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Are Existing Global Scenarios Consistent with Ecological Feedbacks?

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Abstract

Scenarios can help planners and decision makers to think through uncertainties about the future and make decisions that are robust to a variety of possible outcomes. To develop useful scenarios we need to understand the main processes of relevance to the system of interest. Ecological processes, and the feedbacks that they can create between human actions and human well-being, are thought to be important for human societies. Current uncertainties over the long-term resilience of ecosystems and the substitutability of ecosystem goods and services can be translated into three alternative realities: ecosystems may be relatively brittle, relatively resilient, or largely irrelevant. Although these extremes are only rough characterizations of reality, they help us to focus our thinking about the possible outcomes of interactions between humans and the rest of the biosphere. Existing global scenarios can be categorized into a small number of families based on shared themes and assumptions about the future. Considering the internal consistency of four of the main scenario families in relation to the three alternative ecological realities suggests that all existing scenarios make strong, implicit assumptions about the resilience of ecosystems. After a detailed discussion of individual examples, we present a synthesis of the incorporation of ecology in existing scenarios. All current scenarios are inconsistent with at least one possible property of ecosystems and their likely interaction with society. The interrelationships between ecological reality, human views of ecosystems, and social responses to actual and perceived ecological change are complex. For the Millennium Ecosystem Assessment and future scenario exercises, we recommend that essential ecological assumptions should be made explicit to ensure that the details of each scenario are consistent with both the perceived and the actual degree of resilience of ecosystems.

Key words: Global scenarios; ecological feed backs.

Introduction

As humans, we are used to making decisions in relation to an expected or desired outcome. Our perceptions of the relative importance of different processes in determining outcomes play a large role in the decisions that we make. Decisions will usually be more robust if they have taken into account a wider range of possibilities; we frequently change our minds on being presented with more complete information. In similar fashion, professional decision makers typically choose to focus on

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a set of processes that are considered to be of relevance to the decisions that they must make. In scenario-planning exercises, knowledge of these processes and associated uncertainties is combined to produce scenarios. Scenario planning is an approach to coping with the irreducible uncertainties that make the development of long-term policies and management strategies difficult (Wack 1985; Schoemaker 1995; Kleiner 1999; Alcamo 2001; Peterson and others 2003). Scenarios are comprehensive, consistent narratives that cover a range of plausible futures. The aim of a scenario exercise is not to predict the future; instead, well-constructed scenarios will provide a compelling framework that helps decision makers to confront uncertainties (Millett 1988; Van der Heijden 1996).

It is important that scenarios consider an adequate range of the processes that may influence the question that they are intended to address. Although there are a number of detailed, carefully constructed global scenarios in existence, their focus is largely on social, economic, and immediate environmental issues (Raskin, this issue). Environmental changes enter into many existing global scenarios, both explicitly (for example, the biodiversity scenarios of Sala and others [2000], and the IPCC global climate change scenarios [IPCC 1990, 1995, 2001]) and implicitly (for example, as drivers of societal change in most of the GSG scenarios; Raskin and others 2002 and this issue). However, the implications of the many complex feedbacks that characterize real ecosystems (for example, Higgins and others 2002) are not explored or tested in detail in most existing global scenarios (although the global emission scenarios of the IPCC do take into account global feedbacks between climate, land use, and emissions; IPCC 2000). Inclusion of ecological feedbacks is important for global scenarios because the continued provision of ecosystem goods and services is central to the economies of many nations and the well-being of their inhabitants. If anthropogenic impacts on ecosystems lead to such feedbacks as altered rainfall patterns, soil loss, reductions in food production, pest outbreaks, increases in the occurrence and severity of diseases, and reductions in water quality and quantity, then ecological feedbacks may become one of the most important drivers of human social and economic systems over the next few decades.

A new global scenario-planning exercise is currently taking place as part of the Millennium Ecosystem Assessment (MA). The MA is intended to be a comprehensive analysis of the capacity of global ecosystems to provide goods and services important for human development. It will use scenario planning as a way of thinking about the future provision of ecosystem services and their relationship to human well-being. Because of its aims, the MA is approaching the construction of global scenarios from an explicitly ecological perspective. The challenge for the MA is to build on the strengths of existing scenario frameworks while at the same time making sure that the scenarios adequately represent ecological dynamics.

In this article, we explore the potential for existing global scenarios to incorporate ecological feedbacks in a way that is relevant to the goals of the MA. We start by explaining the main themes of existing global scenario families. We then outline three different kinds of possible ecosystem dynamics (ecosystems that are brittle, resilient, or irrelevant) that help us to focus our thinking about the possible outcomes of interactions between humans and the rest of the biosphere. Contrasting each alternative ecosystem property with each of the global scenarios highlights the ecological uncertainties and assumptions that are contained in each scenario. After a detailed discussion of individual examples, we present a synthesis of the incorporation of ecology in existing scenarios.

Approach

Scenario Description

Global scenarios have been developed by several groups. A limited subset of some of the better known scenarios is summarized in Table 1. They can be understood as comprising five scenario families (for more detail, see Raskin, this issue). We focused on only four scenario families: market forces, reformed market, value changes, and higher fences. The fragmented development of the IPCC scenario B2 (multipolar world) has an emphasis on local sustainability without attention to regional and global sustainability. Because of the importance of the linkages between the levels of scale for ecosystems and the necessity of value changes for both, for simplicity we ignore the distinction between the multipolar and value changes worlds. We acknowledge that this reduces the set of scenarios to four cases, of which three assume a continuing globalization of the world economy, albeit in very different directions. Higher fences emphasizes one form of regional barrier; other worlds could develop in which a decreased exchange of technologies and ideas between regions hinders economic integration, and multipolar worlds with more positive outcomes are also pos-

Table 1. MA Summary of Existing Global Scenarios

Name	Keywords	Antecedent
GS-1 Market Forces	Market-driven globalization, trade liberalization, institutional modernization	IPCC: SRES A1 GEO: market first GSG: market forces TARGETS: individualist
GS-2 Reformed Market	As above, except strong policy focus on sustainability; government policies limiting negative social and environmental side effects of market developments	IPCC: A1 based policy scenarios (post-SRES) GEO: policy first GSG: policy reform TARGETS: hierarchist
GS-3 Value Change	Value shift toward sustainability in developed world; policy focus on poverty, sustainability	IPCC: SRES B1 GSG: great transition GEO: sustainability first TARGETS: Egalitarian WWV: Values and Lifestyles
GS-4 Multipolar World	Fragmented development; conservation of local identities; regionalization of economies	IPCC: SRES B2
GS-5 Higher Fences	Elites in fortresses (national or local); poverty and repression outside	IPCC: SRES A2 WWV: business as usual GSG: fortress world GEO: security first

GS stands for Global Scenario. IPCC refers to the scenarios developed by the Intergovernmental Panel on Climate Change (IPCC), see IPCC (2001) and SRES (2000). GEO refers to the GEO3 scenarios developed for the Global Environmental Outlook of UNEP, see UNEP (2002). GSG refers to the scenarios developed by the Global Scenarios Group, see Gallopin and others (1997). WWV refers to the scenarios developed in the World Water Vision for World Water Council, see Gallopín and Rijsberman (1999) and Alcamo and others (2000). TARGETS were scenarios published by Rotmans and De Vries (1997) and De Vries (2001). Value change refers to a change toward greater importance of social and ecological values.

sible. However, for the purposes of this summary, limiting our analysis to the four main story lines that have been well elaborated has little bearing on our central argument.

One of the central and most important uncertainties that we have about ecosystems at the present time is the question of how much change they can cope with before the provision of ecosystem services is compromised (Carpenter 2002). We know that some components of ecosystems, such as the links between some orchid species and their coevolved pollinators (for example, Wong and Schiestl 2002), can be very fragile. Other components of ecosystems are considerably more robust and will continue to function under a much wider variety of circumstances; carbon fixation, for example, is undertaken by green plants across the globe. Clearly, the components of real-world ecosystems may vary considerably in their resilience.

For the sake of this exercise, we simplify the problem by imagining that ecosystems have a single intrinsic nature that can be either brittle or resilient (Holling 1979, 1986). Within the context of global scenarios, a similar approach was adopted by Rotmans and de Vries (1997). They argued that incorporating some of the uncertainty in the ways in which society responds to ecological changes can have major consequences for the consistency of global scenarios and considered the implications of different world views for scenario development. Regardless of human perceptions of nature, if ecosystems are intrinsically brittle, they will be less able to cope with extreme anthropogenic impacts. Nonlinear processes and unexpected thresholds will create surprises and environmental catastrophes, and the irreversible loss of important ecosystem goods and services will have a profound impact on our social and economic systems. If ecosystems are brittle, we have little time for learning and little latitude for large mistakes or trial-and-error learning.

By contrast, if ecosystems are relatively resilient, they will be able to absorb anthropogenic impacts without the loss of essential structure or functions. Although humans may still create a range of environmental problems, these will be reversible and will have considerably less impact on our social and economic well-being. If ecosystems are intrinsically resilient, we have more time in which to understand them and more latitude to make mistakes and learn from them. Obviously, the reality will be somewhere between these contrasting perspec-

tives; ecosystems will be resilient in some ways and brittle in others. It is the nature of where ecosystems are resilient and where they are brittle that will determine the long-tem sustainability of the entire system.

Finally, we also entertain the possibility that technology will develop to such a point that we will be able to substitute technological fixes for most ecosystem goods and services. An extreme view of this situation might include such things as provision of world water needs by desalinization of sea water, carbon fixation by buildings through the use of magnesium compounds in cement, and the development of processing plants that maintain the composition of the earth's atmosphere. If this situation ever comes to pass, human social and economic systems may be able to survive in the absence of functioning ecosystems, and nature becomes irrelevant. Although a world of this kind would be likely to lead to new forms of brittleness and vulnerability, we imagine a situation in which such vulnerabilities do not become critical over a 50–100-year time frame.

Although these three perspectives are obviously a simplified characterization of reality, which incorporates ingredients of each, we have found this simple classification a valuable starting point from which to think about the role of ecological feedbacks in global scenarios. Addressing these assumptions in the scenario development process can be a useful way of systematically thinking through their implications. Importantly, global environmental scenarios at present pay little attention to environmental change and do not explicitly incorporate the impacts of ecological feedbacks on human actions.

Ecological Feedbacks and Global Scenarios

Summary Matrix

To analyze the consistency of current global scenarios with ecological feedbacks, we consider each family of scenarios against the possibilities of a brittle, resilient, or irrelevant natural world, respectively (Table 2). Rotmans and De Vries (1997) used a similar matrix to develop new scenarios in the context of a single global integrated assessment model. In their terminology, consistent sets of world views and management styles (that is, human behavior) would lead to utopias (with relatively low risks), while inconsistent sets would lead to dystopias (with relatively high risks). The theoretical basis for their work was provided by the earlier work on the Cultural Theory of Thompson and others (1990) and Rayner (1991), who claim that only a limited set of consistent perspectives is viable. Although we focus primarily on the ecological consistency of each story line, ecological and social changes are closely interrelated; ideally, scenarios should be evaluated in terms of both social and ecological resilience simultaneously, although this would introduce a far greater level of complexity into the analysis.

Market Forces

The market forces scenario family is inconsistent with a brittle natural world, because brittle ecosystems imply an interruption of ecosystem services to society in the absence of changes to how we currently exploit ecosystems. One of the major causes of this inconsistency is the mismatch of scales between ecological processes and market responses. Markets are typically unable to respond at the long time horizon that is required for the management of ecosystem processes. Examples of market failures in addressing ecological problems include the eutrophication of temperate lakes (Carpenter and others 1999), tropical deforestation (Geist and Lambin 2002), and the lack of an appropriate incentive structure to prevent ecological invasions (Perrings and others 2002). In each of these examples, market forces have not responded adequately to maintain a particular ecosystem service. The slow response of markets to C sequestration may partly be due to the perceptions that existing C sinks are resilient and that global climate change will have little impact during the lifetimes of the people involved.

Similarly, markets struggle to deal with discontinuities and nonlinearities. This means that the type of instruments chosen in a market forces world to incorporate environmental protection could fail in the case of fragile (brittle) ecosystems. For example, if the biosphere is fragile with regard to CO_2 uptake, currently proposed, market-based schemes for C sequestration may fail in the long term. The effects of CO_2 on water balance and plant productivity are already raising doubts over the permanence of C sequestration.

A further problem is that of inadequate markets. There is currently no market for many important components of ecosystems, and their economic valuation (especially for supporting or cultural ecosystem services) is often difficult. In many cases it is not easy to imagine how such markets might work. For example, there is no market for soil quality, soil microorganisms, or crop diversity.

Table 2. Summary of our Characterization of Current Global Scenarios as Either Consistent or Inconsistent with a Particular Property of Nature

		Brittle Property of Nature	Fairly Resilient	Highly Resilient	Irrelevant
Scenario	Market Forces	Inconsistent	Inconsistent	Consistent	Consistent
	Reformed Market	Uncertain	Consistent	Inconsistent	Inconsistent
	Value Change	Consistent	Uncertain	Inconsistent	Inconsistent
	Higher Fences	Inconsistent	Uncertain	Consistent	Consistent

In several instances we discovered that a scenario could be told in a consistent or an inconsistent way, or that there are some key uncertainties that must be resolved before we can evaluate the scenario appropriately from an ecological perspective. Scenarios that fell into these categories are classified as uncertain. One of the key uncertainties is just how resilient nature would have to be in order for each scenario to remain plausible. We have further divided nature resilient into two categories: fairly resilient and highly resilient. Fairly resilient implies a natural world that an optimistic ecologist might envisage; here, natural systems have a limited capability to absorb and cope with significant levels of anthropogenic change. Highly resilient implies a natural world that exhibits a degree of resilience that would be surprisingly high, given our current understanding of ecosystems.

If ecosystems are highly resilient, the implication is that ecosystem services will be maintained despite the environmental pressures resulting from the market forces scenario. In other words, we may be able to continue to exploit natural resources without causing significant or irreversible environmental degradation. The market forces scenario is consistent with a highly resilient natural world, but this is probably an overoptimistic assumption given what we already know about ecosystem responses.

For instance, a variety of agricultural systems have proven themselves fairly resilient in meeting the needs of a growing global population, in part through increases in the efficiency of food production. We note, however, that agricultural systems may be creating long-term debts through soil loss, buildup of pesticides (for example, Carson 1962), salinization (for example, MDBMC 1999), depletion of groundwater, and the decline and extinction of pollinator species (Cane and Tepedino 2001). Since we already know from past experience that some ecosystems are in reality NOT resilient, the market forces scenario can be considered high risk. Consequently, we consider it doubtful that the market forces scenario is sustainable over a 50-year time period without major ecosystem collapses.

The market forces scenario is most consistent in a world where nature is irrelevant to economic prosperity. If ecosystem services are fully substitutable, markets will not be constrained by ecological feedbacks. There are a few current trends that could be considered as movement in this direction (consistent economic growth despite past disregard for ecological limitations; and other current substitutions of ecosystem services), but even in a relatively resilient natural world, we have reservations about their long-term feasibility.

Reformed Markets

We were uncertain about the consistency of the reformed market scenario in a brittle world. One of the key issues here is exactly how much ecological change reformed markets would be able to cope with. If nature is brittle, ecological catastrophes could provide motivation for market reform as envisaged in this scenario; so reformed market scenarios are, in principle, consistent with nature brittle. However, it is unclear whether markets can be reformed rapidly enough to make market reform a feasible scenario.

Reformed markets would have to include a more complete evaluation of environmental costs than are currently included in prices and policies. One difficulty under this scenario would be the imbalance of costs between damaging and fixing the environment. Cleaning up waste or restoring degraded systems is often more expensive than the initial exploitation or development that created the problem. Markets would have to develop strategies for including the costs of righting past wrongs in current transactions.

A second potential problem with the reformed market scenario in a brittle world stems from the issues of scale and enforcement of legislation. This scenario implies a level of global environmental coordination and management that may not be realistic. There have been some global successes and some global failures; in light of these, there is considerable uncertainty about our future ability to develop and enforce appropriate reforms. For example, the introduction of high fuel taxes in Europe has not yet limited the occurrence of ozone episodes in summer; but increased incentives to reduce the sulfur content of emissions from coal-burning power stations have substantially reduced

the occurrence of acid rain in Europe and Canada (Ayres 1997). Other notable management failures under partially reformed markets include the collapse of the North Atlantic fishery and the inability of legislation in Brazil to prevent forest fires.

We envisage that if the global C cycle is brittle, the reformed market may or may not be able to cope, depending on the intricacies of how the problem manifests itself and the precise policies that governments adopt. If clear consequences of climate change become evident, will societies be able to respond fast enough to mitigate the crisis? Successful C sequestration may require dynamic coordination of global forest management; if forests turn out to be highly vulnerable to future changes, it is not clear that international management will be successful. Continuing food shortages suggest that even reformed markets may not be able to cope with the problem of reducing world hunger in the absence of a significant change in societal values. This uncertainty with respect to the effectiveness of policies is one of the reasons why value change scenarios (for example, Great Transitions, Sustainability First) were developed.

It is uncertain whether a reformed markets scenario would be consistent with a resilient natural world. If the environment is highly resilient, the kinds of changes in ecosystem services that would drive market reform will be unlikely to occur. If the environment is fairly but not highly resilient, so that the need for market reform is obvious and reforms can realistically solve environmental problems, then the reformed markets scenario will be consistent. More resilient natural systems will be easier to manage adaptively and will give us more time to develop workable policy options. If natural systems are linear or have high thresholds for nonlinear behaviors, they will be easier to understand and management intervention will be simpler. Because the level of resilience of various systems is unknown, anticipatory market reform could be appropriate, and thus from a different point of view market reform may be consistent with a resilient nature.

For example, New York City was able to meet its water purification needs by restoration of catchments in the Catskills, rather than by building a new water purification plant (Chichilnisky and Heal 1998). Although some environmental degradation had occurred in the catchment, restoration was both possible and effective. In a similar vein, problems with groundwater and food contamination by pesticides may be solved by a shift from conventional to organic farming. Assuming a resilient C cycle implies that no major changes in biosphere will take place. C sequestration will partly compensate for buildup of CO_2 in the atmosphere and future climate variability will not significantly disrupt human society.

Reformed markets are inconsistent with nature irrelevant. The scenario explicitly assumes market reforms driven by environmental changes. If ecosystem services were irrelevant to the market, there would be no need for reform.

Value Change

The value changes scenario family, as we have interpreted it in this article, is highly consistent with nature brittle. For the societal changes in this scenario to come true, society needs to be aware of the brittleness of nature, either on the basis of convincing evidence and information from advocacy groups or (more likely) in response to an apparent ecological crisis and a clear deterioration in the environment.

A limited number of examples suggest that this scenario is feasible; that large portions of society can change their values. For instance, a response to the problems associated with waste disposal and shortages of natural resources has resulted in a change in values leading to a recycling ethic; the shift of the fashion industry away from genuine fur coats was a value shift driven by the animal rights movement; and the current trends toward timber certification and preferential purchases of shade-grown coffee are first-world responses to rainforest depletion. We can envisage that a series of major environmental crises might elicit rapid changes in attitudes, much as the dust storms in Beijing and the sedimentation of the Yangtze have been credited with causing China to rethink its forestry policies and introduce the current logging ban (Xu and others 2000). There are a number of case studies in which ecosystem management has changed for the better following massive unexpected shifts in ecosystems (Gunderson and others 1995). Case studies of surprising change underlie arguments for use of precautionary principles in ecosystem management (Haaremoës and others 2002). It is uncertain whether management systems will be able to learn about threats to ecosystem services in time to take appropriate action.

The majority of the examples of value shifts that we could think of were negative towards the environment; there seem to be many more cases of shifts away from traditional values and customs toward materialist or exploitative values that are significantly more harmful to ecosystem services.

It is uncertain whether the value change scenario is consistent with nature resilient. If the environment is resilient, environmental degradation would be gradual and less severe; we might not see a change in values unless ecological change affected a suitably large proportion of the world's population. Moreover, if ecosystems were highly resilient, the regulations accompanying a value change world could be criticized as unnecessarily constraining. Value change in this instance might be perceived as a world of lost opportunities, creating societal risks for the scenario's consistency. In considering existing examples, there is no clear trend of value change or the lack of it. Rachel Carson's Silent Spring (1962), which came as something of a shock to many people, had a dramatic effect on public awareness of the use of pesticides. However, the heightened public awareness of pesticide contamination led to the introduction of substitutable products rather than a shift to organic production. Similarly, response to chlorofluorocarbons (CFCs) was by a product substitution rather than a change in the use of the products. People in first-world societies continue to use large quantities of fossil fuels even though they are fully aware of the environmental impacts. By contrast, consumer trends such as the new popularity of organic products suggest that people may be prepared to change their habits even in the absence of a major shock to the system.

Clearly, value changes are unnecessary if there is high substitutability of ecosystem services such that technology renders ecosystem services irrelevant. The value changes scenario explicitly assumes a tight coupling of ecosystem changes and human values and so would be inconsistent with nature irrelevant.

Higher Fences

The probability of the higher fences scenario depends first on the motivation that is invoked for the construction of barriers. The development of higher fences might be a consequence of environmentally driven factors such as food shortages or catastrophes or other factors (such as economic inequality and security concerns) that have nothing to do with the environment. There are many examples of linkages between environmental and security problems, but usually the environment is just one factor among many. For example, at the time of writing, farmers in areas of historically low food productivity in Zimbabwe are experiencing a drought. The shortfall in food production, coupled with political instability and the depletion of governmental grain reserves, has created high incentives for people in the poor southern part of the country to cross the border into South Africa where food and jobs are more abundant. The South African border, on the far side of the Limpopo River, is fenced in many places and patrolled regularly by policemen with dogs. The problems in this instance are caused largely by political and social drivers but have been exacerbated by environmental variation.

We believe that the higher fences scenario is not consistent with a world in which nature is brittle because it would not be sustainable for a very long time. Although environmental changes might drive the development of higher fences, they would not offer a long-term basis for such a scenario because of the scale of ecosystem processes and the interconnectedness of physical and biological systems. Changes in global processes have global repercussions. For example, maintenance of biodiversity hotspots inside a fortress would be difficult as climate changes. Similarly, many local and regional processes (such as movements of ground and surface water, or the knock-on effects of extinctions) would create a need for interaction across fences. The world within the fence would inevitably be dependent on inputs from outside the fence, and in a world where nature is brittle, the necessary inputs would not be sustainable.

For these reasons, we concluded that the higher fences scenario relies on a highly resilient natural world and the development of fences as a consequence of social or political change rather than as a response to environmental catastrophes. It is likely that the assumption of the environment as a key driver in current versions of this scenario would make it inconsistent. If the details of the scenario were modified to include higher fences in response to an increasing rich-poor divide, it would be consistent with a highly resilient world.

The higher fences scenario is also compatible with a world in which nature is completely irrelevant. The elite would move behind their fences regardless of the resilience of ecosystems. For similar reasons to those outlined above, higher fences would not necessarily be driven by ecosystem change. Additionally, the level of technology and coordinated policy that would be required to make ecosystem services available to a small elite, regardless of nature's overall resilience, would be quite plausible.

General Issues

We encountered many uncertainties and potential inconsistencies in existing scenarios and in our un-

derstanding of the relationships between different drivers in ecological, social and economic systems.

It is not clear just how interconnected different ecological services really are. For example, biodiversity may drive a multitude of other services (Kinzig and others 2001); groundwater depletion may affect certain components of the biota but leave others untouched' and many organisms may be able to cope relatively well with a change in the variability of the global climate. It is not clear whether apparently resilient ecosystem services are, in reality, dependent on other, much more brittle ecosystem services or vice versa. These uncertainties could make some existing global scenarios either more or less plausible. The issue of scale further complicates the problem. Some ecological changes will create cross-scale feedbacks, whereas others may not have such large implications. Systems may be highly resilient at one scale and very brittle at others. It is difficult to definitively establish the probability and plausibility of different scenarios without a more comprehensive understanding of the cross-scale properties of resilience—currently a frontier in ecological research. Because these ecological uncertainties are critical unknowns, at least some of them should be worked into the MA scenarios in a fundamental manner.

One of the main themes of several global scenarios is that people will respond to environmental change in some way other than by trying their best to ignore it. The social response to change, and the likelihood or otherwise of human value shifts, is of central importance in the future. Humans may change their values only in response to major perturbations, and existing values may themselves be highly resilient. If this is true, then changes to the status quo can come only through an ecological perturbation of a magnitude greater than anything that we have yet experienced, which implies that to achieve an ultimate solution to the earth's environmental problems, we may have to destroy part of our life-support system irretrievably. This catch-22 situation is not made explicit in the scenario literature and may make some of the existing global scenarios excessively optimistic. We note, hopefully, that scenarios (in particular, negative scenarios) might themselves contribute to debate about sustainability and related societal changes, thereby helping societies to avoid some of the negative developments that seem likely at the time of scenario development.

The distinctions between reformed and unreformed markets are somewhat murky in many of the scenario descriptions. If reformed markets are defined as distinct on the basis of value changes, it then becomes difficult to distinguish between the value shift scenario and the reformed markets scenario. We assume that the reformed market enables maintenance or gradual change of current values, whereas the value shift scenario implies a large, deeper and more rapid change in values; however, we are not convinced that truly reformed markets will be possible in the absence of a major value shift. Depending on the precise interpretation, value shift and reformed market scenarios could have considerable overlap.

Conclusions

The exercise of comparing alternative properties of nature with existing scenarios leads to several generalities about global scenarios. It is obvious that current global scenarios incorporate hidden assumptions about nature and its ability to cope with anthropogenic change. These assumptions should be made explicit to ensure that the details of each scenario are consistent with reality. Although most scenarios do make explicit assumptions about the views of the nature held by people within each world, as discussed by De Vries and Rotmans (1997), holding a view of nature is not the same as the actual state or property of nature itself. Ecological processes are clearly important for human societies and should not be excluded from the set of processes that are incorporated into socioeconomic scenarios.

Interestingly, we found that all scenarios are inconsistent with at least one possible property of ecosystems. Existing scenarios, therefore, can not be used uncritically as a basis for ecosystem scenarios. At the same time, however, each scenario is potentially consistent with at least one possible property of ecosystems. This means that existing global scenarios, if combined with the appropriate ecosystem dynamics for that scenario, may not have to be fully reworked to include ecology. The market forces scenario could be considered the weakest of the existing global scenarios because it claims to be consistent with a positive, sustainable future but in reality relies heavily on nature being more resilient than we believe is plausible; under realistic assumptions about ecosystems, it may have to give way to another kind of system trajectory than the one that is envisaged, such as a higher fences world. A tentative conclusion is that to achieve an ultimate solution to the earth's environmental problems, we may have to destroy part of our life-support system irretrievably before rehabilitation could be pursued, with uncertain prospects for success.

Table 3. A Set of Scenarios (and Their Current Equivalents) that Incorporate Contrasting Combinations of Important Uncertainties

	Higher Fences	Market Forces	Reformed Markets	Value Changes
Nature	Highly resilient or Irrelevant	Resilient or irrelevant	Mixed resilience, until thresholds	Brittle
(Environmental) sustainability	Irrelevant, adapt and protect against any changes	Weak; environmental capital can be substituted by economic/human capital	Safe minimum standards; pressure on environment not beyond certain thresholds	Strong; environmental capital cannot be substituted; strict precautionary approach
Sustainability solutions	Higher fences to protect elite; control resources	Invisible hand of the market, no government interference	Incremental policies, often technological solutions	Fundamental changes; includes lifestyle

The ability of markets and the human social system to produce a multiscale response to ecological change is central to the creation of global scenarios. A mismatch of the scales of the relevant variables will create inconsistencies in the scenarios. For example, the scale mismatch between ecological change and many socioeconomic responses makes questionable the assumption that reformed markets could cope with a brittle ecosystem. Existing scenarios will have to be screened for consistency in their assumptions about the linkages between the scales of these processes.

Table 3 shows how existing scenarios can be divided according to their assumptions about nature. If nature really is brittle, scenarios can either be expected to incorporate responses to environmental problems or not. These actions may be focusing on policy-induced changes with a technological character (reformed markets) or on societal changes of values and behavior (values changes). If nature really is resilient or irrelevant, no action to achieve environmental sustainability would be needed; however, the effectiveness of society to address social problems can differ and lead to lower or higher pressures on the environment (market forces and higher fences, respectively). Some interesting questions to be answered in the MA scenario analysis would be: If society were to pursue a market forces world, and was wrong about the resilience of nature, what would the results be? Or similarly: If society were to pursue a reformed market or value changes world, and nature was much more resilient than assumed, what would the implications be? If this is an acceptable conclusion for our analysis, its main implication is that although we can work within the socioeconomic framework of existing global scenarios (with the possible exception of market forces), future global scenarios will need to make explicit assumptions about ecosystem dynamics and the human responses that they elicit and include these in the scenarios if they are to be consistent with reality.

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