledge helps to determine region-specific effects of growth-related policies and the point in time that such policies are most effective (positively or negatively) in terms of biodiversity conservation. Simultaneously it allows us to study long-term correlations between developments in income and resource depletion with respect to different stages in development (initial income levels).

3. Summary and outlook

Living in Anthropocene implies the inclusion of a socio-economic dimension in standard ecological research. This paper presents two sets of criteria: site and pool criteria. The two sets were elaborated upon in order to meet the needs of the Long-Term Ecological Research Network and to transform this towards the Long-Term Socio-Ecological Research Network. Each set can be used, however, by other emerging or existing research networks and sites that wish to broaden the scope to incorporate a socio-economic dimension. Each criterion was designed to study a broad range of activities that span both the ecological and social system. In combination, the criteria can be used to explore both aspects: a quality label for transition of traditional ecological sites, and a matrix for establishing and developing new research areas. As a first stage in ALTER-Net – A Long-Term Biodiversity, Ecosystem and Awareness Research Network – ten sites[5] have been selected to initiate LTSER research as a concerted effort made by European researchers. Eventually this group of sites shall be widened to include a broader diversity of locations in different regions. To select these research sites a host of ecological and taxonomical criteria has been applied. Since LTER and also ALTER Net are research groups dominated by natural scientists (mostly taxonomists and ecologists), criteria that reflect social behaviour and interaction between society and nature have only recently found their way into the selection process. It is therefore an overarching task of future site research to analyze whether socio-economic criteria were sufficiently considered and whether these criteria help with the selection of sites.

With respect to research in the LTSER-sites, a broad range of questions should be answered that touch upon the interface of social and ecological systems. For example:

- What is the social perception of and resource demand from nature, biodiversity and ecosystem services? What are the underlying values, beliefs and attitudes?
- How does the interplay of local, regional and global policy design at various governance levels drive the interaction of dynamic society–nature processes? How are these processes related to the goals of society and how can they be managed to achieve sustainable development?
- Which design of instruments and policy measures integrates economic, social and ecological considerations for sustainable management of biodiversity in a coherent and mutually reinforcing way? What are the adequate governance structures, which allow key functions of biodiversity and ecosystems to mitigate and adapt (within the desired boundaries) from a long-term, cross-scale spatial and multiple actor perspective?

Answering these questions not only calls for an integration of key findings from various disciplines. It also requires the participation of public and private actors to establish a link between scientific tasks and social demands. Moreover it calls for the development of concepts and methodologies that provide a common language for addressing such questions and for transferring knowledge across disciplines and sectors. The future will show whether the selected research sites are capable of providing a basis for LTSER to meet these challenges.

[5] These are in Aberdeenshire in Scotland (UK), Nora in Sweden, Veluwe in The Netherlands, Pilica river catchments in Poland, Pleine Fougères in France, Eisenwurzen in Austria, Balaton lake and catchment in Hungary, Braila islands in Romania, Donana in Spain and recently Leipzig–Halle in Germany.

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