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The value of ecosystem services: putting the issues in perspective

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1. Introduction

How do we develop meaningful indicators of ecosystem services when we have no markets for

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them? This is an important problem that has been hidden by the elegance and availability of other aggregate measures designed to address the completely different problem of measuring human production and accounting income (Daily, 1997). Why would one want to measure the aggregate value of ecosystem services, whether at local, regional, national or global scales? This is a reasonable and necessary exercise to the extent that human welfare depends on whether these services improve or deteriorate. We may have more houses, but if that means we have fewer trees and less viable forests, something is seriously wrong with an accounting system that only adds up houses and presumes that this is a full measure of welfare change. It is also necessary in order to address the question of what is the optimum 'scale' or size of the economy relative to the ecological life support system (Daly, 1992). To address this question one must be able to directly compare the value of ecosystem services lost with the value of other economic services gained (Daly, 1998), something that other methods to assess the importance of ecosystem services (i.e. the 'ecological footprint' (Rees and Wackernagel, 1994)), for all their heuristic value, cannot do.

The purpose of our global valuation exercise (Costanza et al., 1997a) was simply to begin the exercise of measuring the aggregate value of ecosystem services. The results illustrated that even using admittedly narrow and imperfect conventional economic methods, the aggregate value of these services was in the same order of magnitude as global GNP.

We freely admitted the study's many shortcomings, including (a) it assumed too much homogeneity in natural capital forms and economic contexts; (b) it was partial and static rather than general equilibrium and dynamic; and (c) the studies from which the shadow values were taken differed widely in their theoretical and practical relevance. Far from invalidating the results, however, these shortcomings merely beg for further attention to the question. It is a well-accepted method in science to make an initial 'first-approximation' to a complex problem and allow the results to determine whether it is worth investing the effort to do more elaborate studies. The study also raised other questions, as pointed out in the commentaries in this forum (and elsewhere). Below we briefly address some of the major (or at least most frequent) of these.

2. Should we value ecosystem services at all?

The idea that ecosystem valuation is something that we just should not do keeps coming up. While we can certainly appreciate the many sides of this argument, ultimately, we agree with Herendeen (1998) that: "the argument that we lose our souls by economically pricing the environment is silly" and ultimately counterproductive. As we (authors) said in the paper, we (humans—both as a society and as individuals) are forced to make choices and trade-offs about ecosystems every day. These imply valuations. To say that we should not do valuation of ecosystems is to simply deny the reality that we already do, always have and cannot avoid doing so in the future. For example, we may, by political decision, value a natural area and limit economic use of it accordingly. This decision is made on the basis of values which we hold for natural areas, not market prices. But the decision will result, through the market, in a different set of prices for many things, as well as an implicit economic value for the natural area, implied by the political decision. We accept this as reasonable. We do not have to know the implied price ex ante to act on values. But it is still interesting to know what prices are implied by our choices. They may be higher or lower than we would have guessed, and can serve as a cross check on the reasonableness and consistency of our political decisions.

Unfortunately, many seem to be in deep denial on the issue of ecosystem valuation, guaranteeing, as Herendeen (1998) says: "the continuation of two cultures and the costs of continued blind economic growth." Or, as Daly (1998) put it, "If we are to avoid uneconomic growth we must be sure that the value of the natural capital services sacrificed as a result of human expansion is not greater than the value of the services gained for the expanded manmade capital."

However, even though we cannot avoid ecosystem valuation, we are not very far along the road to doing it well (as our paper hopefully made

clear—and as many of the commentaries in this forum reiterate from various perspectives). In a related paper in Gretchen Daily's recent edited book on ecosystem services, which we refer to in the *Nature* paper (Costanza and Folke, 1997), we lay out the limitations of conventional approaches and how we might proceed to improve on them. To summarize the paper's argument: "Valuation ultimately refers to the contribution of an item to meeting a specific goal. A baseball player is valuable to the extent he contributes to the goal of the team's winning. In ecology, a gene is valuable to the extent it contributes to the goal of survival of the individuals possessing it and their progeny. In conventional economics, a commodity is valuable to the extent it contributes to the goal of individual welfare as assessed by willingness to pay. The point is that one cannot state a value without stating the goal being served. Conventional economic value is based on the goal of individual utility maximization. But other goals, and thus other values, are possible. For example, if the goal is sustainability, one should assess value based on the contribution to achieving that goal—in addition to value based on the goals of individual utility maximization, social equity or other goals that may be deemed important. This broadening is particularly important if the goals are potentially in conflict. Ecological economics is built on the three integrated goals of sustainable scale, social fairness and economic efficiency. Ultimately, valuation has to address all three of these goals."

Our *Nature* paper represented a status report and synthesis which indicated that even using crude first estimates from the literature, partial equilibrium analysis, and basically limiting the study to the economic efficiency goal, the total is still very significant. This merely opens the door for more and better research and valuations that go further to address the problems and limitations we identify and clearly acknowledge.

The denial of valuation is not really necessary for another reason, however, because, as we point out in the paper, the exercise of valuation does not preclude or supersede other ways of approaching the problem. But one has to communicate with people in the language they understand (while also perhaps teaching them a new language), and utilize the tools at hand (while at the same time developing new, more appropriate tools). Ecological economics is transdisciplinary and conceptually and methodologically pluralistic (although this way of thinking is difficult to sustain given our generally monistic training). Some have obviously interpreted our *Nature* paper as a retreat to and acceptance of conventional economics. This is not the case. It is rather an acceptance of pluralism and a robust conclusion—arrived at even using admittedly limited, conventional tools: that ecosystem services are "big potatoes" and we had better get busy and pay more attention to them—from many different conceptual and methodological perspectives at once.

3. Aggregate value of ecosystem services and global 'GNP'

One more detailed argument is that the total value of ecosystem services cannot exceed GNP[2] (Ayres, 1998). This is not correct. GNP picks up only marketed goods and services. We argue clearly in our paper that ecosystems provide REAL income (contributions to human welfare), much of which never enters any market. The point of our paper is to estimate that income, which has no direct relationship with current, incomplete GNP. If this income WERE to be internalized (e.g. via ecotaxes) the structure (and probably the magnitude) of GNP would be very different, as we also clearly state in the paper, and ecosystem services would be a component of this revised GNP.

Another way of looking at this is to think of two planets. The two planets are identical except

[2] Several people have pointed out to us that the value we stated for world GNP was low. Actually, we discovered we were using a 1987 world GNP estimate by mistake (18 trillion). The real value for 1994 (our base year for the study) was more like 25 trillion (although there is quite some uncertainty in estimating global GNP as well). This was an unfortunate oversight on our part which somehow survived the review process, but it does not change any of our analyses or conclusions.

the first planet ingeniously prices all of its resources inclusive of ecosystem services at their marginal value to the global economy. All externalities, common property resource problems, etc. have been solved with infinitesimal transactions costs. The second planet prices all of their ecosystem services at zero, and this induces ineffcient prices throughout their economy. The first planet is obviously more efficient in terms of basic economic principles, but unfortunately, we currently live on something more approximating the second planet. Our analysis estimates the value to the global economy of ecosystem services on the second planet. It turns out to exceed the second planet's GNP at existing prices. This is not surprising given the distorted price structure on planet 2 (Norgaard et al., 1998). However, this result does not in any way interfere with the logical existence of the first planet. If the second planet charged the same ecosystem prices as the first, it would become identical to the first. Therefore, it is incorrect to allege that the value of ecosystem services on the second planet cannot exceed the incomplete and distorted GNP on the second planet, when in fact it is the more comprehensive and efficient 'GNP' on the first planet that cannot be exceeded by the value of ecosystem services.

A third way of looking at these issues is to include ecosystem services (E), in both consumer utility and producer production functions, assume typical optimization conditions and solve for 'shadow values'. Letting these values of ecosystem services equal p, the aggregate value of ecosystem services is simply pE. There is no a priori reason to expect the aggregate value of these services to be less than or greater than the aggregate value of other human-made services, such as labor and capital.

4. Marginal vs. total values

Another more detailed argument is the difficulty of aggregating marginal values to get a global total (Ayres, 1998; Daly, 1998). Ecosystem services are obviously a 'limitational' input to human welfare—without them there would be no welfare, as we clearly point out in the paper. But labor and manufactured capital are also 'limitational' in the same sense. What we have done is estimate the equivalent of a 'price' (p) or marginal value per ha of each ecosystem and multiply by the quantity of each ecosystem service currently provided (E). This is identical to what is done in GNP accounting to get the total value of marketed products. One can argue that this has nothing to do with real welfare (a point we make in the paper and have argued ourselves elsewhere on several occasions—cf. Costanza et al., 1997b),—but that argument applies equally well to all macroeconomic accounting. One can also argue that the value of any major component of the economy (say agriculture) is infinite in the limit (just as ecosystem services are) because, without them (i.e. agriculture), there would be no economy. At the current margin, however, we can assume that the 'sum of the marginals equals the total'. To move very far away from the current margin, as we point out in the paper, we need to use dynamic, adaptive, non-linear models which can simulate the way the whole system would adapt and how all values would change, also taking account of the possibility of thresholds and irreversibilities. This estimation of the conditions on 'planet 1' above is a major research challenge for the coming years.

5. Biophysical values vs. monetary values

Knowledge of the biophysical basis of both ecosystems and the economy is critical (cf. Templet, 1998). Most of the valuation studies we cite used both physical and monetary units, and at some level the choice of numeraire is arbitrary. In fact, one of the studies we cite (Costanza and Neill, 1981; Costanza and Hannon 1989) used an energy-based global general equilibrium I–O model, and we manipulated it to estimate the total value of ecosystem services. We converted this to monetary equivalents and concluded that the result was very close ($34 trillion/year in 1994 dollars) to our total in the *Nature* paper ($33 trillion/year). We also cited in the supplementary information several energy-based studies of specific ecosystems, and noted that they gave similar results to the monetary-based estimates (a fact that was noted in at least one previous study, cf. Costanza et al., 1989).

Table 1
NPP and value of ecosystem services for major biomes

Biome	Area (e6 ha)	NPP* (g m^{-2} $year^{-1}$)	Value ($ ha^{-1} $year^{-1}$)
Open ocean	33 200	125	$252
Estuaries	180	1500	$22 832
Seagrass/algae beds	200	2000	$19 004
Coral reefs	62	1000	$6075
Shelf	2660	360	$1610
Lakes/rivers	200	400	$8498
Tropical forest	1900	2000	$2007
Temperate/boreal forest	2955	1000	$302
Grass/rangelands	3898	800	$232
Tidal marsh/mangroves	165	3000	$9990
Swamps/floodplains	165	3500	$19 580

* NPP from Bolin et al. (1977), pp. 25 and 132. All other data from Costanza et al. (1997a).

Another interesting way to look at this issue is to compare the per ha economic values from our *Nature* paper with the solar energy captured per unit area by each biome. We suppose that most economists and many ecologists would not expect to see much of a correlation between these vari-

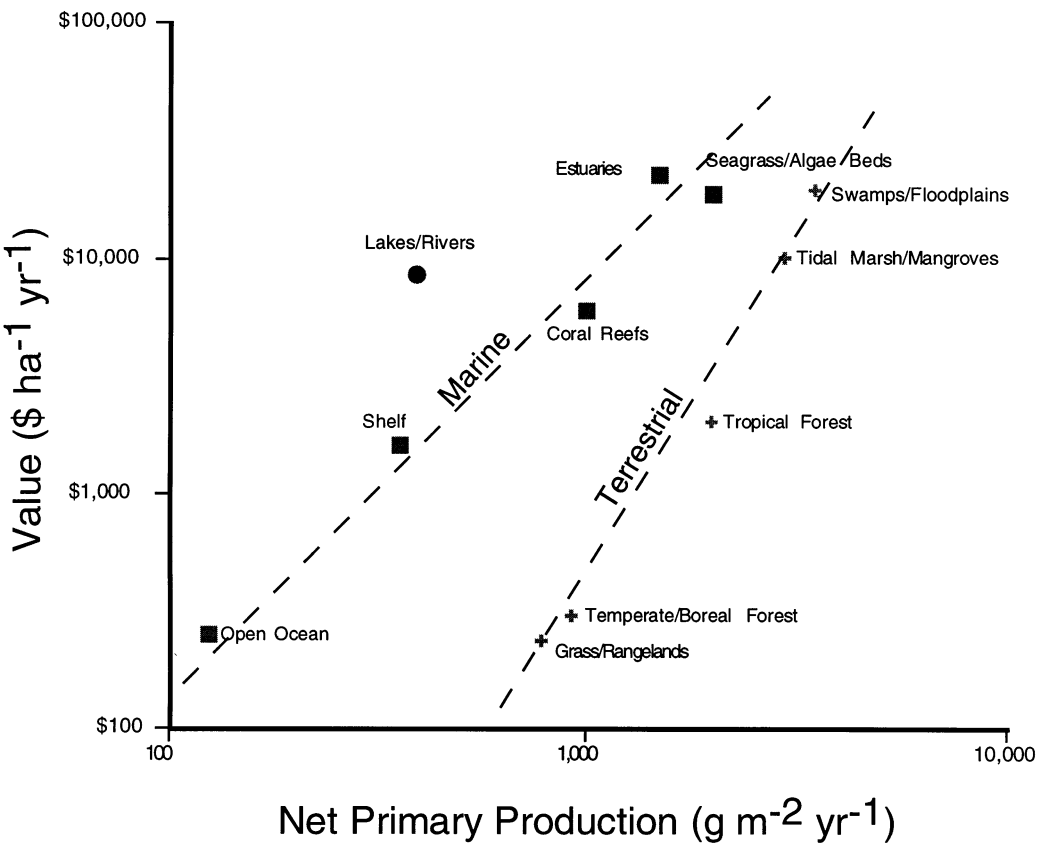

Fig. 1. Plots of NPP vs. value for terrestrial and marine systems.

ables. However, Table 1 and Fig. 1 show some interesting patterns. The measure of solar energy captured in this case is net primary production (NPP) at the ecosystem level (from Whittaker and Likens 1975; Whittaker 1975; as summarized in Bolin et al., 1977). What one sees are strikingly good correlations for terrestrial and marine systems separately ($R^2 \approx 0.98$, significant at the 0.01 level), with lakes/rivers as a significant outlier (note the logarithmic axes for both variables). Given the differences between terrestrial and marine systems, this is not too surprising.

Lakes/rivers show significantly higher value per ha than predicted from their NPP, perhaps indicating the fact that many of their relevant services (like drainage and transport) are not related to primary production. But for the other systems, NPP appears to be highly correlated with the value of ecosystem services we estimated, within the categories of terrestrial and marine systems.

6. Conclusions

Our *Nature* paper was a synthesis study. It was an attempt to synthesize existing information to address a new and important question, and to stimulate additional research and debate. We think we succeeded in that goal, and that both the importance of the question and the limitations of our initial stab at it have been well recognized. Now it is time to take the next steps. We encourage all those concerned with ecosystem services and the sustainability of the planet to actively participate, and we look forward to seeing the results in these pages in the future.

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