



A review of modeling approaches for ecosystem services assessment in the Asian region



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ABSTRACT

The use of various modeling approaches is critical in the assessment of ecosystem services. Although numerous assessments have been conducted as scholarly studies to quantify, map, and value ecosystem services, a well-structured platform is necessary to ensure consistency of the assessment approaches with regard to theories and practices. To identify gaps between practical ecosystem services assessments and scholarly studies in the Asian region, we reviewed assessment cases in the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) catalogue and peer-reviewed literature using Web platforms. We identified 31 assessment cases and 290 such peer-reviewed studies conducted throughout Asia. Our review of recent peer-reviewed studies revealed a bias in the geographic distribution, with numerous Chinese studies and few studies in West Asia. Our comparison of the approaches applied in the assessment cases with those in the peer-reviewed studies revealed that little information on the models was reported in the assessment cases, whereas the approaches used in the peer-reviewed studies were mostly modeling and biophysical indicators. Although the modeling and scenario approaches used in the actual assessments require further clarification in the IPBES catalogue, many scientific modeling studies have been conducted throughout Asia. These scientific data, however, are not easily accessible to those outside of academic communities. Thus, there is an urgent need to develop a new catalogue to guide all the stakeholders involved in ecosystem services assessment at multiple scales.

1. Introduction

Modeling and mapping of multiple ecosystem services has become the focus among communities of scientists and practitioners aiming to implement the concept of ecosystem services in the real world. A multiscale assessment consisting of interlinked assessments at the local, subnational, national, regional, and global scales is crucial. Thus, the Millennium Ecosystem Assessment (MEA) endorsed subglobal assessments (SGA) within various socioeconomic contexts to meet the needs of decision-makers at these multiple scales and to strengthen local findings with global perspectives, data, and models (MEA, 2005). To support policy-makers, the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) encouraged the use of modeling approaches to predict ecosystem changes based on possible future scenarios (IPBES, 2016). Several modeling approaches

have been developed since the MEA report, with most applied in developed countries, particularly the United States and few countries in Europe (Grêt-Regamey et al., 2016). Thus, more effort to model ecosystem services in various regions is needed, especially in the Asian region, with its wide variety of ecological and cultural contexts among subregions and the resulting specific policy requirements.

Publications on ecosystem services have increased drastically in the fields of ecology, economics, and environmental management since 2005, when the MEA synthesis report was released (Chaudhary et al., 2015). Numerous ecosystem services case studies can be found in scientific databases (e.g., Web of Science, Web of Knowledge, Science Direct, Scopus, and Google Scholar), and quantitative reviews of these studies have been conducted to address methodological issues in the assessments (Englund et al., 2017; Schägner et al., 2013; Seppelt et al., 2011; Wolff et al., 2015). Ecosystem services assessments are based on

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biophysical parameters and involve field measurement, monitoring, and modeling of ecosystem functions. One common approach is to use proxy variables (e.g., land cover to represent ecosystem processes) and provide maps of the values, whereas relatively few case studies used simulation models in the assessments (Seppelt et al., 2011). Use of the proxy method based on land-cover type has grown exponentially since Costanza et al. (1997) first mapped global values of ecosystem services, as it is considered to be a relatively simplified approach to quantify the spatial distribution of ecosystem services values (Schägner et al., 2013).

Models are qualitative or quantitative representations of key components of a system and the relationships between those components; a quantitative model is a set of mathematical expressions for which data and coefficients have been attributed to components of a qualitative model describing the relationships among state variables (Jackson et al., 2000). Thus, models can be used to clarify the relationships between ecosystem processes and the supply of ecosystem services as well as the consequences of human-driven changes on biodiversity, ecosystems, and ecosystem goods and services (MEA, 2005). Various approaches and tools have been used to assess and model ecosystem services quantitatively, and the newer models used to analyze and map ecosystem services include GIS-based spatially explicit modeling tools such as Integrated Valuation of Ecosystem Services and Trade-offs (InVEST), Ecopath with Ecosim (EwE), Artificial Intelligence for Ecosystem Services (ARIES), Land Utilisation and Capability Indicator (LUCI), Multiscale Integrated Model of Ecosystem Services (MIMES), and Social Values for Ecosystem Services (SolVES) (Bagstad et al., 2013; IPBES, 2016). The practical performance of these tools has been evaluated with regard to widespread application in public- and private-sector decision-making in U.S. contexts (Bagstad et al., 2013).

Ecological models, especially those based on the theoretical understanding of ecological processes, are powerful tools for evaluating ecosystem functions and predicting the impacts of human activities and climate change on ecosystems (Piroddi et al., 2015). However, there are limitations in applying some traditional ecological process-based models to ecosystem services assessment. For example, two traditional hydrological models, Soil and Water Assessment Tool (SWAT) and Variable Infiltration Capacity model (VIC), have been used to evaluate freshwater-related ecosystem services. Because these models require more inputs than ecosystem services modeling tools, they tend to be less accessible to non-experts. In addition, these traditional hydrological models were developed to assess specific provisioning and regulating services, thus they have limited use for evaluating bundles of ecosystem services (Francesconi et al., 2016; Vigerstol and Aukema, 2011).

The public generally has limited access to scientific literature databases; however, this is not the case of the online platform IPBES Catalogue of Assessments on Biodiversity and Ecosystem Services (hereafter "IPBES catalogue," <http://catalog.ipbes.net/>). This platform was developed and is maintained via close involvement with assessment practitioners within the SGA network. In addition to providing information on the ecosystem services assessments and lessons learned, the online catalogue aims to provide direct access to assessment reports, guidelines, and other documents as a resource for practitioners (IPBES Deliverable 4(a): Catalogue of Relevant Assessments, <http://www.ipbes.net/work-programme/catalogue-assessments>). The United Nations Environment Programme supported building an assessment network in an effort to provide ongoing support to the multiscale assessments and SGA initiatives that have emerged throughout the world. The MEA approved 18 SGAs and an additional 18 assessments as associated cases distributed across various regions (MEA, 2005), which include 12 sites within the Asian region. Although numerous assessments have been conducted as scholarly studies to quantify, map, and value ecosystem services, a well-structured platform is necessary to ensure consistency of the assessment approaches with regard to theories and practices.

The aim of the present review is to identify gaps between practical ecosystem services assessments in the Asian region and scholarly studies in terms of methodological constraints in modeling approaches. We reviewed assessment reports in the IPBES catalogue and peer-reviewed literature accessed via Web platforms. Based on our findings, we summarize the issues raised, address those corresponding to the IPBES conceptual framework, and discuss the implications from a land management perspective.

2. Methods

2.1. Review of assessment reports in the IPBES catalogue

The IPBES catalogue currently contains 244 cases across the world, including SGA assessment cases. For each case, the IPBES catalogue notes the countries covered, geographic coverage, scope and conceptual framework of the assessment, and the types of ecosystems, ecosystem services, and knowledge system (e.g., scientific knowledge, local knowledge) involved in the assessment. All data are registered by the party responsible for the assessment and correspond to responses to the questionnaire provided by the platform. Thus, some data are missing, and many assessments do not cover all 46 IPBES database information fields. In the Asia-Pacific region, on average, about 60% of the fields were completed, and incomplete entries were due to a lack of data or ongoing assessments that have yet to provide the requested information. In addition, some assessments provided documentation or links for further investigation, but about 15% gave no further details on their programs (APN, 2013).

We identified 31 cases in Asian countries in the IPBES catalogue and reviewed all relevant reports of those ecosystem services assessments. Table 1 lists the cases, including 5 assessments in Northeast Asia, 8 assessments in Southeast Asia, 15 assessments in South Asia, 2 assessments in West Asia, and a regional scale assessment. Twelve approved Asian sites for SGA are included in the reviewed cases.

The geographic scales of the assessments are shown in Table 1. Most target the national (6 cases) and subnational scales (15 cases) and are based on the results of national strategies. Only 4 assessments involve regional and global scales that include multiple countries: "Altai-Sayan Ecoregion (i.e., Mongolia, China)," "Trade, Poverty, and the Environment (China, India and Vietnam)," "Tropical Forest Margins Assessment (Philippines, Indonesia, Thailand and Vietnam)," and "Wildlife Picture Index (Laos, Indonesia and Malaysia)." Most assessments target multiple ecosystems and service groups (i.e., provisioning, regulating, supporting, and cultural) using several approaches. Eight cases reported using a "modeling approach" and 11 cases a "scenario approach." We reviewed 32 assessment reports from these cases to extract how modeling and scenario approaches were used. Key information including the types of models and scenarios, time scales, and drivers of changes in ecosystems and ecosystem services were extracted from the reports.

2.2. Review of peer-reviewed journals

The literature on ecosystem services has increased since the MEA synthesis report was released, so we reviewed peer-reviewed journal articles published from January 2006 to April 2016 that assessed ecosystem services in Asia. As a first step, we searched Science Direct for articles with key word combinations of "ecosystem service" and "[names of countries in Asia]" in the title, keyword, and/or abstract. We obtained 451 articles. Of these, 161 studies were excluded because they did not quantitatively assess particular ecosystem services with a specific approach (e.g., review papers and policy analysis papers) or they were studies with a global focus.

For the remaining 290 articles, we categorized the approach used in the articles as: (1) qualitative/literature review; (2) social interview/questionnaire/household survey; (3) statistics; (4) monetary/economic

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