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# Natural capital and ecosystem services

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## 1 A short history of natural capital and ecosystem services

Gomez and De Groot (2010) state that the concept of natural capital was introduced for the first time in 1973 by Schumacher in his book entitled *Small Is Beautiful: A Study of Economics As If People Mattered* (Gómez-Baggethun and De Groot 2010, p. 108). The term "nature's services" appeared for the first time in the literature in a paper published in *Science* by Walter Westman, titled "How much are nature's services worth?" (Westman 1977). "Ecosystem services" as synonymous to "nature's services" was mentioned for the first time in Ehrlich and Ehrlich (1981), and more systematically in Ehrlich and Mooney (1983).



In 1988, Pearce made one of the earliest introductions to the concept of natural capital, stating that "sustainability requires at least a constant stock of natural capital, construed as the set of all environmental assets" (Pearce 1988). Pearce's goal was to stimulate discussion and research around the topic of sustainability within the field of neoclassical economics. As Akerman states, the concept was then redefined by Costanza and Daly, who brought ecosystem thinking into economic analysis, implying a theoretical change in the understanding of how both ecological and economic systems worked, opening the path for the emerging field of ecological economics (Akerman 2003, p. 443). A more detailed history of ecosystem services focused on its economics roots is provided by Gómez-Baggethun, de Groot, Lomas, and Montes (2010) and L. C. Braat and de Groot (2012), who summarize the history of the concept from the perspective of ecology, economics, and ecological economics.

The year 1997 was a turning point in research and the conceptualization of natural capital and ecosystem services. First, the book *Nature's Services: Societal Dependence on Natural Ecosystems* (Daily 1997) was published, the product of a meeting in October 1995 of Pew Scholars in Conservation and the Environment in New Hampshire, which included scholars such as Jane Lubchenco, Stephen Carpenter, Paul Ehrlich, Gretchen Daily, Hal Mooney, Robert Costanza, and others. Second, during this meeting Robert Costanza proposed the idea to synthesize all the information being assembled and develop a global assessment of the value of ecosystem services. This was done through a workshop called "The Total Value of the World's Ecosystem Services and Natural Capital," held on 17–21 June 1996 with the financial support of the U.S. National Science Foundation (NSF)-funded National Center for Ecological Analysis and

Synthesis (NCEAS) and with the participation of 13 scholars from a range of disciplines. The results were published in *Nature* (Costanza et al. 1997). They provided a "meta-analysis" of all existing studies on 17 ecosystem services across 16 biomes that were valued in the range of US$16–54 trillion per year, with an average of US$33 trillion per year, a value significantly higher than gross domestic product (GDP) at the time. These two publications sparked an explosion of research and policy interest in ecosystem services, helping to visualize the dependence that humans have on healthy ecosystems and therefore the importance of protecting natural capital for human well-being.

## 2 Classifying resources: basic principles for natural capital definition

Before analyzing the concept of capital (and specifically natural capital), we need to consider some basic definitions that are implicit in it. First, it is important to make a distinction between types of scarce resources, stock-flow and fund-service. On the one hand, in Daly and Farley (2004), Georgescu-Roegen defines a stock-flow resource as one that is materially transformed into what it produces, can be used at any rate desired, can be stockpiled, and is used up instead of worn out (e.g., goods such as timber, water, minerals, and fish). On the other hand, a fund-service resource is defined as one that cannot be materially transformed into what it produces, can only be used at a given rate, cannot be stockpiled, and is worn out instead of used up (e.g., services such carbon sequestration, erosion control, pollination, and water retention) (Daly and Farley 2004, p. 71).



Second, the classification of resources under the principles of excludability and rivalry is key because it is directly related to the concepts of stock-flow and fund-service. An excludable resource is one which its owner can use while simultaneously denying its use to others (the opposite is a non-excludable resource). A rival resource is one that, when consumed or used by one person, reduces the amount available for everyone else, and a non-rival resource is one in which the use by one person does not affect its use by another. In general terms, most stock-flow resources are rival, while fund-service resources are non-rival (Daly and Farley 2004, p. 73) (Figure 15.1).

These definitions frame both the consumption possibilities of resources as well as their governance, which at the end determines their sustainability, key to maintaining the well-being of current and future generations.

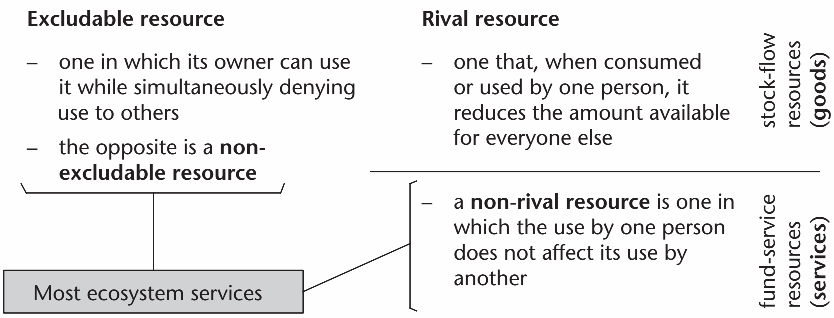


*Figure 15.1* Types of scarce resources. Most ecosystem services are non-excludable and non-rival, which pose a challenge for their sustainable management

## 3 Natural capital concept

Capital can be defined as a "stock of materials or information that exists at a point in time" (Costanza et al. 1997, p. 254) or, moreover, as "a stock of something that yields a flow of useful goods or services" (Costanza et al. 2014, p. 119).

Classical economics identifies three economic factors of production: land, labor, and human-made capital. Neoclassical economics tends to focuses primarily on labor and human-made capital in its production functions, omitting land. Corresponding to these three traditional economic factors of production, three types of capital can be defined as natural, human, and manufactured or built capital (Costanza and Daly 1992, p. 38, and T. Prugh et al. 1995, p. 53). Moreover, Ekins (2003) proposes a disaggregation of the capital stock, adding a fourth type of capital: social capital (Ekins et al. 2003, p. 166). Costanza (2014) states that these four types of capital are necessary to support the economy and its goal of providing human well-being, and describes each one of them as follows:

- Natural capital: the natural environment and its biodiversity; it is the planet's stock of natural resources, the ecosystems that provide benefits to people (i.e., ecosystem services).
- Social capital: the web of interpersonal connections, social networks, cultural heritage, traditional knowledge, and trust, and the institutional arrangements, rules, norms, and values that facilitate human interactions and cooperation between people.
- Human capital: human beings and their attributes, including physical and mental health, knowledge, and other capacities that enable people to be productive members of society.
- Built capital: buildings, machinery, transportation infrastructure, and all other human artifacts and services (Costanza et al. 2014, pp. 129–130).



Following the definition of capital cited earlier, natural capital can be defined as "a stock of natural resources (i.e., ecosystems) that yield a flow of goods and services (i.e., ecosystem services)," such as the case of a mangrove forest that provides food and water filtration to communities. Costanza and Daly explain the flow of goods and services as the "natural income" and the stock that yields the flow as the "natural capital" (Costanza and Daly 1992, p. 38). Sustainability (more on this later) is therefore centered in the wise use of income; depleting the stocks is called capital consumption (T. Prugh et al. 1995, p. 51) and is the reason for ecosystems' loss and degradation.

Berkes and Folke (1992) state that natural capital and built capital are fundamentally complementary; it is not possible to create built capital without support from natural capital. Furthermore, it is important to note that natural capital (i.e., ecosystems) cannot provide benefits to people without its interaction with the other three types of capital. Ecosystem services (defined in the next section) do not flow directly from natural capital to human well-being (Costanza et al. 2014, p. 153). Therefore, "ecosystem services refer to the relative contribution of natural capital to the production of various human benefits, in combination with the three other forms of capital" (Figure 15.2) (Costanza 2012, p. 103).

Perceiving natural capital in insolation from the other forms of capital produces a bias in its management. Often, management of natural capital is the responsibility of the ministries of the environment and does not include other ministries, such as industry, agriculture, or finance. In the private sector, natural capital management is commonly the responsibility of the corporate sustainability department and does not come up in boardrooms (Guerry et al. 2015, p. 7350).

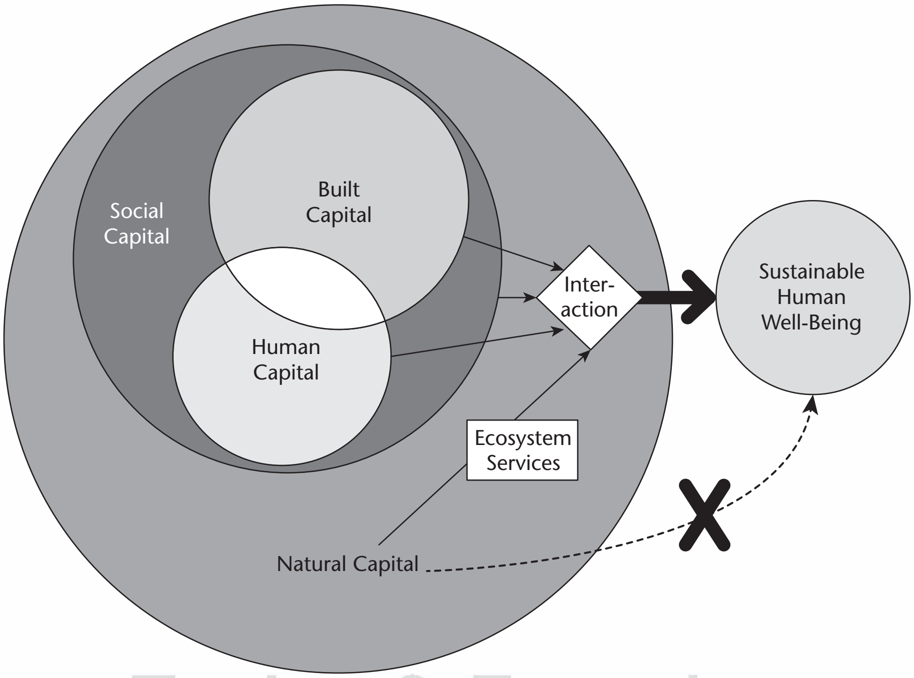


*Figure 15.2* Interaction between social, built, human, and natural capital to contribute to well-being.



### *3.1 Types of natural capital*

According to Costanza and Daly (1992), there are two broad types of natural capital. Renewable natural capital, such as ecosystems, are active and self-maintaining using solar energy; they are analogous to machines and subject to entropic depreciation. Nonrenewable natural capital, such as mineral deposits and fossil fuels, are more passive and generally do not produce services until extracted. They are analogous to inventories and therefore are subject to liquidation (Costanza and Daly 1992, p. 38).

Prugh et al. (1995) describes a third category of natural capital, a hybrid that can be called cultivated natural capital, which includes agricultural and aquacultural systems, as well as planted forests, among other things. The main characteristic of this type of natural capital is that its components are not man-made, but they are not completely natural either (T. Prugh et al. 1995, p. 52).

## 4 Ecosystem services concept

Ecosystem services are defined as "the benefits that people obtain from ecosystems" (MEA 2005, p. v). A more complete definition of ecosystem services is “the benefits people derive from functioning ecosystems, the ecological characteristics, functions, or processes that directly or indirectly contribute to human well-being” (Costanza et al. 2011, p. 1).

Although these definitions of ecosystem services are very straightforward, they have been the subject of debate for two decades, and some clarification is therefore needed. First, it is important to distinguish between ecosystem processes and functions, on the one hand, and ecosystem services, on the other. Ecosystem processes and functions refer to biophysical relationships that exist regardless of whether humans benefit. The opposite is the case with ecosystem services, which only exist if they contribute to human well-being (Braat 2013).

This human-dependent definition of ecosystem services has led some to argue (Thompson and Barton 1994; McCauley 2006) that the concept represents an anthropocentric, utilitarian, or instrumental view of nature: that nature only exists to service humans. Nevertheless, the goal of the concept of ecosystem services is not to be anthropocentric, but rather to recognize the dependence of humans on nature for their well-being and their survival, and to visualize *Homo sapiens* as an integral part of the current biosphere. Moreover, instead of implying that humans are what matter most, or are the only thing that matters, the concept of ecosystem services implies that the whole system matters, both to humans and to the other species we are interdependent with.

### 4.1 Types of ecosystem services

Pearce (1998) classifies the goods and services that flow from natural capital into four categories: (1) supply of natural resource inputs to the economic production process (e.g., water, genetic diversity, and soil quality), (2) assimilation of waste products and residuals from the economic process, (3) source of direct human welfare though aesthetic and spiritual appreciation of nature, and (4) support systems–biogeochemical cycles and general ecosystem functioning (Pearce 1988).

These four categories were used almost two decades later in the Millennium Ecosystem Assessment under the names of provisioning, regulating, cultural, and supporting services:



- Provisioning services, such as timber, water, fiber, and food. A clear example of how these services interact with the other three types of capital is fishing activity, where fish provided to people as food requires fishing boats (built capital), fishermen (human capital), and fishing communities (social capital).
- Regulating services, such as pollination, flood control, water regulation, pest control, climate control, water purification, and air quality maintenance. For example, storm protection provided by wetlands (natural capital) to infrastructure such as hotels and houses on the coast (built capital), protecting its residents and other members of the community. Contrary to provisioning services, these services are not marketed.
- Cultural services that provide spiritual, recreational, and aesthetic benefits. A recreational benefit requires natural capital, such as a waterfall; built capital like a trail or a road; human capital that appreciates the waterfall; and social capital, such as friends and family and the institutions that make the waterfall accessible.
- Supporting services, such as photosynthesis, nutrient cycling, and soil formation. These types of services do not require interaction with human, social, and built capital; they affect human well-being indirectly by maintaining key processes that are necessary for the other three types of services. Using this description of supporting services, some scholars have argued that instead of ecosystem services they are ecosystem functions. Although this is true, supporting services can be used as a proxy to evaluate services in the other categories if more direct measures are not available (Costanza et al. 2011; MEA 2005)

Costanza et al. (1997) identified 17 ecosystem services. Other key reports and initiatives, such as the Millennium Ecosystem Assessment (already mentioned earlier), The Economics of Ecosystems and Biodiversity (TEEB), and, more recently, the Common International Classification of Ecosystem Services (CICES), have established classifications of ecosystem services in order to frame and enable discussions, assessments, modeling, and valuation. Table 15.1 compares these four ecosystem services classification systems, making evident that they are broadly similar.

*Table 15.1* Comparison of four of the main ecosystem services classification systems used worldwide and their differences and similarities (Costanza et al. 2017)

| | *Costanza et al. 1997 (a)* | *Millennium Ecosystem Assessment, 2005* | *TEEB, 2010* | *C1CES 4.3 (v. 2013) (b)* |
|---|---|---|---|---|
| Provisioning | Food production (13) | Food | Food | Biomass – nutrition |
| | Water supply (5) | Fresh water | Water | Water |
| | Raw materials (14) | Fiber etc. | Raw materials | Biomass – fiber, energy, & other materials |
| | | Ornamental resources | Ornamental resources | |
| | Genetic resources (15) | Genetic resources | Genetic resources | |
| | | Biochemicals and natural medicines | Medicinal resources | |
| | X | X | X | Biomass – mechanical energy |
| Regulating & habitat | Gas regulation (1) | Air quality regulation | Air purification | Mediation of gas & air flows |
| | Climate regulation (2) | Climate regulation | Climate regulation | Atmospheric comp. & climate regulation |
| | Disturbance regulation (storm protection & flood control) (3) | Natural hazard regulation | Disturbance prevention or moderation | Mediation of air and liquid flows |
| | Water regulation (4) (e.g., natural irrigation & drought prevention) | Water regulation | Regulation of water flows | Mediation of liquid flows |
| | Waste treatment (9) | Water purification and waste treatment | Waste treatment (esp. water purification) | Mediation of waste, toxics, and other nuisances |
| | Erosion control & sediment retention (8) | Erosion regulation | Erosion prevention | Mediation of mass-flows |
| | Soil formation (7) | Soil formation *(supporting service)* | Maintaining soil fertility | Maintenance of soil formation and composition |
| | Pollination (10) | Pollination | Pollination | Life cycle maintenance (incl. pollination) |
| | Biological control (11) | Regulation of pests & human diseases | Biological control | Maintenance of pest and disease control |

(*Continued*)

*Table 15.1* (Continued)

| | *Costanza et al. 1997 (a)* | *Millennium Ecosystem Assessment, 2005* | *TEEB, 2010* | *C1CES 4.3 (v. 2013) (b)* |
|---|---|---|---|---|
| Supporting & habitat | Nutrient cycling (8) | Nutrient cycling & photosynthesis, primary production | X | X |
| | Refugia (12) (nursery, migration habitat) | "Biodiversity" | Lifecycle maintenance (esp. nursery) | Life cycle maintenance, Habitat, and gene pool protection |
| | | | Gene pool protection | |
| Cultural | Recreation (16), incl. eco-tourism & outdoor activities | Recreation & eco- tourism | Recreation & eco- tourism | Physical and experiential interactions |
| | | Aesthetic values | Aesthetic information | |
| | Cultural (17) (incl. aesthetic, artistic, spiritual, education, & science) | Cultural diversity | Inspiration for culture, art, & design | |
| | | Spirit. & religious val. | Spiritual experience | Spiritual and/or emblematic interactions |
| | | Knowledge systems Educational values | Information for cognitive development | Intellectual and representative interactions |

## 5 Ecosystem services valuation

### *5.1 The concept of value*

Ecosystem services can be valued through different methods depending on the service, but before explaining these methods, it is important to understand the concept of value in this context.

A good start to better comprehend the theory behind the valuation of goods and services is the distinction that Adam Smith made in the eighteenth century between exchange value and use value, wherein he used the diamond–water paradox to explain it. Diamonds have a high exchange value and people are willing to pay a great price depending on the quality of the diamond, but diamonds have low use value because they are mainly useful as jewelry (among other uses that were implemented after Smith). Water, on the other hand, has a low exchange value, which means that people would pay very low prices to consume it, but the use value of water is high since it is a resource we need in order to survive.

Smith used this paradox to dismiss the use value as a basis for exchange value, and he instead formulated a cost of production theory of value based on wages, profit, and rent as the source of exchange value. He suggested a labor theory of exchange value, using the beaver–deer example: if it takes twice the labor to kill a beaver than to kill a deer, then one beaver will be sold for as much as two deer. Therefore, when labor is the only scarce factor, services and goods will be "priced" based on the ratio of labor used (Farber et al. 2002). It is worth noting that this point of view of value excluded completely natural capital, perhaps because at the time it was not a scarce resource.



In the twentieth century, the "marginal" revolution in value theory originated through the convergence of related streams of economic thought. Menger stated that the intensity of desire for one additional unit declines with successive units of the good. Exchanging the term "desire for one additional unit" with the term "marginal utility" results in the economic principle of diminishing marginal utility. The marginal utility theory of value is of great importance in the valuation of ecosystem services, because it can be used to measure use values instead of just exchange values, in monetary units (Farber et al. 2002).

The exchange value of goods and services is determined by the willingness to pay (WTP) to obtain them or the willingness to accept (WTA) compensation for losing them. WTP and WTA can be based on marginal changes in the availability of these goods and services, or on larger changes, including their complete absence. Exchange-based values of goods and services are determined by the prices at which they are exchanged. Overall, economists set the value of a good based on want satisfaction and pleasure, meaning that things only have value if they are desired, which is a problematic point of view in valuing natural capital, as explained later. Furthermore, as the good becomes scarcer, the desire increases, and therefore so does its value (Farber et al. 2002).

### *5.2 Valuation*

As stated earlier, ecosystem services are the benefits people derive from ecosystems; they are provided by natural capital in combination with built, social, and human capital. The value of ecosystem services is therefore the relative contribution of ecosystems to well-being (Turner et al. 2016). This contribution can be expressed in various units (any units of the four types of capitals), where monetary units are often the most used and convenient since most people understand values in these units. Nevertheless, other units, such as time, energy, and land, can also be used. The selection will depend on which units help to better communicate to different stakeholders in a given decision making context (Costanza, et al. 2014). Valuation allows a more efficient use of limited funds by identifying where environmental protection and restoration is economically most significant, supporting the determination of the amount of compensation that should be paid for the degradation and/or loss of ecosystem services, and improving the financial mechanisms (e.g., incentives) for the conservation and sustainable use of natural capital (e.g., Payment for Ecosystem Services) (De Groot et al. 2012).

The value of ecosystem services can also be estimated by determining the cost to replicate them by artificial means (Costanza et al. 1997), for example, how much it would cost a farmer to pollinate his crops artificially. It is useful to attempt to calculate the impact in human well-being from changes in quantity or quality of natural capital that can occur due to different development decisions (Costanza et al. 1997). Valuation is therefore a tool for evaluating the tradeoffs required to achieve a shared goal, where in the past and in the present these tradeoffs have been addressed mainly through marketed goods and services (e.g., fuel or food) using commodity prices, leaving outside the equation other goods and services that currently do not have a price but that contribute equally or even more greatly to well-being (Turner et al. 2016).

Valuing ecosystem services has been criticized as unwise or even impossible because we supposedly cannot put a value on "intangibles" like human life and nature. In reality, we implicitly value these things on a daily basis through, for example, measures to protect human life, such as construction standards for housing and public infrastructure that will require spending more money in order to preserve human lives (Costanza et al. 1997). Therefore, the overall goal is not to put a price tag on nature for exchange purposes, but to visualize the effect of a change in ecosystem services provision to human well-being in terms of a rate of tradeoff against other things people value (Turner et al. 2003).



## *5.3 Valuation methods*

After the identification, quantification, and mapping of ecosystem services for a particular area or scale, there are different types of methods used to conduct a Total Economic Valuation (TEV). These can be divided into revealed preference, stated preference, and non-preference–based methods. Revealed preference methods to estimate the benefits from ecosystems are based on market prices, which limits the use of these methods to only a few ecosystem services that are traded in markets (mostly provisioning services) (Turner et al. 2016). Revealed preference methods analyze the choices of people in real world settings and infer the value from those observed choices (Costanza et al. 2011). Non-preference methods recognize the limits of an individual's information about ecosystem services' connection to their well-being and use modeling and other techniques to estimate these connections.

Stated preference methods try to construct pseudo markets through the use of surveys in which people are asked to state their willingness to pay for ecosystem services that are not traded in current markets. These methods therefore rely on the response of people to hypothetical scenarios (Costanza et al. 2011). Stated preference approaches have limitations because people surveyed often do not completely understand or are not aware of the relation between healthy ecosystems and human well-being, because they do not feel comfortable in stating tradeoffs for ecosystems in monetary units, and finally because the willingness to pay can be significantly different to the real payment when it comes to that point (Turner et al. 2016).

Table 15.2 summarizes the different methods for ecosystem services valuation using conventional economic valuation and non-monetizing valuation (from Turner et al. 2016, which is an adaptation from Farber et al. 2006).

*Table 15.2* List of methods for ecosystem services valuation

| | | |
|---|---|---|
| **Conventional economic valuation** | Revealed-preference approaches | *Travel cost*: valuations of site-based amenities are implied by the costs people incur to enjoy them (e.g., cleaner recreational lakes) |
| | | *Market methods*: valuations are directly obtained from what people must be willing to pay for the service or good (e.g., timber harvest) |
| | | *Hedonic methods*: the value of a service is implied by what people will be willing to pay for the service through purchases in related markets, such as housing markets (e.g., open-space amenities) |
| | | *Production approaches*: service values are assigned from the impacts of those services on economic outputs (e.g., increased shrimp yields from increased area of wetlands) |
| | Stated-preference approaches | *Contingent valuation*: people are directly asked their willingness to pay or accept compensation for some change in ecological service (e.g., willingness to pay for cleaner air) |
| | | *Conjoint analysis*: people are asked to choose or rank different service scenarios or ecological conditions that differ in the mix of those conditions (e.g., choosing between wetlands scenarios with differing levels of flood protection and fishery yields) |
| | Cost-based approaches | *Replacement cost*: the loss of a natural system service is evaluated in terms of what it would cost to replace that service (e.g., tertiary treatment values of wetlands if the cost of replacement is less than the value society places on tertiary treatment) |
| | | *Avoidance cost*: a service is valued on the basis of costs avoided, or of the extent to which it allows the avoidance of costly averting behaviors, including mitigation (e.g., clean water reduces costly incidents of diarrhea) |
| **Non-monetizing valuation** | – | *Individual index-based methods*, including rating or ranking choice models, expert opinion |
| | | *Group-based methods*, including voting mechanisms, focus groups, citizen juries, stakeholder analysis |



Due to the nature of the service, each ecosystem service can be valuated through one or more particular methods. For each service, the amenability to economic valuation and the transferability across sites will vary from low to high. Table 15.3 summarizes the set of methods that are appropriate to valuate each ecosystem service (Turner et al. 2016).

Due to constraints in time and budget, it is often not possible to conduct original/primary studies to value ecosystem services (Wilson and Hoehn 2006; Plummer 2009), which has led to a wider use of secondary data (Richardson, Loomis, Kroeger, and Casey 2015) for this purpose through valuation techniques such as value/benefit transfer. Although this technique has limitations, it is sometimes the only option to inform policy decisions that require a first approximation to natural capital valuation (Richardson et al. 2015).

In simple terms, value transfer consists in "applying economic value estimates from one location to a similar site in another location" (Plummer 2009, p. 38). The site where primary data

*Table 15.3* Valuation methods for each ecosystem service (Farber et al. 2006)

| *Ecosystem services* | | *Amenability to economic valuation* | *Most appropriate method for valuation* | *Transferability across sites* |
|---|---|---|---|---|
| **Provisioning service** | Water supply | High | AC, RC, M, TC | Medium |
| | Food | High | M, P | High |
| | Raw material | High | M, P | High |
| | Genetic resources | Low | M, AC | Low |
| | Medicinal resources | High | AC, RC, P | High |
| | Ornamental resources | High | AC, RC, H | Medium |
| **Regulating services** | Gas regulation | Medium | CV, AC, RC | High |
| | Climate regulation | Low | CV | High |
| | Disturbance regulation | High | AC | Medium |
| | Biological regulation | Medium | AC, P | High |
| | Water regulation | High | M, AC, RC, H, P, CV | Medium |
| | Soil retention | Medium | AC, RC, H | Medium |
| | Waste regulation | High | RC, AC, CV | Medium High |
| | Nutrient regulation | Medium | AC, CV | Medium |
| **Cultural services** | Recreation | High | TC, CV, ranking | Low |
| | Aesthetics | High | H, CV, TC, ranking | Low |
| | Science and education | Low | Ranking | High |
| | Spiritual and historic | Low | CV, ranking | Low |

AC = avoided cost, CV = contingent valuation, H = hedonic pricing, M = market pricing, P = production approach, RC = replacement cost, TC = travel cost.



was collected and processed is called the study site, and the site to which this data (i.e., ecosystem services values) is going to be applied is called the policy site (because the values are commonly used for policy decisions such as land use change or the establishment of financial mechanisms) (Plummer 2009). The transfer can be spatial (across different sites, national, or international) or temporal (where the study site and the policy sites are different moments in time) (Navrud and Bergland 2004).

Other authors have proposed the following definitions of value transfer, all of them sharing the core elements of the technique:

- "Transfer of original ecosystem service value estimates from an existing 'study site' or multiple study sites to an unstudied 'policy site' with similar characteristics that is being evaluated" (Richardson et al. 2015).
- "Transposition of monetary environmental values estimated at one site (study site) through market-based or non-market-based economic valuation techniques to another site (policy site)" (Brouwer 2000).

Although the valuation technique is often referred as benefit transfer, Navrud states that the method can also be related to the transfer of damage estimates, and thus a more accurate term would be value transfer (Navrud and Bergland 2004), which will be used henceforth.

The aggregation of these methods through a value transfer make the technique useful in academic and policy settings in which ecosystem services values are not required with a high level of accuracy but need to be accurate enough to support a project or policy, and are not suitable when more accurate values are required, in cases such as the calculation of compensation payments for environmental damages (polluter pays principle) (Navrud and Ready 2007).

### 5.4 Difficulties in valuing ecosystem services

Valuing natural capital is far from a perfect science but is without any doubt a needed one. Turner et al. (2003) identified the following main difficulties when conducting these assessments:

- Marginality: the data used in ecosystem services are "marginal" values rather than aggregated global values; this is because what it is calculated is the value of ecosystem services' degradation or loss.
- Double counting: this problem can often occur because many ecosystem services are not complementary, which means that the provision of one is precluded by others.
- Typological issues: these are related to the design and strategy of the valuation assessments, where it is important to distinguish between valuations of the *in situ* ecosystem stock and estimates of the value of the flow of goods and services from a given stock.
- Spatial and temporal transfer: these difficulties are specifically for the aggregation method of basic value (or benefit) transfer, including the requirement of good quality studies of similar situations, the potential change of characteristics between time periods, and a failure to assess novel impacts (i.e., thresholds or resilience).
- Distribution of benefits and costs: developing countries invest high local costs to natural capital conservation that yield large global benefits, in contrast to developed countries that tend to incur relatively low local costs that produce lower global benefits.



## 6 Natural capital and sustainability

A key point is the understanding of the relation between sustainability and the maintenance of capital stocks. Ekins et al. (2003) explains that if sustainability depends on the maintenance of the capital stock, then there are two possibilities: (1) maintaining the total stock of capital, allowing substitutions between its components, or (2) whether certain components of capital, mainly natural capital, are non-substitutable. Ekins elaborates on these two possibilities by framing them under two types of sustainability: (1) weak sustainability, which considers that natural capital can be replaced completely by built capital under the perception that welfare is not dependent on a specific form of capital, and (2) strong sustainability, which considers complete substitution of natural capital by built capital to be impossible since natural capital provides a unique contribution to welfare, and ultimately it is the inputs for built capital and the basis of critical life support systems (Ekins et al. 2003, p. 167).

The concept of natural capital, as well as its research and policy implications, becomes relevant more than ever in the current national and global economic growth strategy. In the past (mainly before the industrial revolution), we lived in what some scholars call an empty world, empty of humans and their artifacts, full of natural resources. Now, we live in a full world, full of humans and their artifacts, with an increasingly reduced natural environment. In the former world the limiting factor was built capital, while natural capital and social capital were abundant; in the latter world, quite the contrary abounds.

In order to recognize natural capital as a limiting factor, and therefore its need of conservation and sustainable consumption, a different vision of the interaction between the economic and ecological systems is needed. Fenech et al. (2003, p. 5) propose that, instead of looking at the ecological system as part of the economic system, we need to consider the economy as part of the ecosystem.

The consideration of the economy as part of the ecosystem acknowledges the limits of growth of the economy since the ecosystem is finite. Costanza and Daly state that growth is related to throughput increase, which is destructive of natural capital, with the negative consequence of having higher costs in the medium and long term than the benefits gained in the short term (Costanza and Daly 1992, p. 43). This cost–benefit analysis for natural capital is often ignored by economic interests, undervaluing natural capital and only recognizing its value when it is lost (Ehrlich et al. 2012 p. 70). Development, on the contrary, means an increase of efficiency and quality improvement, and therefore does not reduce natural capital (Costanza and Daly 1992, p. 43).

From the natural capital perspective, development under this framework would mean that natural income must be sustainable, which should be at least the case for renewable natural capital. Since nonrenewable natural capital is reduced with use, income can be constant only if the total natural capital (renewable natural capital plus nonrenewable natural capital) is maintained constant, which implies a certain level of reinvestment of the nonrenewable natural capital consumed into the renewable natural capital (Costanza and Daly 1992, p. 43). This is relevant, especially for low income countries, since they have a higher dependency on natural capital both for growth and development (Pearce 1988).

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