Valuing Ecosystem Functions and Services in the Czech Republic

(Synthesis of the Key Findings: Project of the Czech Ministry of the Environment SP/2d3/99/07)

Seják J. et al.

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Authors:

Doc. RNDr. Pavel Cudlíň, CSc.
Doc. RNDr. Jan Pokorný, CSc.
Doc. Ing. Miloš Zapletal, Dr.
RNDr. Václav Petříček
Mgr. Jiří Guth
RNDr. Tomáš Chuman, PhD.
RNDr. Dušan Romportl
RNDr. Irena Skořepová, CSc.
Ing. Václav Vacek, CSc.
Prof. Ing. Ilja Vyskot, CSc.
Dr. Dipl. Ing. Karel Černý
Mgr. Petra Hesslerová, PhD.
Ing. Renata Včeláková-Burešová, PhD.
Ing. Marcela Prokopová
Ing. Radek Plch
Ing. Barbora Engstová, PhD.
Mgr. Lenka Štěrbová-Stará

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## Contents

1. Introduction ................................................................................................................................... 4  
   1.1 Definitions ....................................................................................................................................... 4  

2. Essential reasons for current unsustainability .............................................................................. 5  

3. Concepts of economic valuation of nature ...................................................................................... 6  

4. Methods for valuing ecosystem functions and services ................................................................. 7  

5. Valuation of biotopes and ecosystem services .............................................................................. 8  
   5.1 Biotope valuation method .................................................................................................................. 8  
   5.2 Energy-water-vegetation-based method for valuation of ecosystem services ...................... 12  

Use of remote sensing data for functional classification of landscape segments, based on solar energy dissipation ........................................................................................................................................................................... 15  

6. Discussion .................................................................................................................................... 19  

7. Conclusions .................................................................................................................................... 19  

Annex 1 Examples of thermocamera images from different biotopes ........................................ 21  
References: ........................................................................................................................................... 22  

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1. Introduction

Human societies and their economies decisively depend on the life supporting functions and services of Earth’s natural habitats (biotopes) and their ecosystems (MEA 2005). Natural ecosystems, driven by solar energy pulses, produce and provide food, fossil fuels, biomass, materials and space, but also protect against harmful cosmic radiation, continually control the composition of the atmosphere, purify air and water, mitigate climate extremes, form fertile soil, maintain biodiversity, control diseases, decompose organic waste, etc. Only provisioning services of natural resources (agricultural land, forest and urban land, mineral and fossil resource sites) have been valued by humans who have been thus creating growing trade-off pressures on the reduction of natural ecosystems and their life-supporting services. The services provided by land as a terrestrial surface (physical substrate and location) have been clearly excludable and rival.

For hundreds of millions of years, the autotrophic natural ecosystems (photosynthetizing vegetation on the land and in the seas and oceans) have been creating the life-supporting conditions (composition of atmosphere, mitigation of temperature extremes, cleaning air and water, retaining nutrients, etc.) for humans and other heterotrophic species. Self-organizing processes in autotrophic terrestrial ecosystems tend toward climax vegetations that are characterized by maximal efficiency in solar energy use and by maximal ability to produce the life-supporting conditions, keeping the nutrients and water inside the ecosystem (Ripl, 2003).

In other words, natural vegetations (deciduous leafy forests in central Europe) as the long-term results of self-organized natural processes are the most efficient land covers to sustain the climate and the chemistry of the planet Earth (Lovelock, 2006). Potential natural vegetations, as a result of mutual cooperation of living forms with their nonliving environment, most efficiently produce and control conditions for living - fulfil the climatic, soil producing and water and nutrient retentive services. However, over the last hundred years, expanding human populations and mainly their insatiable self-interested striving for material wealth have caused half of the most important world natural habitats to be destroyed. And they continue to be destroyed freely. Therefore, it is high time to internalize the negative externalities so that those who economically benefit from the destruction of natural ecosystems face the true costs from their destruction.

Overall goals of our two recent national projects for Ministry of Environment have been to identify systemically the biotopes, including their biodiversity, and the most valuable functions and services of Czech national ecosystems and derive their systemic ranking and monetary valuation for the territory of the Czech Republic. In this booklet you can find our main findings and messages.

1.1 Definitions

Trees and plants: are the most advanced forms of terrestrial autotrophic life yet evolved for degrading incoming solar radiation, giant dissipative processes that capture the high-quality energy of sunlight and degrade most of that energy as evapotranspiration, respiration, and low-grade latent heat. About 1 % of the energy arriving at the plant goes into plant growth (photosynthesis). About 15 % of the radiation hitting a plant is reflected; 18 % is turned into sensible heat. The remaining 66 % of the solar energy is used in evapotranspiration processes (conversion of water into latent heat) by the plant to move water up to the leaves where it evaporates. The energetic role played by plants, trees and forests has been little appreciated up-to-now (Schneider, Sagan, 2005, p. 157, 216-224).

Biotope: a small area with uniform biological conditions such as climate, soil or altitude
(http://www.science-dictionary.com). A complex of all abiotic and biotic factors which, mutually effecting, form the environment of a certain individual, species, population, or community. A biotope is such local environment which meets the requirements characteristic of plant and animal species (Czech Act no. 114/1992 Coll. on the Nature and Landscape Protection).

**Dissipation:** Classical thermodynamics describes an engine in which part of energy is used for work and part is irreversibly wasted (dissipated) as entropy – any isolated, or “closed” physical system will proceed spontaneously in the direction of increasing disorder (p. 117, Prigogine, Stengers, p. 47 Capra). According to the theory of „open systems“ and „non-equilibrium thermodynamics“, living organisms and living systems (ecosystems) are open, far from equilibrium “dissipative systems” in which dissipation of energy is a source of order. Living systems self-organize themselves.

**Ecosystem:** an ecological system is most often defined as “a community of organisms and their physical environment interacting as an ecological unit” (Lincoln et al., 1982). However, this structural view does not describe the substance of the term. The term ‘ecosystem’ evolved to describe mainly the functional relations inside ecosystems and within their network creating the biosphere of the Earth. According to the Czech National Council Act No. 114/1992 on the Protection of Nature and Landscape, “ecosystem is a functional complex of animate and inanimate environmental components that are mutually connected by metabolism, energy flow and the transfer of information, and which mutually influence each other, and develop in a certain area or time”. Ecosystems are non-equilibrium dissipative processes (Schneider, Sagan 2005, p. 186). Ecosystem may be viewed as an active element with processes and structure, configuring itself to capture and degrade as much available solar energy as possible (Schneider, Sagan 2005, p. 226). Temperature differences on the Earth’s surface are degraded with distinct efficiencies by ecosystems, depending on what kind and how mature they are. More rich (higher level of chlorophyll and wetness) and more mature ecosystems utilize (degrade) solar energy more completely than less rich and less mature ecosystems do. Ecological richness correlates with temperature gradient reduction. Forests are cooler than grasslands or bare lands. This is not theory but a fact, produced by nature in self-organized succession processes driven by pulses of solar radiation. Visually, we can easily measure surface temperatures by thermo-camera or through satellite images.

**Natural ecosystem:** long-term results of self-organized succession processes, driven and organized by the solar gradient, the energetic difference between the Sun and the Earth. Succession processes in terrestrial ecosystems occurring over 150-year-long periods - from bare grounds to rapid growers of grasslands, shrubs, and then pine and birch trees substituted by the long-lasting hardwoods, are predictable. The climax ecosystem formation may be looked at as a mosaic of different stages of ecosystem succession. What is important is the fact that phylogenetically mature ecosystems are more efficient in solar energy utilization than their predecessors. A fundamental characteristic of self-organized development in natural systems is the increasing role of cyclic processes while loss processes are correspondingly reduced. This causes a coincidental increase in system efficiency, which is the basis of growing stability and sustainability. Growing sustainability can be seen as an increase of ecological efficiency, which is applicable at all levels up to whole landscapes (Ripl, 2003).

2. **Essential reasons for current unsustainability**

One substantial reason for the rapid destruction of natural ecosystems is the fact that their life-supporting services (supporting and regulating services according to MEA 2005) have not yet been valued and physical and legal persons can freely change them into anthropogenic
surfaces (traditionally into agricultural lands, recently mainly into construction sites, industrial zones, technical infrastructure, etc). “Land development” of natural surfaces has become one of the most profitable businesses in current market economies and hand in hand with the belief in a never-ending economic growth, with growing loans, sub-prime debts and overgrowth of financial assets, it has led to the current financial and economic crises. Developers in the housing sector and in infrastructure construction are destroying natural ecosystems under no penalty and the negative externalities from the loss of ecosystem services are still being transferred to the taxpayers who are not only losing ecosystem services, but also have to pay for ex-post nature restoration activities.

Simultaneously at the macroeconomic level, the system of national accounts and economic indicators like GDP are increasingly recognized as flawed measures of both economic progress and sustainability, because they do not account for the degradation of ecological services and do not record the depletion and degradation of natural and environmental resources (national income as a net flow of marketed goods and services reflects only man-made capital, but does not include the changes in natural and environmental resource stocks).

In the scientific community, a number of imputation methods have been developed in the last three or four decades that try to estimate the total economic value of nature and her ecosystems, mainly by revealing the preferences held by human individuals. All these utilitarian, demand-curve approaches (revealed and stated preference methods, like TCM, CVM, hedonics, etc.) suffer from one substantial defect in relation to less obvious supporting and regulating ecosystem services. Valuations are made by consumers who are far from integrating these “mediated” supporting and regulating ecosystem services into their value systems. In other words, the majority of people undervalue these hidden services although they are crucial for their survival.

3. Concepts of economic valuation of nature

Looking into the history of economic value, we can identify two main economic schools. Classical English political economy (A. Smith, D. Ricardo, J.S. Mill et al.) came from the supply-side approach that labour and costs of production were decisive for economic value, while neoclassical economics came from the utilitarian approach of demand-side and consumer preferences.

The utilitarian approach has been used since the mid-19th century for valuing the natural resource services (e.g. Faustmann, 1849). Natural resources have been valued, as production factors and assets, through their market provisioning services in economic activities (production, exchange and consumption) as a sum of the future net benefits (rents) discounted to present value in finite or infinite time horizons (for non-renewable and renewable natural resources). Cutting the natural vegetation, that in traditional agricultural societies was done to obtain agricultural land for production of food, has been intensified since the beginning of the industrial revolution and became the first primary step in “land development” in order to achieve personal benefits and profits. After two hundred years humans are challenged with a dramatic lack of natural landscapes that are most efficient in producing life-supporting services. At the outset of the 21st century, new methods of non-market valuations of nature are needed for restoring and protecting natural landscapes.

At the same time, it has been known since the early 20th century that only respect to both aspects can reveal the real economic value, As Marshall (1920) wrote, “We might as reasonably dispute whether it is the upper or the under blade of a pair of scissors that cuts a piece of paper, as whether value is governed by utility or cost of production”. It is obvious that economic value concept has psychic roots in human needs satisfaction as well as physical
Applying the “scissors approach” on modern methods of non-market valuations of nature, we can see that they predominantly rely on demand-side only, reflecting different aspects of human preferences. One of the main goals of our research has been to show the second, supply-side for revealing the real economic value of non-market services of ecosystems. A recent TEEB project has presented both these principal approaches to the estimation of nature’s economic values (preference-based and biophysical approaches), but has not yet aspired to integrate them (TEEB, 2010).

Taking into account that the major part of the life-supporting ecosystem services has not yet entered into the value system of human individuals, the replacement cost approach and the values derived seem to be a more effective way to quantify the decisive existential importance of ecosystem services for the human species. As Costanza et al. (1997, p. 255) put it: “In fact, one additional way to think about the value of ecosystem services is to determine what it would cost to replicate them in a technologically produced, artificial biosphere.”

On the threshold of the third millennium, humankind is beginning to look for ways to reverse the negative trends of world ecosystems extinction (the EU’s demand is to stop biodiversity loss). It is the economic (monetary) valuation of habitat that plays an important and possibly irreplaceable role in their incorporation into human thinking and decision-making (MEA, 2005).

4. Methods for valuing ecosystem functions and services

The majority of experts on ecosystem valuation argue that without the services of ecological life-support systems, our economies and our lives would grind to a halt, so in one sense their total value for the economy and for human individuals is infinite (Costanza et al. 1997, p. 253; Toman, 1998).

However, due to an overwhelming absence of real valuations of life-supporting ecosystem services, these “infinite” values easily change into zero in practical decision-making processes, resulting in negative impacts on natural ecosystems, including extinction and degradation. This is also the reason why the EU Renewed Sustainable Development Strategy (2006) formulated the goal of “improving management and avoiding overexploitation of natural resources, recognising the value of ecosystem services”.

In the last two decades, hundreds of ecosystem service valuation studies have been published. Ecosystem services value has mostly been understood as the marginal value, which shows the change in value with the marginal change in service quality or quantity. From the methodological viewpoint, the majority of studies is founded on the theoretical axioms and principles of welfare economics, i.e. is based on deriving the values from preferences (willingness to pay, willingness to accept) of selected human individuals (consumers). Preferential methods can further be divided into methods deriving values from related markets (hedonic methods, travel cost methods, etc.), direct revealed preferences methods (mainly methods of contingent valuations, based on hypothetical behaviour of responders), and benefit transfer methods (Ecosystems and Human Well-Being 2009).

Currently, a well-known example of such monetary valuation on the global level is e.g. the article of Costanza et al. (1997). The team of authors estimated the total value of 17 annual services of 16 world biomes as covering a range of USD 16-54 trillion (trillion=10^{12}) with an average of USD 33 trillion per year, which was approximately 1.8 times the annual world...
GDP (USD 18 trillion). As the authors write (p. 258), “in many cases the values are based on the current willingness-to-pay of individuals for ecosystem services, even though these individuals may be ill-informed and their preferences may not adequately incorporate social fairness, ecological sustainability and other important goals”.

Valuation as the summation of demanded individual services of nature is based on the traditional mechanistic, Cartesian, anthropocentric and individualistic approach that prevents the expression of mutual dependency of all parts in the living ecosystem, i.e. prevents the expression of the idea that the living system has a higher value than the sum of its parts. Such systemic valuation is possible only through ecosystem methods that address an ecosystem as a self-organizing entity.

One of the legitimate expert methods for estimating values of ecosystem services is the replacement cost method. The costs include the cheapest artificial, anthropogenic way of replacing various services performed by ecosystems. Such cost-based methods (estimating a replacement value, see Mitsch and Gosselink, 2000, p. 600) can also be applied to the well-known Biosphere 2 experiment (Hawken, 1999). The aim of this project was to create an artificial ecosystem with 8 people trying to survive for two years in a 3.15 acre sealed greenhouse. The difficulty of the task was demonstrated in 1991-93 when the scientists operating the $200 million experiment in Arizona discovered that it was (after about five months) impossible to maintain life-supporting oxygen levels for the eight people living inside.

5. Valuation of biotopes and ecosystem services

After the political change in 1989, the Czech Republic started to establish a basic legislative framework of environmental protection. All the main environmental laws were passed in the first half and implemented during the second half of the 1990s. Consequently, emissions of basic pollutants were reduced by one order.

5.1 Biotope valuation method

In 2001 our research team was given a chance to modify the so called Hessian valuation method of biotopes for the conditions of the Czech Republic. Utility of the biotope valuation method (BVM) was confirmed by the EU White Paper on environmental liability [COM (2000) 66 final, 9 February 2000] and corresponds to the needs of the EU NATURA 2000 system. BVM is an expert method to establish a list of national biotopes and rank them by point values according to their capacity as specific environments for living plant and animal species (incl. NATURA 2000). Each biotope type has been valued by an interdisciplinary team of scientists from different scientific backgrounds using points according to eight ecological characteristics (maturity, naturalness, diversity of plant species, diversity of animal species, rarity, threat to existence) (method description and complete list of biotope values see http://fzp.ujep.cz/projekty/bvm/bvm.pdf).

Biotope point values are derived from the relative ecological significance of the respective biotope as environments for healthy ecosystems and are transferred into monetary terms by average national costs of restoration measures, necessary for maintaining and improving the biotopes by one point per square metre (Sejak, Dejm al et al., 2003).

The cost analysis covered 136 restoration projects which brought about increases in the point values of these areas. The financial value of one point was counted for one revitalisation project as the sum of its costs divided by the sum of a point increase expected in the long-term future (future values were discounted by a zero discount rate) and finally national average
costs per one point increase were calculated as a weighted arithmetic average. The stock values of biotope types range from zero (chemically contaminated land, impermeable surfaces) to about € 42 per square metre. The size of biotope values shows the average societal costs that society has to pay to maintain the ecological quality of landscape and its variable biotopes. Applying the BVM at the nation-wide level through the CORINE Land-cover categories, we estimated the national natural capital of biotopes in the Czech Republic and its development in time (Table 1).

Table 1: Estimation of the natural capital of the CORINE Land-cover categories in the Czech Republic in 1990, 2000 and 2006 (through the BVM), bln CZK= 10x10^9

<table>
<thead>
<tr>
<th>Biotope Type</th>
<th>1990</th>
<th>2000</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point value</td>
<td>Monetary value</td>
<td>Polygon count</td>
<td>Area [km²]</td>
</tr>
<tr>
<td>Continuous urban fabric</td>
<td>2.39</td>
<td>1.18</td>
<td>14</td>
</tr>
<tr>
<td>Discontinuous urban fabric</td>
<td>10.22</td>
<td>5.06</td>
<td>5417</td>
</tr>
<tr>
<td>Industrial or commercial units</td>
<td>2.95</td>
<td>1.46</td>
<td>828</td>
</tr>
<tr>
<td>Road and rail networks and assoc. land</td>
<td>8.23</td>
<td>4.07</td>
<td>87</td>
</tr>
<tr>
<td>Port areas</td>
<td>8.27</td>
<td>4.09</td>
<td>3</td>
</tr>
<tr>
<td>Airports</td>
<td>11.94</td>
<td>5.90</td>
<td>31</td>
</tr>
<tr>
<td>Mineral extraction sites</td>
<td>13.40</td>
<td>6.63</td>
<td>174</td>
</tr>
<tr>
<td>Dump sites</td>
<td>7.87</td>
<td>3.89</td>
<td>105</td>
</tr>
<tr>
<td>Construction sites</td>
<td>7.12</td>
<td>3.52</td>
<td>34</td>
</tr>
<tr>
<td>Green urban areas</td>
<td>19.27</td>
<td>9.53</td>
<td>120</td>
</tr>
<tr>
<td>Sport and leisure facilities</td>
<td>18.77</td>
<td>9.28</td>
<td>257</td>
</tr>
<tr>
<td>Non-irrigated arable land</td>
<td>11.18</td>
<td>5.53</td>
<td>5256</td>
</tr>
<tr>
<td>Vineyards</td>
<td>15.25</td>
<td>7.54</td>
<td>161</td>
</tr>
<tr>
<td>Fruit trees and berry plantations</td>
<td>14.15</td>
<td>7.00</td>
<td>472</td>
</tr>
<tr>
<td>Pastures</td>
<td>20.79</td>
<td>10.28</td>
<td>3969</td>
</tr>
<tr>
<td>Complex cultivation</td>
<td>14.08</td>
<td>6.96</td>
<td>818</td>
</tr>
<tr>
<td>Land with agricult.&amp; natural vegetation</td>
<td>21.51</td>
<td>10.63</td>
<td>7816</td>
</tr>
<tr>
<td>Broad-leaved forest</td>
<td>39.93</td>
<td>19.77</td>
<td>2057</td>
</tr>
<tr>
<td>Coniferous forest</td>
<td>26.18</td>
<td>12.94</td>
<td>5999</td>
</tr>
<tr>
<td>Mixed forest</td>
<td>28.48</td>
<td>14.08</td>
<td>5000</td>
</tr>
<tr>
<td>Natural grassland</td>
<td>33.02</td>
<td>16.32</td>
<td>256</td>
</tr>
<tr>
<td>Moors and heathland</td>
<td>52.99</td>
<td>26.20</td>
<td>22</td>
</tr>
<tr>
<td>Transitional woodland shrub</td>
<td>23.51</td>
<td>11.62</td>
<td>3907</td>
</tr>
<tr>
<td>Bare rock</td>
<td>39.79</td>
<td>19.67</td>
<td>7</td>
</tr>
<tr>
<td>Sparserly vegetated areas</td>
<td>61.65</td>
<td>30.48</td>
<td>0</td>
</tr>
<tr>
<td>Burnt areas</td>
<td>32.48</td>
<td>16.06</td>
<td>2</td>
</tr>
<tr>
<td>Inland marshes</td>
<td>33.47</td>
<td>16.55</td>
<td>64</td>
</tr>
<tr>
<td>Peatbogs</td>
<td>53.29</td>
<td>26.34</td>
<td>41</td>
</tr>
<tr>
<td>Water courses</td>
<td>23.14</td>
<td>11.44</td>
<td>14</td>
</tr>
<tr>
<td>Water bodies</td>
<td>18.67</td>
<td>9.23</td>
<td>535</td>
</tr>
<tr>
<td>Total CR</td>
<td>43466</td>
<td>78869</td>
<td>712.2</td>
</tr>
</tbody>
</table>

As can be seen from Table 1 and Figs. 1-3, the total monetary value of biotope natural capital in the CR, estimated by the biotope valuation method, grew in the period 1990-2006 from € 712 bln. in 1990 to € 727 bln. in 2000 (Fig. 2) and € 740 bln. in 2006 (Fig. 3). Compared to the GDP of the CR (in const. prices), the stock value of national natural capital was 28-fold higher in 1990, while in 2006 it was approximately 22 times higher than GDP 2006 in constant prices. In 2006 the average value of 1 m² in the Czech Republic amounted to € 9.4.
Biotope natural capital valuations, performed by the BVM, show the minimal “cost” level of the biotopes and are very easily implementable as an instrument for macroeconomic environmental accounting, while at a microeconomic level they are mainly targeted at valuation of environmental damages caused by legal and illegal anthropogenic activities that intervene in nature, inclusive of damages covered by the EU Directive on environmental liability (2004/35/EC). The BVM values biotopes as specific environments for specific organisms; at the same time, they are environments for provision of specific ecosystem functions.

Fig. 1 Biotope values in the Czech Republic 2006 according to the BVM (Seják et al., 2003).
Fig. 2 Structural changes in biotope values between 1990 and 2000 (Seják et al., 2003)

Fig. 3 Structural changes in biotope values between 2000 and 2006 (Seják et al., 2003)
However, the BVM is not able to estimate the real benefits that humans permanently derive and consume in the form of ecosystem services. While *ecosystem functions* are physical, chemical and biological processes or attributes that contribute to the self-maintenance of an ecosystem, *ecosystem services* are the beneficial outcomes for people that result from ecosystem functions. Provisioning services can be identified with the functional group of natural resource base, cultural services with the landscape and amenity resources, and finally supporting and regulating services can be identified with the life supporting functions of ecosystems (Turner, 1994, p. 17).

### 5.2 Energy-water-vegetation-based method for valuation of ecosystem services

In the period 2007-2009, our research team was given a new opportunity to elaborate the second dimension of ecological values of the Czech landscape – values of ecosystem services. Energy-water-vegetation-based (EWV) environmental accounting represents an ecological approach to estimate the non-market value of ecosystem services. This EWV approach draws on the Energy-Transport-Reaction (ETR) model of Ripl (1995, 2003) and estimates the main forms of benefits that nature and her autotrophic ecosystems provide in the form of delivering ecosystem services for society (climate regulation service, water retention service, oxygen production service, wildlife habitat provision, etc.).

By the substitute cost method (sometimes called also replacement costs, avoided costs) in combination with the biotope valuation method, we obtained minimal values of annual ecosystem services for selected natural ecosystems that have not been valued up to now. As can be seen below, from the viewpoint of thermodynamics the dominant role is played by ecosystem climate regulation (climatizing) and water retention services that, within the ecosystem self-organizing processes and according to real monitored data of energy-material flows, tend to be maximized with climax vegetation.

For a *deciduous forest ecosystem* saturated with water, the pilot estimations of services (estimated by replacement value approach and biotope valuation method) are as follows:

1. **Biodiversity:** L2.3 Hardwood forests of lowland rivers are valued according to the BVM at 66 points per 1 m², which for 1 ha means 660,000 points x CZK 12.36 per point = CZK 8,157,600 of stock value. With a 5% discount rate, this means annual service at the level € 16,320

2. **Estimation of forest oxygen production:** In the temperate zone, 1 ha of deciduous forest produces annually around 10 tons of biomass (expressed in dry mass). This corresponds to the release of 10.6 tons of oxygen. Production of oxygen has been calculated from the fundamental equation of photosynthesis where formation of one molecule of 6-carbon sugar is associated with the release of 6 molecules of oxygen, i.e. the formation of 180 grams of sugar (cellulose etc.) is associated with the release of 192 grams of oxygen. From this stoichiometry it follows that the production of 10 metric tons of dry mass (wood) is accompanied by the release of 10.6 metric tons of oxygen. According to Avogadro’s law, one gram-molecule of gas under normal atmospheric pressure and at a temperature of 20°C has a volume of 22.4 litres, i.e. 32 grams of oxygen take up 22.4 litres. Thus, the mass of 1 litre of oxygen is 1.429 g, or 1kg of oxygen has a volume of 700 litres. 10,600 kg/ha x 700 litres = 7.42 mil. litres x € 0.02 per litre (oxygen price) = € 148,400

3. **Forest climatizing (air-conditioning) service:** In the temperate zone, 1 ha of deciduous forest transpires around 600 litres of water from 1m² during the vegetation season. 1 m² of forest saturated with water evaporates around 5 litres of water during a sunny day. Whereas photosynthesis (biomass production) uses less than 1% of the incoming solar energy, by evapotranspiration (latent heat) around 80 % can be used in water saturated vegetation. The latent heat of 1 litre of water is equal to c. 0.7kWh. It is necessary to emphasize the double air-conditioning effect of evapotranspiration: first, a tree cools itself and its environment by evaporation of water (solar energy is used as latent heat), second, water vapour condenses on cool surfaces (or in cool air) and releases latent heat. Considering the double air-conditioning effect (cooling during evapotranspiration and warming during water vapour condensation), annual climatizing service of 1 ha can thus be estimated
4. **Support of short water cycles and water retention services**: evapotranspiration of 600 litres/m$^2$ brings an annual service: \( (600 \text{ litres/m}^2) \times €0.114 \) (distilled water price) \( \times 10,000 \text{ m}^2 \) = €684,000

| Total annual services from 1 ha forest | € | 1,520,720 |

If a natural landscape is drained, as the following account of **drained foothill pasture** (channel straightening and recessing) shows, its ecosystem services substantially decline on the level €738,000.

Note that not only does a drained landscape waste the precipitated water—it usually also demands external inputs of energy for the production of biomass.

### 5.2.1 National scale

For the nation-wide estimations of ecosystem functions and services, the four financially most important services were selected: wildlife habitat provision based on the BVM annual values, production of oxygen, climate regulation service, and short water cycle. Monetary values of four ecosystem services are displayed in Fig. 4

![Map of four ecosystem service monetary values](image)

**Fig. 4** Map of four ecosystem service monetary values (climatizing service, short water cycle, oxygen production, biodiversity service) in CZK.m$^2$.year$^{-1}$ based on CLC 2000.

The following table 2 presents an overview of biotope, ecosystem services and economic capital values for the territory of the Czech Republic. Please note the diametrical contradictions in how people value the territory (economic values, pushed up by draining the surfaces) and how ecosystems (working in synergy of solar energy fluxes, vegetation and water cycles) escalate the values of biotopes (BVM) and mainly values of life-supporting services (ecosystem service values) when left to develop naturally on their own, gradually becoming saturated by water and vegetation.
**Table 2 Biotope capital values, ecosystem service (ES) annual values, ecosystem service capital values and economic capital values of 1 m$^2$ of the Czech territories in €**

<table>
<thead>
<tr>
<th>LAND COVER</th>
<th>Biotope values</th>
<th>Annual ES values</th>
<th>ES capital values</th>
<th>Official prices</th>
<th>Notes</th>
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<tr>
<td>1.1.1. Continuous urban fabric</td>
<td>0 - 1.20</td>
<td>27</td>
<td>535</td>
<td>1.4 - 90</td>
<td>acc. to urban size</td>
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<td>1.1.2. Discontinuous urban fabric</td>
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<td>78</td>
<td>1557</td>
<td>1.4 - 90</td>
<td>acc. to urban size</td>
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<td>1.2.1. Industrial or commercial units</td>
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<td>32</td>
<td>638</td>
<td>1.4 - 90</td>
<td>acc. to urban size</td>
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<td>1.2.2. Road and rail networks and assoc. land</td>
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<td>58</td>
<td>1156</td>
<td>1.4 - 90</td>
<td>acc. to urban size</td>
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<td>1.2.3. Port areas</td>
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<td>70</td>
<td>1398</td>
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<td>acc. to urban size</td>
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<td>1.2.4. Airports</td>
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<td>80</td>
<td>1591</td>
<td>1.4 - 90</td>
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<td>1.3.1. Mineral extraction sites</td>
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<td>43</td>
<td>864</td>
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<td>1.3.2. Dump sites</td>
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<td>99</td>
<td>1981</td>
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<td>1.3.3. Construction sites</td>
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<td>844</td>
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<td>1.4.1. Green urban areas</td>
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<td>2127</td>
<td>1.4 - 33</td>
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<td>1.4.2. Sport and leisure facilities</td>
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<td>79</td>
<td>1589</td>
<td>0.4 - 0.6</td>
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<td>2.1.1. Non-irrigated arable land</td>
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<td>62</td>
<td>1242</td>
<td>0.04 - 0.7</td>
<td>acc. to soil quality</td>
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<td>2.2.1. Vineyards</td>
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<td>88</td>
<td>1769</td>
<td>0.04 - 6.4</td>
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<tr>
<td>2.2.2. Fruit trees and berry plantations</td>
<td>7.00</td>
<td>88</td>
<td>1764</td>
<td>0.04 - 4</td>
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<td>2.3.1. Pastures</td>
<td>10.28</td>
<td>102</td>
<td>2050</td>
<td>0.04 - 0.4</td>
<td>(\text{ann. ES } €75 \text{ m}^2)</td>
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<td>2.4.3. Land with agricult.&amp; natural vegetation</td>
<td>10.64</td>
<td>100</td>
<td>1996</td>
<td>0.04 - 0.4</td>
<td>acc. to soil quality</td>
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<tr>
<td>3.1.1. Broad-leaved forest</td>
<td>20.12</td>
<td>156</td>
<td>3118</td>
<td>0.1 - 4.4</td>
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<td>3.1.2. Coniferous forest</td>
<td>12.96</td>
<td>124</td>
<td>2490</td>
<td>0.1 - 4.4</td>
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<td>3.1.3. Mixed forest</td>
<td>14.08</td>
<td>131</td>
<td>2616</td>
<td>0.1 - 4.4</td>
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<td>3.2.1. Natural grassland</td>
<td>16.32</td>
<td>109</td>
<td>2177</td>
<td>0.04</td>
<td></td>
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<td>3.2.2. Moors and heathland</td>
<td>26.20</td>
<td>129</td>
<td>2576</td>
<td>0.04</td>
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<td>3.2.4. Transitional woodland shrub</td>
<td>11.64</td>
<td>106</td>
<td>2128</td>
<td>0.04</td>
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<td>3.3.2. Bare rock</td>
<td>19.68</td>
<td>107</td>
<td>2144</td>
<td>0.04</td>
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<td>4.1.1. Inland marshes</td>
<td>16.56</td>
<td>159</td>
<td>3174</td>
<td>0.04</td>
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<td>4.1.2. Peatbogs</td>
<td>26.36</td>
<td>168</td>
<td>3361</td>
<td>0.04</td>
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<td>5.1.1. Water courses</td>
<td>11.44</td>
<td>139</td>
<td>2776</td>
<td>0.3</td>
<td></td>
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<tr>
<td>5.1.2. Water bodies</td>
<td>9.24</td>
<td>148</td>
<td>2962</td>
<td>0.3</td>
<td></td>
</tr>
</tbody>
</table>

* Exch. rate: € 1 = CZK 25

According to our estimations, the total amount of annual ecosystem services on the territory of the Czech Republic is about CZK 182 trillions (182x10$^{12}$). Compared to the annual GDP in 2008 (3689x10$^{9}$), four annual ecosystem services are fifty times bigger.

By utilizing these two methods (BVM, EWVM), two scales of ecological values of landscapes (both as flows and stocks) have been derived. Subsequently, these environmental values may be compared with market prices of standard land uses.
5.2.2 Regional scale

The national project on ecosystem identification and valuation incorporated three regional case studies: the upper part of Stropnice river basin, a part of Třeboň district and the former military shooting range Ralsko. Their main goal was a more detailed analysis of landscape functions, identified on the basis of solar energy dissipation by different biotopes mapped by the Natura 2000-BVM method. In this summary, the regional study of Stropnice upper river basin is presented as an example.

The study region is delimited by Stropnice upper river basin with the closing profile at Tomek mill (470 m. altitude). Its area is 112 km$^2$, of which 99 km$^2$ lies in the Czech Republic (mainly České Budějovice district); the rest is in Austria. The main river is Stropnice, the right side effluent of Malše river, North sea-drainage area. The total length of Stropnice is 54 km, of which 20 km are situated in the study region. The highest point in the region is the mountain peak Vysoká (1034 m altitude) near the Austrian borders.

The region is classified as a potato growing region, potato-grain growing type, subtype B3, with the altitude of 400 – 600 m with broken terrain and prevailing brown soils. Phytogeographically (Culek, 1995) the region falls mainly into the Czechomoravian mesophytics (37p-Novohradské foothills, 39-Třeboň basin) and a small southwest part into the Czech ooreophytics (89-Novohradské mountains). Most of the territory falls into the natural park Novohradské hory (except the eastern hook that sets into CHKO Třeboňsko), declared in 1999.

The monetary value of ecosystem services for the region was assessed by the same procedure as for the Czech Republic. CORINE – LC maps were used, as well as more detailed mapping of Natura 2000 – BVM. The values obtained from a more detailed mapping were compared to the values derived from Corine-LC maps (Fig. 6). The results show that the more detailed Natura 2000 – BVM mapping produced higher values (Tab. 3).

<table>
<thead>
<tr>
<th>Table 3. Ecosystem service values in case study region estimated from the map Corine-LC 2000 and from combined maps of Natura 2000-BVM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Regional study</strong></td>
</tr>
<tr>
<td>Stropnice upper river basin</td>
</tr>
</tbody>
</table>

Use of remote sensing data for functional classification of landscape segments, based on solar energy dissipation

Landscape surface temperature is considered to be one of the key characteristics explaining the biophysical and ecological processes that determine the balance between water cycle and energy balance of the landscape. In addition, it plays an important role in the assessment of physiological activity, health status and functioning of ecosystems (Melesse, 2004), affects the energy and matter flows within ecosystems and the hydrological cycle (Ripl, 2003).
Surface temperature is an indicator that expresses the ability of system to dissipate solar energy and thus consider it as a measure of the energy use efficiency (Procházka et al., 2006). The examples of surface temperatures of different land cover types are shown on images in Annex 1.

The proposed classification scheme for landscape dissipation ability assessment (Hesslerová, Pokorný, 2010) was defined as a result of cross-classification analysis of relative radiation temperature and wetness-biomass index, derived from Landsat satellite data. The landscape cover was divided into nine basic dissipation classes, characterizing the landscape in terms of how it distributes solar energy (Fig. 6). One side of the classification scheme is represented by landscape with a high amount of green biomass and moisture which is able to transform the majority of incident solar radiation into latent heat through evapotranspiration. In terms of landscape functions, this category, mainly represented by forest stands, is considered to be the most functional. The other side is characterized by a landscape with a minimal amount of vegetation with high water deficit; sensible heat flux is the dominant component of the solar radiation balance. Such landscape type is the least desirable; depending on the amount of green biomass it is represented by bare ground (urban and industrial areas), or, in some cases, even by agricultural areas. This classification scheme allows for a quick analysis and diagnosis of landscape functions of large and heterogeneous areas.

Within the area of the regional study an impact analysis of the biotopes on the dissipation of solar energy was applied. The analysis was based on the integration of both maps – the biotope map by Bodlák at al. (2008) and the map of dissipation categories, based on Landsat satellite data. Eighty two biotopes were identified, for which it has been found which dissipation categories they belong to. The biotope polygons were assigned to the dissipation category according to the predominant category in the polygon (Fig. 7).
Fig. 6 The scheme of 9 categories incorporated into the method of valuing dissipation abilities of landscape.

Fig. 7 Map of dissipation categories distribution in the area of Stropnice upper river basin. 0 = water bodies
The major categories within the model area are category 1 (36% of the area) characterized as a dense vegetation with high water content and low temperature and category 9 (39% of the area), represented by sites without functional vegetation cover with high wetness deficit.

The individual dissipation categories in terms of biotopes represented in the Stropnice region are characterized as follows:
Category 0 (water bodies): water reservoirs predominate complemented by wetlands
Category 1: forests are predominant, mainly anthropogenically influenced
Category 2: significant representation of anthropogenically influenced forest vegetation
Category 3: forest vegetation dominates, combined with water areas, accompanied by wetlands
Category 4: significant proportion of forest vegetation in combination with arable land and permanent grassland
Category 5: significant proportion of forest vegetation in combination with permanent grassland
Category 6: arable land predominates, supplemented by grassland and forests
Category 7: combination of forest and grassland biotopes
Category 8: significant representation of grassland, complemented by arable land
Category 9: combination of arable land and grassland.

For the area of Stropnice upper river basin, a map of overlaps of dissipation categories and map of biotope types was designed (Fig. 8).

Fig. 8 Map of overlaps of energy dissipation categories and biotope types in the Stropnice upper river basin region. Composed of biotope types and energy dissipation maps, 0 = water body.
6. Discussion

Biosphere 1, i.e. the Planet Earth, produces all ecosystem services daily at no charge for nearly 7 billion people. If Biosphere 2 at the beginning of 1990s needed $200 million investment for eight people, then the natural capital of the global ecosystem could thus be estimated at least at the value level of $165 quadrillion (165 x 10^{15}). Let us note that at the beginning of the 1990s, the world annual GDP of about 6.6 billion people reached approximately USD 16 trillion (16 x 10^{12}), i.e. was ten thousand times lower than the estimated natural capital value of global biosphere.

If we transfer, similarly as Costanza et al. (1997, p. 258), the dimension of natural capital stock into a dimension of annual flow of world ecosystem services (using a 5% discount rate) then the annual value of world ecosystem services would be USD 8 quadrillion (8 x 10^{15}), which means five hundred times higher than the annual world GDP. From this single example it is clear that the estimations of world natural capital, based on substitute costs method, are at the level much higher than the world GDP.

In our approach, solar energy dissipative processes dominate, supported by water and vegetation (energy-water-vegetation). If one item in this natural triple-part self-organizing processes is reduced by humans, as in the case of drained foothill pasture, the level of ecosystem services substantially declines. In the Costanza et al. estimates, the climate regulating services (temperature and precipitation) create no more than 2 % of ecosystem services total value (valued by demand-curve approaches, i.e. by summing individuals' willingness to pay for such services). This comparison shows that for the most decisive life-supporting services of the biosphere, the majority of human individuals still have very weak preferences (that up to now converge to nearly zero) even though from the viewpoint of solar energy throughput and high effectiveness of its use by joint efforts of vegetation and water, these life-supporting services can only partly and very expensively be substituted by man-made technologies.

7. Conclusions

1. The science we elaborate upon in this book deals with solar energy and growing efficiencies of its transformations over succession phases of self-organized development in ecosystems. In this sense, the climax natural vegetations – in terrestrial ecosystems of central Europe mainly deciduous leafy forests – are irreplaceably the best natural controllers to mitigate temperature extremes and retain water and nutrients inside the ecosystems.

2. The present globalized system of market economies is unsustainable as it is progressively degrading major natural ecosystems, destroying thus its own life-supporting environment. It is unsustainable because it is driven by unethical, destructive values and interests of a never-ending expansion of capital on the costs of exploiting both humans and the natural world. One substantial reason for the current unsustainability of the global market economic system is the absence of valuing ecological services of natural environment. The utilitarian approach to standard preferential economic valuation does not value nature but only the future net benefits (rents) from the use and change of natural environment. The economic use of land mostly leads to destruction of natural vegetation.

3. The real transition to a sustainable future requires to develop and implement a systemic valuation of all national territories in order to obtain relative ecological values for all land-cover and land-use categories. In the Czech Republic, two new methods of revealing ecological values of national environment have been developed. The Biotope Valuation
Method (BVM) originally elaborated in the Hessian state of Germany and recommended for dissemination by the EU White Paper on Environmental Liability (2000), brings monetary values of a complete list of national biotopes as specific environments for specific living species. This method is useful primarily for estimating the ecological and biodiversity losses from changing the natural vegetation into some form of anthropogenic use of land. The value *numéraire* is derived from the average national costs per one point increase in 1m$^2$ in restoration projects. The scale of values ranges from zero up to €40/m$^2$.

4. The second ecological value dimension of the Czech national environment introduces four measured life-supporting ecosystem services to estimate the real benefits that the society uses free of charge (i.e. air-conditioning service, water retention service, oxygen production service, biodiversity service). This Energy-Water-Vegetation Method (EWVM) originates in the work of Ripl (1995, 2003). The value *numéraire* is derived from the replacement cost method (minimal costs of technological substitution of natural service). The scale of ecosystem services stock values starts at zero in cases of completely anthropogenized lands; however, in natural and semi-natural ecosystems, the annual values reach even above €3,000 per m$^2$.

5. Using traditional utilitarian demand–side methods, Costanza et al. (1997) estimated the world annual ecosystem services as 1.8-fold of the annual world GDP (USD 18 trillion). Our pilot estimation of four measured annual ecosystem service values in the CR, based on replacement cost methods, assessed that annual ecosystem services surpass the annual GDP at least fifty times.

6. We argue that it is not the replacement cost method that tends to overestimate actual values of these supporting and regulating services of ecosystems, “unknown for the consumer” (as argued by some mainstream economists), but rather the utilitarian methods that expressively underestimate these primary services of nature.
Annex 1 Examples of thermocamera images from different biotopes

Thermovision images acquired in a clear-sky day (25th August 2009) around 13:00 GMT+1 show the temperature differences in biotopes.

Full-grown pine forest. The temperature in the forest is around 20 °C, in the range of 4 °C. The vertical temperature distribution is remarkable. The temperature in undergrowth is often lower than the temperature in the upper canopy. In the case of temperature inversion, humid air does not rise up from the stands and stays inside.

A stubble with a backdrop of trees in the background. The stubble temperature is about 40 °C. In the neighboring forest, the temperature is 20 degrees lower. Images in the forest and of the stubble were taken within a few minutes.

The effect of mesophilic meadow mowing is obvious from the difference of dry grass (35 °C) and non-mowed green grass (25 °C).
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