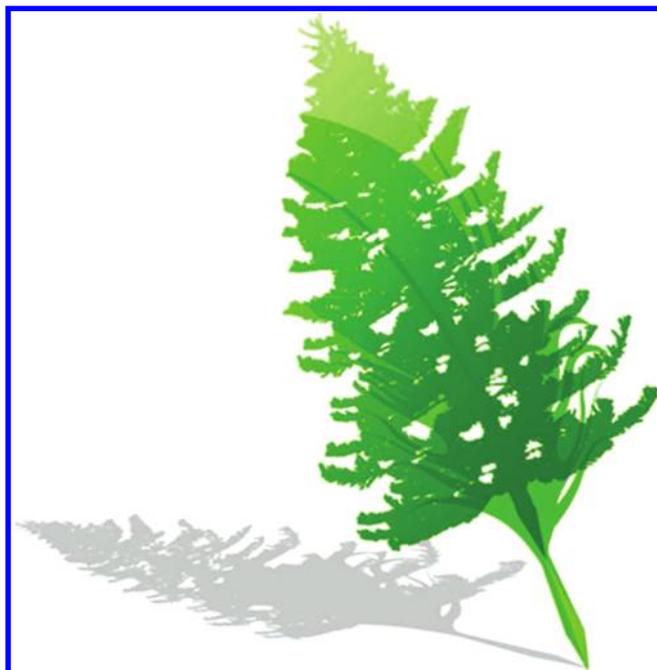


## Ecosystem Service: From Virtual Reality to Ground Truth

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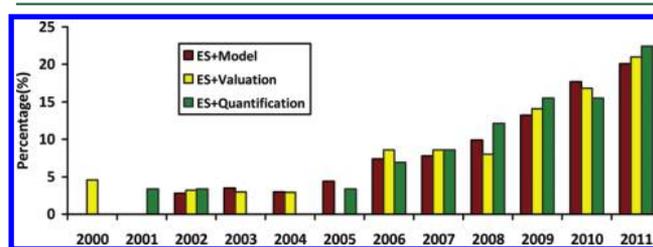


Ecosystem service is the collective name for the benefits that people obtain from ecosystems. As a scientific concept, it can be dated back to the 1960s; whereas, the proliferation of ecosystem service research has been since the late 1990s driving by the increasing environmental concerns of human societies. Ecosystem service has been defined from an anthropocentric perspective that links ecosystems and human society by unilateral benefit flows. Therefore, the heating up of ecosystem service research in the past decade started from the recognition and monetary valuation of the benefit flows from ecosystems to society. The purpose of this movement is to raise serious concerns on the overwhelming importance of healthy ecosystems for human wellbeing and inform wise policies and actions for ecosystem use, conservation, and sustainable management.

The millennium Ecosystem Assessment classified ecosystem services into four broad categories including supporting services, provisioning services, regulating services, and cultural services. This has been widely appreciated but not the items within each category. Former classifications of ecosystem services were challenged on their tendencies to exchange use of ecosystem processes and services as well as insufficient or vague terminologies.<sup>2</sup>

Beyond classification, there comes the modeling, quantification, and valuation of ecosystem services. These processes are indispensable for decision-making in ecosystem management and land use planning to provide quantitative information and tools. We carried out literature searches in the ISI Web of Science using three topic combinations including Search syntax 1

“TS=ecosystem service and TS=model”, Search syntax 2 “TS=ecosystem service and TS=valuation”, and Search syntax 3 “TS=ecosystem service and TS=quantification”. These searches retrieved 1237, 525, and 58 records, respectively. Research articles published in peer-reviewed academic journals dominated these records (over 84%). The yearly percentage distributions on methodological issues in ecosystem service research including modeling, valuation, and quantification (Figure 1).



**Figure 1.** Percentage of publications on methodological research of ecosystem services from ISI Web of Science since 2000. ES = ecosystem service.

Ecosystem service research is blooming, but it is not easy to anticipate fruitful harvests. Ecosystem service research has been hindered practically by the huge complexity and dynamic nature for ecosystems, human societies, and their interactions. Nonlinear dynamics, spatial heterogeneity, surprise, and uncertainty are ubiquitous to these systems and their interactions. The contemporary scientific knowledge on ecosystem services is quite limited. For example, the exact number of species and their dynamics on the planet earth are still not known, needless to say the ecosystem services provided by wild species to people;<sup>3</sup> and efforts taken to improve one ecosystem service such as carbon sequestration may compromise others.<sup>4</sup> Similarly, economics in general and ecological economics in particular still fall short of methodological instruments to quantify the monetary values of some ecosystem services without market or intrinsically intangible. Considering the contrasting paradigms in science and economics on the quantification and valuation of ecosystem services, arguments even point to a potentially impossible mission for quantifying any integrative value on ecosystem services.<sup>5</sup> Therefore, the conceptual and methodological development of ecosystem service research is still at a preliminary stage, which can be called a metaphorical stage of “virtual reality”. However, it has to be brought down to earth as an evidence-based and science-informed discipline to tackle real

Published: February 27, 2012

world issues of environmental education and decision support for sustainable ecosystem management.

Concrete breakthroughs have to be made in the research fields such as the biophysical patterns and processes determining ecosystem service provision as well as social values or norms and behaviors shaping the use and sustainability of ecosystem services. To facilitate these breakthroughs, concerted efforts are urgently needed from disciplinary, interdisciplinary, and transdisciplinary perspectives. Methodological development and implementation should be better targeted at landscape and regional-scale ecosystem service issues for practical and effective solutions. More specifically, we identify five action points in improving ecosystem service research.

First, site and landscape-scale ecosystem structure–process–function dynamics as well as their implications on ecosystem services under biophysical and anthropogenic disturbances need to be monitored and analyzed continuously and adaptively in the long run. This is crucial for the development of robust ecosystem models and acquiring information illuminating ecosystem management for sustainable ecosystem service flows.

Second, the conceptual framework and classification scheme of ecosystem service need to be restructured and fine-tuned along with the evolution of ecosystem science. The evolving concept of ecosystem is originally viewed as the organizational entity that ecological communities integrate with their abiotic environment, and more recently humans are also considered an important component of ecosystems which facilitates paradigm shift to coupled social–ecological systems or coupled human and natural systems. With the development of scientific understanding of ecosystem processes, functions, and the interactions between ecosystems and human society, new ecosystem service or disservice items are bound to be identified in the future.

Third, ecosystem service research should be grounded firmly on disciplinary bases and advanced in multidisciplinary and transdisciplinary manner. There are several closely related domains for ecosystem service science including ecosystem service definition and classification, quantification, valuation, and management. The domain of quantification, biophysical assessment of the quantities in ecosystem service provision, is largely disciplinary and has already developed at least for decades in areas such as hydrology and soil science. Other domains are more complex with inevitable involvement of human perceptions and behaviors, which necessitates multidisciplinary and transdisciplinary approaches covering both natural science and social science.

Fourth, decision support tools useful to users are urgently needed. The development of decision support tools is both the representation and test of scientific knowledge on ecosystem services. To be user-useful, decision support tools need to include at least the operational issues from domains of quantification, valuation, and management.

Finally, project-based adaptive management cycles provide opportunities for improving ecosystem service science. Projects on payment for ecosystem services (PES), no matter whether in the form of ecological conservation or restoration, can be used as grand experiments at various spatiotemporal scales to test and provide feedback to the scientific understanding of ecosystem service management and the development of methodological tools for decision support.

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### Notes

The authors declare no competing financial interest.

## ■ ACKNOWLEDGMENTS

This research was supported by the national basic research program (2009CB421104), the Chinese Academy of Sciences (KZCX2-YW-QN408), and NSFC (41171156).

## ■ REFERENCES

- (1) Vihervaara, P.; Rönkä, M.; Walls, M. Trends in Ecosystem Service Research: Early Steps and Current Drivers. *Ambio* **2010**, *39*, 314–324.
- (2) Wallace, K. J. Classification of ecosystem services: Problems and solutions. *Biol. Conserv.* **2007**, *139*, 235–246.
- (3) Singh, J. S. The biodiversity crisis: A multifaceted review. *Curr. Sci.* **2002**, *82*, 638–647.
- (4) Wang, Y. F.; Cao, S. X. Carbon sequestration may have negative impacts on ecosystem health. *Environ. Sci. Technol.* **2011**, *45*, 1759–1760.
- (5) Sagoff, M. The quantification and valuation of ecosystem services. *Ecol. Econ.* **2011**, *70*, 497–502.