Taylor & Francis
Taylor & Francis Group

Sustainability: Science, Practice and Policy

ISSN: (Print) 1548-7733 (Online) Journal homepage: https://www.tandfonline.com/loi/tsus20

Ecosystem services between sustainability and efficiency

Roland Olschewski & Alexandra Klein

Sustainability: Science, Practice, & Policy
http://sspp.proquest.com

COMMUNITY ESSAY

Ecosystem services between sustainability and efficiency

Roland Olschewski[1] & Alexandra Klein[2]
[1] Economics and Social Sciences Unit, Swiss Federal Research Institute WSL, Zürcherstrasse 111, Birmensdorf, 8903 Switzerland (email: roland.olschewski@wsl.ch)
[2] Ecosystem Functions Group, Institute of Ecology, Leuphana University of Lüneburg, Scharnhorststrasse 1, Lüneburg, 21335 Germany (email: aklein@uni-leuphana.de)

Authors' Personal Statement:

During the last couple of years we (an economist and an ecologist) have been doing joint research on multiple ecosystem services across countries and continents. Realizing that environmental scientists of different disciplines sometimes use the same words—such as sustainability or efficiency—with distinct meanings, a crucial basis for our successful teamwork has been to define clear terminology and a mutual understanding of what we are talking about. Our impression was that many scientists, practitioners, and politicians feel the same, and would appreciate greater clarity concerning technical terms sometimes used in a colloquial way. This situation motivated us to write this essay. The Millennium Ecosystem Assessment has shown that it is an ambitious task to combine fragmented and disciplinary knowledge in a common inter- and transdisciplinary language. Our essay is meant to take up part of this challenge.

Introduction

The notion of ecosystem services cuts across ecology and economy and calls for overcoming science's fragmented and disciplinary nature (Norgaard, 2008). At the same time, clear and comprehensive definitions are required to avoid misunderstandings of the approach as a whole (Ghazoul, 2007a; 2007b; 2008a; 2008b; Allsopp et al. 2008; Klein et al. 2008; Kremen et al. 2008). The Millennium Ecosystem Assessment (MA) defines different kinds of ecosystem services and distinguishes among providing, regulating, supporting, and cultural servicing (MA, 2005). Although a valuable concept, it has been criticized for mixing processes ("means") for achieving services with services themselves ("ends") (Wallace, 2007; compare also Fisher & Turner, 2008).

In this essay we focus on another drawback, namely the challenge of adequately taking "sustainability" into account. As Norgaard (2008) remarks, neither the MA's conceptual framework nor the empirical literature reviewed distinguishes ecological services provided by sustainable ecosystem flows from those generated through ecosystems slowly degrading over time, such as overused forests. We discuss here the ecosystem-service approach using pollination services as an example. We first distinguish between weak and strong sustainability, then consider efficiency requirements and their relationship to sustainability, and finally show the implications for policy recommendations as well as for the overall concept of ecosystem services.

Sustainability

Sustainability refers to a concept of equity across generations and has been generally defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (WCED, 1987). In the following, we discuss two more specific definitions of sustainability: equity-based and utility-based.

The equity-based definition of sustainability requires preserving the rights of future generations as an act of bequeathing based on distributional fairness (Norton & Toman, 1997). In contrast, utility-based sustainability strives to maintain the capacity to provide nondeclining per capita welfare in the future (Neumayer, 2003). Concerning the latter, it is crucial to distinguish between weak and strong sustainability. In the case of weak sustainability, it is assumed that natural resources and the services they provide can be replaced by other forms of capital, such as human-made (built) capital, as long as the same welfare level can be assured (Hartwick, 2000). In contrast, strong sustainability requires a constant level of natural capital without the opportunity of being substituted by built capital (see Figure 1). The physical maintenance of natural capital implies that renewable resources (e.g., habitats or resources of organisms providing ecosystem services) should be used in such

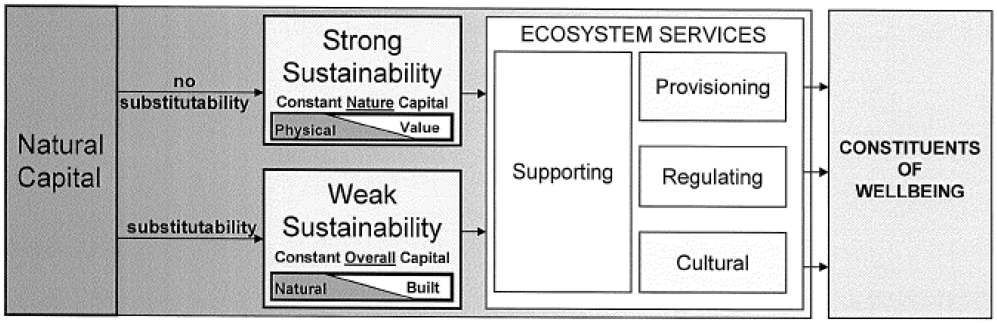

Figure 1 Substitutability of natural capital and its impact on the provision of ecosystem services (based on MA, 2005).

a way that the extraction is compensated by regeneration, while nonrenewable resources should not be extracted at all.

Efficiency

Efficiency in the broad sense is realized if a determined goal is achieved with minimum input or, alternatively, a certain fixed input is used in such a way that it leads to a maximum output. Both cases imply the "absence of waste" as a condition for efficiency (Samuelson & Nordhaus, 2001; Baumgärtner & Quaas, 2010). Efficiency can be claimed at various economic levels: for the household or firm, as well as for a society as a whole. Given that sustainability refers to developments in the future, a corresponding definition of efficiency should also comprise temporal aspects, resulting in the maximization of utility over time, i.e., intertemporal efficiency. This is usually achieved by discounting, which means giving less weight or importance to events that occur in the future. Discounting is often justified (i) by considering a positive time preference of the present generation (regarding future utility, e.g., from consumption, as worth less than today's) or (ii) by expecting future generations to be wealthier than the present one (Neumayer, 2007). However, these assumptions and resulting policy recommendations are controversial. A prominent recent example is the Stern Review, which—based on efficiency calculations—recommends immediate and comprehensive action against climate change (Stern, 2007). The review has been criticized for its economic assumptions and in particular for the low discount rates applied, which substantially increase the weight assigned to costs of climate change occurring in the future (e.g., Tol & Yohe, 2006; Nordhaus, 2007). However, Neumayer (2007) argues that the discounting debate actually misses the point: instead of dealing with efficiency questions, the major question is how to adequately tackle the issue of sustainability, and especially the nonsubstitutable loss of natural capital.

Goals or Constraints

The concepts of both intertemporal efficiency and intergenerational equity have been widely discussed over the last decade, comprising questions such as (i) how to achieve an efficient resource allocation by choosing appropriate discount rates or (ii) how to guarantee a certain level of per capita wellbeing depending on sustainability in terms of the strong or the weak senses. Additionally, several approaches have been developed to deal with uncertainty (Baumgärtner & Quaas, 2009). First is a utility-based interpretation of nature conservation that emphasizes the benefits of delaying irreversible decisions. These benefits can be defined as an "option value": the value of preserving, for example, a habitat to maintain the option to use it for other purposes in the future (Wesseler et al. 2003). Second are ethics-based principles that highlight precautionary aspects such as safe minimum standards for protected areas. Finally, rights-based principles advocate a "fair sharing" of opportunities across generations (Horwarth, 2007).

Evidence points to persisting basic discrepancies among different disciplines due to the way they understand sustainability and efficiency. For instance, while economists might regard efficiency as a goal to avoid wastefulness, and sustainability as a restriction to be considered when striving for this goal, ecologists tend to see sustainability as a goal in itself, reflecting the fundamental "inalienable" rights of future generations or nature itself (Pezzey, 1997; Howarth, 2007). Consequently, policy recommendations might differ substantially.

Pollination as an Ecosystem Service

In the following discussion, we present the implications of applying the ecosystem-service approach, illustrated by the example of pollination services for crop production. Here, capital in the form of natural and semi-natural habitats provides forage and nesting resources for bees, which in turn pollinate crop flowers. Several authors have shown that this service can result in increased fruit production (reviewed in Klein et al. 2007), and, in turn, even increased crop revenues (Ricketts et al. 2004; Olschewski et al. 2006; Veddeler et al. 2008). In its strictest sense, strong sustainability would mean that particular natural habitats (e.g., rainforest or heath land) should be physically preserved. In a wider application, strong sustainability would allow for a *limited* substitution between different forms of *natural* capital, as in the case of conserving bee habitat in agricultural landscapes to promote wild bee populations. In contrast, weak sustainability goes beyond and allows for a *complete substitution*, i.e., the destruction of habitats if their services as a provider of bee resources can be replaced with built capital without negative impacts on human welfare. Such an alternative is, for example, available for some crop species by renting privately owned bee colonies and introducing them into the crop fields, thereby assuring appropriate pollination.

It is important to note that the outcome of a *sustainability* analysis depends crucially on the particular way *substitutability* is applied. In addition, we show that both are interlinked with the question of short- and long-term land-use efficiency. As mentioned above, efficiency requires avoiding wastefulness: the benefits of a land-use decision should be higher than the costs. Therefore, the (opportunity) costs of nature conservation are to be determined and compared with the resulting benefits. Opportunity costs are defined as the benefits forgone by realizing a particular land use A instead of the best alternative B. In our case, these costs are incurred by conserving the pollinator habitats instead of using the land, say, for alternative crop production. Strong sustainability does not allow for substitution, thereby implicitly disregarding opportunity costs (Howarth, 2007). However, local smallholders are unlikely to take this perspective. They are well aware of production alternatives when making short-term land-use and management decisions (Benítez et al. 2006). For them and their livelihoods, weak sustainability can be seen as an appropriate approach concerning local pollination services: if private bee colonies are suitable as a substitute for natural capital, why bear the opportunity costs (forgone revenues) of conserving land as bee habitat?

Conflicts Between Efficiency and Sustainability?

Interestingly, sustainability in the weak sense is unlikely to be a binding constraint, because it allows for substitution within a wide range of different forms of capital. Under such circumstances, efficiency does not need to conflict with sustainability: efficiency would entail using the land for the most profitable alternative. If land use A (crop production) generates higher benefits than land use B (non-managed habitats), then efficiency would suggest replacing these habitats to avoid wastefulness. Moreover (and leaving ethical aspects aside), weak sustainability would allow such destruction of natural habitats as long as a replacement by private bee colonies is possible.

Despite this result, Ghazoul (2007a) points out that a trade-off between ecological and economic sustainability still arises through "the decline in ecological sustainability of the pollination services seemingly at odds with…economic productivity." He argues that renting private honey-bee colonies is economically more efficient for California almond farmers than maintaining bee habitats on their land. However, according to our definition, this situation can only be characterized as a "conflict" when applying sustainability in the strong sense, which is often claimed for so-called life-supporting functions of ecosystems, say, when calling for safe minimum standards of conservation (Neumayer, 2003).

The decisive question is whether it is appropriate to claim strong sustainability for pollination services as a life-supporting function of the natural ecosystem? Recently, Klein et al. (2007) found that up to 35% of global crop production benefits from biotic pollination, mainly from bees. Further, agriculture has become increasingly pollinator dependent over the last five decades and this trend is expected to grow in the future (Aizen et al. 2008).[1] Gallai et al. (2009) calculate that pollinators are responsible for 9.5% of the worldwide crop-production value of human food. Thus, natural and semi-natural habitats as

[1] Agriculture has become increasingly pollinator dependent because of increasing land devoted to pollinator-dependent crop production while land devoted to crop production without pollinators decreased in the developed world and slightly increased in the developing world (Aizen et al. 2008). The observed trend may have been caused by the increasing production of pollinator-dependent bioenergy crops (e.g., canola, rape, jatropha). For soya production, evidence was found that insect pollination can increase production of at least one important cultivar (Klein et al. 2007). A further example is increasing nut production, such as almonds in California. Furthermore, a general trend toward a balanced–diversified–human diet leads to increased production of fruits and vegetables, the majority of which are pollinator dependent (see also Aizen et al. 2008).

providers of diverse bee species substantially contribute to current crop production, thereby supporting the strong sustainability approach.

However, specific flowering conditions for, say, California almonds, lead to seasonal increases in pollinator demand which cannot be satisfied by bees from natural habitats only. Here, almond farmers have to rent privately owned bee hives, including imported ones (Klein et al. 2008). In the extreme case of intensive almond-plantation landscapes, a complete replacement of natural pollination has occurred, whereas in landscapes with remaining natural habitats the rented services can be characterized as a complement rather than a substitute for native bees.

Policy Recommendations Under Economic and Ecological Uncertainty

Public interest and awareness of the economic impact of pollination services is strong. Even the popular publication *The Economist* (2009) has taken up this issue, explaining why the rental of bee hives is currently an efficient solution for California farmers, while also discussing how the short-term volatility of pollination supply and demand is related to factors such as economic development.

In addition to economic uncertainty caused by, for example, price volatility, there is considerable ecological uncertainty due to the temporal variability of the provisioning of ecosystem services. In 2007, the National Academy of Sciences in the United States released a report on the status of pollinators in North America concluding that for most pollinator species long-term population data are lacking and knowledge of basic ecology is incomplete (CSPNA & NRC, 2007). Additionally, several authors have highlighted that, even with currently sufficient pollination services, preserving pollinator diversity provides biological insurance for future services (Winfree et al. 2007; Hoehn et al. 2008; Winfree & Kremen, 2009). Neglecting this aspect by following the weak sustainability approach and failing to consider future conditions for substitutability might lead (i) to inefficiency by making irreversible decisions, and thus losing benefits by destroying option values, and (ii) to unsustainability by causing declining per capita welfare in the long run. We therefore advocate a precautionary approach. Note that this does not necessarily mean abandoning the utilitarian interpretation of sustainability. Both the equity-based approach (claiming inalienable rights of future generations) and the utility-based approach (requiring nondeclining *per capita* welfare) come to the same conclusion if welfare growth is not expected to compensate for the nonsubstitutable loss of natural capital. Under these circumstances, similar policy recommendations result regardless of which concept we use.

However, scientists are skeptical regarding how far such recommendations translate into political decision making. On one hand, Pezzey (1997) remarks that people do not place "overriding importance" on sustainability as an ethical concept for intergenerational equity. On the other hand, intertemporal efficiency calculations based on discounting face limited acceptance through the argument that they are (i) myopically biased toward the present generation, placing an overly low weight on the preferences of future generations, and (ii) overoptimistically assess the welfare of future generations. Neumayer (2007) argues that irreversibility and nonsubstitutability are much closer to real public concerns and these notions provide much stronger justification for present action than the intertemporal efficiency arguments. Here, safe minimum standards, although sometimes characterized as "rules of thumb," might serve as rational criteria for decision making under pronounced uncertainty (Woodward & Bishop, 1997).

Defining such standards on a comprehensive scientific basis requires a broad inter- and transdisciplinary effort, one that takes into account different scales and timeframes as well as approaches to uncertainty. In our example, a partial widening of the narrow interpretation of strong sustainability—one that allows for substitution between different forms of natural capital—would open possibilities to maintain pollination as an ecological process while mitigating the negative effects of habitat loss. However, to do so a better understanding of the complex processes and systems is required. The Millennium Ecosystem Assessment (MA, 2005) has shown that it is not a simple task to combine fragmented and disciplinary knowledge to reach this aim. This essay is meant to take up part of this challenge.

References

Aizen, A., Garibaldi, L., Cunningham, S., & Klein, A. 2008. Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. *Current Biology* 18(20):1–4.

Allsopp, M., de Lange, W., & Veldtman, R. 2008. Valuing insect pollination services with costs of replacement. *PLoS ONE* 3(9):e3128.

Baumgärtner, S. & Quaas, M. 2009. Ecological-economic viability as a criterion of strong sustainability under uncertainty. *Ecological Economics* 68(7):2008–2020.

Baumgärtner, S. & Quaas, M. 2010. What is sustainability economics? *Ecological Economics* 69(3):445–450.

Benítez, P., Kuosmanen, T., Olschewski, R., & van Kooten, G. 2006. Conservation payment under risk: a stochastic dominance approach. *American Journal of Agricultural Economics* 88(1):1–15.

Committee on the Status of Pollinators in North America (CSPNA) & National Research Council (NRC). 2007. *Status of Polli-*

nators in North America. Washington, DC: National Academies Press.

Fisher, B. & Turner, R. 2008. Ecosystem services: classification for valuation. *Biological Conservation* 141(5):1167–1169.

Gallai, N., Salles, J., Settele, J., & Vaissiere, B. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* 68(3):810–821.

Ghazoul, J. 2007a. Recognising the complexities of ecosystem management and the ecosystem service concept. *GAIA* 16(3):161–140.

Ghazoul, J. 2007b. Challenges to the uptake of the ecosystem service rationale for conservation. *Conservation Biology* 21(6):1651–1652.

Ghazoul, J. 2008a. The ecosystem service controversy: there is sufficient evidence for controversy. *GAIA* 17(1):12–16.

Ghazoul, J. 2008b. Debating the ecosystem service rationale for conservation. Conservation Biology 22(3):799–801.

Hartwick, J. 2000. *National Accounting and Capital*. Northampton, MA: Edward Elgar.

Hoehn, P., Tscharntke, T., Tylianakis, J., Steffan-Dewenter, I. 2008. Functional group diversity of bee pollinators increases crop yield. *Proceedings of the Royal Society B* 275(1648): 2283–2291.

Howarth, R. 2007. Towards an operational sustainability criterion. *Ecological Economics* 63(4):656–663.

Klein, A., Vaissière, B., Cane, J., Steffan-Dewenter, I., Cunningham, S., Kremen, C., & Tscharntke, T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* 274(1608):303–313.

Klein, A., Olschewski, R., & Kremen, C. 2008. The ecosystem service controversy: is there sufficient evidence for a "pollination paradox"? *GAIA* 17(1):12–16.

Kremen, C., Daily, G., Klein, A., & Scofield, D. 2008. Inadequate assessment of the ecosystem service rationale for conservation: reply to Ghazoul. *Conservation Biology* 22(3):795–798.

Millenium Ecosystem Assessment (MA). 2005. *Millennium Ecosystem Assessment Ecosystems and Human Well-Being: Synthesis*. Washington, DC: Island Press.

Neumayer, E. 2003. *Weak and Strong Sustainability: Exploring the Limits of Two Opposing Paradigms*. Northampton, MA: Edward Elgar.

Neumayer, E. 2007. A missed opportunity: the Stern Review on climate change fails to tackle the issue of non-substitutable loss of natural capital. *Global Environmental Change* 17(3–4):297–301.

Nordhaus, W. 2007. A review of the Stern Review on the economics of climate change. *Journal of Economic Literature* 45(3):686–702.

Norgaard, R. 2008. Finding hope in the Millennium Ecosystem Assessment. *Conservation Biology* 22(4):862–869.

Norton, B. & Toman, M. 1997. Sustainability: ecological and economic perspectives. *Land Economics* 73(4):553–568.

Olschewski, R., Tscharntke, T., Benítez, P., Schwarze, S., & Klein, A. 2006. Economic evaluation of pollination services comparing coffee landscapes in Ecuador and Indonesia. *Ecology and Society* 11(1):7.

Pezzey, J. 1997. Sustainability constraints versus "optimality" versus intertemporal concern, and axioms versus data. *Land Economics* 73(4):448–466.

Ricketts, T., Daily, G., Ehrlich, P., & Michener, C. 2004. Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Sciences* 101(34):12579–12582.

Samuelson, P. & Nordhaus, W. 2001. *Economics*. New York: MacGraw-Hill.

Stern, N. 2007. T*he Economics of Climate Change: The Stern Review*. New York: Cambridge University Press.

The Economist. 2009. The bees are back in town. May 5.

Tol, R. & Yohe, G. 2006. A review of the Stern Review. *World Economics* 7(4):233–250.

Veddeler, D., Olschewski, R., Tscharntke, T., & Klein, A. 2008. The contribution of wild bees to coffee production: new economic insights based on farm-scale yield data. *Agroforestry Systems* 73(2):109–114.

Wallace, J. 2007. Classification of ecosystem services: problems and solutions. *Biological Conservation* 139(3–4):235–246.

World Commission on Environment and Development (WCED). 1987. *Our Common Future*. New York: Oxford University Press.

Wesseler, J. Weikard, H., & Weaver, R. 2003. Introduction: approaches to risk and uncertainty in environmental and resource economics. In J. Wesseler, H. Weikard, & R. Weaver (Eds.), *Risk and Uncertainty in Environmental and Resource Economics*. pp. 1–6. Northampton, MA: Edward Elgar.

Winfree, R. & Kremen, C. 2009. Are ecosystem services stabilized by differences among species? A test using crop pollination. *Proceedings of the Royal Society B: Biological Sciences* 276(1655):229–237.

Winfree, R., Williams, N., Dushoff, J., & Kremen, C. 2007. Native bees provide insurance against ongoing honey bee losses. *Ecology Letters* 10(11):1105–1113.

Woodward, R. & Bishop, R. 1997. How to decide when experts disagree: uncertainty-based choice rules in environmental policy. *Land Economics* 73(4):492–507.