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Towards Biogeophysically Based "Green Accounts"

Harold Glasser
University of California

Paul P. Craig
University of California

About the Authors: *Harold Glasser & Paul P. Craig* are at the University of California in Davis. Harold Glasser is in Civil and Environmental Engineering, and Paul Craig is with the Graduate Group in Ecology and the Department of Applied Science. Harold Glasser is also the Director of the recently founded *Selected Works of Arne Naess Project* whose aim is to bring Prof. Naess's important writings to the English language audience in a comprehensive series of volumes.

> [A] reliable account is personal at the beginning and religious at the end. This does not mean that a reliable account includes the whole system of systems, for no account can do that. It does mean that the account is made in precise reference to the system of systems — which is another way of saying that it is made in respect for it. Without this respect for the larger structures, the accounting shrinks into the confines of some smaller structure and becomes specialized, partial, and destructive.... In this degenerative accounting, language is almost without the power of designation because it is used conscientiously to refer to nothing in particular. Attention rests upon percentages, categories, abstract functions.... It is not the language that the user will very likely be required to stand by or to act on, for it does not define any personal ground for standing or acting.... And it works directly against the conventionality, the community life, of language, for it holds in contempt, not only all particular grounds of private fidelity and action, but the common ground of human experience, memory, and understanding from which language rises and on which meaning is shaped. (Berry, 1983:51-2).

Theme: Are WE Killing The Golden Goose?

Human impacts upon the environment have created a need for a more robust and thoughtful understanding of the impacts themselves, their causes, and their interrelationships. Efforts to revise national income accounts to incorporate "environmental externalities" ("Green Accounting") may help us to better understand how our social, political, and economic actions impact the environment. A primary motivation behind "Green Accounting" is concern that human activities generate significant environmental damage not captured by conventional accounting techniques. We examine issues relating to improving measurement and accounting strategies for capturing environmental and equity considerations. Scientific understanding cannot overweigh shortsightedness, narrow identification, and avarice but it may help illuminate some of the future consequences of particular decision paths. While our focus here, improving quantitative procedures for accounting, emphasizes a largely instrumental conceptualization of the world, we are in no way recommending a technocratic "management" approach. We recognize the importance of considering qualitative and unquantifiable factors in decision processes..2. Our approach refers to specific entities and factors grounded in human experience. Unlike prescriptive tools (cost- benefit analysis) it reinforces participatory democracy by acting as a descriptive aid for facilitating discussion and debate among a wide range of potential stakeholders.

Optimists argue that technological advances will provide substitutes, and claim that there is no need to worry..3. Pessimists worry that we are destroying irreplaceable resources, diminishing biodiversity, and creating adverse side-effects at an accelerating pace; they fear that disaster looms.

National income accounts, as commonly constituted, inadequately capture some of the most important features of the sustainability discussion. Our approach, which incorporates both stocks and flows, represents a framework for giving context and meaning to Green Accounts. We emphasize the use of biogeophysical measures as direct indicators of particular aspects of sustainability. For instance, biological terms appear best for discussing issues such as the need of species for habitat, healthy food, clean water, adequate range, a minimum viable population, stress resistance, etc. If these and other baseline conditions cannot be provided, species go extinct.

Such issues were raised in the major report: *World Conservation Strategy*(IUCN 1980, Section 4.1):

> Sustainable utilization is somewhat analogous to spending the interest while keeping the capital. A society that insists that all utilization of living resources be sustainable ensures that it will benefit from those resources virtually indefinitely.

The economist Herman Daly provided a useful starting point by observing that:

> [f]or the management of renewable resources there are two obvious principles of sustainable development. First that harvest rates should equal [or be lower than] regeneration rates (sustained yield). Second that waste emission rates should equal [or be lower than] the natural assimilative capacities of the ecosystems into which they are emitted. Regenerative and assimilative capacities must be treated as natural capital, and failure to maintain these capacities must be treated as capital consumption, and therefore not sustainable. [our interjections] (1990:2).

Daly's notions, however, do not allow natural capital to be consumed and transformed into sustainable forms. This may, in certain cases, be desirable. Harvesting of nonrenewables may, in certain instances, prove to be more "sustainable" than harvesting some resource "sustainably." Imagine the case of using a pristine wild river to generate electricity as contrasted with creating solar cells from sand and petrochemicals. Energy from oil may provide a springboard to sustainable photoelectric electricity, while the damming of the river may irreparably destroy ecosystems and native cultures. Static or snapshot analysis is not enough either. A sustainable system should be operated so as to assure resilience against inevitable fluctuations. Determining safe and sustainable harvest levels requires much more information than inventorying natural capital accounts (stock sizes). Careful empirical modelling exercises and field studies are necessary to assess feedbacks, rates of change of stocks, critical cause and effect relationships, hazards, etc.

Accounting systems necessarily and unavoidably reflect our perception of the world and our perspective on limits. The importance of "value judgments" (e.g. regarding perspectives of what the future will and should be like; of the roles future technology will play; of how conceptual frameworks and knowledge bases will change; of whether, and if so, how, to discount the future; and of equity and the allocation of resources among different groups) become amplified when one is dealing with intergenerational issues.

The framework we propose combines biogeophysically based Green Accounts with "transfer models" to provide the context, meaning, and insight necessary to help assess the health of the ultimate "golden goose" — the global life support system.

Why Conceptual Frameworks Matter: Limits And Equity

> [S]tories generate theories and...theories are transformed in the telling, the resultant combinations serving as self-fulfilling prophecies. (Apter 1993).

Environmental accounting, like more traditional national income accounting, does not exist in a vacuum. Data develops meaning and context by placing it within a conceptual framework, a view of the world. Many issues facing society today differ qualitatively from those of a generation ago. Many types of environmental problems of central importance today were unknown a generation ago. It is no surprise that as new issues emerge new accounting and evaluation techniques are needed to reflect society's changing insights and concerns.

To be broadly acceptable, an improved accounting system must be able to cope with the enormous diversity of views on the adaptability of both humankind and the global ecosystem. There exist a wide range of views on the feasibility, necessity, and desirability of adapting to a changing environment. A Harvard economist articulated the "optimists" view:

> There is absolutely no reason why, on the grounds of the existence of depletable resources, that we ought to conserve for future generations.... It is important to remark on the fact that if they have any luck at all...they will be a lot richer than we are.... If history is any guide, the costs of the materials and energy that are produced even from depletable resources will be cheaper then they are to us in real terms.... There is no reason not to use the marketplace.... [T]here are no externalities of this type that ought to be brought to bear. (Jorgenson 1981).

A less optimistic view was expressed in the Brundtland Commission's Report:

> Humanity has the ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits— not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities. (The World Commission on Environment and Development 1987:8).

This view still conveys a strong sense of technological optimism, but it recognizes — albeit grudgingly — the existence of physical limits. A considerably less optimistic view of limits was put forth in the Report of the World Conservation Strategy (IUCN-UNEP-WWF 1980, Section 4.1):

> Sustainable utilization is somewhat analogous to spending the interest while keeping the capital. A society that insists that all utilization of living resources be sustainable ensures that it will benefit from those resources virtually indefinitely.

This report expresses a clear distinction between the fruits of technological innovation and those of the natural world. Sustainable resource utilization cannot result from technological innovation alone. Political will, along with much more careful planning and management, are needed to approach sustainability.

Herman Daly emphasizes that the existence of natural limits and imperfect substitutability directly limit the fungibility of natural and human-made capital.

> It must be clear to anyone who can see beyond paper-and-pencil operations on a neoclassical production function, that material transformed and tools of transformation are compliments, not substitutes. Do extra sawmills substitute for diminishing forests? Do more refineries substitute for depleted oil wells? Do larger nets substitute for declining fish populations? On the contrary, the productivity of sawmills, refineries, and fishing nets (manmade capital) will decline with the decline in forests, oil deposits, and fish. Natural capital as a provider of raw material and energy is complimentary to manmade capital. Natural capital as absorber of waste products is also complementary to the manmade capital which generates those wastes. (Daly 1990:3).

A direct attack on the limits of technological innovation, linking concerns over sustainability directly to ethical issues, was put forth by Rajni Kothari.

> Economic growth, propelled by intensive technology and fuelled by an excessive exploitation of nature, was once viewed as a major factor in environmental degradation; it has suddenly been given the central role in solving the environmental crisis. (Kothari 1990:27).

Kothari argues for a sustainability notion rooted in ethics, not neoclassical economy:

> Without such striving [based on ethical guidelines], sustainability is an empty term, because the current model of development destroys nature's wealth and hence is non- sustainable. And it is ecologically destructive *because* it is ethically vacuous — not impelled by basic values, and not anchored in concepts of rights and responsibilities. Thinking and acting ecologically is basically a matter of ethics, of respecting other beings, both human and non-human. (Kothari 1990:27-28).

A definition of sustainable development that explicitly incorporates equity concerns has been put forth by a coalition of about 130 NGO, People's, and Church Organizations in the Philippines. The "Green Forum" (1991) defines sustainable development as:

> [a] development course that is not prone to interruption by forces of its own creation which push environmental destruction to intolerable limits, exhaust resources, and exacerbate social inequalities to the point of disruptive political conflict.

The philosopher Arne Naess calls for a broader construal of the equity notion that emphasizes sustaining human cultural diversity along with ecological diversity. Naess (1992:307) begins with the positive requirement that sustainable development " assures long range elimination of abject poverty." He also expresses a symmetrical concern over the destructive aspect of excessive wealth engendered by over consumption. He points to a distinction between "needs" and "vital needs." The "Brundtland Report" made no such distinction. Naess' broader construal of equity views extra parking spaces and huge estates as "needs" which may be left unsatisfied while maintenance of species diversity is more vital. Naess contends that there can be "ecological sustainability if and only if the richness and diversity of life forms are sustained."

Our purpose in highlighting this wide variety of views on technological innovation and preconditions for sustainability is to illustrate how conceptions of the world influence the process of framing issues. Environmental science is a social process that entails discourse and debate along with the acquisition and analysis of data (Norgaard, 1992). The development of Green Accounts poses three particularly difficult questions:

- How do we characterize the "health" of ecosystems? How do we assess sustainable yields, develop appropriate conservation, practices, support species diversity, etc.?
- What is the role of technological innovation and what are the limits of substituting human capital for natural capital?
- How does one deal with winners and losers (both human and non-human)? What happens if project proponents are socio-economically better off than the losers (who may also become culturally impoverished), and a proposed project leads to the widening of this gap?

An acceptable approach to Green Accounting should incorporate the perspectives of those who believe that "development" means much more than "economic development." It should attempt to represent the full set of goods and services that we obtain from the global ecosystem. It should be designed so as to include factors valued by those advocating a multiplicity of notions of sustainability and a variety of conceptions of the notion of externalities. It must reflect the concerns of those who view themselves as being or becoming worse off along with those who see themselves as advantaged.

Green Accounts

The idea of redefining national accounting systems is itself not new. In fact, conventional national accounting systems were designed to match a theoretical conception of how the economic subsystem works. National Income Accounts derive from a conceptual framework developed by John Maynard Keynes. As Anderson (1991:17) put it:

> Many of the economic statistics collected by governments in the post-war (World War II) period have been designed essentially to produce figures to put into the equations set out in, or which have been derived from, the *General Theory*.

Views on limits and equity necessarily enter into accounting procedures, either explicitly or implicitly. Discussions of responses to greenhouse warming illustrate how the salience of issues depends on what information is available and individuals' perceptions of the world. In the absence of theoretical constructs [the absorption of solar radiation by atmospheric carbon dioxide] atmospheric carbon dioxide concentrations would be of only minor scientific interest. Over three decades ago when Roger Revelle suggested to Charles D. Keeling that he undertake sustained precision measurements on atmospheric CO.2. almost no one believed these measurements would be of more than minor academic interest. Today they may be among the most important measurements ever taken by Earth scientists!

The Case For Biogeophysical Green Accounts

In this section we briefly review existing national income accounting, look at several econometric approaches designed to internalize environmental externalities, touch upon the intergenerational discount rate controversy, discuss the fallacy of the single numeraire, and review biogeophysical approaches. We conclude that monetized natural capital accounts, while necessarily derivative of desegregated biogeophysical data, are limited in their ability to reflect physical changes in the environment. Monetization reduces data certainty, inhibits application with alternative transfer models, constrains policy insights, and can result in significant added cost.

Some Difficulties With Existing Systems of National Accounts

We note four "failures" in existing systems of national accounts (SNAs) (e.g. GNP and GDP measures):.4.

- Failure to separate "goods" and "bads." Medical care resulting from air pollution adds to GNP as do restoration efforts, pollution control equipment, and attempts to preserve species. Similarly, highly efficient or conserving practices with many positive externalities, but a very long payback period, fail to receive adequate consideration. One can imagine a society with an ever increasing standard of living and an ever diminishing quality of life.
- Failure to take account of opportunities foregone, "*option value*," the prospective value of species, or wilderness to future generations. This difficulty becomes particularly important when we consider that a market basket of goods today includes many goods that were previously not marketed or non-existent one hundred years ago. Methodologies such as "contingent valuation" attempt to deal with some of these problems, but the methodology appears extremely sensitive to the degree to which a problem is currently popularized. Such techniques also have difficulty with aggregation when a range of alternative projects exist..5.
- Failure to account for goods and services provided outside the market place. Current examples include housekeeper services provided by a homemaker, barter, fuelwood collection, and hunting and gathering. Non-monetised farm work a century ago was a huge contributor to national well-being. As the structure of society has changed and the number of small farms has dropped, this factor has decreased. On generational time frames even greater shifts could occur.
- Failure to account for the value of time spent on voluntary and leisure activities.

Some of these difficulties can undoubtedly be dealt with by incremental improvements to existing accounting procedures. Other problems, such as inherent theoretical inconsistencies and bounded knowledge—synthesis limitations of the economic paradigm (Norgaard, 1990), appear more fundamental. For instance, while global warming may be troublesome to coastal dwellers in temperate regions it may be seen as a boon to those in northern Siberia..6.

In the next two sub-sections we discuss two particular difficulties characteristic of monetized green accounts.

Intergenerational Discount Rates

Virtually all economic analysis makes use of the concept of time value of money. There is, however, little consensus on how to use discounting for intergenerational time frames.

The work of Mishan (1975:208-209) is aptly quoted by Cline (1992:239):

> Whenever intergenerational comparisons are involved...it is as well to recognize that there is no satisfactory way of determining social worth at different points of time. In such cases, a zero rate of time preference, though arbitrary, is probably more acceptable than the use today of existing individual's rate of time preference or of a rate of interest that would arise in a market solely for consumption loans.

Cline (1992:Chapter 6) observes: "Taken literally, Mishan's admonition would rule out benefit-cost analysis of the greenhouse effect." Cline's review of the literature on long-term discount rates leads to the conclusion that the "social rate of time preference," which corresponds to the intergenerational discount rate, is somewhere in the range of 1—1.5

percent per year. He concludes his discussion of these matters with a clear awareness that economic analysis may, even at its best, leave out considerations of importance to the public.

> [E]conomists will do well to interpret the political reaction to alternative public initiatives as perhaps conveying information otherwise left out of the calculations.... Either the pubic is naive and sentimental and cannot make consistent calculations when it comes to the environment as opposed to other goods and services, or the public may be appropriately attaching some valuation in the environmental case that the economic analysis has failed to measure.... It should not be assumed automatically that the former is the case (p. 269).

Norgaard and Howarth explored intergenerational issues from the perspective of choice of intergenerational discount rates (Norgaard and Howarth 1992; Howarth and Norgaard 1992). Their fundamental conclusions are that distributional decisions should not be discounted, and that distributional decisions affect discount rates. Accordingly, society necessarily makes choices that impact discount rates, either implicitly or explicitly. Models that assume the same discount rate for all generations represent special cases with no particular claim to validity relative to other choices. (See also Norgaard 1991 and Howarth and Monahan (1992).

The work of Norgaard and his collaborators provides a clear analytical demonstration that value judgments unavoidably enter into intergenerational economic analysis.

Fallacy of the Single Numeraire

Most current national income accounts rely on the notion that all factors of importance can be expressed in terms of a single numeraire, usually monetary. The assumption is that a single monetized equation can be written to capture all relevant senses of value. This sum, which consists of "use value," "option value," and "existence value," is referred to as total economic value (TEV=use value+option value+existence value). A critical question for "Green Accounting" is whether or not to adopt this perspective. Norgaard (1990) argues that the problems that we seek to resolve through developing Green Accounts are entangled in the issue of monetary valuation itself. He refers to this issue as the "value—aggregation dilemma."

Our discussion of this topic focuses on the work of Pearce, Barbier, Markandya, and Turner. These scholars have been among the most effective advocates for the single numeraire point of view.

Pearce and Turner argue that all relevant multiple senses of value can be incorporated into existing economic tools:

> [T]he passing-on of the resource base `intact', i.e. constant natural capital stock *K.* N., over the next few generations is central to the concept of sustainable economic development. Such a managed growth policy, although directed primarily toward the satisfaction of human needs, would also necessarily ensure the survival of the majority of non-human nature and its natural inhabitants. (Pearce and Turner, 1990:238).

The core idea underlying Pearce and Turner's "sustainability principle" is the hypothesis that there exists in principle a scalar quantity, *K.* N. which completely characterizes the "natural capital stock." They argue that keeping this single numeraire constant will ensure that both human and non-human life will thrive. While the symbol is clear enough, the procedure for operationalizing it is not. How might one include in such a measure the functional integrity of ecosystems, species diversity, ecosystem health, the economic value of natural resources, and human quality of life in a single optimization equation? It would seem that the attempt to aggregate so many diverse quantities into a single scalar must result in the loss of essential characteristics of systems?

Von Neuman and Morganstern, in their classic work, *Theory of Games and Economic Behavior* (1947), underscored the conceptual and theoretical impossibility of solving such implied pseudo- maximum problems.

> This [form of optimization problem in the context of a social exchange economy] is certainly no maximum problem, but a peculiar and disconcerting mixture of several conflicting maximum problems.... This kind of problem is nowhere dealt with in classical mathematics. We emphasize at the risk of being pedantic that this is no conditional maximum problem, no problem of the calculus of variations, of functional analysis, etc. (von Neuman and Morganstern 1947:11).

Von Neuman and Morganstern's admonishment has not been adequately recognized. The popular misunderstanding motivating attempts to "solve" such pseudo-maximization problems still persists. We must re-emphasize von Neuman and Morganstern's warning (1947:11) that "[a] guiding principle cannot be formulated by the requirement of maximizing two (or more) functions at once." That this maxim is not always recognized may be noted from the frequent references one hears to the desirability of policies leading to "the greatest good for the greatest number" — a clear example of "one too many `greatests'" (Daly 1980a:353).

A corollary effect, of further theoretical and philosophical concern is this approach's dependence upon "compensating projects" to mitigate the negative environmental effects of the other projects in the program. This approach still allows whole ecosystems and human cultures to be annihilated as long as the net "natural capital stock" is maintained.

In another paper Pearce and Barbier adopt a more conservative stance by accepting that many natural resource functions cannot be substituted by man-made capital (Barbier, et al., 1990:1260). Nevertheless, they persist in their belief that cost-benefit analysis (CBA) should be maintained. They argue that alternative objective functions can be chosen which "extend" the CBA framework beyond economic efficiency. Turner and Pearce even argue that "moral" and "cultural" capital can be incorporated into CBA (Turner and Pearce, 1993).

In order to accommodate economic sustainability considerations they modify the usual economic efficiency (positive net benefits) with an additional constraint that requires zero or negative natural capital depreciation. They do not contend that their approach is useful for the evaluation of single projects (our primary emphasis here); it is oriented towards evaluating an array of projects at the program level. Pearce and his collaborators posit a "weak sustainability" criterion that aggregates in the time dimension, requiring the sum of individual damages to be zero or negative (i.e. the present value of the sum of environmental damages is constrained to be non-positive). They also propose a "strong sustainability" criterion which constrains the sum of environmental damages to be non-positive for *each* time period. By requiring local sustainability, Pearce and his collaborators attempt to integrate sustainability considerations into the CBA through the concept of shadow or environmentally compensating projects (Barbier, et al., 1990:1260-1261). Our concern, however, is that sustainability considerations cannot be adequately evaluated by a modified utilitarian calculus.

Work in these areas is still largely conceptual. It remains to be seen whether it can be operationalized in a manner that will find broad acceptance. However, in our view analytical approaches that presume the existence of compensating projects, especially when the types of losses and impacts are not well understood, are on shaky footing.

Biogeophysical and Energy-Related Approaches

Many ideas for modifying traditional accounting procedures to better include environmental considerations have been proposed. Some of these are based on modifications of economic accounting techniques. e.g. (Cobb 1989; Ahmad and others 1989; Anderson 1991). Other approaches focus on physical accounting, especially energy (IFIAS 1975; Hannon 1982; Slesser 1978). A wide range of ecological indicators for assessing the state of the environment were discussed in a special issue of *Environmental Monitoring and Assessment* (Piekarz 1990). Two recent edited books address indicators of sustainable development (Kuik and Verbruggen 1991) and modelling for sustainable development (Gilbert and Braat 1991).

Pearce et al. (1989) discuss several approaches to revised national income accounts, including the French and Norwegian physically based accounts, the monetized Japanese Net National Income approach, and the Indonesian Sustainable Income approach. These are promising approaches, since they recognize that monetized approaches are necessarily derivative of desegregated biogeophysical accounts, which are later monetized. Monetization, while allowing single-objective functions and hence optimization, can lead to problems such as information loss, difficulties in incorporating uncertainty and in performing sensitivity analyses. Monetization can also add significant costs (Hufschmidt 1983). In our view, the sum of the shortcomings in single-objective approaches makes us dubious of the efficacy of continuing to focus upon monetized accounts for addressing environmental problems, especially those that exist on intergenerational time scales. This is not to say that traditional economic analysis has no role. That role comes after policy goals have been established and after a range of acceptable paths, projects or policies have been identified. Traditional economic analysis is most useful for assessing which of a group of desirable choices or transition paths are most cost-effective.

Transfer Models

How do Transfer Models Differ From Indicator?.7.

Transfer models are theoretical frameworks that codify the implications of models. They use indicators (economic values, biogeophysical data, etc.) as their inputs. Our approach to Green Accounting is directly coupled to the development of transfer models that can improve our understanding of the technical basis for concerns over the pace of anthropogenic changes to the biosphere. Transfer models are what give context and meaning to Green Accounts. The transfer model methodology we advocate is designed to show explicitly how concepts and linkages relate observables to effects. We favor the development of new risk-based (Morgan and Henrion 1990) and multi-criteria approaches (Nijkamp 1980; Rietveld 1980; Nijkamp 1990; and Chen 1992) to attempts at revising cost-benefit analysis. New ways of communicating the consequences of action, and of inaction, are needed.

In the absence of theoretical frameworks, there is generally no rationale for linkaging observable effects to causes. By way of example, atmospheric carbon dioxide is an important indicator of greenhouse warming. In the absence of theoretical structures relating C0.2. to warming, the indicators have little interest. Transfer models are designed to focus on quantities of direct interest for understanding how the future may evolve, and for planning interventions to address prospective future events. They can increase our ability to observe the previously unseen — but not unforeseeable — consequences of our actions. Transfer models take into account the present state of technical and social knowledge, and known or suspected uncertainties in this knowledge. Transfer models, like all other models, cannot take account of concepts that have not yet been thought of, or biogeophysical phenomena that have not been discovered. They can, however, be structured so as to incorporate the widest plausible ranges of views on particular issues. Transfer models may include "state-of-the-art" knowledge in every relevant area, but may still provide inadequate pictures of how events will unfold (Ludwig, 1993).

Directions

Green Accounting for the long-term is inextricably intertwined with goal setting and social values. It begins with envisioning desirable images of the future, and tempering these with equal doses of technological realism and humility. Green Accounts have the potential to help us analyze feasible paths for realizing desirable future states.

There are many views of the future. To optimists, technological ingenuity and "progress" will provide future gen-erations with undreamed of op- portunities and few adverse side effects. To pessimists, our generation is depleting the world of irreplaceable re- sources and impoverishing both our descendants and the rest of the world. A successful Green Accounting system must be capable of representing the views of optimists, pessimists, and the wide range in between. It should take account of the possibility that if technological optimists turn out to be wrong we may be left with a diminished, and possibly unrestorable world. While the alternative scenarios are in no way symmetrical, we must recognize that if the pessimists are wrong we will have foregone certain opportunities. These considerations lead to several general observations:

- The structure of existing accounting systems contains biases particularly in favor of quantities that enter into commerce, in favor of flow quantities, and against stocks.
- Innovation has created "resources" where none previously existed, but has also lead to new types of side effects. Improved procedures are needed for anticipating side effects which are uncertain in character and delayed in time.
- The concept of limits is not made explicit in most prevailing accounting systems. Limits may be reached so rapidly that there is inadequate time to develop alternatives. In addition, the mere fact of approaching limits may result in bifurcations and irreversibilities (e.g. indirect species extinction resulting from loss of critical habitat).
- Today's pace of change is enormous. Changes may be set in motion so fast that there isn't time to correct errors.
- Many kinds of measurement units should be included in Green Accounting systems. Biogeophysical and equity indicators must figure prominently. Econometric techniques become most important after goals have been set and near-term policy decisions are required.
- Green Accounting systems should be fashioned so that very different types of indicators, with different spatial and temporal scales, can be constructed. Some of these will be highly aggregated; others will focus on highly specialized questions (e.g. the number and health of particular species in a given region).
- Uncertainty must be intrinsic and explicit. Green Accounting systems must admit minority views, thereby recognizing that today's minority position may be tomorrow's reigning paradigm.
- Green Accounting systems should be dynamic and flexible. They should be structured so that their internal organization can be updated as new indicators and information become available.
- Green Accounting systems must be linked to specific conceptual models of economy-environment interaction. Massive amounts of data cannot be comprehended except in the context of logical structures. Data bases need to be constructed so that they are accessible to a wide range of transfer models. An example is the connection between anthropogenic carbon emission and climate. Lacking a conceptual framework (in this case climate models) data in this area would be incomprehensible.
- When considering the results of transfer model analyses the role of "best" answers or "optimized solutions" should be scrutinized carefully.

Fine-tuning of existing national income accounts — valuable as such exercises may be — will necessarily be inadequate to the task of fully assessing economy-environment interaction. The problems are far too complex. For now, what is needed is a selection of different approaches for developing Green Accounts. These must be subjected to debate and tested by asking a variety of users whether transfer models which they consider important can easily make use of this data. Accounting systems must allow each user to frame and analyze his/her most important questions. Because of the extreme complexity of this problem and the changing nature of theoretical understanding, Green Accounting must be viewed as a dynamic and ongoing process rather than a one-time activity.

The process of developing Green Accounting systems is as important as the systems themselves. The development process should focus on articulating and integrating conceptual frameworks in each topical area where threats to sustainability are believed to exist (e.g. agriculture, forestry, fisheries, climate, species diversity, air, water, and land quality, etc.). The process should include practitioners as well as researchers. In the field of agriculture, for example, there should be involvement from organic farmers (both large and small scale), genetic engineers, corporate farmers, and consumers. Those with long practice in sustainable agriculture (e.g. Amish farmers), should also be involved.

The final stage is to develop transfer models to relate key concepts and data, and to include ambiguity and uncertainty. These should be constructed so as to be useful for addressing issues on a wide variety of spatial and temporal scales, ranging from local to global. With an extended set of indicators decision making processes can be more soundly based on scientific knowledge, and planning can include a broad spectrum of attitudes toward goals, aspirations, risk, progress and limits.

We have argued that no satisfactory Green Accounting system exists. We also outlined our concerns regarding the misuse of technique for developing such accounts. We argued that feasible and robust Green Accounts for sustainable environmental policy analysis must be based upon biogeophysical indicators. *It's time for ecological economists to take ecological and analytical realities seriously and present alternative approaches for accounting and policy analysis.* Accomplishing the outlined goals will require much research and commitment.

Notes

1. Much of this work was originally presented at the NAS/NRC Workshop "Valuing Natural Capital for Sustainable Development" Woods Hole, MA July 1-3, 1993 (Craig and Glasser 1994). An alternative version of the current paper, focusing upon the "transfer model approach" (with schematized examples for the impact of anthropogenic carbon dioxide upon agriculture and radioactive waste) was submitted to *Ecological Economics* in April 1994.

2. In several earlier papers we discussed the importance of openly encouraging the introduction of ethical and value based arguments into the policy analysis process. See Glasser et al. (1994); Craig et al. (1993); and Kempton et al (1993).

3. These differences were clear in the intense discussions at the NAS/NRC workshop "Valuing natural capital in planning for sustainable development" for which an earlier version of this paper was prepared.

4. A list of 16 problems is compiled by Anderson 1991:21-32.

5. It is common in contingent valuation studies to conclude that people would pay large

amounts for preservation of a particular amenity such as a lake or a flyway, but to also find that when one contemplates the result of an array of such studies taken together, the total implied expenditures become enormous. This is just one of many consistency problems that we suspect are intrinsic to the methodology.

6. Even in Siberia warming may be a mixed blessing if it is associated with decreases in precipitation or other adverse weather consequences.

7. In another paper, "Transfer Models and Explicit Uncertainty: An Approach to Intergenerational "Green Accounting," submitted to *Ecological Economics* in April 1994, we schematize transfer models in two areas: greenhouse warming, and radioactive waste disposal.

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