The Ecology of Sustainability

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The World Book Encyclopedia provides three different definitions of Ecology: the branch of biology that deals with the relation of living things to their environment and to each other, the branch of sociology that deals with the relations between human beings and their environment, and the balanced or harmonious relationship of living things to their environment. All three are appropriate and relevant to issues of sustainability.

Sustainability is a question – a big question – as the late Bob Rodale, an early pioneer of sustainable agriculture, used to say. How can we meet the needs of people today, all people today, while leaving equal or better opportunities for those of the future? How can we ensure the long run health and productivity of the natural ecosystem? How can we create a healthy, enduring society? To achieve and maintain sustainability, we must integrate the ecology of biology and sociology with a new ecology of economics in finding ways to work and to live in harmony and balance with each other, other living things, and our natural environment.

Today, we are confronted with growing evidence that contemporary, modern society is not sustainable. Industrialization, the dominant development paradigm of the past two centuries, is not a sustainable approach to development of either natural or human resources. Industrial systems are inherently extractive, exploitative, and are ultimately dependent upon finite stocks of non-renewable resources. Industrial systems eventually will degrade and deplete the resources upon which its productivity depends, and thus, are not sustainable. Industrialization is the physical manifestation of a specific philosophy of economics, a specific concept of science, and a specific worldview. Thus, if we are to develop a sustainable society, we must be willing to reexamine the conceptual foundation upon which our current unsustainable society is built.

The mechanistic philosophical worldview emerged during the 1600's to 1700's. It was first articulated by early scientists such as Rene Descartes and Isaac Newton. During this "Age of Reason," the world came to be viewed as a large complex machine with many interrelated parts – as clock-like. The foundation of modern science was laid during this period with development of the "scientific method" of inquiry and the "reductionist" approach to research. Following the scientific methods, scientists could reduce complex systems to their elemental parts, isolating individual causes and effects, and thus, gaining understanding of systems as wholes by examining their component parts.

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Classical economics had its roots in this same period of "Enlightenment." However, it was not until the early 1800's that neo-classical economists abandoned the "pursuit of happiness," with its inherent social and moral implications, pursuing instead "maximization of utility" and turning economics into a "mechanistic social science." Today, the mechanistic scientific worldview, neo-classical philosophy of economics, and industrial paradigm of development dominate virtually every aspect of modern society – including the new electronic information and biological technologies.

To build a sustainable society, we must first be willing to rethink our fundamental concepts of science, economics, and society. We must build a new sustainable society on the philosophical foundation of a new worldview, a new approach to science, a new economics of sustainability.

The big questions of sustainability are rooted in some of the most basic laws of nature. For example, the first law of thermodynamics, the law of conservation of mass and energy, might seem to suggest that sustainability is ensured. Matter may be converted to energy and energy converted to matter, but energy and matter in total are conserved, and thus, remains undiminished. However, the second law of thermodynamics suggests that each time matter is converted to energy, or energy to matter, some of the "usefulness" is lost. This loss in usefulness is identified with the concept of entropy, "the ultimate state reached in degradation of matter and energy; a state of inert uniformity of component elements; absence of form, pattern, hierarchy, or differentiation." So, the second law of thermodynamics might suggest that sustainability is impossible.

However, the first and second laws of thermodynamics relate to "closed systems" – where nothing is lost to the outside and nothing comes in from the outside. With "closed systems," entropy is inevitable. Thus, the possibility of long run sustainability of life on earth is a consequence only of the "openness" of the biosphere, as a system, to the inflow of energy from the sun. Sustainability is possible only because the earth, as an "open system," is capable of capturing and storing sufficient amounts of "useful" solar energy to offset the declining "usefulness" associated with the inevitable tendency toward entropy.

This dependence on solar energy suggests that sustainable development ultimately is dependent upon "living systems." Living systems, by nature, are "open systems." Living organisms capture energy from the sun, convert it to more diverse and "useful" forms, and thus, have the capacity to offset the inevitable degradation of usefulness of energy and matter. The natural tendency of "living systems" is toward greater diversity in structure, form, hierarchy, and pattern – away from entropy. Scientists continue to explore the potential of other "open systems" – of various kinds of synthetic solar collectors and solar energy carried by wind and water. But living plants on land and living phytoplankton in the seas remain the only practical collectors of significant amounts of solar energy. Thus, the sustainability of human life on earth remains dependent upon the sustainability of other living systems.

A sustainable human society must conserve, recycle, and reuse materials and energy, if it is to slow, rather than accelerate, the process of entropy. And ultimately, human population and per capita consumption must accommodate the limited carrying capacity of the earth. But, the carrying capacity of the earth depends at least as much on our effectiveness in nurturing and using living systems to capture and store solar energy as on our efficiency in using stocks of energy and material with which the earth is endowed. Sustainability depends upon "living systems."

Sustainable living systems must be regenerative systems; they must be capable of renewing and reproducing themselves, of maintaining their productivity and vitality from generation to generation, indefinitely. Living systems are "self-making." Non-living or dead systems are not. Bacteria, insects, plants, animals, and humans, are examples of living systems. Clocks, bicycles, automobiles, machines, and factories, are examples of dead systems. All systems, both living and dead, can be characterized by pattern, structure, and process. But, the processes by which structure is created and recreated are fundamentally different for living and dead systems.

The "pattern" of a dead system is the organizational concept – the plan or blueprint by which it is constructed. The "pattern" of a living system is encoded in its DNA – the genetic code, which guides its process of development. The "structure" of both living and dead systems is the physical embodiment of pattern. For both living and dead systems, the structure is the thing that you can see, feel, touch, or otherwise perceive using your physical senses. The "process" of a system defines the means by which the system performs the functions necessary to fulfill its purpose. Something useful or meaningful results from the "processes" of both living and dead systems.

The primary difference between living and dead systems is in the "process" by which their "structure" is made and remade. Non-living systems must be constructed according to some plan or blueprint, which must be developed before construction begins. If non-living systems wear out, become obsolete, or otherwise lose their usefulness, they must be redesigned and rebuilt. Once built, the structure of dead systems remains constant. Dead systems may break or wear out, but their basic structure remains unchanged. Non-living systems can be remodeled, rebuilt, or redesigned, but they cannot make, remake, or redesign themselves.

Living systems, on the other hand, make and remake themselves, according to their genetic code, and given time, are even capable of redesigning themselves. All living organisms are living systems. Living organisms, including humans, are born, mature, reproduce, grow old, and eventually die – by nature. Throughout its life, the physical structure of a living organism is continually changing, although its genetic pattern remains unchanged. The cells of living organisms are replaced continuously, even in mature organisms, creating essentially new structures, often many times during a single life span. While the pattern of an individual living organism remains unchanged during its lifetime, living species are capable of evolving over time, redesigning themselves to accommodate a changing natural environment. Living and dead systems may both perform useful and productive processes, but part of the process of a living system is the remaking of its structure.

The capacity of a living system to produce, renew, and regenerate depends upon its strength and health. The health and strength of any living organism depends on the health and strength of the relationships among its various structural units or components. Cells are a fundamental structural unit of all living organisms. All living cells are surrounded by membranes, which separate the water-rich cytoplasm inside the cell from a significantly different outside environment. The membranes, which define the boundaries of each cell, are "semi-permeable" – they let some things pass through, but keep other things in and out. Cells that are either permeable or are non-permeable, rather than semi-permeable, cannot support life. A cell that doesn't keep anything in will dry up. A cell that doesn't let anything out will explode. A cell that doesn't let anything in or out is a closed system – it is dead. If living cells weren't semi-permeable, they wouldn't be able to retain moisture or minerals; they wouldn't be able to metabolize food, release energy, or eliminate waste. The organism would die. All living organisms are made up of cells, which are defined by semi-permeable boundaries.

This principle of semi-permeable boundaries extends beyond the cellular level to many other aspects of life. All living organisms are defined by boundaries – skin, bark, leaf surface, scales, etc. – which give them structure, form, and identity. As with cells, the boundaries of organisms must be semi-permeable or selective with respect to what they allow to pass through and what they keep in or keep out. The human skin protects the body against all sorts of physical and biological threats, but it must also be permeable to allow for transpiration and respiration. Plants exchange nutrients stored in their roots for nutrients needed from the soil, and the root boundaries are very selective in what they let in and let out. Boundaries are necessary, but they must be semi-permeable or selective.

To accomplish the miracle of new life, living organisms must create new forms and structures, which are defined by new boundaries. The natural tendency of living systems toward the creation of greater biological diversity implies a tendency toward more complexity, more species, more varieties, more variations of organisms, and thus, a tendency toward more boundaries. For example, after a field has been stripped of all vegetation, the first life to return to a field likely will be a single species, or perhaps a few species, of weeds. The weeds will mature, reproduce, and die, but their rotted residue will create a favorable environment for other plant species. As the succession of regeneration processes continues, an increasing diversity of plant species will create a favorable habitat for an increasing diversity of microorganism, insect, and animal species. This increasing diversity of form and structure is defined by a multitude of new boundaries.

On the other hand, the natural tendency of closed systems, of "dead things," toward entropy, is reflected in their tendency toward the dissolution or destruction of boundaries. Again, the ultimate state of entropy is characterized as "a state of inert uniformity of component elements; absence of form, pattern, hierarchy, or differentiation." Entropy implies the absence of boundaries. The reference to "degradation of energy and matter," in the definition of entropy, relates to the fact that boundaries are destroyed as energy is released from matter and that new energy is required to rebuild boundaries. Whenever energy is released from matter, some energy must be used to restore the boundaries of matter, leaving less "useful energy" than before – thus, the tendency toward entropy.

When an oak log is burned, energy, in the form of heat, is released from the wood and the structure of the wood is turned to ashes. The boundaries that once defined the structure of the log are destroyed through the releasing of energy. And, new energy will be required to replace the oak now turned to ashes. The human body converts food to energy by a similar process of digesting or breaking down the structure of the foods that we eat. In both cases, the energy consumed is renewable because new boundaries can be built and new energy can be captured from the sun by other living organisms.

Fossil fuels, on the other hand, are non-renewable sources of energy – at least non-renewable in a reasonable human timeframe. Lacking a new infusion of energy from "outside" – as from the sun – systems that depend on non-renewable energy slowly lose their ability to restore the structural boundaries of matter, and thus, slowly lose their ability to store and release energy. This is the essence of entropy – the degradation of energy and matter, as systems lose their form, structure, and diversity through the destruction of boundaries.

Such contrasts of living and dead systems, of sustainability and entropy, are equally relevant to cultural, political, and economic systems. The dissolution of boundaries among cultures increases the efficiency of social and political processes, releasing the energy previously bound by cultural constraints. The dissolution of political boundaries, likewise, releases the energy bound by conflicting laws, regulations, and other political constraints. The dissolution of cultural and political boundaries removes constraints to economic specialization, standardization, and consolidation, the key characteristics of industrialization, thus allowing maximum productivity and economic efficiency. Thus, strong social and economic incentives exist to remove all cultural and political boundaries.

In farming, for example, tremendous gains in productivity and economic efficiency have been achieved through the removal of boundaries. Farmers removed fences that had separated fields, as they moved toward more mechanized and standardized systems of farming. The diversity of crops and livestock enterprises that once defined the structure of typical family farms was abandoned to achieve greater specialization. The "landscapes" of many farms were left without form, pattern, hierarchy, or differentiation.

These new "more efficient" farming methods allowed farms to consolidate, to become larger by removing the boundaries of ownership and economic identity that once defined different farms within communities. As farms became larger, farmers reached beyond the boundaries of the local communities to market their products and purchase their inputs because it was "more efficient" to do so.

This transformation, this industrialization of agriculture, resulted in tremendous gains in agricultural productivity and economic efficiency. As with industrialization in general, it has released tremendous stocks of stored energy that were constrained by the boundaries that once defined different fields, enterprises, farms, and farming communities. Industrialization removes the boundaries allowing stored energy to be released. But, the industrial paradigm provides no means of restoring the inevitably lost energy. Neither does the neo-classical paradigm of economics, the reductionist paradigm of science, or the mechanistic worldview.

Industrial development, neo-classical economics, and reductionist science are paradigms of "dead" systems. They have led to the destruction of ecological, cultural, and economic boundaries and the extraction of stored energy from land, water, air, plants, animals, and people. They provide no means of restoring boundaries, no means of recreating matter, and thus, no means of renewing sources of energy for the future. The mechanistic worldview of modern science is fundamentally incapable of addressing the most critical issues of life – of healthy interdependent relationships among diverse elements within holistic, living systems.

If we continue to regard the world as a big complex machine, we will continue to push the biosphere toward entropy – toward degradation of matter and energy; toward a state of inert uniformity; toward an absence of form, pattern, hierarchy, or differentiation. A lifeless desert is about as close to entropy as most people have seen. It is without form, pattern, hierarchy, or differentiation – essentially, without boundaries. Such will be the ultimate result of pursuing our current dominant paradigms of science, economics, and resource development.

Thankfully, an alternative worldview and alternative paradigms of science, economics, and resource development are emerging. Sustainable development is the name most commonly linked to this alternative, although many people do not yet realize that sustainability will require different paradigms of economics and science, based on an organismic rather than mechanistic worldview. Sustainable agriculture is but a part, albeit an important part, of the search for an alternative sustainable paradigm of resource development.

The new paradigm of agricultural sustainability is being developed by thousands of farmers all across the American continent and around the globe. They are doing it with little help from scientists, from government, or anyone other than each other. These farmers and ranchers may label themselves as organic, biodynamic, holistic, biological, ecological, practical, innovative, or accept no label other than family farmer. However, they share a common philosophy of farming that fits under the conceptual umbrella of agricultural sustainability. [2]

A sustainable system of farming must be ecologically sound, economically viable, and socially responsible. The living ecological, economic, and social sub-systems, which constitute a sustainable farm, must all be renewable and regenerative. A farm that is not ecologically regenerative cannot be sustained over time, no matter how profitable or socially responsible it may be in the short run. A farm that is not economically regenerative is not sustainable, no matter how ecologically sound and socially responsible it may otherwise be. And, a farm that is not responsive to the needs of society will not be supported by society, no matter how ecologically sound or profitable it might be. A farm is a living organism – soils, plants, animals, people, all are living, growing, evolving living entities, and the farm exists in a living economic, ecological, and social environment. The ecological, economic, and social organs must all remain healthy and strong, if the farming organism is to be regenerative, and thus, sustainable.

Each sustainable farming operation is site-specific, individualistic, and dynamic. To farm sustainably, the farming systems must fit the ecological, physical, and intellectual resources of the individual farm operation, which being a living system, continually changes and evolves over time. However, some general underlying characteristics of successful sustainable agricultural operations

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[2] For 50 examples of these new sustainable farmers, see "The New American Farmer – Profiles in Agricultural Innovation," the SARE Program, USDA, Washington DC. ($10 US – call: 802-656-0484 or e-mail: sanpubs@uvm.edu , also available free on line at http://www.sare.org/newfarmer)

are beginning to emerge from the diverse experiences of these new farmers. From these characteristics, we can begin to understand how sustainable farms and other sustainable systems must be organized and managed.

Industrial management is characterized by specialization, standardization, and consolidation of control. Sustainable farm management must be fundamentally different. Sustainable farm managers can realize economic gains from appropriate levels of specialization, standardization, and consolidation, but must do so without sacrificing the social, ecological, and economic benefits of positive relationships among diverse elements within holistically managed, interdependent systems. Instances of specialization, uniformity, and hierarchy can also be found within natural ecosystems, but only within the boundaries of nature. Sustainable farming systems, likewise, must respect the natural limits of living systems, including the economic and social systems within which they must function.

Sustainable farms must be managed holistically. In holistic management, each component of the farming operation – each practice, method, or enterprise – is treated as an inseparable aspect or dimension of the farm as a whole. Each rearrangement creates a new set of relationships among the components of a holistically managed operation, and thus, constitutes a new and different whole. In essence, the addition of a new crop or livestock enterprise or a change in production or marketing strategy creates a new farming system. When viewed holistically, farms embody something more than the simple sum of their parts. Relationships among parts are as important as the parts themselves. That something more in the whole, i.e. synergy, is the product of positive relationships.

Holistic managers create various spatial arrangements of crops, pastures, animals, etc. across the landscapes of their farms. They create different temporal arrangements by rotating crops, forages, and pastures, by sequencing different animal species on pastures, etc. during each season or from one season to the next. They arrange various types of plant, animal, and marketing enterprises so that the output of one enterprise becomes the input of another or the waste from one becomes a resource to another. And they arrange people so that the right people, including themselves, can do the right thing at the right time so that the things they produce can meet the individual wants and needs of their customers.

Sustainable farms must be managed for diversity. Nature is diverse, and the diversity of an ecologically sound farming operation must reflect the diversity of its ecological "place." People are diverse, and the diversity of a socially responsible farming operation must reflect the diversity of the people who operate the farm and the customers it serves. Horizontal diversity is reflected in the number and nature of different practices, methods, and enterprises carried out on a specific farm, which allows farmers to fit what they do to the needs and capacities of the land. Vertical diversity is reflected in the number and nature of different functions performed in transforming raw materials into finished products, which allows farmers to fit what they do to the needs and preferences of their customers. By reconnecting vertically, sustainable farmers are helping to recreate local, community-based food systems, which can be reconnected horizontally to form regional, national, and global food networks – without sacrificing diversity. Diversity creates opportunities for "economic synergy," across space, among people, and over time, which allow ecologically sound and socially responsible farming operations to achieve economic viability.

Sustainable farms must maintain interdependent relationships, rather than strive for independence or accept dependence. Interdependent relationships are relationships of choice, not necessity. Obviously, we humans are dependent on nature, because we must breath, drink, and eat if we are to live. However, we humans are now capable of degrading, if not destroying, nature, and thus, nature also depends upon us. Thus, we must recognize that nature will not continue to support us, at least not many of us very well, unless we humans choose to conserve and protect our natural environment. We must create an interdependent relationship with nature, in which we choose to take care of nature so nature will take care of us. Sustainable farms must maintain an interdependent relationship with the land.

Sustainable farmers also must maintain interdependent relationships with each other, with their neighbors, and with their customers. They must recognize that past struggles for greater independence has separated farmers from their families, their neighbors, and their customers, and ultimately, has led to their economic demise. In a confrontation of farmer against farmer, farmer against neighbor, farmer against consumers, and ultimately, farmer against corporation, the independent farmer was destined to lose. But neither can farmers be sustained through dependent relationships. The sustainable farm can't depend upon the charity of its neighbors or customers, nor can it depend upon government subsidies or corporate contracts; it must produce things of value and expect value in return.

Interdependent relationships are the ultimate consequence of holistically managed, diverse living systems. And, interdependent relationships depend on healthy semi-permeable or selective ecological, economic, and social boundaries. By maintaining healthy, selective boundaries, sustainable farming systems are able to realize the synergy inherent in holism and diversity, through win-win relationships with nature and with people, rather than through extraction and exploitation. Sustainable farmers sustain their productivity and profitability by caring for the earth and caring for people. Sustainable farms are renewing, regenerative, healthy living systems.

These lessons of sustainable farmers can help inform the choices of human society. We can realize economic gains from appropriate levels of specialization, standardization, and consolidation, but we must do so without sacrificing the social, ecological, and economic benefits of positive relationships among diverse elements within holistically managed, interdependent systems. We must respect the natural boundaries that separate geographic regions, cultures, and economies. To sustain healthy ecosystems, societies, and economies, the boundaries defining them must be selective – allowing relationships within to be different from relationships among.

We can choose holism, rather than reductionism, recognizing that we cannot find truth through analysis or separation, but instead must seek truth in the whole of things. The ecological, economic, and social dimensions of alternatives are inseparable aspects of the whole of human experience. The personal, interpersonal, and spiritual are inseparable aspects of our quality of life, which is inherently affected by our choices. All bioregions, economies, and societies are all inseparable parts of the global ecosystem, global economy, and global culture, which are inseparable parts of the biosphere – the same whole. We must learn to make choices, giving due consideration to the whole.

We can choose diversity, rather than homogeneity, recognizing that diversity is necessary to ensure resistance, resilience, regeneration, and sustainability. Loss of diversity inherently leads to loss of form, structure, identity, toward dissipation of matter and energy, toward entropy. We can choose to maintain the separate identities of our families, communities, regions, nations, and cultures, without sacrificing the sustainability of human society. We can maintain diverse ecosystems, economies, cultures, and still realize the benefits of appropriate specialization, standardization, and consolidation. In fact, we must choose diversity if we are to sustain those benefits.

We can choose interdependence, rather than dependence or independence, recognizing the mutual benefit to be gained from relationships of choice. Interdependent relationships among diverse elements of holistic organizations are the key to a sustainable quality of life – for farms, families, communities, nations, and humanity. Relationships of choice require healthy, selective boundaries among farms, families, communities, regions, and nations. Each living entity must be free to make the choices necessary to protect themselves from domination and exploitation, if all are to benefit from their relationships with others. Mutual benefits are assured only by relationships of choice, not of necessity.

We can choose sustainability by choosing paradigms of scientific, economics, and resource development appropriate for living, regenerative systems. We need not wait for the rest of society to change before we, as individuals, can choose sustainability. We make choices every day regarding our own bodies, our relationships with families and friends, and our relationships with nature – choices affecting harmony and balance within a living biological and social environment. We need only extend these same living principles to all of our choices affecting ecosystems, economics, and society. Our common sense insights into the nature of life are our most valuable assets in understanding the ecology of sustainability.