POLICY FORUM

ECONOMICS AND THE ENVIRONMENT

Progress in natural capital accounting for ecosystems

Global statistical standards are being developed

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Reversing the ongoing degradation of the planet's ecosystems requires timely and detailed monitoring of ecosystem change and uses. Yet, the System of National Accounts (SNA), first developed in response to the economic crisis of the 1930s and used by statistical offices worldwide to record economic activity (for example, production, consumption, and asset accumulation), does not make explicit either inputs from the environment to the economy or the cost of environmental degradation (*1, 2*). Experimental Ecosystem Accounting (EEA), part of the System of Environmental-Economic Accounting (SEEA), has been developed to monitor and report on ecosystem change and use, using the same accounting approach, concepts, and classifications as the SNA (*3*). The EEA is part of the statistical community's response to move SNA measurement "beyond gross domestic product (GDP)." With the first generation of ecosystem accounts now published in 24 countries, and with a push to finalize a United Nations (UN) statistical standard for ecosystem accounting by 2021, we highlight key advances, challenges, and opportunities.

PROGRESS TO DATE

Led by the UN Statistical Commission (UNSC) and involving statistical offices from all continents, international organizations such as the European Commission and the World Bank, and several hundred scientists and nongovernmental organization representatives, the SEEA is the world's leading natural capital accounting approach. The SEEA includes two parts: the Central Framework (CF), adopted as a statistical standard by the UNSC in 2012 (*4*), and the EEA framework (not yet a standard), first published in 2014 (*5*). In an accounting sense, the CF extends the asset boundary of the SNA (in physical, not monetary, terms), whereas the EEA also extends the production and consumption boundary. The CF measures emissions, stocks and uses of individual natural resources, and transactions related to environmental management. The CF is used, in particular, to report on water; energy, including oil and natural gas reserves; mineral ores; and emissions to air. The EEA provides a framework for measuring ecosystems and their uses and recognizes that ecosystems generate multiple types of services (provisioning, regulating, and cultural). By broadening measures of production, consumption, income, and asset value, ecosystems' contributions to society become visible. Furthermore, in recognition of the spatial heterogeneity of ecosystems, the EEA uses maps for analytical and reporting purposes. The EEA includes individual accounts recording: the extent of different ecosystem types, their condition, physical and monetary flows of ecosystem services, and the monetary value of ecosystem assets. Additionally, the EEA includes thematic accounts for land, water, carbon, and biodiversity (*6*). Countries typically compile the most policy-relevant accounts first. Because of their spatial nature, the EEA can report by ecosystem types, watersheds, or administrative units.

To maintain consistency with the SNA, monetary valuation in the SEEA is based on exchange prices—prices at which goods, services, or assets are or could be transacted. Monetary values in the SEEA thus complement those provided in the SNA and can be used to analyze the contribution of natural capital to the economy or compare the costs of ecosystem degradation with increases in economic output, among others.

EEA accounts have now been published in 24 countries [see the figure and supplementary materials (SM), section 1]. The United Kingdom (*7*) and the Netherlands (*8*) have published the most comprehensive accounts to date. Both countries' accounts include detailed maps and physical and monetary accounting tables. In Australia, several accounts have been published at the national and local scale (*9*). In Andalusia (Spain), ecosystem service accounts have been compiled and environmental income assessed (*10*). In South Africa, national ecosystem accounts have been developed for the extent and condition of rivers (*11*). Supranational accounts have been developed for the European Union (*12*). In Organisation for Economic Co-operation and Development (OECD) countries, national governments financed the compilation of accounts, whereas in many developing countries, donors have contributed, either directly or through UN or World Bank programs. Statistical agencies differ in their capacity to analyze ecosystems and their services and have often collaborated with specialized research institutes and universities.

POLICY APPLICATIONS

A key feature of the accounts is to show ecosystems' contributions to the economy. For example, the contributions of nature recreation and tourism and crop provisioning services to the economy are relatively high in the United Kingdom and the Netherlands (*7, 8*). This reflects both the relative contribution of ecosystems to the tourism sector and agriculture and the economic importance of these activities. Per-hectare monetary values are around 50% higher in the Netherlands. This is mainly due to broader coverage for the service "recreation and tourism."

EEA accounts can inform various natural resource management decisions (*13*). In the Netherlands, for example, EEA accounts show that in peat areas used for dairy farming, the combined costs of maintaining infrastructure and controlling water levels and carbon dioxide emissions considerably exceed farmers' profits. This has led to new policies aimed at reducing drainage in peatlands and converting farmland back to natural ecosystems (*14*). In Indonesia, local governments have responsibility for land-use planning but often lack spatial information on forest extent, condition, and use. Accounts can facilitate local government efforts to plan, implement, monitor, and enforce forest management policies, provided that statistical offices make high-resolution spatial data available.

The accounts can enhance transparency and fairness of ecosystem use. For example, information is often lacking on rents resulting from the exploitation of ecosystems (for example, for timber extraction or plantation agriculture). EEA accounts show these rents in a spatially explicit manner, providing an objective basis for their taxation. The EEA also allows trends in ecosystem extent, condition, and use to be monitored, including UN Sustainable Development Goals indicators. The EEA accounts can provide comprehensive and objective baseline data

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Countries that have compiled SEEA EEA accounts

Some countries have published all accounts that they have compiled, and others have published only some. China, Japan, and the United States have compiled accounts but not published them (see supplementary materials, section 1). The scope and resolution of the accounts vary between countries. The figure presents a snapshot—countries continue to compile and publish accounts. SEEA, System of Environmental-Economic Accounting; EEA, Experimental Ecosystem Accounting.

GRAPHIC: X. LIU/*SCIENCE*

for private-sector natural capital accounting, for example, with the Natural Capital Protocol. This allows businesses to better understand their impacts and dependency on natural capital.

CHALLENGES AND OPPORTUNITIES

Ecosystem accounts published to date vary in scope and level of (spatial) detail. This reflects differences in budget, technical capacity, and data between countries, with notable constraints in developing countries. Compiling the full suite of ecosystem accounts requires substantial data and use of multiple biophysical models (see SM, section 2). The Netherlands ecosystem accounts provide 90 policy-relevant indicators, derived from various datasets and models. They indicate, for example, how small landscape elements such as hedgerows contribute to crop production by maintaining pollinator populations.

Institutional challenges occur, for instance, in relation to integrating data from different agencies: Data may be in incompatible formats, or there may be a reluctance to share it. Furthermore, the SEEA has a different measurement approach compared with some existing reporting systems (for example, carbon reporting under the UN Framework Convention on Climate Change). Collaboration between government institutes holding different datasets facilitates enhanced data integration and greater commonality in terminology and definitions (*13*).

Some technical challenges remain. For instance, the diversity of ecosystems makes selection of ecosystem condition and biodiversity indicators challenging. In South African and Australian accounts, ecosystem condition has been defined in relation to pre-European settlement conditions, which is not useful for western Europe with its long ecosystem-use history. Challenges also exist in valuing nonmarket ecosystem services such as water regulation and air filtration.

The EEA's inherent limitations should be considered when the accounts are used in policy-making. The EEA accounts produced to date do not include indicators for ecosystem resilience or consider probabilities of sudden future collapses of overexploited ecosystems (*15*). Furthermore, exchange prices of ecosystem services reflect current pricing mechanisms and market conditions. Given that the SEEA does not record the welfare generated by using natural capital (*2*), it is imperative that monetary values in the EEA are not interpreted as representing "the value of nature" (see SM, section 3).

Several ongoing efforts address remaining challenges to the global implementation of the EEA. The UNSC is working with scientists and statisticians toward establishing a statistical standard for the EEA by 2021. Working groups have been established to address remaining technical issues, including defining metrics expressing ecosystem condition, biodiversity, and the capacity of ecosystems to supply services and valuing nonmarket ecosystem services (for instance, on the basis of simulated exchange values). Through various scientific efforts connected to the EEA, such as the Earth Observation for Ecosystem Accounting initiative of the Group on Earth Observations, tests are being done to examine how ecosystem extent, condition, and regulating services can be modeled across large countries or even continents at high resolution using data from remote-sensing and global datasets. Increasingly, machine-learning techniques are used, for instance, to assess the impacts of ecosystem changes on hydrological cycles and the availability of water for people. Social media posts can be used to analyze recreation in ecosystems, for example. The EEA is making large datasets available to a variety of users, and global, high-resolution modeling of critical ecosystem characteristics and services will facilitate easier uptake of the EEA in developing countries.

The EEA allows consistent (over time and between countries), comprehensive, and high-resolution analysis and reporting on ecosystems and their use. The EEA accounts do not capture all connections between people and nature and have limited capacity to consider ecosystem complexities such as thresholds and feedbacks. These caveats need to be clearly articulated when EEA accounts are published. Nonetheless, the EEA considerably enhances the scope and accuracy of information available in support of ecosystem management, facilitating better management of global natural capital. ■

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SUPPLEMENTARY MATERIALS

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