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Ecosystem services: From eye-opening metaphor to complexity blinder

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ABSTRACT

What started as a humble metaphor to help us think about our relation to nature has become integral to how we are addressing the future of humanity and the course of biological evolution. The metaphor of nature as a stock that provides a flow of services is insufficient for the difficulties we are in or the task ahead. Indeed, combined with the mistaken presumption that we can analyze a global problem within a partial equilibrium economic framework and reach a new economy project-by-project without major institutional change, the simplicity of the stock-flow framework blinds us to the complexity of the human predicament. The ecosystem services approach can be a part of a larger solution, but its dominance in our characterization of our situation and the solution is blinding us to the ecological, economic, and political complexities of the challenges we actually face.

In an effort to communicate the delusion of economic growth and the essence of environmental sustainability, ecological economists helped advance the metaphor of nature as a fixed stock of capital that can sustain a limited flow of ecosystem services (Costanza and Daly, 1992; Jansson et al., 1994; Prugh et al., 1999). Conservation biologists, joining with environmental economists, also saw this metaphor as a way to help describe our relation to nature and build support for conservation (Daily, 1997; Daily et al., 2000). There was a strong sense that, however revolting for those who intrinsically value nature, the use of market metaphors was necessary to awaken a public deeply embedded in a global economy and distant from natural processes. The eye-opening metaphor, however, soon rose to become a central framework for scientifically assessing ecosystem change (Millennium Ecosystem Assessment, 2003, 2005). The Millennium Assessment, in turn, led to calls for ecologists to direct their research toward developing stronger theory and empirical documentation of how the stock of nature delivers flows of services (Carpenter et al., 2006; Armsworth et al., 2007).

The transition from metaphor to scientific framework was complemented by the search for innovative approaches to reduce environmental degradation in developing countries. Economic services became a paradigm for thinking about development and environment and for designing environmental management programs (Pagiola et al., 2004; Ranganathan et al., 2008; UNEP, 2008; World Bank, 2009). Simultaneously, with the belief in market solutions heavily swaying the national and international politics, plans for capping greenhouse gases and issuing tradable permits initiated a massive market for carbon offsets through the sequestration of carbon in forests and other biomass on a global scale. Many of the same economists and ecologists working on the initial communication and subsequent scientific front participated in the discourse on the possibilities of markets for environmental services. The transition from communication metaphor to scientific and developmental model paralleled an exponential rise in the use of the term "ecosystem services" in academic journals (Fisher et al., 2009).

Over a period of about 15 years, an eye-opening metaphor intended to awaken society to think more deeply about the importance of nature and its destruction through excessive energy and material consumption transformed into a dominant model for environmental policy and management in developing countries and for the globe as a whole. There is now a thriving industry of professionals providing advice on ecosystem services. The metaphor's ties to the problems of continued global economic growth have largely been broken. Indeed, through carbon offsets and optimizing the use of ecosystem services in poor countries, the delusion of continuing consumption along its old path in the rich countries is being sustained.

In this paper, I make three critical points. First, while the stock-flow framework underlying the concept of ecosystem services conceptually links ecological and economic systems, this framework only utilizes one of the many ways ecologists understand ecosystems, leaving out many of the other frameworks. While many ecologists have noted the "limits" of ecology for defining ecosystem services, valuing them, and designing payments for ecosystem services (PES) and related projects, the problem is really with the limits of stock-flow models (Palmer and Filoso, 2009). Ecologists understand the complexity of nature using many different frameworks, each of which helps them understand different aspects of natural systems. By

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focusing on the stock-flow framework, the valuation of ecosystem services and implementation of PES and related projects will have unintended consequences that could have been better foreseen and avoided or adapted to by using additional patterns of thinking. The ecosystem service metaphor now blinds us to the complexity of natural systems, the ecological knowledge available to work with that complexity, and the amount of effort, or transactions costs, necessary to seriously and effectively engage with ecosystem management.

Second, the theoretical literature on ecosystem services, their valuation, and payments for ecosystem services have been framed within a partial equilibrium framework that assumes "other things are equal" (*ceteris paribus*). Similarly, the implementation of the concept of ecosystem services has been on a project-by-project basis within existing national and global institutional structures. Yet the driving motivation, from the initial use of the ecosystem metaphor to the implementation of PES projects, has been to instigate significant institutional and consequent economic change in response to what are perceived to be very serious environmental problems generated by the economy we have. Using a general equilibrium framework, I show that the more significant one thinks our environmental problems are, the more inappropriate has been the partial equilibrium and project-by-project approach for utilizing the concept of ecosystem services.

Third, we need new global institutions and far more resources devoted to environmental governance. The flurry of enthusiasm for optimizing the economy by including ecosystem services has blinded us to the more important question of how we are going to make the substantial institutional changes to significantly reduce human pressure on ecosystems, especially by the rich, and to adapt to and work effectively with the rapid ecosystem changes being driven by existing and foreseeable climate dynamics.

1. The richness of the ecological sciences

Today's ecology does not have the predictive capacity to identify the sustainable use of any particular ecosystem service, to describe the tradeoffs between uses of ecosystem services, and to be able to do this, furthermore, not only in particular contexts but in the face of ecosystem change from climate and other drivers (Norgaard, 2008a; Palmer and Filoso, 2009). Ecologists, even those supportive of the concept of ecosystem services, frequently characterize the ecology as weak and not sufficiently predictive to support the application of the concept (Daily et al., 2000; Carpenter et al., 2006; Armsworth et al., 2007). The hope that ecology will have this predictive ability is pretentious, denies the many other ways that ecologists actually do understand ecosystems that expose the pretentiousness, and is dangerous that the pretense of eventually knowing forecloses our use of the diversity of ways of knowing the ecological sciences that we already have and should continue to broadly support.

The Millennium Ecosystem Assessment (MA) provides critically important insights into this broad concern. The MA was a five-year effort by some 1400 scientists from around the world that assessed the state of ecosystem services, the drivers of ecosystem change, and the implications for human well-being (Millennium Ecosystem Assessment, 2005). In the process of preparing to undertake the MA, general frameworks describing the relationship between ecosystems and human well-being were discussed. A team of over fifty scholars and practitioners settled on and elaborated a dynamic, multi-scale systems view (Fig. 1) within which ecosystems were thought of as natural capital that provided ecosystem services, a stock-flow model (Millennium Ecosystem Assessment, 2003). Note that Fig. 1 effectively incorporates how PES is expected to work. By paying for the services represented by the vertical arrow in the lower left of Fig. 1, those who manage ecosystems will have an incentive to protect the ecological capital represented by the box on the lower left that generates the services. Doing this entails combating or counteracting the direct drivers of change to the ecosystems indicated in the box on the lower right.

The MA framework, however, also reminds us that there is a larger system of concern, that there are different goals we are trying to attain, and that ecological and social phenomena happen on multiple scales and over different time periods that also match with the scalars of different social institutions (Wilson et al., 1999; Folke et al., 2005). Looking at the box on the lower right, an important point becomes immediately clear. While landowners or managers can influence some direct drivers of change listed in this box such as "harvest and resource consumption" and "technological adaptation and use", they have much less influence over species introductions and removals and no influence over climate change or "natural, physical and biological drivers" such as evolution or volcanoes. Similarly, while local institutions may be adapted to better accommodate individual ecosystem service projects, national and global institutions are taken as given.

The stock-flow framework illustrated in Fig. 1 helped the participants in the Millennium Ecosystem Assessment identify critical questions, but the model proved far less useful in the assessment than expected. Fortunately, the assessment was guided but not constrained by this particular framework. The following difficulties arose.

First, certainly the greatest difficulty of using the MA general framework was that very little ecological research has been conducted within an ecosystem service framework. Rather, ecologists think in terms of population dynamics, food webs, energy flows, interactive behaviors, biogeochemical cycles, spatial organization across landscapes, and co-evolutionary processes, among others. Furthermore, most ecological researches do not address human well-being. Similarly, most of the researches on human behavior and social systems neither fit a stock-flow model nor connect to the ecosystem services or to how social systems drive ecosystems. In short, the literatures representing our scientific understanding do not fit neatly into the ecosystem service framework, or even provide information appropriate for any particular quadrant of the MA model.

This is not simply a problem of natural scientists ignoring the social and social scientists ignoring the natural. The major issue is that only some of the ways in which ecologists think, for example food webs or energetics models, can be interpreted as stock-flow models that fit the lower left quadrant of Fig. 1. Most of the ways ecologists think, however, do not fit the stock-flow framework. Evolutionary and behavioral ecology, for example, provide insights into the nature and management of ecosystems, but these frameworks do not reduce to a stock-flow model. Indeed, to the extent that these other frameworks do provide insights, the insights are cautionary rather than complementary to the mechanistic prediction and control facilitated by stock-flow models. Similarly, much of the social science literature cautions against the dominance of the framework of society as individuals linked through markets rather than complements its use.

Scientists see different aspects of complex systems through different models (Norgaard and Baer, 2005a,b) most of which do not fit within a stock-flow meta-framework underlying the concept of ecosystem services. While many ecologists have described the ecology as being very weak, my concern is that ecology in fact is very rich and that much of the ecology we know does not support the ecosystem service perspective. Rather than jettison the multiple patterns of reasoning in ecology and emphasizing stock-flow models, we should be using the richness of ecological ways of knowing to help us see the poverty of thinking predominantly in stock-flow terms. An emphasis on interpreting and responding through a stock-flow framework sets other patterns of understanding off to the side and increases the likelihood of making serious mistakes. The ecosystem service perspective suggests we can achieve gains by further fine-tuning along our current path while the heterogeneity of ecological knowledge questions the current course.

Fully thinking through ecosystem service projects from multiple perspectives means society must establish standing institutional mechanisms for bringing out, sorting through, and using complex, contradictory insights in environmental management. Many more aspects of the environment must be monitored to support multiple

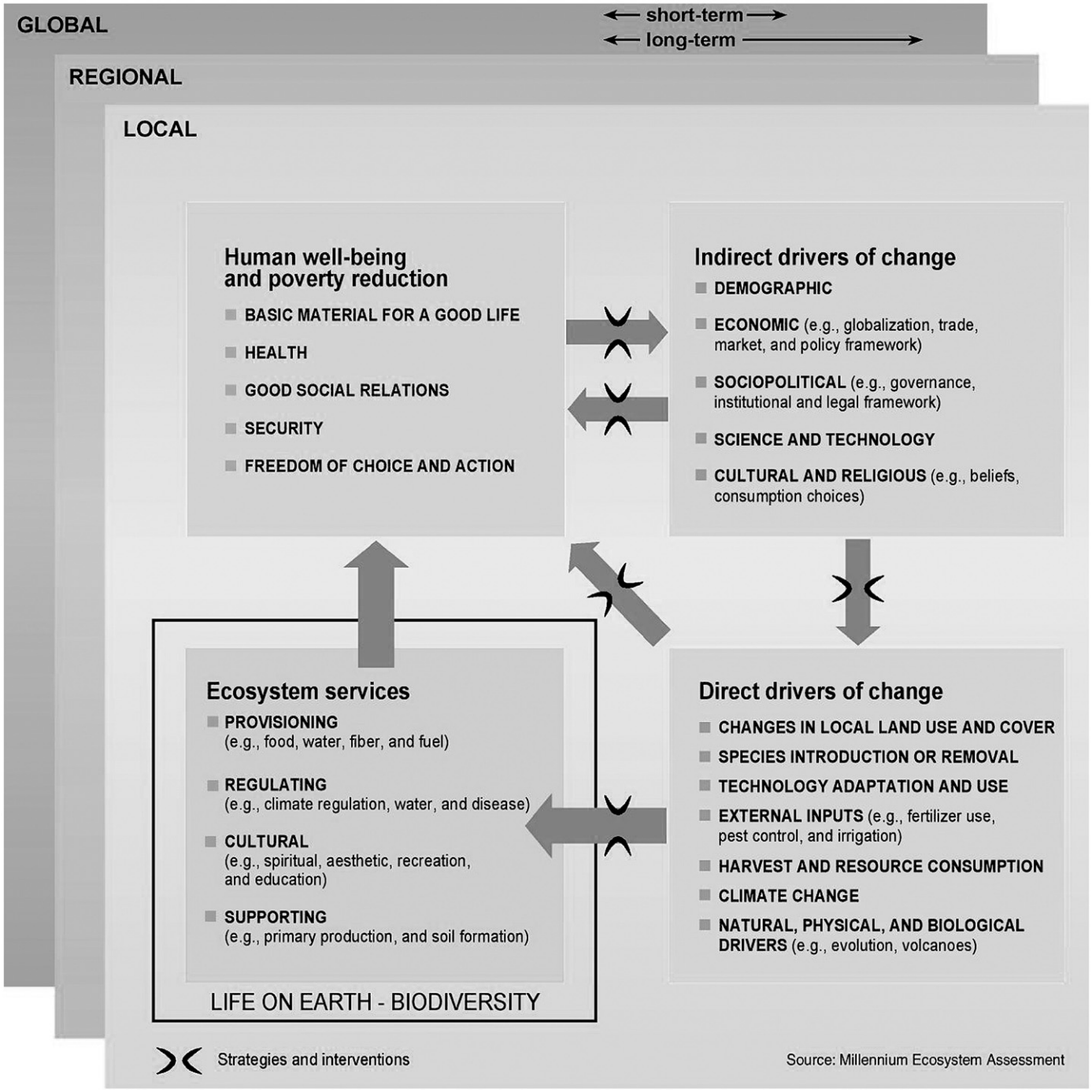

Fig. 1. The Millennium Ecosystem Assessment adapted an ecosystem service framework through which to assess the literature on ecosystem transformation and human well-being.

ways of understanding ecological systems. All of this entails high transaction costs, the bane of fine-tuning systems, whether through markets or other institutions. If the transaction costs were not high, market failure would not be a problem (Coase, 1960). We should always be open to ways of engaging with each other and nature that have lower transaction costs, assuming away the complexity of socio-ecological systems and the diverse ways we understand that complexity will surely lead to lower transaction costs, but it will also lead to ineffective to disastrous outcomes.

Second, in the process of assessing the global significance of ecosystems and their services, participants in the MA were frustrated by two problems. What they had learned in one ecosystem did not easily translate to another ecosystem, even if it seemed to be a quite similar ecosystem. Rather, the literature across seemingly similar ecosystems indicated many more differences than expected, many of them apparently due to different histories of human influence. Other scholars (Daily et al., 2000; Muradian et al., 2010—this issue; Pascual, et al, 2010—this issue; Vatn, 2010—this issue) have noted the contextuality of ecosystem service projects, and how each must be, and to some extent are, designed on their own terms. A closely related problem, however, was that the quality of the background data on key variables such as climate and soil conditions were insufficient to match knowledge gained in one area to another (Biggs et al., 2009). The implication for application of ecosystem service projects is that the relationships between services and ecosystem states need to be determined for each location to assure a realistic connection between payments, services, and approaches to

ecosystem management and conservation (National Research Council, 2007). Furthermore, as the pace of ecosystem change speeds up, ecosystem service projects will have to be followed closely and adjusted frequently. This is an additional reason why the transaction costs for well-designed and well-maintained ecosystem service projects will be high.

Third, participants in the MA discovered that they could say very little about how the provisioning of one service affects the availability of other services or the state of the ecosystem over the medium to long-term. Relationships between ecosystem services as well as the relationships between levels of ecosystem services and the long-term condition of ecosystems are only rarely known. A critical aspect of this knowledge deficit is that the MA scientists were not able to document there ever having been anything approaching a consensus among ecologists that a population was about to crash or that an ecosystem was about to transform from one state to another. Individual ecologists have predicted crashes and state transitions and been proven correct after the fact, but other ecologists had argued at the time to the contrary. Ecologists have only recently advocated developing a database that might assist in developing improved predictive capability with respect to dire changes in populations and ecosystems (Walker and Meyers, 2003). This means that science is far from being able to predict smaller shifts in the delivery of services. This means that research needs to be conducted site by site to understand underlying relationships and continuous monitoring will be necessary to assure that our ecological understanding is correct and adapts as conditions change. And, of course, ecosystem service projects themselves must change as the underlying ecological understanding changes. Again, this is another reason why the transaction costs of well-designed and well-maintained ecosystem service projects will be high.

It is interesting to note that implementing the concept of ecosystem services is primarily being advocated for developing countries while in the developed countries, with a few exceptions, it is much less frequently advocated, let alone implemented. This is curious given that the environmental sciences are far better developed in the rich countries. Similarly, monitoring and applied research are far more extensive in the developed nations. Furthermore, the techniques of environmental valuation originated and are probably most meaningful in developed economies since rich nations are already more monetized. In the developed world where markets flourish, there can be better institutional support for ecosystem service projects. Let me suggest that a significant reason why there are so few ecosystem service projects in the developed world is because scientific disagreement is also rampant where ecological understanding is deeper, *i.e.* heterogeneous. Ecosystem service valuation is not being advocated to resolve California's many environmental problems associated with conflicts over economic development and water scarcity because the controversies stemming from the diversity of ecological ways of knowing make almost any such approach impossible. Furthermore, as environmental scientists increasingly incorporate climate change into their conceptual thinking and applied research on water management and economic development in California, they become less confident of their ability to predict and manage and thereby satisfy expectations for attaining any particular mix of development and environmental goals (Healy et al., 2008; Norgaard et al., 2009). We also know that new, more sustainable, solutions in California will require significant reallocations of property rights between historic users and new public interests (Hanemann and Dyckman, 2009).

As we enter a century or two of rapid ecological change, property rights will need to be redefined and reallocated more frequently to meet social goals most effectively. We are entering a period when the relative advantage of property and markets are probably lower than they have been. In any case, we should expect adaptive governance in times of ecosystem change to entail more transaction costs than more stable governance during times of less change.

The Millennium Ecosystem Assessment provides interesting insights on the issues of equity as well. The MA says very little about the monetary values much less about whether users should pay for ecosystem services or providers should compensate users for the loss of services. This was partly because the valuation literature was not assessed; it was not deemed part of the study from the beginning. Yet at various times in the process of conducting the MA, being able to put monetary values on ecosystem services would have been helpful, for example, in order to aggregate different services across regions or between types. When the possible use of monetary values arose, however, there was typically a modest howl of protest by some of the many participants from developing nations. They expressed concern that the dollars of rich, northern ecotourists, or even the urban rich in developing countries, would dominate and outweigh the values of local poor people who needed access to ecosystems to meet basic needs. Similarly, MA participants recognized that we have the goal of sustaining ecosystem services so that future generations will not suffer. Future generations, however, are not directly in markets and affecting prices, are not affecting the behavior of current people sufficiently if we think ecosystem conservation is insufficient, or available to answer contingent valuation questionnaires (Bromley, 1989; Howarth and Norgaard, 1992). For these reasons, environmental valuation as currently practiced was generally deemed inappropriate.

The frameworks of ecology that can be reduced to stock-flow models will no doubt receive more research funding and scholarly attention. These ways of knowing within ecology will likely improve faster than they would have otherwise while other ways of knowing will wane. The enterprise of science has always coevolved with dominant forms of social organization, available technologies, and the range of social values as well as with nature and environmental problems as perceived at the time (Norgaard, 1994). Of course we want science to advance to support human needs. But we also know that nuclear physics has had a disproportionate share of the scientific budget because of its relation to the need for defense. Environmental toxicology arose as a field largely to establish health thresholds for pollutants. But the thresholds were established independently without considering other pollutants and as if people's ages, nutritional status, or other diseases did not matter (Jasanoff, 1990). The science was distorted because of the need for simple, enforceable, regulatory standards. Scientists in the U.S. Forest Service rationalized how excessive logging rates could be sustained by over-estimating growth rates because public policy mandated sustainability (Hirt, 1994). Ecology will coevolve with the dominance of market thinking and how this dominance affects whose needs are expressed. We should be aware, however, that this will likely lead to dominant ways of thinking in ecology that could substantially reduce scientific and public understanding of the true complexities of ecosystems that will lead to narrow management and future crises. A stronger, broader awareness of how science coevolves in society could help science coevolve more richly to benefit a broader constituency including future generations.

The arguments in favor of sustaining the richness of ecological understanding parallel those for methodological pluralism in ecological economics (Norgaard, 1989; Zellmer et al., 2006; Farrell et al., 2009). There are strong interests that benefit from the status quo who do not want society to dwell on how the dominance of market thinking has transformed society in ways that do not benefit all (Polanyi, 1944). We can expect parallel interests to arise that will favor limited ways of ecological thinking, much as powerful economic interests historically promoted chemical over biological understandings of soil. Grappling with the complexity of combined socio-ecological systems will not be easy, but merely hoping or imagining that they can be reduced, with transaction costs diminishing in the process, would be like putting on blinders.

2. Ecosystem services and sustainability in a general equilibrium framework

The dominant literature on ecosystem services and their valuation in practice follow the tradition of project analysis where the analyst

assumes "all other things are held equal" (*ceteris paribus*) and then proceeds within a partial equilibrium framework. Setting the boundaries of the analysis as a project and doing analyses of ecosystem services project-by-project assuming that the economy as a whole is not affected by the projects might have made sense historically. Yet even under the historic conditions in which project analysis evolved, one could surely argue that water projects, for example, entailed plans for multiple dams along whole river systems and sweeping changes in the use of land with the explicit intention of transforming the regional economy.

It is just such a sweeping economic transformation that is needed now and should be done globally. We are in a global ecological–economic crisis that threatens human well-being through climate change, ecosystem degradation, and species loss driven by our economic choices. Marginal adjustments in the economy will not suffice. Rather we are trying to understand the appropriate speed and extent of what will likely be a significant economic transition around new energy technologies and institutions affecting how we interact with nature, especially biocarbon stocks and flows. The dynamics of ecosystems and the future of biodiversity and their values will be mischaracterized if we simply think of this transition in terms of individual projects from within the economy we have.

At the project level, holding other things, equal implies that the analyst accepts existing regional to global institutions, whether they support sustainability or not. If institutions supported sustainability overall, project structured around the concept of ecosystem services could fine-tune the market to correct a particular inefficiency. But if the broader institutions supporting sustainability are not in place, local fine-tuning will have a little effect. We can move to this broader perspective through general equilibrium analysis. Using an overlapping generations, general equilibrium model, Howarth and Norgaard (1992) found that shifting to a sustainable development path results in both environmental services being more highly valued and the rate of interest being lower. Thus with sustainability, the marginal value of an ecosystem is higher and future values are discounted less because of the lower rate of interest than in an unsustainable economy. Current valuation methods only help us "see" ecosystem services and their values from within our unsustainable economy. We are "seeing" them, and working with them, less favorably than we would be in the economy we are trying to reach. Ironically, we are trying to reach a sustainable economy by invoking the value of ecosystem services but doing so less effectively than needed because our point of view is the economy we have rather than the economy we are trying to attain.

This simple argument is graphically presented in Fig. 2 where we have ecosystem services consumed by the current generation on the *X*-axis and ecosystem services consumed by future generations on the *Y*-axis. Every point on the possibility frontier is efficient in that neither current nor future generations can become better off without hurting the other. At every point on the possibility frontier, there is a different set of efficient prices, including an interest rate that is directly represented by the slope of the frontier showing how ecosystem services are weighted between generations.

Being at different points on the frontier requires different distributions of property rights, regulations, obligations, and other institutions that set the underlying rules of who has what and how individual choices are made in markets. The public choice of where to be on the possibility frontier requires a criterion from outside of economics that economists have referred to as a "social welfare function" that generates curves of equal social well-being analogous to preference curves for individuals choosing between two goods. Since the figure is already pretty busy, the different levels of social welfare are not portrayed. The essential point is that better markets can only move society toward the frontier while social preferences guide society to a point on the frontier. Specific institutions are necessary to reach any particular point and keep the economy at that point rather than being at another on the frontier. Thus the underlying

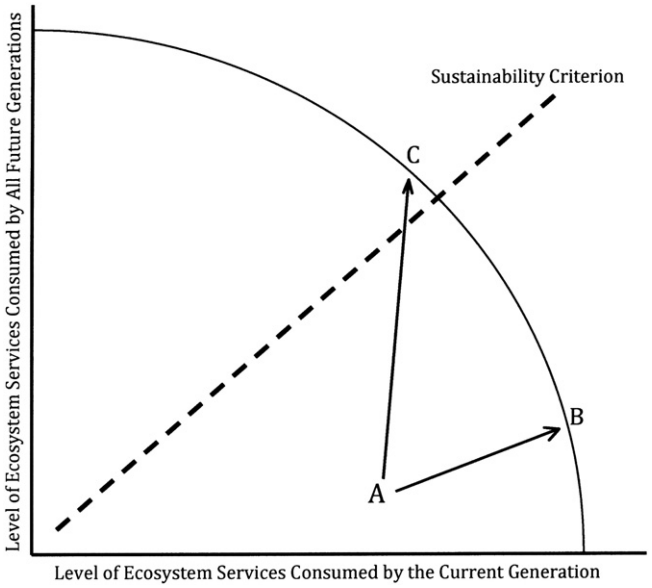

Fig. 2. Unless the overall institutional conditions are in place to support sustainability, incorporating ecosystem services into the economy project-by-project will take the economy to the efficient point B, which is unsustainable, rather than C, which is sustainable.

institutions that help us express our care across generations determine prices and the rate of interest.

Let me assert that the economy is positioned at point A that is inefficient because ecosystem services are not included in the market to the extent that they can be given transaction costs. Within the economy we have, *i.e.* given the existing distribution of rights between present and future generations, internalizing the externalities through PES projects, or including the values of ecosystem services in public projects, might move the economy to a position such as point B where both current and future generations are better off (at least for the medium run) yet the economy is not sustainable.

Note, however, that Fig. 2 also includes a (strong) sustainability criterion above which future generations are able to consume as many or more ecosystem services as current generations. When the economy is operating below the sustainability criterion, current generations are consuming ecosystem services at a rate that is depleting natural capital. Above the sustainability criterion, investments are being made in natural capital. Our concern, documented by the Millennium Ecosystem Assessment (2005), is that our existing environmental governance structure puts the economy at a point such as A, while a sustainable point such as point C is preferred. Though one cannot directly compare values between points on the curve without knowing what prices maintain the different points, the findings of Howarth and Norgaard (1992), and simple logic, indicate that ecosystem services will be more highly valued in a society that sustains them and that the interest rate will be lower, as shown, at point C as compared to point B.

I argue that this underestimation of the importance and value of ecosystem services is further compounded by the rapid transition in scientific understanding, reinforced by the emergence of new evidence of climate change, in the last decade. This transition indicates we are trading off more in future well-being through current consumption than we had thought we were. We have been overly optimistic about the possibilities of new technologies releasing new, or substituting for existing, environmental services and we have thus been consuming natural capital rather than simply living off of services (Millennium Ecosystem Assessment, 2005; Hansen et al., 2008; Barnosky, 2009). I illustrate this in Fig. 3 with an "actual" possibility frontier that is well inward of the "mistaken" frontier we have thought existed. Note that the actual frontier is within the mistaken frontier both because our scientific understanding indicates that the tradeoff between current and future

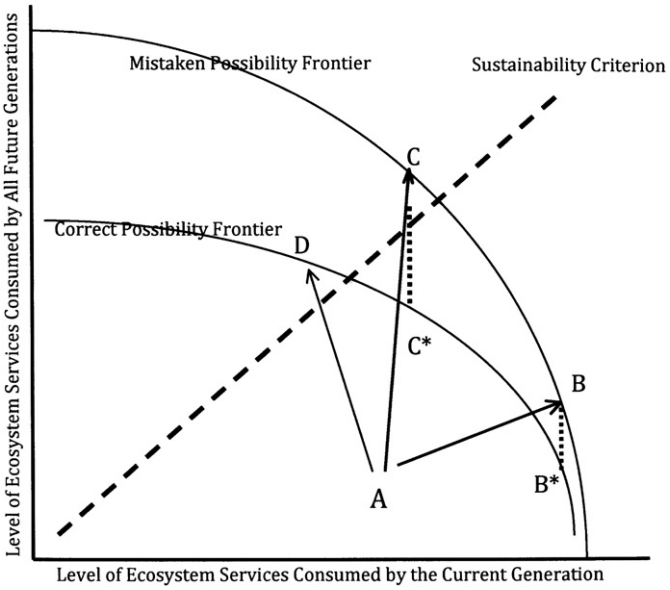

Fig. 3. Given recent climate science and empirical evidence, the possibility frontier has moved inward significantly such that society now needs to move to a point such as point D. This would entail reducing the consumption of ecosystem services by the current generation. Note that attempting to move to point B or C would likely take society to point B* or C*.

consumption is different than previously thought and because past consumption of ecosystem services, mostly by the rich, depleted the natural stock and reduced future options (the two-period, comparative static, illustration emphasizing flows veils the changes in stocks over time illustrated in the work of Howarth and Norgaard, 1992).

The difference between the actual and mistaken frontiers helps us see several important issues. First, trying to move to point B on the premises of the mistaken frontier could leave society at point B* on the actual frontier where future generations are quite possibly worse off than they were at the beginning point A. Similarly, trying to move to point C would actually leave future generations at point C*. The difference between the possibility curves illustrates a substantial correction in our knowledge that also indicates we need a substantial correction in our actions. Given the actual frontier and the preference for sustainability, society needs to move to a position such as point D. Now we see how having fewer possibilities for future generations should affect our choices today, *i.e.* the current generation should consume fewer ecosystem services so that future generations can consume at least as many services as current generations. Indeed, many climate scientists (Mastrandrea and Schneider, 2004; Baer and Mastrandrea, 2006; Hansen et al., 2008) are advocating much more aggressive climate mitigation than most economists (Nordhaus, 2008) or even economists making more effort to address risk and future people (Stern, 2007) have been talking about because of the new understanding of even greater risks of disaster identified by the most recent climate science and emerging evidence. The key point here is that, if we think that our environmental problems are serious, we should not simply be thinking in terms of fine-tuning the direction of development. Rather, we need to completely reassess how we can quickly move to something closer to the path we would have chosen historically had we known earlier what we know now.

In this sense, the IPCC scenarios derived in the early mid 1990s and only now being updated and used in the assessments of possible climate futures until recently do not take the gravity of the new scientific understanding and empirical evidence of the past decade seriously. Rather than presenting alternative transitions to something closer to the path we would have been on if we had been more knowledgeable, the scenarios simply present alternative paths from where our incomplete knowledge brought us. This is comparable to building a house, realizing along the way that the construction project had gone way off course, and then, rather than undoing the mistakes, simply proceeding on top of the mistakes. In Fig. 3, this is comparable to implementing ecosystem service projects as if the prices and behavior observed in a state of delusion at point A were approximately correct rather than totally wrong. This is my sense of what is happening overall. We are ignoring that we want to move to a point such as D where, once fully realized, prices and behavior will be different than at point A, B, or C (the latter two not actually being possible, leaving society at point B* or C*).

Moving from point A to point D will require much stronger governance regimes, from local to global, to monitor and manage environmental services than the ones that have allowed ecosystem deterioration. To reach stronger governance at the much needed global level, the rich will have to acknowledge that the reduction in options for future generations has resulted largely from their activities (Srinivasan et al., 2008), and it is the rich by any reasonable criterion of justice who should be cutting back on their use of environmental services so that we can move to point D. In short, we need a major new global contract between rich nations and poor and between the rich and poor within nations that revamps our relation to nature and the future. To reach that contract, society will have to acknowledge the inequities of past development and environmental change (Baer et al., 2008). Once such institutions are in place, project building on the concept of ecosystem services could then help fine-tune economies to move to the possibilities frontier at point D. In short, it is point D that should provide the design criteria for significant institutional change and, when these changes are in place, the valuation of and payments for ecosystem services can be used for fine-tuning.

Many thoughtful scholars writing on ecosystem services recognize the importance of the institutional context (Grieg-Gran, et al., 2005; Pagiola et al., 2005; Lant, Ruhl and Kraft, 2008; Vatn, 2009, 2010—this issue). The guides to ecosystem service management pay considerable attention to local institutions and questions of equity (Ranganathan et al., 2008; UNEP, 2008). Some scholars are documenting how the dominance of partial equilibrium market analysis in ecosystem service projects has blinded us to how policies will actually turn out, especially with respect to equity, when implemented (McAfee, 1999; Corbera et al., 2007; Shapiro and McAfee, 2008). Nevertheless, few explore the problems with respect to humanity's shriveled ecological options and gross social injustices as starkly or as globally as I have. Yet, none who promotes the concept of ecosystem services, whether in the scientific literature or through practice, argues, to my knowledge, that our environmental problems are few, small and local, that the global institutions needed for sustainability are largely in place, and that the new climate and ecosystem change science is neither important nor alerting us to more rapid change ahead.

We should not let the intricacies of partial equilibrium analysis and project-by-project practice blind us to this bigger picture. Indeed, ecological economists should be acutely aware of and helping policy-makers and the public understand how economists began to uncover this larger picture starting with Cournot (1838), then fully elaborated it over the next century, and then systematically rationalized away its relevance to public understanding and application to policy analysis, ending with Harberger (1971).

Taking off the blinders of partial equilibrium analysis and incorporating the insights from a general equilibrium framework into the necessary politics, local to global, to bring about systemic change will be difficult. The available data, both ecological and economic, are concentrated around point A. Empiricists will plead that we must look for solutions under this lamppost where the light shines. Existing economic interests will support this realist claim as objective. The world we know can be used to help ground macro simulations of the economy and its possible other states in order to shed light on how we can get to where we want to go. The major changes need to be accomplished at the level of national and global politics, not project analysis. Nevertheless,

simulations rooted in the general equilibrium theory of the economy that we want to have could be undertaken by development and environment agencies, from international to local, to help guide individual project analysis and design and update them periodically as appropriate.

3. Becoming serious about environmental governance

The multiple ways ecologists understand aspects of ecological complexity highlighted in Section 1 raise questions about how ecology is being skewed to inform markets rather than being drawn on more fully to inform governance. The general equilibrium framework presented in Section 2 helps us see the relation between markets, governing institutions and the goal of sustainability. We have experienced three decades of free market fundamentalism during which public understanding has been reduced to ideology extolling markets while government agencies have been denigrated and their budgets shrunk. During this period, markets have been guided and regulated more by internal power and market mythology, less through democratic institutions and informed reason, compared to more pragmatic times following the Great Depression and World War II. The shift toward thinking of ecosystems as having services and of conservation through payments for ecosystem services rose to dominance during this period of faith in markets with little public guidance and weakened regulation.

The global economic crisis that arose in 2008 as the U.S. mortgage market bubble burst has reawakened economists and the public at large to how markets depend on effective institutions. This reawakening can, in turn, affect how we think about institutions and markets more broadly for environmental governance. Let me identify and briefly describe some key areas where more serious thinking is needed, both within ecological economics and beyond.

First, economic thought, the ways it has linked with other ways of thinking, and its application in practice have to be understood in historical context. Economics changes with the times as it changes the times; it influences reality, especially the immediate reality within which we live, while broader real forces must also be addressed. We are at a time when the reality of climate change and ecosystem transformation could affect economic thinking significantly. Many ecological economists have been helping keep economics in historical perspective (Martinez-Alier and Schlupman, 1987, Kosoy and Corbera, 2010—this issue), and we need to sustain such efforts. In practice, ecological economists need to resist using current dominate ways of thinking to reach short-run, partial solutions and favor both emerging and the multiplicity of less dominant ways of analyzing problems to promote a rich understanding of the complexities of society and nature.

Second, there needs to be a serious enrichment in the understanding of economists, the scholarly community as a whole, policy-makers, and the public about the interplay between markets and institutions. While institutional economists are very well represented within ecological economics and provide excellent input (see, for example, Söderbaum, 2000; Vatn, 2005; Bromley, 2007), the perspective that markets and institutions, across scales, work together still needs to become more integral for more ecological economists. We also need to strive further to extend the public's understanding of how markets and institutions work together. As the new institutional economists stress, we should be focusing on the combination of markets and institutions that best reach social goals given transaction costs (Coase, 1937; Ostrom, 1990; Williamson, 1996). Taking such a combined view is not easy, but it should be the perspective when framing an environmental issue, designing environmental policy, and assessing analytical or actual outcomes. While we find a stress on transaction costs and institutions in ecological economic analyses (see, for example, Haddad, 2000), this approach needs to be more integral to ecological economics and this framing needs to be spread more broadly.

While we should seek the combination of institutions and markets for reaching social goals with the lowest transaction costs, surely the transaction costs of living sustainably will be considerably higher than we have become accustomed to within the social organization, approaches to understanding, and deployment of technologies that have facilitated high levels of individual and corporate choice with respect to energy and material extraction and consumption, choices that have been destroying the natural system we depend on in common. Sustainability is difficult, *i.e.* transaction costs will be high; working with rapidly changing ecosystems will entail even higher transaction costs and continually rethinking property rights in light of changing ecological dynamics, changing ecological knowledge, and changing social goals as new problems arise.

Third, whatever the appropriate institutional mix of government and markets, environmental governance must be informed in a balanced way, as fully as transaction costs constraints allow, to be effective. Environmental governance can no more succeed around the metaphor of ecosystem services apart from the richness of ecological thinking than mortgage markets can succeed on the myth that housing prices will always rise. The more we learn about the complexity of environmental systems and how phenomena interact across scales, the more we realize that compartmentalized science and specialization in social organization have increased transaction costs and facilitated our unsustainable economy. Somehow, we need to make a significant transition toward richer ways of understanding and governing. The current evidence indicates these ways will be more collective, participatory, and discursive forms of learning, knowing, and governing (Dryzek, 1987; Wilson and Howarth, 2002; Zellmer et al., 2006; Norgaard, 2008b; Jäger, 2009). This is a major challenge that will entail considerable social reorganization and far more collective human effort going into knowing and understanding (Adger and Jordan, 2009). Much as Vatn (2009a) argues that valuation needs to be understood as being integral with the institutional contexts of valuation, we need to think of knowledge and valuation together in a new systemic institutional context to effect change (Nowotny et al., 2001).

Fourth, the current political acceptance of a cap and trade system as the primary approach to managing carbon and other greenhouse gases to mitigate climate change carries with it the presumption that we can monitor and manage to maintain existing net biocarbon stocks throughout the biosphere and, as offsets to fossil hydrocarbon emissions, invest in and monitor new biocarbon stocks. This presumption is girded by the rise in the stock and flow framing of nature and the idea that markets can solve problems apart from broader institutional contexts. Of course, short of physically geoengineering a solution to climate change, to successfully mitigate and adapt to climate change we will have to develop the technology and institutional conditions to substantially improve our ability to monitor and manage existing biocarbon regardless of the institutional framework for sharing the burden of the reduction in emissions from fossil hydrocarbon combustion. It is disturbing, however, that there are now new institutions being proposed under UN-REDD (UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) for the management of biocarbon that largely ignore both the long history of institutional failure in stemming tropical deforestation and the vulnerability of biocarbon stocks themselves to climate change (United Nations, 2008; UNFAO, UNDP, UNEP, 2008). The REDD program appears to be driven by the necessity of its existence to stabilize baseline biocarbon stocks, a requirement for meaningful global carbon markets, along with the desire of rich nations to continue combusting fossil hydrocarbons and the poor to receive compensation for protecting nature. The ecosystem service framework and belief in markets apart from institutions, let alone the limits of institutions, foster this naïveté. Rather than thinking of biocarbon as offsets to fossil hydrocarbon combustion, we should be reducing fossil hydrocarbon combustion even more rapidly than we had previously thought necessary because of the vulnerability of biocarbon stocks under climate change.

Fifth, the idea of natural limits is fundamental to ecological economics (Georgescu-Roegen, 1971; Daly, 1973; Daly and Farley, 2004). The general equilibrium framework inherently expresses limits and allows us to see how new knowledge adjusts these limits. The move from point A to point D would require some current people to use fewer ecosystem services because of limits and our desire for a future for our children. Yet, even as ecological economists we still too rarely argue that turning down the economic drivers and/or decoupling economic activity from environmental consequences should be the first steps toward a solution. As we better acknowledge the higher transaction costs and institutional limits of living sustainably with nature, let alone with rapid socio-ecological change, the need for turning down the economic drivers should be increasingly clear. At the same time, though limits surely exist, we cannot put the burden on ecologists to declare what they are in any detail. Limits are many, contextual, and interrelated. The observable condition of the planet and the collective assessments of scientists (Millennium Ecosystem Assessment, 2005; IPCC, 2007) are as specific as we can be.

Sixth, and lastly, sustainability is ultimately a distributional question, a matter of ethics or environmental justice within and between generations. Designing better environmental governance always entails addressing the question: better for whom? While economists have been unusually successful at averting the ethical questions, and in the process supporting those who currently benefit from the governance structure, this avoidance has become central to the problems we know have in reaching a global accord. Global climate negotiations have been stalled for over a decade because of ethical disagreements with respect to addressing both historical and future responsibility, not the technicalities of economic efficiency. A cap and trade mechanism is preferred to a carbon tax until negotiations over the distribution of emission rights become explicit. Moving from a point such as A in Fig. 3 to one such as D must be an ethical decision, and it will be a difficult one. While economic reasoning has been firmly rooted in weighing likely consequences, the unpredictability of climate change, ecosystem transformation, and their interplay, let alone the uncertainties of social system responses, combined with what is at stake means we need to become more adept with *a priori* ethical reasoning for public decisions as well as move toward new individual virtue ethics (Sachs and Santarius, 2005; Meyer and Roser, 2006; Vanderheiden, 2008).

4. Conclusions

What started as a humble metaphor to help us think about our relation to nature has become integral to how we are addressing the future of humanity, the management of ecosystems, and the course of biological evolution. The metaphor of nature as a stock that provides a flow of services is insufficient for the difficulties we are in or the task ahead. Indeed, combined with the mistaken presumption that we can analyze a global problem within a partial equilibrium economic framework and reach a new economy project-by-project without major institutional change, the simplicity of the stock-flow framework blinds us to the complexity of the human predicament. The ecosystem services approach can be a part of a larger solution, but its dominance in our characterization of our situation and the solution is blinding us to the complexity of the challenges we actually face.

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