ELSEVIER

Land Use Policy 21 (2004) 193–198

Land Use Policy

www.elsevier.com/locate/landusepol

Editorial

Land use and sustainability indicators. An introduction

Abstract

Bioproductive land is one of the most significant natural resources. People use the land for receiving ecological services. This leads to humans using and favouring certain species, while competing with all other species. Land use can create diverse cultural landscapes of outstanding aesthetic, economic and ecological value, but it may equally result in land degradation, soil loss and impoverished ecosystems. Hence land use is shaped by processes of society–nature interaction. These processes can detract from sustainability—in other words, society–nature interaction may deplete the natural capital upon which the provision of ecosystem services for humans depends. Sustainability indicators aim at monitoring key aspects of society–nature interaction in order to generate information needed to document the current state and the history leading up to it. Moreover, they are useful to communicate complex sustainability problems within the scientific community, to policy-makers and the broad public. This paper introduces a special issue that seeks to contribute to the development of sustainability indicators that track society–nature interaction. We focus on a variety of concepts that measure socio-economic metabolism. All the discussed approaches relate socio-economic energy and material flows to the bioproductive area needed to support them, above all, the ecological footprint and the human appropriation of net primary production. In addition, this special issue also analyses the consequences of land use intensity on the diversity, naturalness and patterns of landscapes.

Keywords: Sustainability; Sustainability indicators; Land use; Ecological footprint; Socio-economic metabolism; Landscape ecology

Introduction

There is ample evidence to suggest that the sheer scale of human activities on Earth is unprecedented. While it took human world population 100 years from 1850 to 1950 to double from 1.2 billions to 2.4 billions, world population increased by a factor of 2.4 to about 6 billions in only 50 years since 1950 (Cohen, 1995). Of the global terrestrial vertebrate biomass, only about 3% are wild living animals. Human bodies account for about one-third of the remaining 97%: the remainder are domesticated animals (Smil, 1992). According to one study, about 36% of the Earth's bioproductive area is currently entirely dominated by man, 37% is partially disturbed, and only about 27% undisturbed (Hannah et al., 1994). Another study comes to the conclusion that 83% of the terrestrial surface is under direct human influence (Sanderson et al., 2002). Humanity's total energy input currently amounts to about 30% of the potential net primary production (NPP) of terrestrial ecosystems and will be about 50% of terrestrial NPP in just 50 years if current trends continue (Haberl, 2000). Through deforestation and fossil fuel use, humans have already increased the atmospheric concentration of CO_2 by about one-third in the last 150 years. Taken together, these and other examples impressively demonstrate the degree to which humans "dominate" global ecological processes (Vitousek et al., 1997). It is now widely recognized that these processes result in global environmental changes that occur at an increasing pace (Steffen et al., 2002).

At the same time about 1.2 billion people, one-fifth of the world population, live in extreme poverty on less than US$1 per capita and day—although the world economy grew by 3.1% annually between 1980 and 1990, and by 2.5% annually between 1990 and 1998. Poverty and inequity are main factors resulting in hunger, lack of education, sanitation and clean drinking water, poor health, short life expectancies, etc. There is growing conviction not only that the increasing number of global environmental problems requires international solutions, but also that it is necessary to solve environmental, social and economic problems at the same time. This is the core of the notion of sustainable development (UNEP, 2002).

Attempting to tackle these daunting problems requires new solutions. There is ample evidence—also in this special issue (Krausmann et al., 2004)—that the

0264-8377/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.landusepol.2003.10.004

traditional sectoral, disciplinary approaches will not work. The sustainability debate has shown that economic, social and environmental concerns need to be seen and solved in the context of each other. All the above mentioned problems are shaped by society–nature interaction, processes that can only be examined through interdisciplinary research that cuts across traditional boundaries between the social sciences and humanities on the one hand, and natural sciences on the other. One such approach is socio-economic metabolism: In this approach socio-economic systems are conceptualised in a dual way, as symbolic and biophysical entities at the same time. Such an approach is useful because it builds bridges between social and natural sciences (Fischer-Kowalski and Weisz, 1999; see Haberl et al., 2004a for more details).

This special issue assembles a set of papers that aim at deriving sustainability indicators based on the socio-economic metabolism concept. Its focus is on indicators that relate socio-economic metabolism to land use, one of the most dominant processes of society–nature interaction that contribute to environmental change. Indicators, be they economic, social or environmental, are important because many social, economic and environmental processes are not directly visible on the scales on which political decisions are taken; e.g., on the regional or national scale. Indicators are powerful tools to simplify, quantify and communicate information on processes such as society–nature interaction that are too complex to be measured and perceived directly (Hammond et al., 1995). They are meant to contribute to informing and sharpening debates on sustainability, land use and economic policies aimed at solving the problems outlined above.

In this vein, this special issue assembles ten complementary papers that discuss tools and their applications as well as the significance and opportunities measures of socio-economic metabolism present for policy-making. Six of the papers focus on methods to derive indicators: of these, four examine the most recent approaches and applications of ecological footprints (Erb, 2004; Monfreda et al., 2004; Wackernagel et al., 2004a, b). One considers the 'material and energy flow accounting' (MEFA) toolbox that also includes human appropriation of net primary production (HANPP) (Krausmann et al., 2004), and one an approach for comparing the sustainability of landscapes based on remotely sensed GIS data (Peterseil et al., 2004). Two papers focus on conceptual and theoretical issues that are common to a number of tools: Haberl et al. (2004a) discuss basic conceptual issues of observing progress towards sustainability, whereas Haberl et al. (2004b) compare basic conceptual considerations and research questions driving HANPP on the one hand, and the ecological footprint on the other. Three papers present case studies, two on Austria (Erb, 2004; Wrbka et al., 2004), one compares three countries (Austria, South Korea, and the Philippines) to the global level (Wackernagel et al., 2004a). One paper uses broad empirical datasets to test hypotheses on the relations between HANPP and landscape structure (Wrbka et al., 2004).

All ten papers underline the importance of reliable measurement tools in managing for sustainability. They also recognize that a number of tools are necessary, since each tool is limited to specific research questions. Hence part of the challenge is to choose the right tool for the right task, and another one is to make sure each tool can deliver what it has set out to do. The following sections outline the main arguments that each paper contributes to this overall effort.

Socio-economic metabolism and sustainability

The paper by Haberl et al. (2004a) discusses how the analysis of socio-economic material and energy flows within the so-called MEFA framework contributes to understanding society–nature interaction. The paper argues that MEFA provides a consistent toolbox to track biophysical flows associated with the operation of socio-economic systems for regions of any scale over time. Moreover, the MEFA framework is organised in a way that allows the linking of all physical flows to social and economic data and indicators, which is especially rewarding on the national scale on which most socio-economic data are available. Because sustainability requires to maintain vital physical exchange processes between societies and their natural environment, while at the same time improving economic prosperity and social equity, the compatibility of MEFA and socio-economic accounts is essential for providing analytical links among these domains.

How the MEFA framework can be used to analyse the relations between socio-economic metabolism and economic development is demonstrated by Krausmann et al. (2004). The paper starts by discussing methodological issues of materials and energy flow accounting, and then uses Austria 1950–2000 to show how MEFA tools can be used to analyse the relations between economic growth, socio-economic metabolism and land use. One of the most stunning results presented in this paper is that import and export flows, measured in physical units such as tonnes or joules, increased exponentially over the whole period analysed, whereas domestic extraction saturated and remained more or less constant over the last decades, demonstrating the increasing integration of industrial economies in a global market. The paper also challenges the convenient notion of the 'Environmental Kuznets Curve' (EKC) that environmental pressures are bound to dwindle with increasing per-capita GDP after some turning point has been reached: it shows that, even if EKCs have been demonstrated for pollutants that can be reduced through end-of-pipe technologies, overall material and energy flows have shown stronger coupling with economic growth.

Both papers make a compelling case that material and energy flow accounts that can be linked to social and economic data and indicators are important databases for further research. For example, such databases are needed for the development of ecological-economic models that could be used to investigate, among others, how changes in lifestyles, policy measures, economic policy or many other social, economic or political factors might influence GDP, income distribution, and many other economic variables on the one hand, and biophysical dimensions such as material resources, energy or land on the other hand (Duchin, 1998). Moreover, such data are also needed for sociological analyses that could reveal how household income and the physical consumption of households might be related to lifestyles or the quality of life (Fischer-Kowalski, 1998). Nevertheless, while it may be plausible that increases in materials and energy throughput are detrimental to sustainability (Haberl et al., 2004a), much work remains to be done to establish a more explicit link between socio-economic metabolism and sustainability.

Human footprints on the earth

An approach which has received a lot of attention in recent years because it captures in a simple yet comprehensive way humanity's draw on nature is the ecological footprint. The ecological footprint casts a strictly utilitarian view on society–nature interaction by comparing the amount of bioproductive area available to the amount required to maintain the resource flows of a defined human population. More specifically, ecological footprint studies evaluate how much bioproductive area is needed to produce the biomass consumed, to host the buildings and infrastructure, and to absorb the wastes (above all, CO_2) generated by a human population. On a global level, the interpretation of a footprint calculation is straightforward: if humanity consumes more resources than the biosphere can regenerate this must lead to the depletion of natural capital and cannot be sustainable. Current calculations indicate that it takes the biosphere at least 1.2 years to regenerate what humanity consumes in 1 year (Wackernagel et al., 2002).

Four papers in this special issue are focused on footprinting. Monfreda et al. (2004) present the most advanced methods for calculating detailed ecological footprints of nations. Building on earlier accounts such as the one presented by Wackernagel et al. (1999), this paper starts by discussing the research question that is driving the accounting model, and the underlying assumptions that make it possible to provide a quantitative answer to the research question. Then the paper details the new data sources used, the most recent calculation method to analyse the demand on pasture and on fisheries, the way land categories of various uses and productivities are normalized, and the way energy footprints are calculated.

This methodological paper is followed by two empirical studies that present time series of national demands on nature. One uses the conventional ecological footprint approach (Wackernagel et al., 2004a), the other one builds on a related method to assess the "actual area demand" of an economy (Erb, 2004). Because (un)sustainability refers to a dynamic interaction process between socio-economic and ecological systems (Haberl et al., 2004a), being able to monitor resource demand and supply over time is central to sustainability science. Moreover, as previous attempts to establish footprint time series have shown (Haberl et al., 2001; Wackernagel et al., 2002), time series require an even greater amount of conceptual clarity, transparency of assumptions, and methodological sophistication than "snapshot" studies. Footprint studies attempt to answer different research questions, each of which requires a different set of assumptions (Haberl et al, 2004b; Wackernagel et al., 2004b). For example, one can ask how much of the global bioproductivity is appropriated by a country, or one can ask how much area is actually used to support this country's resource consumption.

Erb (2004) poses the second question. In a heroic number crunching effort he succeeded in calculating the total amount of bioproductive area required to support Austria's resource consumption over the time period of 1926–2000. In doing so, he considers the yields in all countries from which Austria imported biomass over this whole period and is hence able to show exactly where on Earth the areas are located from which Austria imported. He shows that despite the impressive increase in Austria's biomass metabolism analysed in the paper by Krausmann et al. (2004), the actual area needed to support these biomass flows remained about constant and was about as large as the bioproductive area contained in Austria's domestic territory throughout the whole time period—a remarkable result that can be explained by the massive increases of yields throughout this period. Since agricultural intensification may result in a host of environmental problems (e.g., biodiversity loss, soil depletion, ground water contamination, soaring energy inputs, etc.) the sustainability of these yield increases needs to be scrutinized (e.g., Krausmann et al., 2003).

Wackernagel et al. (2004a) present ecological footprint time series from 1961 to 1999 for three countries: Austria, the Philippines, and South Korea. This study uses two approaches, first the most recent version of the conventional ecological footprint method (Monfreda et al., 2004), and second an 'actual area demand' approach, similar to that employed by Erb (2004). A methodological difference between the two approaches is that the paper by Wackernagel et al. (2004a) uses a globally uniform 'yield of traded agricultural goods' to calculate the footprint of biomass imports. The study shows the growing ecological deficits of all the analysed countries, but also provides various ways of interpreting the data. For instance, the results can be put in the national or global context leading to different trends due to different population growth rates. Most striking is the example of South Korea. This country moved, over the last four decades, from being a low income to a highly industrialized country. At this time, South Korea moved from a footprint slightly smaller than its Biocapacity to a footprint nearly five times larger than its own Biocapacity.

Conceptual challenges encountered in calculating and interpreting Ecological Footprint time series are discussed in the complementary paper by Wackernagel et al. (2004b). It clarifies the underlying objective: documenting overshoot. Building on this premise, it identifies which research questions lead to what kind of calculation methods, particularly for translating resource amounts into area. The two main paths are using global yields when calculating the demand proportional to Biocapacity, and local yields when calculating actual area demand. It also illuminates questions and concerns from the literature about the Footprint of trade and why it may be misplaced to call the Footprint of fossil fuel 'hypothetical'.

The paper by Haberl et al. (2004b) compares the Ecological Footprint to a second aggregate measure used to assess human societies' draw on nature, the HANPP. While both measures relate socio-economic metabolism to land use and aim at providing insights about the sustainability of society–nature interaction—and the notions have even been used interchangeably (Field, 2001)—there are important differences between the two concepts. The paper compares the two concepts by discussing the research questions driving each of them. It concludes that the Ecological Footprint evaluates the aggregate amount of bioproductive area needed exclusively for resource extraction, waste assimilation and infrastructure of a defined population and is especially useful to compare the resource consumption profiles of different human populations. In contrast, HANPP identifies the intensity with which humans use the land on a defined territory. Its advantage is that it can map the intensity of socio-economic use of ecosystems in a spatially explicit manner.

Land use intensity and landscape structure

This ability of HANPP to relate socio-economic activities and metabolism to the intensity of land use in specific regions is exploited in the paper by Wrbka et al. (2004). This article presents an empirical study of the correlations between spatial patterns of HANPP and landscape structure in a study region located around St. Pölten in central Lower Austria (*Niederösterreich*). The study shows that, even in industrialized countries, spatial patterns of land use intensity—assessed as HANPP—can be explained to some extent by landform indicators such as elevation, slope, relief roughness. This indicates that natural preconditions are still setting limits to economically viable land use. Moreover, the study shows that HANPP correlates well with commonly used landscape ecological indicators of the naturalness of landscapes, confirming the hypothesis that there must be strong relations between patterns and process in landscape ecosystems. The most policy-relevant finding of the paper is that landscape diversity is largest in landscape cells ($1 \times 1\,\mathrm{km}^2$ sample plots used in this study) with intermediate levels of HANPP. Because landscape diversity is positively correlated with biodiversity, this means that in order to conserve biodiversity land use policy should aim at intermediate HANPP levels by conserving mixed land use patterns; i.e., diverse landscapes in which cropland agriculture, grasslands, and forestry coexist in small-scale patterns—contrary to the trend that can be observed throughout the last decades (Krausmann et al., 2003).

It would not have been possible to examine these interrelations between pattern and process in landscape ecosystems without a broad empirical basis. Creating this knowledge base for Austria's highly diverse landscapes was one of the aims of the SINUS project. Its methodological approach and some selected results are outlined in a separate article (Peterseil et al., 2004). The conceptual basis of this paper is the 'pattern and process' paradigm (Forman and Godron, 1986) and hierarchy theory (Allen and Starr, 1982). The SINUS approach focuses on the systematic linkages between two geographical scales: the regional and the local landscape level. For both scales independent datasets on the spatial configuration of landscape elements were created. Whereas an automatic classification of satellite images yielded a land-cover map of Austria's whole territory, a detailed field survey of landscape structure was conducted in 200 statistically representative sample sites of $1 \times 1\,\mathrm{km}^2$. The resulting database includes information about key attributes of Austrian agricultural landscapes like habitats, land management, patch origin types, naturalness and species richness. Two different methods—one using fuzzy logic algorithms, the other based on a regression model—were used to obtain maps describing the relative (un)sustainability of agricultural land use in Austria.

Land use can create diverse cultural landscapes of outstanding aesthetic, economic and ecological value, but it may also result in land degradation, soil loss and impoverished ecosystems. By trying to relate socio-economic processes to landscape-ecological patterns, these two papers aim to contribute to the development of land use policies—including resource, agriculture, forestry, and energy policies—that might eventually succeed in integrating economic, social, and ecological aims and would, thus, foster sustainability.

Concluding remarks

We offer the conceptual, methodological advances and empirical analyses presented in this special issue as a contribution to the growing literature on biophysical analyses of socio-economic development (Cleveland et al., 1984; Daniels and Moore, 2001; Martinez-Alier, 1987; Zonneveld and Forman, 1989), above all to strengthen their focus on the relationship between socio-economic metabolism and land use. Bioproductive land area is one of the most important and scarce natural resources on Earth. In using the land, humans compete with most other species for space and trophic energy. While HANPP studies show which percentage of the yearly energy flow in ecosystems is appropriated by humans and therefore unavailable for most other species (except those used by humans), the Ecological Footprint assesses whether the regenerative capacity of the biosphere in a given year with the given technology suffices to regenerate the resources people have used in this year. While the former focuses on the intensity of human use of ecosystems, the latter is able to inform us about possible overuse of resources (‘overshoot’). Moreover, the work presented in this special issue also demonstrates that HANPP is related to landscape structure and diversity, which is, in turn, relevant for biodiversity. All these pieces of information are necessary for the future development of integrated biophysical/economic models as well as for social-scientific research on the interrelations between lifestyles, population, resource efficiency, consumption levels, and income that could contribute to sustainability science and policy.

Acknowledgements

The research presented in this article was funded by the Austrian Federal Ministry of Education, Science and Culture in the research programme “*Kulturlandschaftsforschung*” (Cultural Landscapes Research; http://www.klf.at). The study is part of the project “Land use change and socio-economic metabolism: a long-term perspective” formally endorsed by the “Land-Use and Cover Change” (LUCC) project jointly sponsored by the IGBP and the IHDP (for details on this project see http://www.iff.ac.at/socec/affil/ihdp/htm/fslucmet.htm).

References

Allen, T.F.H., Starr, T.B., 1982. Hierarchy: Perspectives for Ecological Complexity. University of Chicago Press, Chicago.

Cleveland, C.J., Costanza, R., Hall, C.A.S., Kaufmann, R.K., 1984. Energy and the US economy: a biophysical perspective. Science 225, 890–897.

Cohen, J.E., 1995. How Many People Can the Earth Support? W.W. Norton & Company, New York, London.

Daniels, P.L., Moore, S., 2001. Approaches for quantifying the metabolism of physical economies, Part I: methodological overview. Journal of Industrial Ecology 5 (4), 69–93.

Duchin, F., 1998. Structural economics. Measuring change in technology, lifestyles, and the environment. The United Nations University, Island Press, Washington, DC; Covelo, CA.

Erb, K.-H., 2004. Actual land demand of Austria 1926–2000: a variation on ecological footprint assessments. Land Use Policy, doi:10.1016/j.landusepol.2003.10.010.

Field, C.B., 2001. Sharing the garden. Science 294, 2490–2491.

Fischer-Kowalski, M., 1998. Das magische Dreieck von Wirtschaft, Lebensqualität und Umweltbelastung: Kopplungen und Entkopplungen. In: Krainz, E.E., Simsa, R. (Eds.), Die Zukunft kommt-wohin geht die Wirtschaft? Gesellschaftliche Herausforderungen für Management und Organisationsberatung. Wiesbaden, Gabler, pp. 56–73.

Fischer-Kowalski, M., Weisz, H., 1999. Society as hybrid between material and symbolic realms, toward a theoretical framework of society–nature interrelation. Advances in Human Ecology 8, 215–251.

Forman, R.T.T., Godron, M., 1986. Landscape Ecology. Wiley, London, New York.

Haberl, H., 2000. Energetischer Stoffwechsel und nachhaltige Entwicklung. Natur und Kultur 1 (1), 32–47.

Haberl, H., Erb, K.H., Krausmann, F., 2001. How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926–1995. Ecological Economics 38 (1), 25–45.

Haberl, H., Fischer-Kowalski, M., Krausmann, F., Weisz, H., Winiwarter, V., 2004a. Progress towards sustainability? What the conceptual framework of material and energy flow accounting (MEFA) can offer. Land Use Policy, doi:10.1016/j.landusepol.2003.10.013.

Haberl, H., Wackernagel, M., Krausmann, F., Erb, K.-H., Monfreda, C., 2004b. Ecological footprints and human appropriation of net primary production: a comparison. Land Use Policy, doi:10.1016/j.landusepol.2003.10.008.

Hammond, A., Adriaanse, A., Rodenburg, E., Bryant, D., Woodward, R., 1995. Environmental Indicators, a Systematic Approach to Measuring and Reporting on Environmental Policy Performance in the Context of Sustainable Development. World Resources Institute, Washington, DC.

Hannah, L., Lohse, D., Hutchinson, C., Carr, J.L., Lankerani, A., 1994. A preliminary inventory of human disturbance of world ecosystems. Ambio 23 (4–5), 246–250.

Krausmann, F., Haberl, H., Schulz, N., Erb, K.-H., Darge, E., Gaube, V., 2003. Land-use change and socioeconomic metabolism in Austria, Part I: driving forces of land-use change 1950–1995. Land Use Policy 20 (1), 1–20.

Krausmann, F., Haberl, H., Erb, K.-H., Wackernagel, M., 2004. Resource flows and land use in Austria 1950–2000: using the MEFA framework to monitor society–nature interaction for sustainability. Land Use Policy, doi:10.1016/j.landusepol.2003.10.005.

Martinez-Alier, J., 1987. Ecological Economics. Energy, Environment and Society. Basil Blackwell, Oxford.

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed ecological footprint and biological capacity accounts. Land Use Policy, doi:10.1016/j.landusepol.2003.10.009.

Peterseil, J., Wrbka, T., Plutzar, C., Schmitzberger, I., Kiss, A., Szerencsits, E., Schneider, W., Suppan, F., Beissmann, H., 2004. Evaluating the ecological sustainability of Austrian agricultural landscapes—the SINUS approach. Land Use Policy, submitted for publication.

Sanderson, E., Jaiteh, M., Levy, M., Redford, K., Wannebo, A., Woolmer, G., 2002. The human footprint and the last of the wild. BioScience 52 (10), 891–904.

Smil, V., 1992. General energetics, energy in the biosphere and civilization. Wiley, New York.

Steffen, W., Jäger, J., Carson, D.J., Bradshaw, C. (Eds.), 2002. Challenges of a Changing Earth. Springer, Berlin.

UNEP, 2002. Global environment outlook 3, Past, present and future perspectives, United Nations Environment Programme (UNEP). Earthscan Publications, London.

Vitousek, P.M., Mooney, H.A., Lubchenko, J., Melillo, J.M., 1997. Human domination of earth's ecosystems. Science 277, 494–499.

Wackernagel, M., Onisto, L., Bello, P., Callejas Linares, A., López Falfán, I.S., Méndez García, J., Suárez Guerrero, A.I., Suárez Guerrero, M.A., 1999. National natural capital accounting with the ecological footprint concept. Ecological Economics 29 (3), 375–390.

Wackernagel, M., Schulz, N.B., Deumling, D., Linares, A.C., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., Randers, J., 2002. Tracking the ecological overshoot of the human economy. Proceedings of the National Academy of Sciences 99 (14), 9266–9271.

Wackernagel, M., Monfreda, C, Erb, K.-H., Haberl, H., Schulz, N., 2004a. Ecological footprint time series of Austria, the Philippines, and South Korea for 1961–1999: comparing the conventional approach to an "actual land demand" approach. Land Use Policy, doi:10.1016/j.landusepol.2003.10.007.

Wackernagel, M., Monfreda, C., Schulz, N.B., Erb, K.-H., Haberl, H., Krausmann, F., 2004b. Calculating national and global ecological footprint time series: resolving conceptual challenges. Land Use Policy, doi:10.1016/j.landusepol.2003.10.006.

Wrbka, T., Erb, K.-H., Schulz, N.B., Peterseil, J., Hahn, C.O., Haberl, H., 2004. Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators. Land Use Policy, doi:10.1016/j.landusepol.2003.10.012.

Zonneveld, I., Forman, R. (Eds.), 1989. Changing Landscapes: An Ecological Perspective. Springer, New York, Berlin.

Helmut Haberl
Department of Social Ecology, Institute for
Interdisciplinary Studies of Austrian Universities,
University of Vienna, Schottenfeldgasse 29,
1070 Vienna, Austria
E-mail address: helmut.haberl@univie.ac.at
URL: http://www.iff.ac.at/socec

Mathis Wackernagel
Redefining Progress,1904 Franklin Street, Oakland,
CA 94612, USA
E-mail address: wackernagel@RedefiningProgress.org

Thomas Wrbka
Department of Conservation Biology, Institute of
Ecology and Conservation Biology, University of Vienna,
Vegetation Ecology and Landscape Ecology,
Althanstraße 14, 1090 Vienna, Austria
URL: http://www.univie.ac.at/IECB