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Valuing ecosystem services from Maryland forests using environmental accounting

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ABSTRACT

Forests provide a multitude of benefits vital to the ecosystems, economies and people of Maryland. While markets exist to set the price for an economic good like timber, ecosystem services are viewed as free externalities. This research enumerates the biophysical value of forest ecosystem services in Maryland and provides a connection between biophysical and economic methods for valuing the environment. The hydrology, soil, carbon, air pollution, pollination and biodiversity of a forest are measured from a biophysical standpoint with emergy and converted to dollars using new emergy-to-dollar ratios, termed eco-prices. The functioning of the forest is compared to the most likely alternative land-use in Maryland (suburbia) and biophysical value is assigned based on this difference. The research seeks to value ecosystem services provided by forests in Maryland and proposes that society should invest commensurate value in the production and perpetuation of ecosystem services. To help ensure that Maryland forests continue to produce ecosystem services at the current rate, investment should total between \$273 and \$744 million per year in the State of Maryland, \$270–\$736 per year for a typical hectare of forest.

1. Introduction

Forests in Maryland provide a multitude of ecosystem services, economic goods and social amenities to society. The ecosystem services provided by forests include providing wildlife habitat, generating and maintaining soils, improving water quality, dampening storm flows, abating air pollution, and reducing the urban heat island effect. The dominant economic good is timber, which is used in lumber, veneer, plywood, and pulp & paper production. Social amenities of forest ecosystems include hunting, fishing, hiking, camping, birding, horseback riding, and automotive touring. While markets exist to set the price for an economic good like timber and the economic impact of social amenities can be parsed, many ecosystem services are poorly valued by the economy, if at all. As Antle (2006) stated, "left to their own devices, markets will tend to over-produce market goods and under-produce ecosystem services." If private and public forest lands are to be managed to sustain the delivery of both poorly valued ecosystem services and market-priced economic goods, then novel financial mechanisms need to be developed that encourage forest stewards to produce ecosystem services, social amenities, and economic goods. In this research, ecosystem services are quantified using biophysical models, subsequently converted to emergy units using standard methodology (Odum, 1996), and expressed in monetary terms using a novel method that we term the "eco-price", an evolution of the emprice calculation (Odum, 1996; Brown and Buranakarn, 2003; Cuadra and Rydberg, 2006). Emergy synthesis is a method of environmental accounting where the cumulative energy necessary to produce the observed components of the studied system is accounted for. Ecosystem services can be defined as any benefit to humanity derived from the environment; however, this research only considers ecosystem services that exist external to existing markets.

We determined the emergy value of the following key ecosystem services – soil generation and maintenance, carbon sequestration, air pollutant removal, biodiversity protection, stormwater runoff avoidance, groundwater recharge promotion, pollination by wild insects, and water quality improvement. The eco-price method was used to determine the economic value of Maryland forest ecosystem services (Campbell, 2012; Campbell and Tilley, accepted for publication). We suggest that this value should equate to compensation generated from consumers of ecosystem services. Traditional emergy analysis assesses the biophysical contribution that ecosystems make to society and equates this to dollar value, but assumes that people value environmental work in the same way they value other types of work (human labor, energy from non-renewable resources, etc). Please see the companion article in this journal for an examination of how emergy and money are related, and presentation of the argument for valuing environmental work differently (Campbell and Tilley, accepted for publication).

The emergy required to produce each ecosystem service was determined by developing simulation models for each service that identify how energies are consumed in the production of

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Table 1
Relevant terminology and definitions.

Term	Definition
Ecosystem service	Benefit that people derive from nature, either passively or actively
Emergy	The available energy of one kind that is used up in transformations directly and indirectly to make a product or service
Solar emjoule (sej)	The unit of emergy, a solar equivalent joule. Solar is the most diffuse energy, thus the logical base unit
Transformity	The cumulative available energy (emergy) used to create one unit of matter, available energy, information, etc.
Renewable emergy baseline	This is the quantity of renewable emergy input to the earth in a given year, consisting of solar, deep heat and tides, and used to determine transformities of global renewable flows like rain and wind. We use 15.83E24 sej/yr as the global renewable emergy baseline
Empower	Emergy per unit time
Eco-price	Ratio of the emergy of an ecosystem service to a previously expressed measure of monetary preference for ecosystem services or analogs (see Campbell and Tilley, accepted for publication)
Emdollar ratio	Ratio of emergy supporting an economic system to the dollars circulating in the same economic system (units = sej/$)
Emdollar (em$)	The US dollar equivalent of emergy, computed by multiplying emergy by the emdollar ratio
Fair payment value	Monetary value of an ecosystem service determined through the eco-price. We suggest this value be used in potential payment for ecosystem service policies or programs
Public value	The total benefit, in biophysical terms measured by emergy, to society derived from an ecosystem service

each. A series of eco-prices were found by evaluating the amount of money paid directly or indirectly for the services rendered by nature to existing markets, such as stormwater fees, carbon markets, watershed protection fees, air pollutant avoidance costs; the money paid to existing markets was compared to the amount of emergy associated with the service (Campbell, 2012).

Environmental accounting (emergy synthesis) was developed in order to provide valuation external to the economy and adherent to the fundamental laws of thermodynamics (Odum, 1988, 1996). The emergy method accounts for all types of energy, from the environment and humanity, of all forms, used both directly and indirectly, to produce a product or service. This allows for the differences in “quality”, or ability to do work, of said products or services to be realized and compared (see Table 1 for definition of common terms). This system of valuation allows the connections between nature's production of ecosystem services and people's consumption of them to be quantified in the same physical unit and translated into financial terms. This research attempts to join the biophysical measurement of ecosystem function (donor value) with the economic value (receiver value) that people place upon that function. Environmental accounting has attempted to value ecosystem services (Campbell and Brown, 2012; Pulselli et al., 2011; Giannetti et al., 2011) but these evaluations still tend towards the biophysical perspective and fail to capture how society values ecosystem services. This method should allow more informed decision-making for both the sustainability of ecosystems and humanity since both biophysical and economic value is considered.

Ecosystem services (ES) have been defined differently by a diverse group of organizations and researchers (Farber et al, 2002; Boyd and Banzhaf, 2007; EPA, 2011; USFS, 2011; MEA, 2005). A general definition is that ES are benefits people receive from ecosystems and are thought of as being wholly inclusive, with any benefit derived from an ecosystem considered an ecosystem service. The Millennium Ecosystem Assessment (MEA, 2005) categorizes ecosystem services as provisioning, regulating, supporting, and cultural. These categories comprise providing goods to humanity, regulating systems that humanity depends on, supporting systems that provide goods, and enhancing people’s intellectual or recreational experiences, respectively. This study restricts the definition to only services from ecosystems that provide a tangible benefit to society (i.e. not aesthetics) and are not already paid for in some way (e.g. recreation), thus included in the existing economic system. If the values are already integrated into the economy it would be unfair to consumers to pay for these services again.

This study uses the term “public value”. Public value is an estimate of the total benefit, in biophysical terms measured by emergy, to society derived from an ecosystem service. A dollar estimate for public value is obtained by using the average emergy to dollar ratio for the state economy (the ratio of total emergy use in the state to Gross State Product, termed the emdollar ratio) to convert the emergy of an ecosystem service to dollars. Emergy values are indicative of the ability of a flow or storage of energy to do work or cause influence in a system; the public value is the value of ecosystem services if all forms of energy (originating from the environment or humanity) were given equal consideration. In practical terms, the public value measures the free subsidy being provided by the ecosystem to humanity. We compare this to the fair payment value, the suggested monetary exchange for ecosystem services based on past exchanges of emergy and money (the eco-price, Campbell and Tilley, accepted for publication).

The methodology and results for the models estimating ecosystem services in Maryland forests have been abbreviated. We present the full methods and results for calculating stormwater runoff mitigation and groundwater recharge promotion and generalized methods with key results for the remainder of the ecosystem services considered.

2. Methods

Ecosystem services were quantified by their energy or mass value, defined as the additional energy/mass flow provided by forests compared to a most likely alternative land-use. When compared to alternative land-uses, forests sequester more carbon, air pollutants, and nutrients, produce less erosion and water runoff and more recharge to groundwater aquifers as well as provide better wildlife habitat with higher native biodiversity. To determine the solar emergy value of the ecosystem services energy or mass value was multiplied by the appropriate unit emergy value. This emergy value represents the additional benefit, adjusted for energy quality, which forests provide above developed land. The most likely alternative land-use in this study was suburban development, defined in this study as 40% impervious cover, 20% tree cover and 40% grass/herbaceous/bare land. These conditions are typical of suburban development in Maryland (Maryland Department of Planning, 2011). The models were calibrated for typical conditions in Maryland forests and suburban development. The emergy embodied in ecosystem services is ultimately from the same source, the global renewable emergy budget, raising the issue of potential double counting. We suggest that because ecosystem services are, by definition, relative to the benefit