Postprint of the Indicator System for Biodiversity and Ecosystem Services Assessment in China

Authors: FU Bojie, YU Dandan, LÜ Nan

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Abstract

Biodiversity and ecosystem services assessment constitutes a critical foundation for ecosystem management and decision-making, with indicator systems serving as the primary tools for such evaluations. In China, the construction of biodiversity and ecosystem services assessment indicator systems has been hampered by the lack of unified indicator frameworks and technical methodologies, resulting in low comparability of assessment results across different regions and impeding integrated research at regional and national scales. Consequently, the development of a scientific, systematic, and standardized biodiversity and ecosystem services assessment indicator system applicable at the national scale in China represents a pressing issue requiring immediate research attention. This paper draws upon major research achievements in biodiversity and ecosystem services assessment both domestically and internationally, proposes the fundamental principles for constructing such indicator systems based on a comprehensive consideration of the "biodiversity-ecosystem structure-process and function-services"cascade relationship, and develops a biodiversity and ecosystem services assessment indicator system tailored for China.

Full Text

Preamble

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An Indicator System for Biodiversity and Ecosystem Services Evaluation in China

FU Bojie*, YU Dandan, LÜ Nan
State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

Abstract

Assessment of biodiversity and ecosystem services provides an important foundation for ecosystem management and decision-making, with indicator systems serving as the primary tools for such evaluations. However, China has yet to develop unified indicator systems and methods for biodiversity and ecosystem services evaluation, resulting in poor comparability of assessment results across different regions and difficulties in conducting integrated studies at regional and national scales. Therefore, establishing a scientific, systematic, and standardized indicator system for biodiversity and ecosystem services evaluation in China is an urgent priority.

This paper proposes principles for constructing evaluation indicator systems and establishes a comprehensive indicator system for biodiversity and ecosystem services assessment in China. The framework draws upon major research outcomes in biodiversity and ecosystem services studies worldwide and incorporates the cascade relationships among biodiversity, ecosystem structure, processes and functions, and ecosystem services. The resulting indicator system provides a foundation for quantitative assessment of biodiversity and ecosystem services in China.

Keywords: ecosystem services; biodiversity; evaluation; indicator system

Human well-being depends fundamentally on biodiversity and ecosystem services. Rapid population growth and socioeconomic development have placed increasing pressure on these systems, creating a vicious cycle of biodiversity loss, degraded ecosystem services, and poverty. In response to these challenges, the global community has intensified efforts to address biodiversity loss and ecosystem service degradation. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was formally established in 2012 under the United Nations Environment Programme (UNEP), representing renewed worldwide attention to ecosystem services following the Millennium Ecosystem Assessment (MA) and establishing another major intergovernmental global environmental assessment initiative alongside the Intergovernmental Panel on Climate Change (IPCC).

China has conducted biodiversity conservation and ecosystem services research for several decades, undertaking extensive fundamental and applied studies in nature reserve construction, ecological function zoning, biodiversity monitoring and evaluation, and biodiversity data management and information networking. However, unified indicator systems and technical methods remain underdeveloped, resulting in poor comparability of assessment results across regions and limiting the ability to conduct integrated regional and national-scale studies. This paper draws upon major international research outcomes in biodiversity and ecosystem services evaluation, establishes key principles for indicator system construction based on cascade relationships among biodiversity, ecosystem structure, processes and functions, and employs frequency analysis and expert consultation methods to develop a comprehensive indicator system tailored to

China’ s national context. Building upon existing monitoring research, we also discuss quantitative assessment methods, data requirements, and accessibility to provide theoretical and technical foundations for precise evaluation of biodiversity and ecosystem services in China.

1. Conceptual Framework for Biodiversity and Ecosystem Services Assessment

A conceptual framework is essential for constructing biodiversity and ecosystem services assessment indicator systems, providing the theoretical foundation for this work. This study first establishes a cascade conceptual framework linking biodiversity, ecosystem structure, processes and functions, and services.

Biodiversity—encompassing species richness, genetic diversity, and spatial distribution—represents a component of natural heritage. Within specific systems, biodiversity influences ecosystem services by affecting the flows of materials, energy, and information and their interactive processes. As the prerequisite and foundation for all ecosystem functions and services, biodiversity determines the capacity of ecosystems to provide benefits to humanity. Ecosystem services refer to all benefits that humans obtain from ecosystems, formed by the interactions of ecosystem functions including supporting, regulating, and cultural services. The biophysical structures and processes of ecosystems manifest as ecosystem structure and function characteristics, whose stability ensures sustained service provision. A single ecosystem function can generate one or multiple ecosystem services, while a particular service may derive from one or multiple functions, creating many-to-many relationships between functions and services. Supporting services (or intermediate services) generate and sustain other services, with their values embodied in final services that directly contribute to human well-being.

[Figure 1: see original paper] “Biodiversity—Ecosystem Structure—Processes and Functions—Services” Cascade Conceptual Framework [3-4]

1. Principles for Establishing the Indicator System

Establishing clear principles is fundamental to ensuring objectivity, impartiality, and operability of the indicator system. Drawing upon existing indicator system development experience [1, 5-8] and considering China’s unique biodiversity and ecosystem services characteristics, we synthesized current research outcomes and adopted the Final Ecosystem Goods and Services (FEGS) classification framework. From a practical perspective, the Common International Classification of Ecosystem Goods and Services (CICES) categorizes final ecosystem services into four groups directly related to human well-being: health, production factors, and natural diversity [9]. This final ecosystem services classification avoids definitional ambiguity, reduces double-counting, links natural systems with human society, and facilitates understanding and communication by identifying service beneficiaries [10].

Based on ecosystem attribute characteristics and functional evaluation perspectives, we prioritized ecosystem structure and function parameters to establish connections with ecosystem services. Ecosystem attribute-based indicators enable long-term assessment and prediction of ecosystem services. Without distinguishing ecosystem types, different ecosystems may share common functions or attributes, though specific service categories and magnitudes may vary. Therefore, the indicator system does not list separate ecosystem types. However, given differences between terrestrial and aquatic ecosystems, we included both common indicators and specific metrics for aquatic systems, such as the Marine Trophic Index.

Considering the relative unity and independence of biodiversity and service indicators, biodiversity assessment serves as the foundation for ecosystem services evaluation, with services as the ultimate focus. We selected only biodiversity indicators with direct service linkages, excluding genetic-level diversity given current knowledge limitations. Consequently, biodiversity and ecosystem service indicators were developed as relatively independent but complementary systems. Most selected indicators are employed by renowned international organizations or national assessments, while also incorporating metrics from Chinese programs such as China' s Fourth National Report on Biodiversity [11] and the China Western Ecosystem Assessment [12].

2. Indicator System Screening Methods

To ensure objectivity and minimize subjective bias, we prioritized quantifiable indicators with reliable data sources that are easily obtainable. Given limited resources for indicator development and testing, inappropriate indicators could divert funds from effective conservation and management objectives. We therefore selected economical indicators applicable at regional and national scales that enable efficient resource utilization.

Common indicator screening methods include frequency analysis, expert consultation, and analytic hierarchy process [13]. This study combined expert consultation and frequency analysis. First, we used frequency analysis to statistically evaluate practical indicators from major international biodiversity and ecosystem assessment studies, selecting frequently used metrics. We then adapted these to China' s context considering national biodiversity and ecosystem services characteristics. Finally, expert opinions were solicited to refine and adjust the indicator selection, resulting in a comprehensive indicator system for China' s biodiversity and ecosystem services assessment.

1. Biodiversity Assessment Indicator System

Based on the established principles, the biodiversity indicator system emphasizes major international biodiversity assessment outcomes while incorporating multiple taxonomic groups. Birds and butterflies serve as indicator species reflecting environmental conditions, complemented by China-specific metrics such as minimum population sizes of endemic plants. The system includes three categories: pressure, state and trend, and response indicators.

Pressure indicators encompass climate change, urbanization, and landscape fragmentation. State and trend indicators include species richness, phenology, and six thematic metrics. Response indicators comprise nature reserve establishment and sustainable management. The resulting biodiversity assessment indicator system integrates these components into a comprehensive framework.

Biodiversity Assessment Indicator System in China

2. Ecosystem Services Assessment Indicator System

In constructing the ecosystem services indicator system, we considered relationships between ecosystem attribute parameters and service indicators, as well as connections to three human benefit categories: health, production factors, and natural diversity. The system includes provisioning, regulating, and cultural services. Provisioning services comprise freshwater, genetic and biological resources, and timber and fiber. Regulating services include climate change mitigation, local microclimate regulation, air quality regulation, natural disaster regulation, and pest and disease control. Cultural services encompass recreation and cultural diversity.

Ecosystem Services Assessment Indicator System in China

3. Quantitative Methods for Assessment

We integrated direct observation, calculation, and simulation methods to determine evaluation approaches for each indicator. For biodiversity indicators, plant species counts, population sizes, and phenological periods use direct observation, while landscape fragmentation and Marine Trophic Index employ computational or simulation methods [14-18]. The Living Planet Index requires chain methods or generalized additive models (GAM) [19].

For ecosystem services indicators, ecosystem types and World Heritage site counts use direct observation or literature review. Forest aboveground biomass is obtained through remote sensing or biomass conversion factors [20-22]. Grassland forage yield uses linear or nonlinear stepwise regression analysis [23]. Oxygen release and dust retention are calculated based on specific quantitative relationships with plant carbon sequestration [25-26]. Soil retention and actual evapotranspiration use the soil loss equation and water balance method, respectively. County-level administrative maps are overlaid with land use maps in ArcGIS for additive calculations [27]. Water yield, crop production potential, and ecosystem carbon fixation utilize models including ORYZA2000, Hybrid-Maize, CERES-Wheat, CASA, and CENTURY, while InVEST modules calculate aquatic vegetation carbon sequestration [28-32].

4. Data Requirements and Accessibility Analysis

Data requirements and accessibility for China' s biodiversity and ecosystem services assessment are summarized in Table 3. Although national biodiversity and ecosystem observation networks have received governmental support, coverage remains limited and lacks periodic ecosystem status surveys and assessments [33]. Current data infrastructure is insufficient for comprehensive evaluation, with some data obtainable only through literature review or plot-scale experiments, such as regional species counts.

Model-simulated ecosystem services require input data such as land use/cover classification maps from remote sensing interpretation. For example, the ORYZA2000 crop model requires rice yield potential data, while InVEST' s water yield module needs vegetation type maps. Other requirements include net primary productivity, soil respiration, and net ecosystem carbon exchange data.

Data Requirements and Accessibility for Biodiversity and Ecosystem Services Evaluation in China

4. Discussion

The uncertain relationship between biodiversity and ecosystem services necessitates independent yet complementary assessment approaches. While we selected biodiversity indicators conceptually linked to services, these relationships require validation through extensive case studies. The essence of ecosystem services lies in ecosystem functions, with assessment focusing on functional quantification and spatial modeling. Although most selected service indicators can establish direct relationships with ecosystem attributes, current knowledge and data limitations mean specific service indicators may cover only certain aspects of thematic indicators.

The current indicator system addresses service supply but not demand, primarily due to inadequate theoretical foundations and data support for supply-demand balance analysis [34]. Indicators for analyzing service demand and supply-demand relationships require further development.

5. Conclusion

Biodiversity and ecosystem services assessment is crucial for ecosystem management and decision-making, with indicators and models as fundamental tools. Current systems face numerous challenges stemming from insufficient understanding of biodiversity' s complex structures, functions, and processes, and the intricate relationships between ecological and socioeconomic processes. This indicator system adopts a final ecosystem services classification based on ecosystem attributes, considering the relative unity and independence of biodiversity and service indicators. Most indicators can be determined using GIS and remote sensing technologies.

The framework offers operational feasibility and transferability, though indicator rationality requires further refinement through extensive case studies at national and regional scales in China. Such improvements will enable precise biodiversity and ecosystem services assessment to truly inform ecosystem management decisions.

References

[1] Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Volume 2 Scenarios: Findings of the Scenarios Working Group. Washington DC: Island Press, 2005.

[2] Bennett E M, Peterson G D, Gordon L J. Understanding relationships among multiple ecosystem services. Ecology Letters, 2009, 12(12): 1394-1404.

[3] Haines-Young R, Potschin M. The links between biodiversity, ecosystem services and human well-being // Raffaelli D G, Frid C L J, eds. Ecosystem Ecology: A New Synthesis. Cambridge: Cambridge University Press, 2010.

[4] Martín-López B, Gómez-Baggethun E, García-Llorente M, Montes C. Trade-offs across value-domains in ecosystem services assessment. Ecological Indicators, 2014, 37: 220-228.

[5] BfN. Policy-Related Indicators: Measure the Effectiveness of the German National Strategy on Biological Diversity. Berlin: Federal Agency for Nature Conservation, 2008.

[6] Defra. UK Biodiversity Indicators in your Pocket 2009: Measuring Progress Towards Halting Biodiversity Loss. London: Defra, 2009.

[7] Staub C, Ott W, Heusi F, Klingler G, Jenny A, Hacki M, Hauser A. Indicators for Ecosystem Goods and Services: Framework, Methodology and Recommendations for A Welfare-Related Environmental Reporting. Bern: Federal Office for the Environment, 2011.

[8] Collen B, Rist J. Streamlining European 2010 Biodiversity Indicators (SEBI 2010): Developing A Methodology for Using Bats as Indicator Species and Testing the Usability of GBIF Data for Use in 2010 Biodiversity Indicators. EEA/BSS/07/008. Copenhagen: European Environment Agency, 2008.

[9] Haines-Young R, Potschin M. Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for Integrated Environmental and Economic Accounting. New York: European Environment Agency, 2010.

[10] Nahlik A M, Kentula M E, Fennnessy M S, Landers D H. Where is the consensus? A proposed foundation for moving ecosystem service concepts into practice. Ecological Economics, 2012, 77: 27-35.

[11] Ministry of Environmental Protection of the People' s Republic of China. Fourth National Report on Biodiversity. Beijing: China Environmental Science Press, 2009.

[12] State Environmental Protection Administration. China Western Ecosystem Assessment. Beijing: Meteorological Press, 2006.

[13] [Reference incomplete in original]

[14-18] [Citations for computational methods]

[19] Di Fonzo M, Collen B, Mace G M. A new method for identifying rapid decline dynamics in wild vertebrate populations. Ecology and Evolution, 2013, 3(7): 2378-2391.

[20] Gilabert M A, Gandía S, Melia J. Analyses of spectral-biophysical relationships for a corn canopy. Remote Sensing of Environment, 1996, 55(1): 11-20.

[21] Fang J Y, Chen A P, Peng C H, Zhao S Q, Ci L J. Changes in forest biomass carbon storage in China between 1949 and 1998. Science, 2001, 292(5525): 2320-2322.

[22] State Forestry Administration. Study on Forest Ecosystem Biomass and Its Allocation in China. Beijing: China Forestry Publishing House, 2013.

[23] [Reference for grassland yield estimation]

[24] [Citation for net primary productivity]

[25-26] Zhang L, Dawes W R, Walker G R. Response of mean annual evapotranspiration to vegetation changes at catchment scale. Water Resources Research, 2001, 37(3): 701-708.

[27] [Citation for additive calculations]

[28-32] [Citations for various ecosystem models]

[33] [Citation for ecosystem monitoring limitations]

[34] Turner R K, Paavola J, Cooper P, Farber S, Jessamy V, Georgiou S. Valuing nature: lessons learned and future research directions. Ecological Economics, 2003, 46(3): 493-510.

Note: Figure translations are in progress. See original paper for figures.