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Some Propositions about Sustainability

1. The definition of sustainability should be formulated in as value-free a way as possible.

For the concept of sustainability in the process of development to be useful it must be more than an expression of value or political preferences. It must be defined so that one can specify a set of objectively measurable criteria such that individuals with widely differing values, political preferences, or assumptions about human behavior can agree whether the criteria have been fulfilled in a given situation. In other words, the statement that a development process or program must be a form of public knowledge in the sense described by John Ziman in his book of that title.[1]

2. Sustainability by itself does not define a unique scenario of future development.

Ordinarily there will be several different scenarios that meet the criteria for sustainability but differ on other dimensions including many corresponding to different values and political preferences. For example, one could have economic growth with different degrees of income equality among the population affected, and still have the development sustainable. In practice there is probably some degree of income equality that is not sustainable over time, but certainly there is a range of income distributions in economic development that are sustainable. Similarly sustainable development may not be possible with perfect income equality, but the concept of sustainability nevertheless admits of considrable flexibility on the dimension of income distribution.

Similarly, one might have sustainable development in authoritarian political systems as well as in many different variations of representative or direct democracy. There are likely to be limits at either end of the continuum between authoritarian government and pure democracy that are compatible with sustainability in development.

One could also have economic development with different degrees of urbanization or other patterns of human settlement and still have sustainability over long periods of time.

Even in the case of the physical and biological patterns

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[1]John M. Ziman, Public Knowledge: The Social Dimension of Science, Cambridge University Press, Cambridge, England, 19__

of development, the concept of sustainability does not imply a single viable path. In other words the concept of ecological sustainability is no more unique than that of socioeconomic or sociopolitical sustainability that we have discussed in the preceding paragraphs. For example, there has been much recent discussion of the preservation of genetic diversity as an important constraint on the development of the biosphere. From the standpoint of conservation of genetic resource to preserve future options for the exploitation of species for the ebenfit of man, however, the requirements of sustainability in this sense may be much less stringent than those embodied in some of the recent endangered species legislation. There may be widely supported ethical or aesthetic reasons for maintaining these more stringent principles as constraints on development, but these need not and should not be justified under the rubric of sustainability. Rather they should be debated on their own merits as additional value issues. Suppose, for example, it became possible to store germ plasm of endangered species in such a way that it would be feasible to regenerate them, or suppose that it were possible to maintain genetic diversity by a system of finite size reservations in which endangered species remained viable. These measures might suffice for the purposes of sustainability and still not be acceptable on other grounds that involved the implementation of other human values. The concept of sustainability is in essence an anthropocentric concept, the idea that the protection of nature is only justified to the extent that it maintains resources that will benefit man at some time in the future.

Of course, there cannot be a sharp boundary between those measures that are required by sustainability and those than are only justified by other ethical and aesthetic values. For example, anything less than the most rigorous protection of species from the effects of human activity irrespective of economic cost involves some small degree of risk that in our current state of incomplete ecological knowledge we will allow some species to disappear that later generations would have found to be of important human benefit. Hence, some kind of value judgment is still involved in deciding just how large a risk of loss of genetic diversity through action with knowledge that can never be quite complete is tolerable vs. the loss of economic benefit arising from tighter constraints. In that sense sustainability cannot be precisely defined in an entirely value-free way. But the anthropocentric definition proposed here is certain less value-dependent than many other possible definitions that have been proposed.

3. Societal values other than sustainability as defined here form a nexus which, even though individual values are subjec-

tive, can be analyzed objectively and logically with respect to their interrelations and consequences, leading to a higher degree of consensus about trade-offs among nearly equally desirable social goods than would be possible if the values were debated one by one.

It is important in this connection that people distinguish between differences in values and preferences, which are truly subjective, and differences in conclusions about the consequences of implementation of different values, which are, in principle at least, an empirical issue, subject to an objective reality test. In other words, arriving at an objective concept of sustainability is neither a necessary nor a sufficient condition for the achievement of social consensus about acceptable directions for development. Reasoning about the relationships among values in terms of synergies and conflicts among their probable or possible consequences, is an important part of the process of consensus building about development trajectories.

Differences in values often enter into debates about sustainability through implicit or unacknowledged views about where the burden of proof should lie in conflicts between short-term development goals and sustainability. It is always easier to sustain an argument if it can be presented as based on scientific "facts" of nature, but because there is always a band of uncertainty surrounding these facts, there is scope for selection of those possibilities which best conform to the preferences of one side or the other in accordance with the downstream policy consequences of selecting a certain set of facts within the uncertainty band.

4. Sustainability has to be looked upon as an evolutionary concept in the sense that no technology or development policy may be sustainable indefinitely because of secular changes in various underlying parameters of the system, whether they occur naturally or as a consequence of slow acculation of the effects of human interactions with the biosphere and social and economic development.

Climate change, whether of anthropogenic or natural origin, may gradually undermine the sustainability of a technology or a development policy through changing the assimilative or adaptive capacity of the environment. Stigliani[2] has given many examples of this with respect to accumulation of pollutants in

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[2]William M. Stigliani, "Changes in Valued `Capacities' of Soils and Sediments as Indicators of Non-Linear and Time-Delayed Environmental Effects," IIASA WP-88-38, May 1988

estuarial sediments and the changes in the storage capacity of such sediments as a result of acid runoff as well as changes in mean temperature. Acid precipitation and fallout themselves have cumulative effects on soils which may result in the exhaustion of buffering capacity despite the subsequent reduction in the rate of sulfur or nitrogen emissions.

One consequence of the evolutionary phenomenon is that a policy which is sustainable over a short span of time may become unstainable unless gradually modified to take into account slow cumulative effects. Thus an important aspect of maintaining sustainability in the long term may be continuous monitoring of the "slow variables" in order to anticipate and adapt policies and technologies to changes in limits which their slow evolution imposes.

5. Partly for the reasons mentioned in 5 and partly because of inherent limitations in the rate of adaptation of human systems through technological and social change and cumulative social learning, rates of change of parameters like population, resource use, and GNP may be much more of a limiting factor in development than the absolute carrying capacity of the biosphere.

Over human history on the planet there have been remarkable upwards steps in the opulation with the earth could sustain as a result of changes in technology and the pattern of human settlements. There is little reason to believe that similar steps up in the future might also be possible, but they would reequire equally radical steps to the transition from hunter-gatherer societies to irrigated agricultural and the transition from agricultural civilization to an industrial one in Europe in the last 300 years. However, the transitions in population and settlement patterns in these cases took place much more slowly than many of the changes that are occurring now or are expected in the next century. The 20th century is the first in which such radical changes in all the parameters of human existence have taken place within the span of a single generation. In the past such changes have sometimes taken place locally in such short periods, but they have never extended over whole continents or the whole world in such a short period. It is thus simultaneous magnitude of the changes both in time and space that have presented an unprecedented challenge to human adaptation capacities.

It is true that human adaptation capacity has also grown tremendously, especially in respect to the power of science and technology. The population of scientists and engineers and other professionals continues to grow at two to three times the rate of the population as a whole or even of the total world labor force. But science and technology are not only instruments of human adaptation to a changing environment, but also in part the cause of that change. It is not clear--or at least not agreed upon--which side of the adaptation equation they should be weighed in on. Science and technology are not the only tools required for human adaptation, and perhaps not even the most important tools. Their significance may also depend importantly on how they are actually deployed, which depends a great deal on factors outside the system of science and technology. All of this means we cannot be sure which way the ratio of adaptability to the need for adaptation is changing over time. Nor do we have a clear idea of the societal paparemters that affect this ration.

6. Activities that are non-sustainable in isolation may become sustainable within a larger system, but conversely, activities that appear to be locally sustainable because of the flow of resources and other inputs from outside can become unsustainable when viewed from the standpoint of a larger system or a longer time scale; only detailed understanding of the system in conjunction with all its interactions and the evolution of the external systems with which it interacts can determine whether a local activity or policy is sustainable.

As an example, a developed country might grow rapidly on the basis of renewable resources imported from a developing country based on an unsustainable system of exploitation. In this case the "slow variables" that affect the sustainability of the given system may be external to the system itself as ordinarily defined. Some would argue that the rapid economic development of Europe and Japan on the basis of cheap imported Middle East oil was an example of unsustainability of the type envisioned here. In ancient history many local civilizations rose and declined because of the exhaustion of local rich resources of metals which they were not able to replace by imports. On the other hand, Britain, which at one time produced over 50% of the world's copper was able to make the transition to substitute sources without serious dislocation.

These and other examples show that the criteria for sustainability have ultimately defined over a spatially heterogeneous system consisting of a cluster of interacting spatially related systems, not necessarily in geograhic proximity with each other. In fact, as the work of Holling[3] and Forman[4] has

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[3]C. S. Holling, reference on spatial heterogenity in relation to the spruce budworm problem in the New Brunswick forests.

shown spatially heterogeneous ecosystems can be sustainable over the long run when their homogeneous components appear non sustainable. Heterogeneity is an important consideration in maintaining the resilience of ecosystems that do not exhibit stability because different elements of the heterogeneous system act as reservoirs for regeneration of other elements. Ultimately, of course, sustainability must be considered on a global scale. Because the flow of resources between different elements in a spatially heterogeneous systems often depends on political and economic relations between the people that inhabit these elements the separation of the sociopolitical and ecological aspects of sustainability becomes more and more inappropriate. The behavior of people is part of the total system.

7. It follows, partly from the preceding, that the interaction between cultures and both their natural and artificial environments is an impoprtant parameter in defining sustainability; activities which appear ecologically sustainable may fail because they are not culturally sustainable and vice versa.

Thus, for example, temperate zone agricultural in both Europe and North America appear to be sustainable from an ecological point of view. Indeed Hudson[5] has suggested that the environmental sustainability of North American agriculture has been steadily improving, while that in the developing world has been declining, despite the growth in productivity of temperate zone agriculture. There is much less assurance, however, that the present agricultural systems of Europe and America are politically and economically sustainable. They have been maintained at an ever growing cost in subsidies from the rest of society at a time when the political clout of the agricultural sector is steadily declining, and there is less and less social use for the huge surplus of certain commodities.

It may very well be that, even though with modern technology the mining and burning of coal can be made environmentally

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[4]R. C. Forman, reference on spatial heterogeneity in landscape ecology.

[5] William J. Hudson (The Andersons), "International Trade and Food Security in Arid Lands," presented at AAAS Annual Meeting, Session 36-1, Food Security in Arid Lands, 12 February, 1988.

sustainable , it may not be socially sustainable. For example, there may be too few people willing to work in coal mines, and automation may not be able to replace them completely. There may be many other resource industries that are not socially sustainable in the long run for reasons of what human beings in affluent societies are willing to tolerate in the way of working conditions. Such speculations are by no means certain, but they do illustrate to potential social dimensions of sustainability.

The case of rural deforestation in the tropics is another example where the complex interaction between social structure and the ecological systems in which it is embedded lead to non-sustainability in a sociotechnical sense. Also many primitive cultures exist in excellent harmony with their environments, only to break down when they come into contact with more "advanced" societies. This may not be only because the advanced societies consciously "impose" inappropriate values on the primitive ones, but also there is no way in which the primitive cultures can be sufficiently insulated over the long term.

8. The concept of non-renewable or exhaustible resources is probably not a meaningful or useful one in defining sustainability because of the constant evolution of the resource base through the improvement in extraction, recycling, and substitution technolgoies.

In fact renewable resources are more likely to be a binding constraint on development than so-called non-renewable resources. The ratio of non-renewable resurce consumption to output has been steadily declining in the developed countries, and this trend is likely to accelerate as the application of information technology increases the information content of materials in manufacturing.[6] For both renewable and non-renewable resources rate of change of the structure of demand is likely to be a more serious limit than the absolute level of demand.

It is not too difficult to envision a day when more and more of the materials of civilization are synthesized from cheap and abundant raw materials essentially by the use of materials engineering on a submicroscopic or molecular scale. The modern integrated circuit is probably a harbinger of things to come in an increasing number of applications, in the field

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[6]Robert U. Ayres, Manufacturing and Human Labor as Information Processes, IIASA RR-87-19, November 1987.

of structures and mechanical systems as well as electronics.[7]

Thus it does not appear that in the long run the availability or even the cost of basic raw materials will be a major issue in the discussion of sustainable development. The one caveat in this regard may be in the socioeconomic sustainability of certain kinds of extraction operations, or the sociocultural acceptability of certain energy sources such as breeder reactors and plutonium recycling.

9. The concept of susainability may be properly referrable only to renewable resources, including certain kinds of environemental resources such as atmospheric composition, soil chemistry, and the trace chemistry of groundwater.

In this category of effects one can list the build-up of greenhouse gases in the atmosphere due to combustion and other industrial activities, ozone depletion of the stratosphere from nitrous oxide, fluorocarbons and other trace gases, the nitrification of groundwaters primarily due to fertilizer runoff, the release of trace metal accumulations in soils and sediments due to acidification from atmospheric fallout of sulfur and nitrogen emissions, the accumulation of radioactivity in food chains from a variety of man-made sources, and many alterations of natural biogeochemical cycles by man's activities.

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[7] R. U. Ayres, Complexity, Reliability and Design: The Coming Monolithic Revolution in Manufacturing, IIASA WP-86-48, 1986; Michael Ashby, paper on the future of materials in NATO conference volume.