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SPECIAL ISSUE: The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives

Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation

Paul C. Sutton [a,*], Robert Costanza [b,1,2]

[a] *Department of Geography, University of Denver, Denver, CO 80208, USA*
[b] *Department of Biology, Center for Environmental Science, Institute for Ecological Economics, University of Maryland, Box 38, 1 Williams St., Solomons, MD 20688-0038, USA*

Abstract

We estimated global marketed and non-marketed economic value from two classified satellite images with global coverage at 1 km^2 resolution. GDP (a measure of marketed economic output) is correlated with the amount of light energy (LE) emitted by that nation as measured by nighttime satellite images. LE emitted is more spatially explicit than whole country GDP, may (for some nations or regions) be a more accurate indicator of economic activity than GDP itself, can be directly observed, and can be easily updated on an annual basis. As far as we know, this is the first global map of estimated economic activity produced at this high spatial resolution (1 km^2). Ecosystem services product (ESP) is an important type of non-marketed value. ESP at 1 km^2 resolution was estimated using the IGBP land-cover dataset and unit ecosystem service values estimated by Costanza et al. [Valuing Ecosystem Services with Efficiency, Fairness and Sustainability as Goals. *Nature's Services*, Island Press, Washington DC, pp. 49–70]. The sum of these two (GDP + ESP) = SEP is a measure of the subtotal ecological–economic product (marketed plus a significant portion of the non-marketed). The ratio: (ESP/SEP) × 100 = %ESP is a measure of proportion of the SEP from ecosystem services. Both SEP and %ESP were calculated and mapped for each 1 km^2 pixel on the earth's surface, and aggregated by country. Results show the detailed spatial patterns of GDP, ESP, and SEP (also available at: http://www.du.edu/ ~ psutton/esiindexisee/EcolEconESI.htm). Globally, while GDP is concentrated in the northern industrialized countries, ESP is concentrated in tropical regions and in wetlands and other coastal systems. %ESP ranges from 1% for Belgium and Luxembourg to 3% for the Netherlands, 18% for India, 22% for the United States, 49% for Costa Rica, 57% for Chile, 73% for Brazil, and 92% for Russia. While GDP per capita has the usual northern industrialized countries at the top of the list, SEP per capita shows a quite different picture, with a mixture of countries with either high GDP/capita, high ESP/capita, or a combination near the top of the list. Finally, we compare our results with two other indices: (1) The *2001 Environmental Sustainability Index* (ESI) derived as an

* Corresponding author. Tel.: + 1-303-871-2399
E-mail addresses: psutton@du.edu (P.C. Sutton), costza@cbl.umces.edu (R. Costanza).
[1] Tel.: + 1-410-326-7263.
[2] As of 09/01/2002, this author can be reached at the Gund Institute for Ecological Economics, University of Vermont, School of Natural Resources, George D. Aiken Center, Burlington VT 05405–0088, USA.

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initiative of the Global Leaders of Tomorrow Environment Task Force, World Economic Forum, and (2) *Ecological Footprints of Nations: How much Nature do they use? How much Nature do they have?* developed by Mathis Wackernagel and others. While both of these indices purport to measure sustainability, the ESI is actually mainly a measure of economic activity (and is correlated with GDP), while the Eco-Footprint index is a measure of environmental impact. The related eco-deficit (national ecological capacity minus national footprint) correlates well with %ESP.

Keywords: Satellite images; Ecosystem service valuation; Satellite imagery

1. Introduction

Economic activity is fundamentally a spatial phenomenon. Both traditional marketed economic activities (like manufacturing, sales, and final consumption) and 'non-marketed' ecosystem services occur at specific spatial locations and are associated with specific natural, agricultural, or urban ecosystems. A necessary step toward better understanding these activities and services is to map their spatial patterns. That is what we have tried to do in this paper, at both the global and national level.

Various measures of 'economic activity' and environmental quality are also important as 'indicators' for policy decisions. Key questions here revolve around exactly what the indicators measure. Gross Domestic Product (GDP) is the most popular indicator of economic performance. But GDP measures only marketed economic *activity* or gross income (Costanza et al., 2001). It was never intended as a measure of economic welfare, and it functions very poorly as a welfare measure. Yet it is inappropriately used as a national welfare measure in far too many circumstances.

What are the problems with GDP as a welfare measure? First, lumping all activity or income together does not separate desirable, welfare enhancing activity from undesirable welfare reducing activity. For example, an oil spill increases GDP because someone has to clean it up, but it obviously detracts from welfare. From the perspective of GDP, more crime, more sickness, more war, more pollution, more fires, storms, and pestilence are all good things, since they can increase marketed activity in the economy. Second, GDP leaves out many things that currently *do* enhance welfare but are outside the market. The unpaid work of mothers caring for their own children at home doesn't show up in GDP, but if they decide to work outside the home to pay for child care, GDP suddenly increases. The non-marketed services of nature in providing clean air and water, food and natural resources do not show up in GDP, but if those services are damaged and we have to pay to fix or replace them, then GDP suddenly increases. Third, GDP takes no account of the distribution of income among individuals. But it is well known that an additional $1 worth of income produces more *welfare* if one is poor rather than rich (Daly and Cobb, 1989).

In this paper we look at the spatial patterns of conventional GDP and also at the value of non-marketed ecosystem services that are not currently included in GDP (de Groot et al., 2002; Costanza et al., 1997a,b). We do not address the other important shortcomings of GDP (including distribution, unpaid domestic labor, pollution, etc.)—leaving those for future work. In this paper we focus on the subtotal of economic value represented by the sum of conventional marketed economic goods and services (as measured by GDP) and non-marketed ecosystem goods and services. A list of these ecosystem services and their approximate dollar values for a range of ecosystems are given in Costanza et al. (1997a,b). A more detailed description of these services and their links to ecosystem functions is given in de Groot et al. (2002).

Other indicators at the global and national level are also proliferating. In particular, there are many new proposed indicators of 'sustainability'. We contend that none of these proposed indicators of sustainability actually measure sustainability. They are generally indicators of economic