Ecosystem Services

Advanced article

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Article Contents

Online posting date: 15th December 2011

Ecosystem services represent all the things that functioning ecosystems do for people that people generally do not have to pay for. Examples include a forested hillside filtering water and retaining topsoil/sediments, how trees remove carbon from the atmosphere, or how a mangrove buffers surrounding low-lying lands from wave action and storm surge. When ecosystem services are lost, the human-made substitutes (such as a water filtration plant, erosion retaining walls, etc.) are often costly, and costly to maintain. Environmental management decisions are increasingly incorporating estimates of ecosystem service values as part of the cost–benefit evaluations. The intent of many ecosystem service efforts are to internalise ecosystem contributions into decision-making, thus stemming ecosystem service loss. However, accomplishing this requires not only stemming the loss of ecosystem services, but also addressing the increasing human demands for them.

Definition

Ecosystem services are broadly defined as those processes of ecosystems that support (directly or indirectly) human well-being (MEA, 2005). Common examples are goods and services, which are provisioned (drinking water, firewood, berry picking, game meats and fish), regulate (carbon sequestration, flood control and vegetation, which regulates stream water temperature), provide cultural services (such as recreation, spiritual enrichment and educational opportunities), or which support the above services (biological diversity, nutrient cycling, etc.). Ecosystem services may be experienced by people directly or indirectly (**Figure 1**).

eLS subject area: Ecology

How to cite:
Patterson, Trista M (December 2011) Ecosystem Services. In: eLS. John Wiley & Sons, Ltd: Chichester.
DOI: 10.1002/9780470015902.a0021902

There is a surprising diversity of definitions in the literature (see for review, de Groot *et al*., 2002; Costanza, 2008; Fisher and Turner, 2008). Those definitions which are most general are often used to draw attention for the importance of healthy ecosystems (MEA, 2005; Daily, 1997; Collins and Larry, 2007). More specific definitions may be used to estimate replacement cost of lost ecosystem services, or incorporate these benefits into conceptual framing of important social issues (Costanza *et al*., 1997; US EPA, 2006). The most narrow definitions are needed to be so, as they provide the criteria for specific accounting and decision-making (Boyd and Banzhaf, 2007). The range of definitions also depict differences in interpretation. More or less attention may be paid to ecosystem service supply versus ecosystem service demand, or market versus nonmarket values. Definitions also may reflect more or less complexity with respect to temporal and spatial scales, or units of measurement. The scope ecosystem service definition may also vary; in whether supporting services are accounted as they contribute to the ecosystem service directly experienced (the endpoint), or whether impacts are tracked between ecosystem origin and use (the life-cycle).

A Brief History

The ecosystem service concept has a lengthy history in the literature, with multiple disciplines contributing. Economic and ecological treatments of the concept do not always appear coordinated but a few hallmark contributions seeded the concept as we understand it today. Krutilla (1967, p. 788) was one of the first to cite 'present and future amenities associated with unspoiled natural environments, for which the market fails to make adequate provision'. This definition, became a touchstone for the economics community for much of the valuation work which followed. From the ecological perspective, the MIT Study of Critical Environmental Problems (SCEP, 1970) described a suite of environmental services that faced decline if ecosystem function were impaired or lost. Publications which followed referred to 'public-service functions of the global environment'/'global ecosystem', 'nature's services', each precursors to the currently used

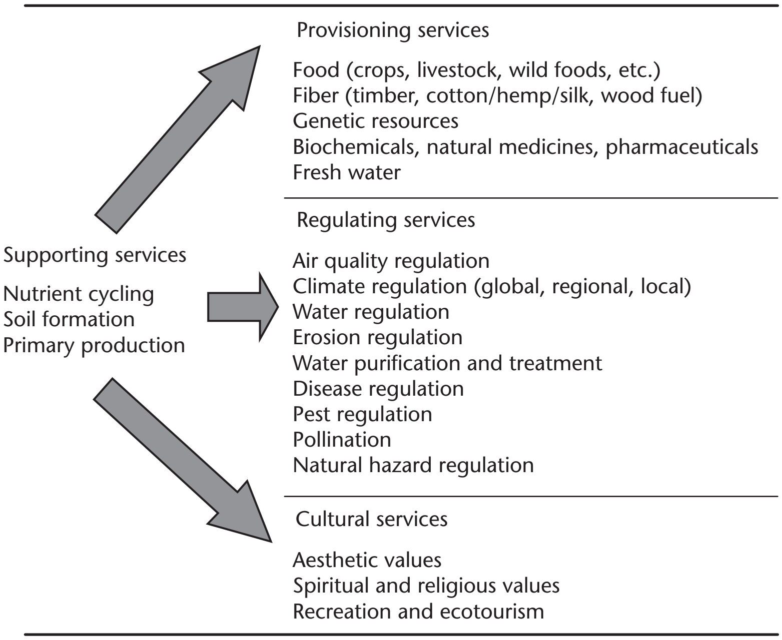

Figure 1 Broad categories of ecosystem services. Reproduced with permission from Patterson and Coelho (2009); MEA (2005).

'ecosystem services' (Holdren and Ehrlich, 1974; Ehrlich *et al.*, 1977; Westman, 1977; Ehrlich and Ehrlich, 1981, respectively). Currently, the two works most often used as citations for the ecosystem service concept were both published in 1997. Both documented the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life, and support quality of life on earth (Daily, 1997; Costanza *et al.*, 1997).

Conceptually speaking, ecosystem services and their loss, are a prominent example of the conflict described by Schumacher (1973) and Daly (1977, 1991, 1996), both of whom pointed out that the world's growing 'man made economy' would one day bump up against immutable laws of physics, as increasing material and energy are used to fuel economic growth. These works underscore the underlying challenge: *to address declines in ecosystem services requires reducing energy and material inputs to the economy (and the resulting waste and emissions) to a point which will allow humans to thrive within the biological and physical limits of living on a single, finite planet*.

Examples

A newcomer to the terms may find it challenging to distinguish between the terms ecosystem services and natural capital. To illustrate the point above, one can use the example of a checking account. The amount of money in a checking account represents a stock of financial capital. If it is an interest bearing account the account will grow over time. You can spend that interest, without reducing the amount of capital in the account. Similarly, the stock of natural capital – the living material that covers the planet – provides a flow of ecosystem services. The flow of interest from the checking account and the flow of ecosystem services depend on the amount of capital you began with and the productive conditions under which it grows over the course of the year. We describe individuals that 'live off the interest' of their capital investments as being financially independent. Similarly, we can describe many criteria of sustainability if the world's human were to 'live off the interest' of the planet's natural capital.

The current concern about ecosystem services is that we know humanity's aggregate consumption habits do not adhere to these guidelines. Habits, lifestyle, technology, and social norms, rules and incentives/penalties all determine the rate at which humans collectively use ecosystem service flows. It is often said that if every person on the planet consumed ecosystem services like a typical US resident did, we would need several planets to generate these high flows of ecosystem services each year. The planet's population is growing, as well as are rates of material and energy consumption. When we overharvest them, we impair the system's ability to regenerate. In other words, we are effectively making withdrawals from our initial stocks of natural capital. As we do so, we affect the amount of future interest that will flow to the present generation and generations in the future.

Ecological Principles

Ecosystem function is the maintenance of *natural processes* (i.e. energy flow, nutrient cycling) and *properties*. It is this function that facilitates the production of ecosystem services (de Groot *et al*., 2002). Quantitative assessments (especially those used in dynamic models or future projections) require particularly specific distinctions between the stocks of natural capital, and flows of ecosystem services. This is not a trivial task. A sound grasp of ecological principles, ecological relations and components is needed to move beyond the most general discussions of ecosystem services. Of specific concern is how change to ecosystem function is related to quantitative change in flows of ecosystem services, and thus an estimation of how many people may be affected by those changes , and for how long.

Ecosystem services are far more difficult to account than funds in banking. In this sense, ecological principles have been tremendously useful in describing ecosystems as a fundamental basis for production (Kline *et al*., 2009). Economists are increasingly using ecosystems and ecological processes to organise the way they describe a system by which people receive benefits. Meanwhile, ecologists are increasingly using the ecosystem service concept to describe the tradeoffs in benefits, which might arise from various management alternatives. Ecological principles are particularly valuable in describing temporal and spatial variation in ecosystem services – and help to explain the difficult inter-relationships among various scales – how ecosystem services originate from, and extend to users at local and global scales.

Substantial challenges remain. Our most common economic indicators (e.g. Gross Domestic Product (GDP)) do not account for quantity or quality of natural capital stocks. Thus the indicators we base most civic decisions upon do not weigh the consequences of ecosystem service losses. Further, ecosystem service harvests, uses, and exchange often do not take place in markets. They might be collected by individuals, or shared amongst family and friends (game meat, salmon, mushrooms, etc.). They may accrue to everyone publically as part of ecosystem function, and may not be particularly visible to us (as is the case of carbon sequestration, water purification, etc.). Yet these services have real value, in social, cultural, ecological and economic senses. The fact that they can be disrupted, underscores the importance of accounting for them in planning and management of resources. Managing for ecosystem services up front is often far less costly than reinitiating the service once lost.

Role for Human Well-being

Over the course of the last 40 years, the world's population has doubled and the global economy has increased sixfold. The important contributions of ecosystem services to human well-being have never been more important, to more people. The Millennium Ecosystem Assessment, a collective effort among scientists worldwide documented in 2005 a decline in over 60% of the world's ecosystem services (MEA, 2005). Although the attention for these trends is a notable advancement, the principal drivers to this decline remain as prominent elements of our society. Although certain strategies have emerged, such as payment for ecosystem services (PES), systemic efforts to redress this decline remain elusive.

We can expect these challenges to be among the most difficult society has faced, because they represent not only trends in almost every natural system on the planet, but also because they involve issues of equity, complexity, and because there are lags both in time and space between action and consequence. Population growth, affluence and technology are all elements which will influence this trend in the future, though theorists hold varying degrees of optimism as to the extent that technology can resolve the increasing scarcity of nonrenewable resources and healthy ecosystems. Ultimately, ecosystem services underscore that man-made capital cannot substitute for the rate at which natural capital is being impacted by human beings (Ehrlich and Ehrlich, 1990; Haberl *et al*., 2007; Deutsch *et al*., 2003).

Measurement

Quantifying ecosystem services is especially difficult because of the challenge of separating the concept of 'stock' (our earlier example as a checking account) from 'flow' (the interest that is generated from account over a given period of time). Recall that we described ecosystem services as flowing from a stock of natural capital. The more impaired the ecosystem function the less interest (ecosystem services) generated.

A second challenge in measuring ecosystem services has to do with the fact that ecosystem services originate from ecosystems and accrue to beneficiaries in complex systems, complete with time-lags and distributed over large distances. That is to say, it is very difficult to link a particular action or intervention on the landscape with a predetermined consequent reaction in ecosystem service flow, and to account for the variety of beneficiaries that will be affected, or the length of time that impact will endure. Consider also that some beneficiaries may be very local (e.g. when a specific water source is impaired), or they may be very global (e.g. in the case of greenhouse gasses accumulating in the global atmosphere).

A third complicating factor to ecosystem service measurement is that just because an ecosystem is producing things that in theory *can* be used, does not mean that people actually *are* collecting or using them. For example, just because a hillside is full of blueberries, does not mean that someone has time, access, or interest in harvesting them. The literature is ambiguous as to whether the potential use, or the actual use should be measured when quantifying ecosystem services. To clarify, more recent studies have distinguished geospatial data on ecosystem service supply, ecosystem service demand, and past, present, or future projections of disturbance to ecosystem service provision (often an unintended consequence of ecosystem service demand outstripping supply) (Beier *et al*., 2008). Categorising ecosystem service data according to these more specific datasets can help prioritise geographic areas for research, restoration and monitoring of natural capital systems.

The future of ecosystem service measurement lies in our ability to link data and illuminate factors, which influence ecosystem service supply, with factors which help us understand and moderate ecosystem service demand. Frequently, it is less cost intensive to control or reduce demands for ecosystem services, than to incur the cost of mitigating disturbance to natural capital systems. In this sense, many innovative contributions have come not from the ecosystem service literature itself, but those which have quantified human reliance on the biosphere. That is, those that have attempted to capture, in quantified form, the human reliance on the biosphere. Ecological footprints, carbon calculators, sustainability indicators and sustainability report cards are being used globally and by nations, states, cities, corporations and individuals. Each represents quantified means to indicate when human demands have outstripped planetary natural capital, and insight to how to address these challenges in the most cost-effective way.

Usefulness in Ecosystem Conservation and Sustainable Management

The usefulness of the ecosystem service concept in ecosystem conservation and management for sustainability is that it shows the human reliance on the biosphere in a way that is particularly quantified and conceptually accessible. Documenting the disparity between our demands for resources and that which can be supplied in perpetuity is especially necessary because without these indications, societal demands will continue to outstrip the systems that provide for the foundation of human well-being.

To safeguard critical natural capital, it is necessary to incorporate the value of ecological systems into public decision-making. There have been a variety of attempts to do so, but most current attention has oriented around valuation of ecosystem services, and attempts to construct markets and payment architectures. The goals of these interventions is (in the former) to make values that were previously invisible, visible, and (in the latter) to stimulate supply of ecosystem services via market forces (**Figure 2**). However, the effort to place these values on a level commensurate with the other factors, which currently form the basis of social decision-making, or which addresses an ecosystem service deficit, remains elusive (see Patterson and Coelho (2009) for review).

One of the first and most well-known valuation exercises was a study which estimated the value of ecosystem services worldwide (Costanza *et al.*, 1997). At US$33 trillion, this value was 1.8 times the world's GDP, an idea that generated a great deal of discussion over whether natural or built capital was more valuable in supporting the earth's household accounting systems and ultimately human well-being.

There are a variety of ways in which valuation of ecosystem services are currently approached, and within each approach, various methods. The ecosystem service concept has proven valuable to those who wish to secure ecological systems a seat at the decision table. More specifically, they might provide quantifiable evidence of the relevance of a particular ecosystem (e.g. forests or wetlands) to society, or they may provide input to a cost–benefit analysis. One suite of methods involves estimating a consumer's willingness to pay (e.g. Brouwer, 2000; Wilson and Carpenter, 1999), which could then be used, for example,

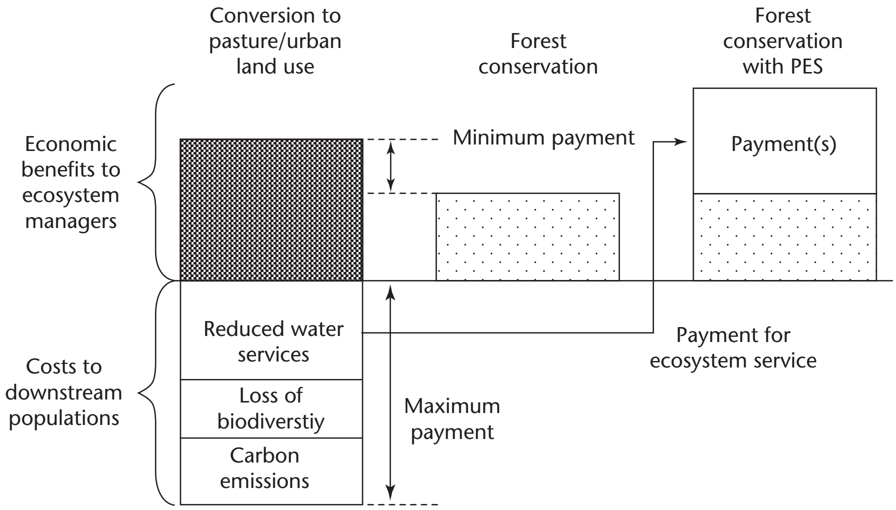

Figure 2 Payment for Ecosystem Service (PES) systems are designed to internalise otherwise external costs. The three columns illustrate private benefits (above the bar) and public costs (below the bar) as measured for business as usual (left column), conservation only strategy (middle column), and conservation paired with PES (right column). It is anticipated that a land manager will choose the option heanticipates will deliver the highest private benefit. In the third column, PES is proposed to turn what would be a public cost into a private benefit. Reproduced with permission from Patterson and Coelho (2009); Engel *et al.* (2008).

to construct a solution such as a skier might purchase a 'green-tag' to offset the carbon emissions resulting from their day skiing.

Another approach to ecosystem service valuation indirectly estimates ecosystem service values by either *benefit transfer* (adapting the results from existing studies, as reviewed in Spash and Vatn, 2006) or *damage cost avoided* (calculating the monetary cost of replacing those services, should they be lost, e.g. Brouwer, 2000). A third, and emerging approach, is to facilitate *group deliberative techniques* wherein a group is assembled and facilitated in the aims of coming to common agreement on value (Howarth and Wilson, 2006; Spash, 2007).

The accounting approach to ecosystem services has been cited for its ability to engage new perspectives in protecting and restoring flows of ecosystem services. This might occur through governance, payment systems and markets, adjustments to the life-cycle of a product (tracking a product from extraction through production to consumption to disposal and reassimilation), or other means. The concept has provided some hope that markets for ecosystem services may provide landowners and investors to alternative revenue streams, as well as disincentive to activities, which would otherwise degrade natural capital. Poverty alleviation and integrated conservation management goals may be incorporated into ecosystem service market architecture. However, the performance against those goals over time requires careful consideration of transparency, benchmarking, 'additionality' (the payment is incentivising benefits, which would not occur its absence) and other important factors (Wunder, 2005, 2007; Engel *et al*., 2008).

The concept of ecosystem services helps us to understand the value of ecosystems as life support, and how contributions (outside of the marketplace and economic growth) support quality of life. Stemming ecosystem service losses means confronting the possibilities and limitations of markets in resolving social challenges. These challenges are compounded for the resources that are 'public goods' or collectively owned or shared as 'the commons' between populations (Hardin, 1968; Ostrom, 1990). With this information we begin to illustrate a picture of whether current rates of energy and resource use exceed the planet's ability to replenish them, and begin to construct a pathway by which we safeguard our natural capital for present and future generations.

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