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National indicators for observing ecosystem service change

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ABSTRACT

Earth's life-support systems are in rapid decline, yet we have few metrics or indicators with which to track these changes. The world's governments are calling for biodiversity and ecosystem-service monitoring to guide and evaluate international conservation policy as well as to incorporate natural capital into their national accounts. The Group on Earth Observations Biodiversity Observation Network (GEO BON) has been tasked with setting up this monitoring system. Here we explore the immediate feasibility of creating a global ecosystem-service monitoring platform under the GEO BON framework through combining data from national statistics, global vegetation models, and production function models. We found that nine ecosystem services could be annually reported at a national scale in the short term: carbon sequestration, water supply for hydropower, and non-fisheries marine products, crop, livestock, game meat, fisheries, mariculture, and timber production. Reported changes in service delivery over time reflected ecological shocks (e.g., droughts and disease outbreaks), highlighting the immediate utility of this monitoring system. Our work also identified three opportunities for creating a more comprehensive monitoring system. First, investing in input data for ecological process models (e.g., global land-use maps) would allow many more regulating services to be monitored. Currently, only 1 of 9 services that can be reported is a regulating service. Second, household surveys and censuses could help evaluate how nature affects people and provides non-monetary benefits. Finally, to forecast the sustainability of service delivery, research efforts could focus on calculating the total remaining biophysical stocks of provisioning services. Regardless, we demonstrated that a preliminary ecosystem-service monitoring platform is immediately feasible. With sufficient international investment, the platform could evolve further into a much-needed system to track changes in our planet's life-support systems.

1. Introduction

Human activities and associated pressures have caused more rapid global change now than Earth has experienced over the past 12,000 years (Barnosky et al., 2012; Ehrlich et al., 2012). As climate

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change, biodiversity loss, and biogeochemical alterations continue, it is expected that sudden, rapid, and surprising global state shifts will degrade the benefits that nature provides and that support human wellbeing—ecosystem services (Rockström et al., 2009; Barnosky et al., 2012). For example, the Millennium Ecosystem Assessment (MA) (Millenium Ecosystem Assessment, 2005) brought global attention to the state of ecosystem services, and the relevance of their ongoing loss, by reporting on the change in 24 ecosystem services (Millenium Ecosystem Assessment, 2005). This one time assessment, however, did not indicate what has happened since, and we currently have no centralized monitoring system for detecting and reporting on global ecosystem service change. Without a tracking system, we are flying blind, unable to understand mounting risks or anticipate future ecosystem state changes and how they will affect the services upon which we rely (Tallis et al., 2012).

Moreover, the MA calculated changes over relatively long time horizons (e.g., between ~1960 and 2000), at best reporting decadal average changes. Estimates were done this way to show longer-term trends and to take best advantage of temporally sparse data. Such long-term analyses are powerful for bringing attention to large changes and for identifying major opportunities for bolstering ecosystem services. However, many regular government and private sector decisions are made on much shorter time scales, and adaptive management can be informed, most ideally, by paired long-term and short-term views of ongoing changes. For example, governments generally function on administrative terms ranging from ~2 to 5 years. Therefore, a monitoring system that reports the state of biodiversity, ecosystems, and ecosystem services regularly and on shorter time scales would be very relevant to short-term decisions. To address the current lack of such a system, the world's governments formed a Biodiversity Observation Network through the Group on Earth Observations (GEO BON) that functions as a centralized platform to coordinate, harmonize, and combine existing biodiversity and ecosystem-service monitoring streams (Scholes et al., 2008, 2012).

We focus here on the immediate need for an ecosystem-service monitoring platform. Major governmental and non-governmental conservation decisions informed by international assessments such as the Global Biodiversity Outlook (GBO) and Sub-Global Assessments (SGA) are made on limited data (Tallis et al., 2012). Countries struggle to report on progress towards environmental goals such as the Convention on Biological Diversity's (CBD) targets. These CBD targets now explicitly include ecosystem services, but tracking the ecosystem services targets for 2010 failed in part because necessary data were not globally available for calculating indicators and reporting progress (Walpole et al., 2009; CBD, 2014). Furthermore, efforts are underway by The World Bank and other international organizations to measure natural capital and more holistically account for the wealth of nations. Such accounting will require regular monitoring to assess changes in natural capital (stocks) and ecosystem services (flows) over time (The World Bank, 2011; UNSD EEA and The World Bank, 2011; UNU-IHDP and UNEP, 2014), but often the relevant data are lacking.

Effective monitoring of ecosystem services requires tracking multiple types of services at multiple stages of delivery (Tallis et al., 2012). Broadly, ecosystem services can be classified into three categories. Provisioning services are the material goods that flow from nature, such as food, fuel, and water. Regulating services are processes that control the dynamics of socio-ecological systems, including pollination, water filtration, and flood control. Cultural services are the benefits from nature that enrich human life and often seem intangible; for example, the spirituality, heritage, and identity derived from nature (Chan et al., 2012; CBD, 2014). An ideal monitoring system would track the supply, delivery, and value of services in each of these categories (Tallis et al., 2012).

Services in any of these categories flow from nature to people along a "supply chain," which can be measured and monitored at several distinct steps along the path. Supply refers to the total biophysical potential of an ecosystem to provide a service to people, irrespective of whether people actually benefit. For example, the supply of coastal protection may measure how coastal habitats buffer storm surge in areas with and without human habitation. The delivery of a service is the degree to which humans actually consume, access, receive, or enjoy an ecosystem service. At the final stage of ecosystem service delivery to people, value reflects people's preferences for the amount of benefits provided by ecosystem services, which can be expressed in several ways, including but not limited to monetary values. Regional ecosystem-service mapping programs often seek to develop and map indicators of all three stages of the ecosystem-service cascade. For example, efforts are underway to map the supply, delivery, and value of a suite of services across Europe (Maes et al., 2012a,b) and in other regions worldwide for diverse decision contexts (Ruckelshaus et al., 2013). Yet few elements of the ecosystem-service cascade are reported regularly over time in large-scale monitoring programs. Instead, indicators focus on the prevalence of habitats, species, or populations that could potentially provide services (CBD, 2011), and one is left to infer if or how changes in these indicators translate into changes in service supply, delivery, or value.

Here, we explore how diverse, existing data streams could be combined, in the short term, to create an initial ecosystem-service monitoring platform. We focus explicitly at the national scale so that monitoring could easily feed into major intergovernmental agreements such as CBD and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) and major governmental activities such as national accounting. Rather than reporting changes in the abundance or protection of habitats or species that could potentially provide services, we combine biophysical models and national statistics to report, whenever possible, the supply, delivery, and value of services over time. As a starting point, we have extended the five services that were identified as possible to monitor globally (see Table 1 in Tallis et al., 2012) by four additional services, including three marine services. Despite these efforts, our exercise is coarse, incomplete, and subject to improvement, reflecting the current state of global monitoring systems. In conducting this initial assessment, however, we demonstrate what can be achieved with existing data as an example of what could be expanded upon if major gaps were filled to produce a more comprehensive ecosystem-service monitoring platform.

2. Methods

2.1. Overview of reported services

We compiled indicators of the supply, delivery, and monetary value of ecosystem services at national scales from 1996 to 2005, focusing only on services that are annually reported or can be modeled at that time step for a large number of countries worldwide. We have chosen this time frame to evaluate annual changes in ecosystem services over an exemplary decade, which can be regarded as a starting point for monitoring as well as a call for regularly updating datasets. We found adequate temporal and spatial coverage for eight provisioning services (water supply for hydropower, non-fisheries marine products, crop, livestock, game meat, fisheries, mariculture, and timber production), and one regulating service (carbon sequestration). Data were not sufficient to include any cultural services at this stage, although their relevance is well recognized. When possible, we calculated the supply, delivery, and monetary value for each service; however, data gaps precluded reporting of all three metrics for each service.