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Article *in* Ecosystem Services · September 2022

DOI: 10.1016/j.ecoser.2022.101469

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Ecosystem Services 57 (2022) 101469

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Ecosystem Services

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Why ecosystem services should be counterbalanced by nature's thermodynamic costs

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ARTICLE INFO

Keywords
Climax ecosystems
Ecosystem services
Economic value
Evapotranspiration
Value relations

ABSTRACT

The neoclassical, unilaterally-defined value concept of ecosystem services (ES) as 'benefits' must be counterbalanced by a transparent and valid assessment of thermodynamic costs that result from degrading mature climax ecosystems. It is because willingness to pay-based methods of ES valuations produce unsustainable value relations that promote continuation of business-as-usual and further destruction of the fragments of nature. The authors argue that conversions from temperate forest to built environments result in economic losses of supporting and regulating ES that are more than two hundred times greater than the economic benefits. The loss of the cooling effect from evapotranspiration, replaced by warming from sensible heat creation in built environments, results in energetic impacts that are two orders of magnitude greater than those from greenhouse gas emissions. This is why, for sustainable landscape decision-making, the preference method results have to be compared to the costs that nature and humans have to bear due to anthropogenic changes in the natural landscape. Economic agents should start to pay for their 'heat footprint', ie. for thermodynamic losses caused by their transformation of natural ecosystems. By incorporating solar energy dissipation losses as costs to ecosystems, the proper value relations can be achieved, with climax forests as the most valuable producers of supporting and regulating ES. Humans are unable to equivalently substitute such forests using human technologies.

Ecosystem services (ES) as benefits for humans are a useful, but highly anthropocentric concept. They allow us to identify most of nature's contributions to people. Their anthropocentrism follows from the fact that they almost completely omit the costs nature has to bear in order to provide them. While nature provides for humans and, in succession processes, maximizes the efficiency of incoming solar energy and entropic production (Skene, 2013), leading to climatic homeostasis (Lovelock, 2007), human individuals pursue their own self-interest and personal enrichment. The satisfaction of principally unlimited human desires has brought the Earth's biosphere near to collapse and produces increasing extremes in climate.

Among scientists, the thermodynamic and energetic foundation of the entire universe, including the solar system and life on Earth, is already broadly accepted. As E. Odum proved, solar energy inflows are linked to succession phases, in which nature is increasing its efficiency in the use of solar energy step by step, with the maximum being reached in climax vegetation (Odum, 1969). Unfortunately, the embodied energy method, as elaborated by the Odum brothers, takes into account only the small photosynthetic share of incoming solar energy, but not the much larger amount that vegetation directly changes into cooling and water-retaining ecosystem functions (Schneider and Sagan, 2005).

While nature, through ecological succession, maximizes the efficiency of solar energy transformations and entropic production, most human economic activities in the landscape reduce this efficiency. Economic agents in a globally hypertrophied economic system have substantially fragmented the originally unified network of natural (mostly forest) ecosystems, increasingly disturbed the sensitive balance of processes among autotrophic and heterotrophic forms of life and elicited climate extremes. Most supporting and regulating ES are delivered by nature as positive externalities and freely accessible public goods, while in the dominant subjective value systems of market economies these services are most seriously threatened by human activities and are rapidly vanishing from the Earth's biosphere. In such a situation, the internalization of negative thermodynamic externalities (heat

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https://doi.org/10.1016/j.ecoser.2022.101469
Received 9 February 2021; Received in revised form 12 April 2021; Accepted 11 August 2022
Available online 22 August 2022

Table 1
Comparing ES value relations generated by preferential methods and by the replacement costs of four primary ecosystem functions. The 'relations' columns represent the ratio between a given biotope and a temperate forest where the temperate forest values are set as unity.

biome, biotope groups	Costanza et al., 2014				Sejak et al., 2018	
	1997	2011	1997	2011	2018	2018
	$/ha/year		relations	relations	€/ha/year	relations
Temperate/boreal forest	417	3,137	**1**	**1**	1,060,000–1,400,000	**1**
Tropical forest	2,769	5,382	**6.6**	**1.7**	2,000,000–2,800,000	**2**
Grasslands	321	4,166	**0.77**	**1.3**	600,000–800,000	**0.6**
Floodplains	27,021	25,681	**64.8**	**8.2**	800,000–1,400,000	**0.9**
Lakes, rivers	11,727	12,512	**28.1**	**4**	1,110,000–1,360,000	**1**
Croplands	126	5,567	**0.3**	**1.8**	510,000–780,000	**0.5**
Urban lands	–	6,661	**–**	**2.1**	140,000–650,000	**0.3**

footprint) caused by anthropogenic alteration of the natural landscape appears to be a rational solution, akin to addressing environmental pollution problems in the second half of 20th century.

And this is exactly what our Energy-Water-Vegetation Method (EWVM) measures, as it evaluates cooling, warming, water retention, biodiversity nursery services and production of oxygen as basic supporting and regulating functions of autotrophic ecosystems. This in turn allows the quantification of thermodynamic costs in the form of ecological losses of solar energy (losses of latent heat) caused by anthropogenic changes of the natural environment (Sejak et al., 2018).

When we take into account this decisive aspect of solar energy change (latent heat in living land cover), it substantially changes the perception of the importance of natural vegetation and proves that most anthropogenic changes driven by economic reasons are activities with higher thermodynamic costs than achieved benefits. Until now individuals (as private owners or land users) mainly determined land-cover changes. However looking ahead, all three benefits (individual, societal, ecosystem) must carefully be evaluated by municipal representatives and stewards of the entire planet, as outlined by Daly (1992) and correctly underlined in Costanza's article (2020).

Humans have a new task for the full post-COVID world: besides producing enough food and other natural materials, they also must contribute to restoring the natural capital of the Earth's continents in order to assure healthy ecosystems and a sustainable future for the human species.

For sustainable decisions in landscape management, the preferential methods as reviewed and summarized from hundreds of studies by Costanza et al. (2014) are needed (as they reflect nature's contributions for humans), as well as our costs values (Table 1) that show high losses of latent heat (=costs) from anthropogenic changes to natural vegetation land-covers and give proper value relations for sustainable future landscape management. In the context of a new decision-making framework, when many economic projects would bring much higher thermodynamic costs than expected benefits, we must allow much more space for natural capital restoration and for responsible decision-making at all relevant levels as reflected in the S-value of ecosystem services in Costanza (2020) or in returning water to the landscape in Seják et al. (2022). In integrative valuations, only the best benefit-cost comparisons will lead to a sustainable path to mitigation of climate extremes and to the survival of the human species.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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