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Commentary

Defining and predicting sustainability

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Abstract

This paper attempts to separate the definition of sustainability (which is argued to be quite straightforward) from related issues concerning: (1) which system, subsystem, or characteristics are to be sustained; (2) for how long they are to be sustained; and (3) when we can assess whether the system has actually been sustained. We argue that because we can only assess sustainability after the fact, it is a prediction problem more than a definition problem. We also propose that in order for evolutionary adaptation to occur, there must be an ordered, hierarchical relationship between the expected (finite) life spans of systems and their space and time scales.

Keywords: Sustainability

1. Introduction

There is much discussion these days about how one "defines" sustainability, sustainable development, and related concepts (cf. WCED, 1987; Pezzey, 1989; Costanza, 1991; Pearce and Atkinson, 1993). Critics argue that the concept is useless because it cannot be "adequately defined." Much of this discussion is misdirected because: (1) it casts the problem as definitional, when in fact it is more one of prediction of what will last, and of achieving consensus on what we want to last, and (2) it fails to account for the range of interrelated time and space scales over which the concept must apply.

The basic idea of sustainability is quite straightforward: *a sustainable system is one which survives or persists.*

But there are three additional complicating questions: (1) ***What system*** *or subsystems or characteristics of systems persist?* (2) *For* ***how long?*** (3) ***When*** *do we assess whether the system or subsystem or characteristic has persisted?*

This paper attempts to address these questions by acknowledging that sustainability can only be assessed after the fact, that one must look at systems and subsystems as hierarchically interconnected over a range of time and space scales, and that each of these systems and subsystems has a necessarily finite life span.

2. When?

Biologically, sustainability means avoiding extinction and living to survive and reproduce. Eco-

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nomically, it means avoiding major disruptions and collapses, hedging against instabilities and discontinuities. Sustainability, at its base, always concerns temporality, and in particular, longevity.

The problem is that, like "fitness" in evolutionary biology, determinations of sustainability can only be made *after the fact*. An organism alive right now is fit to the extent that its progeny survive and contribute to the gene pool of future generations. The assessment of fitness today must wait until tomorrow. The assessment of sustainability must also wait until after the fact.

What passes as *definitions* of sustainability are therefore often *predictions* of actions taken today that one hopes will lead to sustainability. For example, keeping harvest rates of a resource system below rates of natural renewal should, one could argue, lead to a sustainable extraction system—but that is a prediction, not a definition. It is, in fact, the foundation of MSY-theory (maximum sustainable yield), for many years the basis for management of exploited wildlife and fisheries populations (Roedel, 1975). As learned in these fields, a system can only be known to be sustainable after there has been time to observe if the prediction holds true. Usually there is so much uncertainty in estimating natural rates of renewal, and observing and regulating harvest rates, that a simple prediction such as this, as Ludwig et al. (1993) correctly observe, is always highly suspect, especially if it is erroneously thought of as a definition.

Similarly, the sustainability of any economic system can only be observed after the fact. Many elements of sustainability definitions are really predictions of system characteristics that one hopes lead to sustainability, not really elements of a definition. Like all predictions, they are uncertain and should rightly be the subject of much elaboration, discussion, and disagreement.

3. What system?

A second question has to do with what system or subsystem or characteristics of these systems one is interested in sustaining. A particular ecological system? A particular species or the total of all species (biodiversity)? The current economic system? A particular culture? A particular business or industry? Here, definitions of sustainability usually end up as a list of preferred characteristics, most often pertaining to the global socioeconomic system in the context of its ecological life support system. For example, most definitions of sustainable development (WCED, 1987; Pezzey, 1989; Costanza, 1991) contain elements of: (1) a sustainable *scale* of the economy relative to its ecological life-support system; (2) an equitable *distribution* of resources and opportunities between present and future generations; and (3) an efficient *allocation* of resources that adequately accounts for natural capital.

It is important that we achieve consensus on these characteristics as desirable social goals. This process will be aided by separating this consensus-building

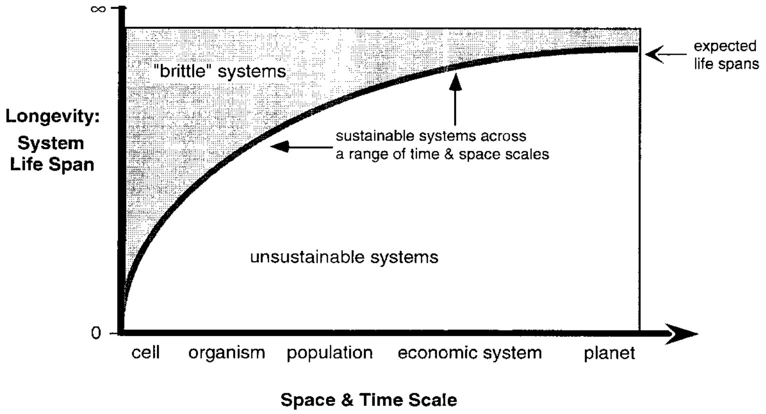

Fig. 1. Sustainability as scale (time and space) dependent concepts.

process from the definition of sustainability and the other related questions we elaborate here. For example, in addition to their desirability as social goals, the three general characteristics listed above also are predictors of the necessary characteristics that will allow the system to be sustained. They are thought to be both necessary conditions (predictors) for sustainability and desirable social goals as well. But choosing particular systems or subsystems and specific characteristics as the objects to sustain (presumably forever) hides the hierarchical interactions between systems and subsystems over a range of scales in space and time. This brings us to the final question of spatial and temporal extent.

4. How long?

The third problem is that when one says a system has achieved sustainability, one has to specify the time span involved. Some would argue that sustainability means ''maintenance forever.'' But nothing lasts forever, not even the universe as a whole. Sustainability thus cannot mean an infinite life span or nothing would be sustainable. Instead, we argue it means a life span that is consistent with the system's time and space scale. Fig. 1 indicates this relationship by plotting a hypothetical curve of system life expectancy on the y axis vs. time and space scale on the x axis. We expect a cell in an organism to have a relatively short life span, the organism to have a longer life span, a population of organisms to have an even longer life span, an economic system to have an even longer life span, and the planet as a whole to have a longer life span. But no system (even the universe) is expected to have an infinite life span. A sustainable system in this context is thus one that attains its full expected life span within the nested hierarchy of systems within which it is embedded. We refer to this nested hierarchy of systems and subsystems over a range of time and space scales as the ''metasystem.''

Individual humans are sustainable in this metasystem if they achieve their ''normal'' maximum life span. At the population level, average life expectancy is often used as an indicator of health and well-being of the population, but the population itself is expected to have a much longer life span than any individual, and would not be considered to be sustainable if it were to crash prematurely, even if all the individuals in the population were living out their full ''sustainable'' life spans. As a thought experiment, what would happen to sustainability if all individual humans actually lived forever? As we argue below, immortality of any subsystem is not sustainable because it cuts off evolutionary adaptation.

Since ecosystems experience succession as a result of changing climatic conditions and internal developmental changes, they too have a limited (albeit very long) life span. The key is differentiating between changes due to normal life span limits and changes that cut short the life span of the system.

Under this definition, anything that reduces a system's natural longevity also reduces its sustainability. Thus, in humans, factors like cancer, AIDS, accidents, and a host of other causes decrease sustainability. Humans' interventions in ecosystems frequently have deleterious consequences:

- cultural eutrophication of water bodies decreases the longevity of oligotrophic states, degrades water quality, and accelerates the arrival of dystrophic senescence;
- commercial lumbering ahead of sustainable schedules necessitates later sacrifice of non-extractive social values when ''saw timber'' forestry must be converted to a ''pulp and chip'' industry, and remnant old-growth forests must be harvested to ''preserve jobs'';
- high-technology agriculture can only be sustained through exogenous subsidies of energy, fertilizers, pesticides, and gene pools.

These and other uses of natural capital interrupt normal function and both truncate natural longevity and hasten senescent decline. The exact consequences depend on the nature and state of the impacted system and the kind and severity of disturbance.

More formally, this aspect of sustainability can be thought of in terms of the system and its component parts' longevity (Patten and Costanza, 1995): A system is sustainable if and only if it persists in nominal behavioral states as long as or longer than its expected natural longevity or existence time; and-Neither component- nor system-level sustainability, as assessed by the longevity criterion, confers sustainability to the other level.

But one can now ask: why should small-scale systems have shorter life spans than larger-scale systems? Why don't cells or individual organisms last forever? We suggest that this is an outcome of the nested hierarchical interrelationship of systems across scales (the metasystem) that is necessary for evolutionary adaptation. Evolution cannot occur unless there is limited longevity of the component parts so that new alternatives can be selected. And this longevity has to be increasing hierarchically with scale as shown schematically in Fig. 1. Larger systems can attain longer life spans because their component parts have shorter life spans which allows the system to adapt to changing conditions. But without "death" at the lower scale, there can be no evolutionary change at the higher scale. Sustaining life requires death.

Systems with an improper balance of longevity across scales can become either "brittle" when their parts last too long and they cannot adapt fast enough (Holling, 1992) or "unsustainable" when their parts do not last long enough and the higher level system's longevity is cut unnecessarily short.

5. Conclusions

We have separated the problem of *defining* sustainability from three other, more basic questions, and have provided some tentative answers to those questions in order to motivate further discussion:

Q1. **What system** or subsystems or characteristics of systems persist?

A1. A nested hierarchy of systems over a range of time and space scales must be considered (the metasystem). Within the socioeconomic subsystem, a social consensus on *desired* characteristics which are consistent with the relationship of these subsystems with other subsystems in the hierarchy (notably ecosystems) must be arrived at. These characteristics also function as predictors of what kind of system will actually be sustainable.

Q2. For **how long**?

A2. All systems are of limited longevity, so sustainability cannot mean "maintenance forever." To maintain a sustainably evolving metasystem, we hypothesize that a particular relationship between the longevity of component subsystems and their time and space scales (Fig. 1) may be necessary.

Q3. **When** do we assess whether the system or subsystem has persisted?

A3. This can only be done after the fact, so the emphasis shifts to methods to enable us to better predict what configurations will persist, and to policies and instruments to deal with the remaining uncertainty. Given the huge uncertainties involved in the scale of the socioeconomic system, it is of particular importance in this regard to select policies that are precautionary (Costanza and Perrings, 1990; Costanza and Cornwell, 1992) in that they do not take unnecessary risks with sustainability and they do not count on hoped-for technological fixes for their success.

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