

Development and Fundamentals of the ES Approach

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2.1 Key Terms

K. Grunewald and O. Bastian

“We know the price of everything and the value of nothing (adapted from Oscar Wilde).”

Despite, or perhaps because of the wide distribution and almost inflationary use of the ES term there is no question that a clear and uncontroversial, universally accepted definition does not exist. For example, what distinguishes the service of an arable land from the service of a natural ecosystem? What are the limitations of what we may call ‘service’? What is an ecosystem property of the underlying service? What do we mean by a potential and what is meant by a function?

In the context of an integrative ES concept, it is important to create a concept system, similarly understood and accepted by economics, ecology, and sociology, by scientists, practitioners, and policy-makers. That this only partly succeeded is partly due to the distinct subject-specific names (delimitation of a field of knowledge through technical terms). On the other hand, there are differences between regional common definitions and their contents. An example of this is the concept of function, which is described in German as the service of the ecosystem for humans (Bastian and Schreiber 1994), but is mostly used in English as ‘functioning’ of the ecosystem (see below).

As the environmental debate presently as far is largely determined by climate change and energy policy issues in Central Europe, the concept of sustainable development is overlayed by the **ecosystem service** term (definition, ► Chap. 1). The term ecosystem service was introduced by Ehrlich and Ehrlich (1981) respectively Ehrlich and Mooney (1983). Probably in the knowledge of the, inter alia, by Neef (1966) and Haase (1978) developed approach of ‘natural potential’, van der Maarel and colleagues designed in the Netherlands a ‘global-ecological model’ (van der Maarel and Dauvellier 1978), which later was further developed to the ES concept (Albert et al. 2012) by de Groot (1992) and working groups in the USA (Daily 1997).

The ES concept has the political agenda to foster awareness in society in regards to the position and importance of the environment. This corresponds

to the choice of the metaphorical term ‘service’, which is subject to natural and legal persons in the national economy as well as in the daily linguistic usage, which provides the services (‘Nature as a service provider’). Services or goods always have a specific purpose, usually according to an individual’s requirement. Nature exerts negative effects on humans (so-called disservices), for example volcanic eruptions, earthquakes, floods, or avalanches.

In the current scientific literature, mainly the following definitions of ES are cited: ES are the conditions and processes through which natural ecosystems and the species they represent, sustain and fill human life (Daily 1997); advantage or benefit of ecological systems for humans (Costanza et al. 1997b; MEA 2005) or direct and indirect contributions of ecosystems to human well-being (de Groot et al. 2010).

Other authors explicitly differentiate between ES and the benefits from these, for example, Boyd and Banzhaf (2007): ‘Benefits = the welfare the services generate’. According to Boyd and Banzhaf (2007) ES are ‘ecological components’ in physical terms (not monetarily measurable). The authors argue things or characteristics as well as end products of nature (i.e. in fact ‘goods’) that are consumed directly or that can be enjoyed and produce human well-being. They complain that many of the services mentioned by Daily (1997) or the Millennium Ecosystem Assessment (MEA 2005) are ecosystem processes in fact. The simultaneous use of the terms functions and services, without clarity to define both and to distinguish from each other, is not uncommon (e.g. Vejre 2009; Willemen et al. 2008).

The definitions have in common that ES are always defined by the societal view on the ecosystem, biophysical processes, and functions (Fisher et al. 2009). However, the authors provide different views on how functions and ES can be differentiated analytically and how they can be heuristically distinguished between ES and the benefits or the value of ES (Boyd and Banzhaf 2007; Wallace 2007; Costanza 2008; Fisher et al. 2009; Loft and Lux 2010). Following and in particular in the context of the case studies (► Sect. 6.1), common features and definitional boundaries of the ES term and its content will be further specified in relation to biodiversity and sustainability.

■ Ecosystem (Nature, Resources and Landscape)

With focus on 'nature', the **ecosystem term** (definition, ► Chap. 1) has been established in the international ES debate. The term 'nature services', proposed by Westman (1977), did not gain acceptance.

An important basis for the ecosystem concept was developed in the context of a major research project carried out in West Germany in the 1960s under the influence of a crisis, which was in relation to the forest dieback in the Central German mountain ranges. The 'Solling Project' carried out in Lower Saxony under the leadership of Heinz Ellenberg (1973) examined the structures, functions, and processes of a Central European beech forest. Since then the ecosystem has been understood as an interactive structure between organisms and the environment, which is open to other systems, but differs from these in terms of its own structures and its own composition (Haber 2004; Nentwig et al. 2004; Steinhart et al. 2011). Therefore, structures and processes of the earth system at different levels of scale play the main role in the ecosystem approach.

However, the *resource term* in the strictest sense includes raw materials and energy, whereas in a broader sense the natural basis of human life, such as air, water, soil, flora, fauna, and the interactions between them. The latter correspond to the (environmental) protection goods of nature protection in accordance with § 1 and 10 of the German Federal Nature Conservation Act (BNatSchG 2009). Natural resources are divided into renewable and non-renewable. There is a differentiation from the ES concept that focuses in general only on renewable resources (MEA 2005; ► Chap. 1).

As a metaphor for biotic and abiotic components of the earth, the term *natural capital* is used. In a broader sense, ecosystems, biodiversity, and natural resources are included therein (BESWS 2010). Thereby the connection between nature and economy and the generation of values for human society due to the condition and processes of nature should be expressed. Natural capital provides as capital in kind a stock for services (Common and Stagl 2005). ES can be regarded as components of natural capital. The latter can be partially replaced by work performance (e.g. water treatment), which is associated with economic costs.

One difficulty is to separate methodologically explicitly between services of nature (ecosystem processes, natural capital) and activities of humans (means of production, technological processes, human capital). Therefore Matzdorf and Lorenz (2010) use the term 'environmental services', as the realisation of benefits (e.g. crops, biomass) of cultural shaped ecosystems (arable land, grassland) in addition to the ecological processes human work and artificial matter input (farming, fertilisation, maintenance, etc.) is required.

From landscape ecology and landscape planning the term *landscape services* was introduced into the discussion (Termorshuizen and Opdam 2009; Grunewald and Bastian 2010; Kienast 2010; Hermann et al. 2011; Albert et al. 2012), among others, to assess better the spatial relationships of ES or cultural landscapes with their characteristic elements (► Sect. 3.4). In this regard, the question of the usefulness of a further term is not entirely unjustified, especially as the decades-long and sometimes controversial running discussions on landscape cannot be overlooked and today there remains no unanimity regarding the content and application of the landscape concept, but there are quite different patterns of interpretation. Thus, landscape can be understood as a territorial entity a 'manageable space', which can be seen as positivistic (landscape as an ecosystem complex; e.g. Neef 1967), and constructivistic (as an aesthetic phenomenon or even mental construct; Leibenath and Gailing 2012) or as a space of action (Blotevogel 1995, Kirchhoff et al. 2012).

According to the MEA 2005, a landscape is typically composed of a number of different ecosystems, each generate a whole bundle of different ES. Therefore, it is justified to identify landscapes with similar or alike overall character (or to use as reference units) in order to interpret their conditions for effective and at the same time sustainable use by society (Bernhardt et al. 1986; Hein et al. 2006; TEEB 2010).

Also, new terms such as 'Green or Blue infrastructure' finally mean properties, functions, or services that are provided through a network of suitable ecosystems, with a particular focus on the connectivity.

■ Potentials of Nature and Ecosystems

The 'geographical concept of potential' was introduced in the German literature by Bobek and Schmithüsen as early as 1949, initially as a 'spatial arrangement of naturally provided possibilities for development'. The technical literature moreover contains such concepts as 'natural potential' (Langer 1970; Buchwald 1973) and 'natural performance power' (Buchwald 1973); Lüttig and Pfeiffer (1974) drew 'maps of nature potentials' (for related attempts Durwen 1995 and Leser 1997). In botany, the term 'potential' appeared in the form of 'potential natural vegetation', which was an integral used to indicate the totality of growth conditions at a given site (Tüxen 1956).

By making natural landscape potentials scientific categories and having them ascertained according to specific parameters of natural processes, they can be distinguished from natural resources, which represent an economic category (Mannsfeld 1983). Haase (1973, 1978) offered a way out of this hardly manageable complexity by suggesting that instead of a summary energy standard for a theoretically conceivable overall potential specific factors (properties, indicators) should be addressed in a particular case, and so-called partial natural spatial potentials defined with a clear focus on more specific socio-economic or societal goals and basic functions. These would include for example biotic yield potentials and regulatory potentials, water supply and disposal potentials, and construction and recreational potentials. The 'concept of potential' assesses nature's gifts from the point of view of the potential user, by means of a primarily scientific mode of operation. It elaborates the service capacities of an ecosystem or physical landscape as a field of options available to society for use, and also to take into account resilience, which limits or may even exclude certain intended uses (Grunewald and Bastian 2010).

Parallel to that, van der Maarel (1978) and Lahaye et al. (1979) in the Netherlands addressed 'landscape potencies', which might contribute to the fulfilment of certain societal needs (!). The term 'potential' is also found e. g. in Bierhals (1988), Finke (1994) and Durwen (1995), while e.g. Marks et al. (1992) and Leser (1997) prefer the terms 'service capability' or 'capacity' of the landscape balance. The

international preferred term is 'capacity' of ecosystems (to sustain a specific function) (e.g. Führer 2000; Burkhard et al. 2012).

'Land-use suitability' on the other hand, focuses more on a certain use claim, which is considered primarily in societal, less in scientific terms. To determine land-use suitability, reference to the type of land use is definitely necessary (Niemann 1982). According to Messerli (1986), land use represents a 'decisive hinge position between societal and natural processes' (■ Fig. 2.4, ► Chap. 6), ... by mediating as a link between processes in the socio-economic and natural systems. It enables the transfer of processes of an economic, social and cultural nature, which are describable in factual dimensions, to spatial dimensions, thus making them relevant ecologically, and in a reversed direction, of ecological, aesthetic and emotional information to society'. Land-use suitability can be seen 'potentially' ('use possibility'), e.g. the suitability of a field or a landscape for maize cultivation (without having maize actually being cultivated there at present), or an existing maize field can be assessed as to whether it is really suitable for such use, e.g. maize cultivation might involve intolerable risks.

This is illustrated in ■ Fig. 2.1 exemplarily. Thanks to the fertile loess soil, the Lommatzscher Pflege landscape in Saxony not only has the potential for productive agriculture, but that potential has in fact long been used, so that it fulfils a societal function (or provides ES). However, the increasing intensification, particularly the expansion of rapeseed and maize cultivation, is giving rise to conflicts, e.g. with regard to protection of the soil and water (erosion, eutrophication), species and biotope protection (reduction of biodiversity), and the value of the landscape as an experience (monotony). The hill fortification of Zschaitz, which was already settled during the early Iron Age (800–500 B.C.), and refortified once more during the tenth century AD, is not suitable for agriculture—although it is at present so used—since soil removal is severely damaging this nationally significant archaeological site. Since, unlike the crops produced in this area, ideational or scientific values (or services) have no market, it is difficult to gain acceptance for any restriction of agricultural use.



■ **Fig. 2.1** The increasingly intensive use (= social function) of the fertile loess soils of Lommatzscher Pflege landscape in Saxony (high production potential) leads to an impairment of archaeological sites on the plateau of the hill fortification of Zschaitz by soil erosion © Olaf Bastian

■ Functions

While potentials describe the possibility of the use of nature, the reality of the use of nature is expressed in the functional concept. According to this functional-spatial viewpoint, every part of the earth's surface fulfils societal functions. The Latin term 'function' (*fungi*) generally means 'carrying out' 'managing' or 'task' or 'activity' (Brockhaus Encyclopaedia 1996).

Thus, Speidel (1966) described the multifariousness of the functions of the forest, which benefit humankind, and which go far beyond wood production. Niemann later designed a methodology for ascertaining the degree of functional performance of landscape elements and units (Niemann 1977, 1982). Preobrazhenski (1980) referred to the natural functions of landscape, De Groot (1992) generally to 'functions of nature'. In spatial and regional planning, functions are defined as 'tasks which an area is to fulfil for the needs of life of the people' (ARL 1995). According to Wiggering et al. (2003),

the determination of the multiple ecological, social, and economic functions of the landscape (multi-functionality) in their regional differentiation is the prerequisite for sustainable land use. The protection of efficacy and functionality is today provided by, e. g. the German Federal Conservation Law and the Federal Soil Protection Act.

However, the term 'function' is not used uniformly in the literature, frequently leading to terminological uncertainties and misunderstandings (Jax 2005). Thus, a purely ecological interpretation is common, in the sense of ecosystemic 'functioning' or the 'manner of function', as a scientifically determined organisation of structural-procedural contexts (e.g. food chains and nutrient cycles; cf. Forman and Godron 1986, where function is 'the interactions among the spatial elements, that is, the flows of energy, materials, and species among the component ecosystem'). In the TEEB study (TEEB 2009), functions are also regarded as purely ecological phenomena. According to

Costanza et al. (1997b), and in the MEA (2005), functions can support ecosystem services (ES). For Boyd and Banzhaf (2007), functions are ‘intermediate products’ of ES. Eliáš (1983) distinguished between two basic groups of functions: ecological functions (important for the existence of the ecosystems, regardless of concrete societal use claims), and social functions (which reflect societal needs).

Additional imprecisions of definition appear in the widespread blurring of the difference between function and potential. Thus, Marks et al. (1992) refer to the ‘functions and potentials of the landscape balance’ without providing any logical, conclusive differentiation between the two. De Groot et al. (2002) see ‘ecosystem functions’ as ‘the capacity of natural processes and components to provide goods and services which directly and/or indirectly satisfy human needs’.

Petry (2001) sees the distinction between functions and potentials as a discussion within German-speaking, geographically oriented landscape ecology, which, while highlighting theoretical differences in meaning, causes more confusion than clarity at the international level, and with regard to application. Mannsfeld too (in Bastian and Schreiber 1994) noted: “A juxtaposition of the concept of natural landscape potentials as a structural aspect, and the performance possibilities of the ecosystemic functional viewpoint based on the gifts of nature, ... shows that a sharp separation of the two approaches is neither useful nor appropriate.” Here, however, the objection is that it is not at all inconsequential whether one refers to the capacity of ability to render socially utilisable services (the potential concept), or of its actual realisation, or the actual rendering of such a service (the function concept).

The difference between potential and function can be illustrated as follows, using an example: An undeveloped South Sea island might have a high recreational potential; however, its recreational function will only be fulfilled if it is actually discovered and visited by tourists.

■ Figure 2.2 shows a coastal section (ecosystem and landscape) in Mecklenburg-Western Pomerania. The recreational potential (possibility) is used by many tourists (realisation of the recreational function), and contributes to the well-being of the visitors (beneficial relevance of ES).

Another example illustrates ■ Fig. 2.3: Due to centuries of withdrawal of fallen conifer needles as straw for cattle stables (straw use: a function and ES), the forest soils in question have been degraded, accompanied by a reduction of its biotic yield potential. Such forest forms have now become rare, and represent not only a habitat for animal and plant species in decline but also a valuable cultural-historical relict of past methods of economic use—with a potential for environmental education and tourism that has hardly been utilised to date.

■ Governance of ES

Spatial distributions and socio-economic aspects are of particular interest for benefits and welfare effects of ecosystems in the sense of the ES approach. This is reflected in ■ Fig. 2.4 on the one hand by the change of land use and on the other by the delta of the incentive structures originated from the social side. Conceptually, the ecosystem structures and processes are related to ecology, the benefits and values to social and economic sciences. ES should be bridging both (for more details see ► Sect. 3.1).

The control and regulating system for ES is not only dominated by the State, so that the term *governance* comes into play. Governance refers not only to the structure and process organisation of government, administration, and community but also by private or public organisations (Ostrom 2011). Governance processes take place at several levels and need to be coordinated through the institutions acting in accordance to the principles of (1) accountability, (2) responsibility, (3) openness and transparency of structures and processes, and (4) fairness (Ostrom 2011; ► Sect. 5.4).

Ecosystem Services (ES)

ES has become established as a conceptual framework on the international stage. In German-speaking countries the conceptual system is oriented to functions and ‘objects of protection’ of nature so far (BNatSchG 2009), so it should be adjusted and further developed. Although the distinction between functions, services and benefits, is to be regarded as important especially for the economic evaluation, often no consistent classifications can be made, because smooth transitions, overlaps, and different interpretations of these terms exist.



■ **Fig. 2.2** Many visitors use the recovery potential of the Baltic Sea beach in Kühlungsborn—the potential has turned to ES. The visitors have benefits (recreation, health). The potential remains depending on the ecosystem structures and processes. © Karsten Grunewald

ES generate human well-being in combination with the means of production and human capital. The largest welfare effect results from the optimum interaction between them. Individual ES can be replaced by technology and labour up to a certain extent. At a complete loss, the welfare effect is equal to zero and human existence cannot be maintained. Changes in the natural capital of any kind lead to changes of costs or benefits for ensuring human well-being.

2.2 ES in Retrospect

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■ Scientific-Historical Roots

Currently, the concept of ecosystem services is one of the central themes in the scientific and environmental policy debates over the goal of preserving our natural resources. If, as stated above, this term is meant to encompass the benefits that society draws

from the functions and capabilities of the ecosystem, then it is important to consider the lengthy evolution of the basic concepts behind this modern terminology for a fundamental societal goal. First empirically and then increasingly systematically, humankind has experienced the benefits, potentials, and also the risks and hazards associated with the use of nature, and, with increasing knowledge, has begun to put these insights to use.

A holistic view of our ambient spatial structures as a synthesis of natural and societal processes is indispensable in order to fully grasp the entire context of ecosystem services. The earliest signs for such a view can possibly be attributed to Alexander von Humboldt (1769–1859), who, by means of observation and measurement, sought to determine the ‘Totalcharakter’ (translating roughly as total character) of the region of the earth, and who therefore, in his later works, observed that only research that keeps the balance between specialisation and integration in nature as a whole could guarantee the desirable conditions for human life.



■ **Fig. 2.3** Bizarre pines in the protected area Königsbrücke Heath, Saxony: Straw use has reduced the biotic yield potential but formed the potential for environmental education and tourism. © Olaf Bastian

Hence, Humboldt's basic concept of the character of nature as a whole with reference to societal and natural-scientific aspects is still a fundamental and challenging question in the present day (Neef 1971).

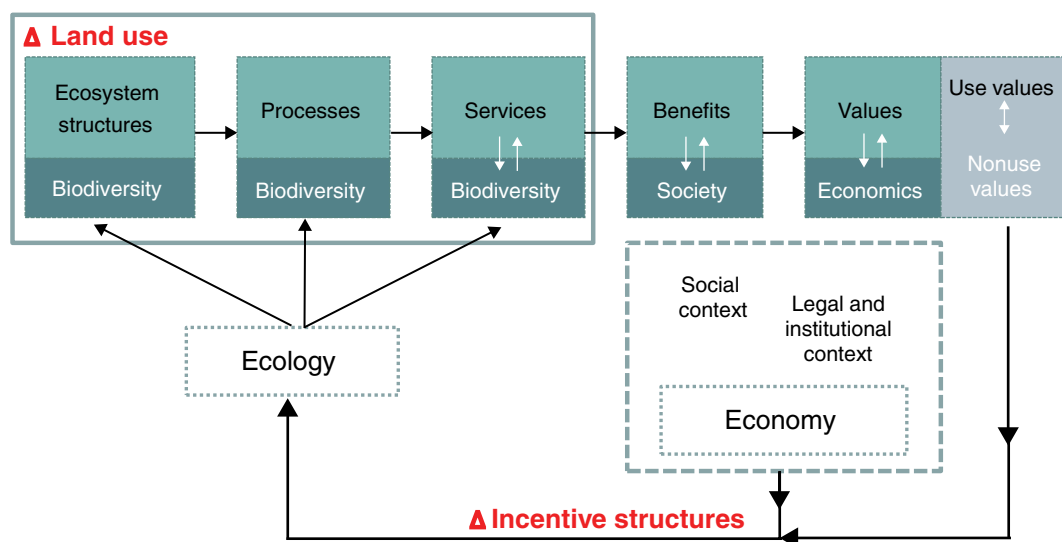
Only shortly thereafter, Ernst Haeckel (1866), who approached the issue from the biological point of view, coined the term 'ecology' to describe this 'interaction' between the animate and inanimate elements in nature; later, with Troll's (1939) landscape ecology, the term would very consciously incorporate the inseparable links between the biological and the geological components of our environment, by encompassing anthropogenic effect factors, and thus describing and emphasising the systemic context, which the theory of landscape ecology saw in the effective connection between nature, technology, and society (Neef 1967, p. 41). Neef describes this complex as follows:

"Hence, landscape ecology, although oriented toward the natural-scientific order of matter, must incorporate all factors which stem from the work of humankind and which will impact the natural balance."

In the decades after Humboldt's death, the analyses and interpretations of his 'total character of spatial phenomena on the Earth's surface' began to increasingly—albeit hesitantly—consider the factor humankind, and, conversely, recognise the positive and negative effects of natural factors on human desires for utilisation. However, it was a lengthy process for the research-historical unilateralism, which only considered anthropogenic effects in the landscape when they were clearly dependent on the balance of nature to be overcome, especially in geological and biological sciences. One milestone in overcoming this deterministic view with regard to the anthropogenic component in the real environment was the influence of late nineteenth-century economists on the theoretical conceptualisation of the footprint of humankind in nature and environment. They pointed out a problem in the then-accepted views of the relationships between humankind and nature, and should therefore be seen as 'contributors' to today's modern ES concepts. Specifically, they emphasised labour processes as the key factor in the interaction between humankind and nature, by which the necessary conditions for human existence were generated and upheld—entirely on the basis of natural and environmental conditions. In this respect, we should mention not only Adam Smith, Johann Heinrich von Thünen and others, but also Karl Marx in particular.

Marx used the term 'metabolism between society and nature' to describe the category under which he subsumed the role of humankind in withdrawing those materials from the landscape which were needed for its economic activity, so as to fulfil the necessities of life. He wrote:

"Labour is, in the first place, a process in which both man [sic] and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature. He opposes himself to Nature as one



■ **Fig. 2.4** Identification and evaluation of ES as well as integration into instruments and incentive structures.

© Ring 2010 based on Brouwer et al. 2011

of her own forces.” (Marx 1867; ► <https://www.marxists.org/archive/marx/works/1867-c1/ch07.htm>)

In this context, he also pointed to the so-called ‘free services’ of nature, which positively affected the process of this metabolism. He noted that, as a result of the effects of natural forces—i.e. with no labour effort—such services of nature as photosynthesis, pollination, groundwater recharging, etc. positively accompany this metabolism, and thus substitute for human activity.

We can credit Carl Ritter (1779–1859; quoted in Leser and Schneider-Sliwa 1999), with calling upon the predominant specialised research activities in the geographic disciplines not to neglect the practical interests of their results. Later, Alfred Hettner (1859–1941) raised the postulate of a ‘practical geography’ (Hettner 1927), the core statement of which was to evaluate and predict the effects of human impacts and changes on the basis of knowledge of the causal contexts of natural processes. From that, he drew the conclusion that such an evaluation should primarily be derived from the given state of the natural systems in the cultural landscape, and that scientifically grounded proposals for improving utilisation should include concepts to preserve and pro-

tect the forces of nature. His conceptual proximity to the instrument of compensation/offsetting the impacts of human use of natural resources—which is still in use today—or the environmental impact assessment can hardly be overlooked.

The key realisation upon which this history-of-science oriented reflection is based is that if Marx’s metabolic process becomes critical, which is the case today on both local and global levels, the effects caused by use processes must be ascertained systematically and according to a number of different standards. Otherwise, given the continued overtaxing of nature’s ‘free services’ the healthy development of ecosystems, i.e. a development subjected to only low levels of disturbance and detrimental interference, can no longer be guaranteed. In this respect, it is no coincidence that the ES concept and its numerous predecessors (see below) have placed the preservation of the precious forces of nature at the centre of their considerations.

With reference to the global character of the growing imbalance between availability of natural resources and the degree of utilisation and the resulting destruction of landscape structures and their ecosystems, the report prepared by the World Commission on Environment and Development (WCED) at the end of the twentieth century gave

a stern warning for humankind to reconsider its dealings with nature from an economic, social and ecological viewpoint. The core statement of the so-called Brundtland Report (WCED 1987) is as follows: Sustainable development is a development which meets the requirements of the present without endangering the ability of future generations to meet their own requirements.

This basic statement of sustainable development has proven to be of great relevance with regard to setting goals for a permanent environmentally appropriate economic and social order. On the other hand, there has to this day been no feasible methodological concept following up on this sustainability triad; it is largely a regulatory idea, a guiding concept characterised by the ethical principle of generational justice. Nonetheless, today the term carries significant meaning whenever policy-makers, business leaders or academics employ it to identify the linkage between economic development and ecological carrying capacity as a major goal of today's societal policy, so as to be able to leave a liveable and usable environment to future generations. Indisputably, the ES approach, which is currently being widely discussed, is viewed as a fundamentally suitable instrument for the implementation of the idea of sustainability.

■ The Substantive and Methodological Precursors of ES

Especially, the German geographic community has, by way of a number of small steps, begun to approach the question of the extent to which it is necessary and possible to refer to the service capacity of a natural abundance (natural balance) which functions in a manner appropriate to the ecosystem (► Sect. 2.1). One early source is an essay by Schmithüsen (1942) on site ecology and its importance for the cultural landscape, in which he explains that people use the service possibilities existing in the natural plan of a landscape to secure their livelihoods, by drafting a 'cultural service plan' of natural and labour processes for distinguishable spatial structures. A few years later, Bobek and Schmithüsen (1949) designated 'regional nature' (*Landesnatur*; a term meaning the totality of naturally provided interactive contexts) in the cultural landscape as a range of potentials, and hence a spa-

tial pattern of arrangements for naturally provided development possibilities (societal use intentions). Schultze (1957) defined the suitability of certain earth regions for use purposes even more concretely, and suggested that this determination of suitability be reformulated into a determination of the cultural-geographical potential of an area.

The growing exploitation of natural resources, with the well-known consequences for the condition of 'protected goods', as we would call them today, confronted society and hence a number of scientific disciplines with the task of seeking answers and proposing solutions as to how to ascertain the service capacity of natural systems and how to preserve and secure them over the long term. Within the geographic community which, as we know, has to deal with hybrid material systems in the cultural landscape surrounding us (abiotic, biotic and societal/cultural components), Neef (1966) presented an initial study for the evaluation of the potentials of natural systems, the essence of which involve the idea of making all aspects of natural factors comparable with the anthropogenic creations in the cultural landscape, and similarly capable of valuation, by defining their various elements in terms of energy content. He entitled this study in which he describes the use of this energy content concept for the elucidation of the relationships between naturally related and economic components of societal activity in the natural environment 'Questions of regional economic potentials', clearly highlighting what he believed was involved. He saw it as an important part of this concept and also an absolute necessity to transfer natural scientific findings into societally familiar, i.e. primarily economic, categories if utility, sustainability, resilience and protection of natural resources were to be considered as societal activities at all.

The epistemological phenomenon which he describes as the 'transformation problem' became part of the application-oriented foundations of East German landscape research. Neef saw his proposal as an important bridge towards objectifying the various processes of nature and society, and the transition from one causal area to another, and towards making the metabolism between human society and nature, which had up to that time been described only as a fairly general phenomenon, us-

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