The Human Ecosystem
Part I: The Human Ecosystem as an Organizing Concept in Ecosystem Management

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The organization and description of a comprehensive ecosystem model useful to ecosystem management is necessary. In this article, we propose the human ecosystem *as an organizing concept for ecosystem management. First, we describe the history of the human ecosystem idea; both biological ecology and mainstream social theories provide useful guidance. Next, we present the key elements of a* human ecosystem *model: critical resources (natural, socioeconomic, and cultural), social institutions, social cycles, and social order (identities, norms, and hierarchies). In each element, we (1) provide a general definition and description, (2) suggest ways that the variable can be measured, and (3) give selected examples of how it may influence other components of the human ecosystem. The article concludes with specific suggestions as to how the human ecosystem model can play an organizing role in ecosystem management.*

Keywords ecosystem management, human ecology, human ecosystems, social theory

> [*T*]*he* ultimate *challenge for Ecology is to integrate and synthesize the ecological information available from all levels of inquiry into an understanding that is meaningful and useful to managers and decision makers.* G. E. Likens (1992, 3)

In the early decades of the twenty-first century, a major challenge likely will confront the natural resource professions. Depending on one's source, somewhere around 2020, the

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globe will contain 6 to 8 billion humans (Demeny 1990; World Resources Institute 1994). There is little evidence that this human population, with its ever-increasing expectations, will experience a voluntary redistribution of resources from the well-to-do regions, classes, and persons to the poorer regions, classes, and persons. Our past hopes have been based on technologically induced supply increases from a finite resource base that would permit some trickle-down effects. In the United States, trends suggest more polarization between rich and poor, and increased struggle over resources.

Consequently, the natural resource professions will need to intensify their search for models of resource systems that include the forces driving infinite human desires, along with the more limited possibilities of satisfying those desires with increased natural resource productivity. Human variables as both the cause and consequence of system change will need to be joined to the traditional biophysical concerns of the forester, agriculturalist, range manager, and park superintendent.

Since 1990, "ecosystem management" has carried the most hopes for finding some coherent and comprehensive means for systematically fitting human demand within biophysical and sociopolitical realities.[1] The organization and description of a comprehensive ecosystem management model is only recently under way; the inclusion of *Homo sapiens* is unrealized. Biologists have focused on "impact" measures of humans, a strategy that puts our species outside the ecosystem as, at most, a permanent perturbation. Social scientists have focused largely on idiosyncratic "human dimensions" outside of and immune to biological reality. The traditional academic divisions have played at intellectual balkanization, seeking advances in territory rather than a more inclusive paradigm that would be truly helpful to resource management professionals. Such a paradigm would be a new kind of life science, one that treats the biosocial reality of human beings as a serious part of its approach toward ecosystem management.

In this article, we describe one version of what a human ecological perspective might offer ecosystem managers. We propose the *human ecosystem* as an organizing concept for ecosystem management. Because our goal is to describe the human ecosystem as a useful structure, we emphasize description of component parts (as a trophic level model might do) rather than critical processes (as a model of succession might do). First, we outline the genealogy of the human ecosystem idea; we draw on a long tradition of intellectual risk taking by many biologists and social scientists. Next, we present the critical elements of a human ecosystem model, followed by a detailed description of the individual variables and their relevance to ecosystem management. We conclude with specific suggestions as to how the human ecosystem model can play a useful role in managing the natural resources of the twenty-first century.

We make no pretense of resolving the larger issues surrounding environment/human studies. Our belief is that the most sustainable joining of biology and social science will come only when both approach the task as equals, with mutual respect for the theory and methods of the other. Our effort is a statement of ecology from a human perspective, with due consideration for biologically centered ecosystem models and social science derived constructs. Our hope is a fusion that transcends the arcane division of the biophysical and the sociocultural—one that is truly ecological.

Background

Studies of the patterns and processes in ecosystems emphasize the diversity and complexity of the elements affecting the systems. This was the central theme of R. L. Lindeman's breakthrough lake studies (1942) and the pioneering Hubbard Brook ecosystem research

(Bormann and Likens 1979; Likens et al. 1977). Their emphasis was on the dynamics of ecosystems in terms of flows, exchanges, and cycles of factors such as materials, nutrients, and energy. From the Hubbard Brook data, Likens et al. noted that

> a vast number of variables, including biologic structure and diversity, geologic heterogeneity, climate, and season, control the flux of both water and chemicals through ecosystems. (Likens et al. 1977, 2)

More recently, F. B. Golley also emphasized ecosystem complexity:

> the ecosystem consists of co-evolved suites of organisms . . . there are keystone species that provide special environments for many other groups. There are also social organisms, such as ants, that form yet another pattern of organization. This means that the actual organization of an ecosystem is much more complex than the network model suggests. Indeed, the organization of a large city might be a better model than the systems models of textbooks, the links of which if very complicated look like a bowl of spaghetti. (Golley 1993, 203)

It is partly this complexity that has caused biologists generally to exclude human behavior from their models, and social scientists to remain largely at the level of metaphor.[2]

As the social sciences emerged as self-conscious disciplines in the nineteenth century, they struggled with the problem of how much human behavior should be attributed to our biological nature and how much to our social nature. Obviously, humanity shares characteristics with the animal kingdom, particularly the large nonhuman primates. At the same time, there is a sense of great difference. Causal priority seems to shift from one polarity to another. For some, human behavior is determined by genes, or anatomy, or chemistry. For others, human behavior is determined by norms, or moral values, or the mind, linguistic constructs, demography, or God's grand design. Human ecology is particularly at risk in such discussions, as it attempts to account for environmental variables and biological predispositions, and to merge these with social variables unique to humans such as symbolic language, elaborate normative systems, values, and meanings.

P. A. Sorokin, in criticizing the application of organismic analogies to human society, captured the reality of social science attempts to include the biological domain. He noted that

> sociology has to be based on biology; that the principles of biology are to be taken into consideration in an interpretation of social phenomena; that human society is not entirely an artificial creation; and that it represents a kind of a living unity different from a mere sum of the isolated individuals. These principles could scarcely be questioned. They are valid. (Sorokin 1928, 207)

He went on to critique organicist, biosocial, geographic determinist, and demographic approaches to explaining human behavior and the patterns and processes of human society. To Sorokin, all such explanations suffered from too much dependence on analogy and too strong a desire for single causes. Yet, each of the mainstream theories critiqued by Sorokin, and those that have emerged since, have had to find some rationale for attributing, incorporating, excluding, or compartmentalizing the priorities of environment, biology, and human culture. Each theory must assume that the observed regularities in human social life have an explanation.

Mainstream social theories have tended to cluster around certain biophysical and environmental determinants as key. For example, the structure of a society and its processes of stability and change have long been attributed to "carrying capacity" levels as population presses against resource constraints (Catton 1982; Durkheim 1933; Sumner and Keller 1927). Or, the structures and processes may be attributed to spatial differences in resource "meanings" (Hawley 1950, 1986; Park and Burgess 1921). Or, the ecological processes and environmental conditions may be considered as aspects of symbolic systems (Firey 1960; Wirth 1928). Or, the variety of human organizational patterns and processes may be seen as shaped by environmental variation (Duncan 1964; Selznick 1966). Or, societal patterns and processes are mediated by adaptive technologies, for which the cultural elements exhibit a poor or better ability to accommodate to the technological modifiers (Cottrell 1955; Ogburn 1950). Or, the structure of political power may determine (Marx 1972), and in turn, be shaped (Weber 1968; West 1982) by characteristics of natural resources.

Our point is twofold. The first is that, contrary to contemporary commentary such as Dunlap and Catton (1994), environmental sociology is neither a recent product of sociologists nor distinct from mainstream social theory. The second is to remind the reader that, either explicitly or implicitly, traditional mainstream social theory must make an accommodation to the dilemma of reconciling social and biological facts in understanding our species. An ecology that includes humans is like other zoological studies in that it begins with the biological and environmental conditions of the observed species (Udry 1995), rather than a determined assertion as to how little such factors matter in explaining the observed behavioral patterns. Indeed, our goal is movement toward a unified theory of ecology (Allen and Hoekstra 1992) that ultimately can account for the ecologies of all life-forms. And, a critical starting point is the ecosystem concept.

The Roots of Human Ecology and the Human Ecosystem

The ecosystem was defined formally by Sir Arthur Tansley in 1935,[3] and brought into common application by E. P. Odum's use of the ecosystem as an organizing concept in his 1953 text, *Fundamentals of Ecology*. Several contemporary histories of the ecosystem idea have been published, notably J. Hagen's *An Entangled Bank: The Origins of Ecosystem Ecology* (1992) and Golley's *A History of the Ecosystem Concept in Ecology* (1993). Both limit their discussions to the rise of a biological ecology that excludes *Homo sapiens*.

The roots of a human ecology lie primarily in general ecology, sociology, and anthropology, as documented by comprehensive literature reviews (Field and Burch 1988; Micklin 1977) and texts (Hawley 1950, 1986). The application of general ecological principles to human activity was sparked by sociologists at the University of Chicago in the 1920s and 1930s. Sociologists R. E. Park and E. W. Burgess (1921) drew analogies between human and nonhuman communities, describing society's symbiotic and competitive relationships as an organic web (Faris 1967). Simultaneously, anthropologists such as J. H. Steward (1955), J. W. Bennett (1976), and others began to employ the ecosystem as a tool for organizing fieldwork and research. While the Chicago "school" treated the community (and, for them, that meant the city) as a key unit of analysis, the limited focus on spatial relationships and urban life eventually led to a search for a more holistic framework.

That search (active in the 1950s and 1960s) led to the POET model. This model defined the human ecosystem as the interaction between *population*, *organization*, and *technology* in response to the *environment* (Catton 1982; Duncan 1964). These were to be human ecology's "master variables"; their interaction the human ecologist's central concern. A derivative IPAT model (Dietz and Rosa 1994; Erlich and Erlich 1970) modified the interactions to estimate *environmental impacts* as a function of *population, affluence,* and *technology,* rather than describe human ecosystems.

In the 1980s and early 1990s, anthropologists such as E. F. Moran (1990), sociologists such as W. R. Burch Jr. and his colleagues and students (Burch and DeLuca 1984), and ecologists such as H. T. Odum (1983) and E. P. Odum (1993) employed the human ecosystem as a theoretical framework. It was applied to archeological research (Butzer 1990), energy policy (Burch and DeLuca 1984), threats to national parks (Machlis and Tichnell 1985), and anthropogenic impacts on biodiversity (Machlis 1992).

The Human Ecosystem Defined and Described

In this article, the *human ecosystem* is defined as a coherent system of biophysical and social factors capable of adaptation and sustainability over time. For example, a rural community can be considered a human ecosystem if it exhibits boundaries, resource flows, social structures, and dynamic continuity. Human ecosystems can be described at several spatial scales, and these scales are hierarchically linked. Hence, a family unit, community, county, region, nation, even the planet, can fruitfully be treated as a human ecosystem.

While the scale of human ecosystems can vary, there are several essential elements. Figure 1 outlines these elements in a basic model of a human ecosystem. A set of *critical resources* is required in order to provide the system with necessary supplies. These resources are of three kinds: (1) natural resources (such as energy, fauna, wood, or water), (2) socioeconomic resources (such as labor or capital), and (3) cultural resources (such as myths and beliefs). These resources keep the human ecosystem functioning; their flow and distribution are critical to sustainability. Some critical resources may be indigenous to the local area (and used locally or exported), others may be imported from adjacent or faraway locales. For example, urban sources of investment capital and national media sources of information are integral parts of rural human ecosystems, as are other distantly produced, but critical, supplies.

The flow and use of these critical resources is regulated by the *social system,* the set of general social structures that guide much of human behavior. The social system is composed of three subsystems. The first subsystem is a set of *social institutions,* defined as collective solutions to universal social challenges or needs. For example, the collective challenge of maintaining human health leads to medical institutions, which can range from traditional shamans to modern hospital systems, rural health cooperatives, and preventive care. Other social institutions deal with universal challenges such as justice (law), faith (religion), and sustenance (agriculture and resource management).

The second subsystem is a series of *social cycles,* which are the temporal patterns for allocating human activity. Time is both a fixed resource as well as a key organizing tool for human behavior. Some cycles may be physiological (such as diurnal patterns); others institutional (permitted hunting seasons). Still others may be specific to the individual (such as graveyard shifts) or environment (such as climate change). Social cycles significantly influence the distribution of critical resources. An example is the set of collective rhythms within a community or culture that organize its calendar, festivals, harvests, fishing seasons, business days, and so forth.

The third subsystem is the *social order,* which is a set of cultural patterns for organizing interaction among people and groups. The social order includes three key mechanisms for ordering behavior: personal identities (such as age or gender), norms (rules for

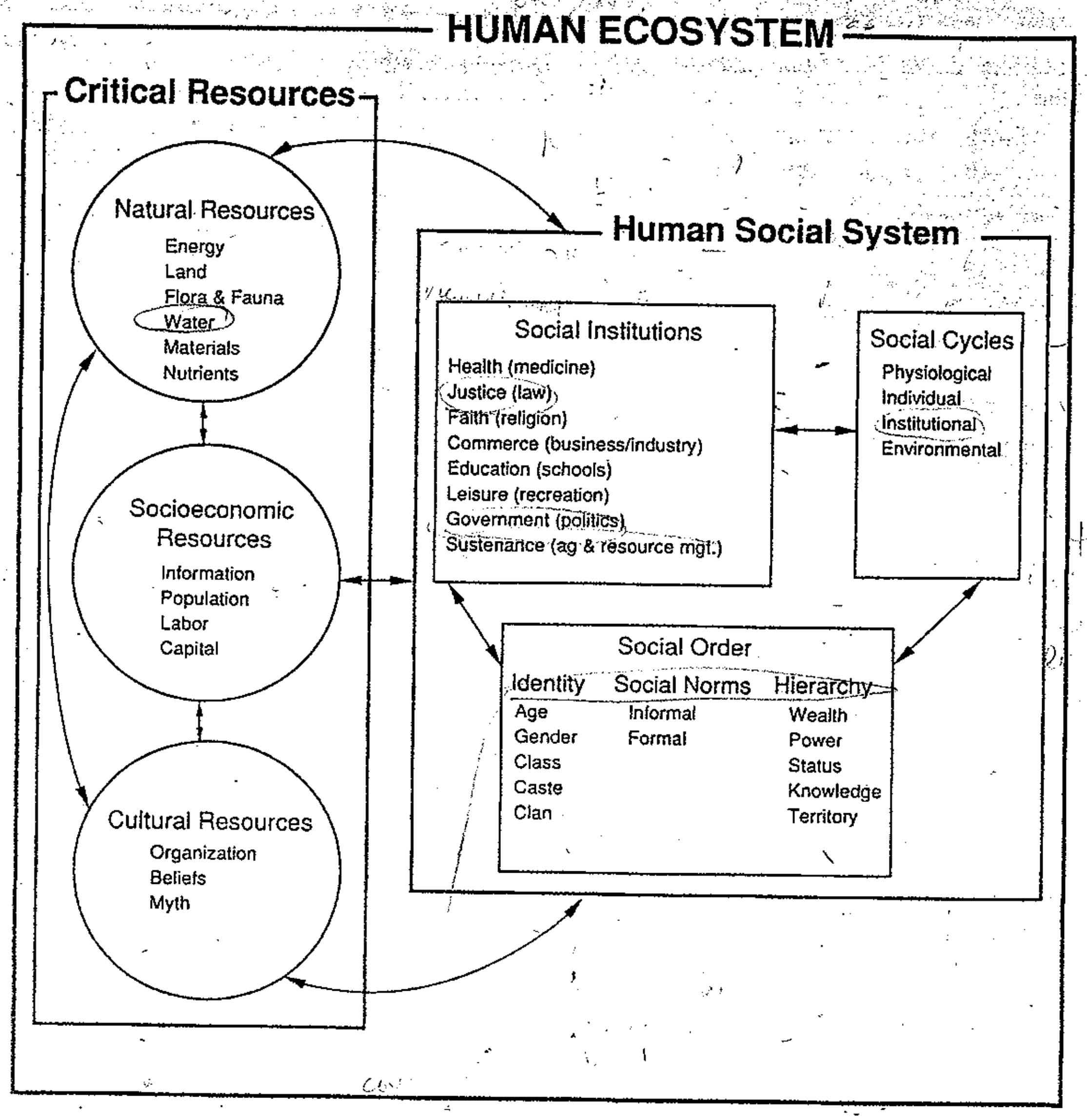

Figure 1. Working model of the human ecosystem.

behaving), and hierarchies (for example, of wealth or power). Hence, certain predictions about interaction are created when one can identify the age, gender, status, and power of individuals or groups, and such expectations allow the social system to function.

The social order (individually, collectively, and in relationship to social institutions and social cycles) provides high predictability in much of human behavior. Taken together, social institutions, social cycles, and the social order constitute the social system. Combined with the flow of critical resources, this creates the human ecosystem. Each of these elements substantially influences the others. For example, changes in the flow of energy (such as an embargo and resultant rationing) may alter hierarchies of power (those with fuel get more) and norms for behavior (such as informal sanctions against wasting fuel).

Adaptation is continuous in human ecosystems (Bennett 1976); social institutions adapt to changes in resource flows, and in turn, alter such flows. The result is a perpetually dynamic system. For example, political institutions may adapt to the increased demands on forest resources by altering decision-making processes (such as increased public participation) and the resource flow (as when the legal system issues injunctions against timber cutting). Adaptation is used here in a nonvalued sense; what is adaptive (or advantageous) for one institution or social group may be maladaptive (or harmful) for another (Bennett 1976, 1993).

Finally, a particular human ecosystem may be hierarchically nested within human ecosystems at different scales. Hence, the rural community as a human ecosystem may be linked to a larger watershed, region, and state, and to smaller human ecosystems such as clans or households. Changes in a human ecosystem at one scale may have effects at larger and smaller scales. For example, a rise in rural unemployment may impact family health conditions, increase demands on community doctors, and deplete state medical funds.

This human ecosystem model provides an organizing framework for ecosystem management. Each of its key components is discussed below.

Key Components in the Human Ecosystem

In this section, we identify and describe the key components in human ecosystems as shown in Figure 1. For each component or variable, we (1) provide a general definition and description, (2) suggest ways the variable can be measured, and (3) give selected examples of how it may influence other components of the human ecosystem.

Natural Resources

Energy. Energy is the ability to do work or create heat. Energy is a critical natural resource and its influence on social systems is well documented (see, for example, Rosa et al. 1988). As Cottrell (1955) noted, the energy available to humans "limits what we can do, and influences what we will do." Energy flows vary by type of source (hydroelectricity, petroleum, natural gas, solar, nuclear, wood, and so forth) as well as quality (high or low entropy) and flow (continuous, cyclical, or interruptible). An important element is the locus and scale of control (external or internal, local or global, multinational or household). Energy can be measured by heat output (kcal) or economic value ($/kcal). Changes in energy flows can dramatically alter social cycles and the social order (witness the North American oil shortages in 1973 and 1979), and can force social institutions (such as the recreation industry or agriculture) to make significant adaptations.

Land. Land includes both terrestrial surface, subsoil, and underground features. Land is a critical resource for both its economic and cultural value (Zelinsky 1973). It can be characterized by ownership patterns (public or private), cover (vegetation or plant community types), use (such as agricultural, forestry, urban), and economic value. Changes in land use often can be measured in hectares/land cover–land use type. Such changes often follow restricted and predictable trajectories, as forested land is altered to agricultural and then urban uses (Turner et al. 1990). Land ownership powerfully influences many social institutions (sustenance and commerce are examples), and changes in land use often are reflected in altered hierarchies of wealth, power, and territory through shifts in land tenure and property rights. social order hierarchy

Water. Water includes surface, subsurface, and marine supplies. Groundwater (quickly renewed) and aquifers (a form of capital stock not easily renewable) both can be integrated into human ecosystems. Water resources can be characterized by quality, flow (acre-feet/second), distribution patterns, and cyclical trends (such as wet years or drought periods). The control and distribution of water is a major source of economic, social, and political power (Reisner 1986). Changes in water quality can impact social institutions such as health and commerce; water rights are crucial to maintaining social order, while access to water influences wealth.

Materials. Materials include basic products largely derived from natural resources. Examples include fertilizers (petroleum as a source), dimension lumber (wood), silver and other minerals (ore), plastic (oil), and glass, concrete, cocaine, and denim. The variety of materials used by human ecosystems varies by culture, stage of economic development, and consumption patterns. Common measures include economic value/unit and the flow of raw product (by ton, pound, ounce, or milligram). Much of the sustenance and commerce institutions are based on the production, distribution, and exchange of materials. When flows are altered, norms for use can be impacted (conservation incentives increase with price), and certain materials may be critical for specific institutions such as precious gems for industrial use or coca paste for the illegal drug trade (Morales 1989).

Nutrients. Nutrients include the full range of food sources used by a human population. The range of tolerance for nutrient gain or loss is relatively small in *Homo sapiens* (Clapham 1981), making food a critical resource on a continuous basis. Such resources may vary by culture (religious proscriptions may make certain foodstuffs inedible) as well as climate, and both the caloric value and nutritional supplies (such as amino acids) are critical. Modern human ecosystems include a wide range of imported foods (witness espresso coffee beans from Brazil being brewed in Montana gas stations), and few are self-reliant even for short, seasonal periods. The need for food resources certainly influences sustenance institutions such as agriculture. Food carries mythic connotations (the spiritual value of salmon to several indigenous tribes in the Northwest; the turkey as a celebratory poultry). Hence, changes in nutrient flows can alter human health, social norms, and cultural beliefs.

Flora and fauna. Flora and fauna are critical resources beyond their function as nutrient and material sources; a wide range of flora have ecological, sociocultural, and economic value. Plants are vital sources of pharmacopeia (Wilson 1992), myth (the cedars of Lebanon and the redwoods of California are examples), and status (the American lawn; see Bormann et al. 1993). Fauna, including domesticated livestock, pets, feral animals, and wildlife, have significant economic value through activities as wide-ranging as hunting, bird-watching, pet keeping, and in some cultures the production of aphrodisiacs. Flora and fauna can be valued biologically (such as species richness, number of endemic species, population size, genetic diversity), economically (dollar value per bushel, board foot, pelt, head, horn, or hoof), or culturally (proportion of citizens interested in preserving a species). Changes in flora and fauna, such as the threat of extinction or overpopulation, can lead to changes in nutrient supplies, myth, law, sustenance (particularly, wildlife management and farming practices), and social norms toward the natural world.

Socioeconomic Resources

Information. Information is a necessary supply for any biophysical or social system. Information flow (and its potential for feedback) is central to general systems theory (von Bertalanffy 1968), sociobiology (Wilson 1975, 1978), and human ecology (Burch and DeLuca 1984; Hawley 1950). Information may be coded and transmitted in numerous ways: genes, "body language," oral traditions, electronic (digital data), print (local weeklies, national dailies, news magazines), film, radio, and television. It can be measured by both transmission rates (such as amount of local radio programming) and consumption patterns (such as newspaper circulation rates). Information flow can significantly alter numerous components of social systems such as educational institutions or hierarchies of knowledge. Its impact on other critical resources is also substantial (for example, the importance of maps in land management).

Population. Population includes both the number of individuals and the number of social groups and cohorts within a social system. Population as a socioeconomic resource includes the consumption impacts of people, as well as their creative actions (accreting knowledge, engaging in sexual behavior, providing labor, and so forth). Human population growth is a dominant factor influencing much of human ecology (Hawley 1986) and social systems (Durkheim 1933), both historically (Turner et al. 1990) and within contemporary nation-states, regions, and cities. Growth can be measured by natural increases (births over deaths/year) as well as migration flows. While population can act as an ecosystem stressor, it also is a supply source for many critical components within human ecosystems such as labor, information (including genetic code), and social institutions (Geertz 1963).

Labor. Labor has many definitions; in the human ecosystem model, it is defined as the individual's capacity for work (economists sometimes label this as labor power; Thompson 1983). Applied to raw materials and machinery, labor can create commodities and is a critical socioeconomic resource. There are many measures: labor time needed to create a unit of economic value (hrs/$100 value), labor value (measured in real wages), labor output (units of production per worker or hour labor), or surplus labor capacity (unemployment rates) are examples. Labor is critical to human ecosystems both for its energy and information content; that is, both relatively unskilled yet physically demanding labor (such as harvesting crops) and specialized, sedentary skills (such as resource planning or stockbroking) have economic and sociocultural importance. Changes in labor (such as increased unemployment) can impact a variety of social institutions and hierarchies from health care to income distribution.

Capital. Capital can have a range of meanings. A narrow definition treats capital as the "durable physical goods produced in the economic system to be used for the production of other goods and services" (Eckaus 1972). Other definitions include "human capital," financial capital, and so forth (McConnell 1975). In the human ecosystem model, capital is defined as the economic instruments of production; that is, financial resources (money or credit supply), technological tools (machinery), and resource values (such as underground oil). Hence, technology, a critical variable in the POET model, is considered a form of capital available for application in the human ecosystem. These instruments of production provide the basic materials for producing (with labor inputs) commodities. Capital is a critical socioeconomic resource; its influence over production, consumption, transformation of natural resources, and creation of by-products (such as pollution) is significant. Capital often is measured in dollar values, either for commodities produced or the stock of capital on hand. Changes in capital, either in its mix of sources (a new processing plant or mill) or output (a reduction in profits earned by the plant or mill), can alter social institutions as well as hierarchies of wealth, class identities, and other features of the human social system.

Cultural Resources

Organization. In the human ecosystem model, organization is treated as a cultural resource, for it provides the structural flexibility needed to create and sustain human social systems. That is, the special ability of our species to create numerous and complex organizational forms is a necessary skill in interacting with nature and society (Wilson 1978). It is a cultural resource because there is demonstrated wide variation among cultures in how these generic organizing skills are employed. For example, citizens of the United States are willing to create, continually and often, new organizations to deal with collective issues: building a water supply system (irrigation districts), managing education (school boards), caring for the poor (welfare societies), and so forth. Organization can be measured by its diversity (the range of organizational types), intensity (the number of organizations), or saturation (the percentage of the population that claims membership). Organization is critical to natural resource management; ecosystem management itself is an experiment in new ways of organizing the relations between human and nonhuman domains.

Beliefs. Beliefs are statements about reality that are accepted by an individual as true (Boudon and Bourricaud 1989; Theodorson and Theodorson 1969); citizens may have the belief that forests are being overcut, that water quality is low, or that certain salmon stocks may not be endangered. (Beliefs differ from values, which are opinions about the desirability of a condition.) Beliefs arise from many sources: personal observation, mass media, tradition, ideologies, testimony of others, faith, logic, and science. Beliefs are crucial to human ecosystem functioning, for they supply a set of "social facts" (Durkheim 1938) that individuals, social groups, and organizations use in interacting with the world. Hence, environmental interest groups and industry associations rely on a public set of beliefs concerning environmental crises (which may or may not be factual) to energize and increase their membership. Beliefs can be measured by their ideological content (liberal or conservative), intensity (the proportion of a population that feels strongly about a belief), and public acceptance (the proportion of a population that shares a similar belief). As beliefs change, social institutions often are forced to respond. For example, the changing public beliefs concerning the safety of nuclear power has led to a decline in nuclear power production in the United States (Dunlap et al. 1993).

Myths. To the human ecologist, myths are narrative accounts of the sacred in a society; they legitimate social arrangements (Malinowski 1948) and explain collective experiences (Burch 1971). Hence, myths are an important supply variable because they provide reasons and purposes for human action. Myths are critical to human ecosystems as guides to appropriate and predictable behavior (witness Smokey Bear's admonitions about fire); they give meaning to and rationale for a wide range of social institutions and social ordering mechanisms. For example, the myth of "manifest destiny" provided U.S. citizens at the turn of the century with a rationale for the permanent and private development of the American West; indigenous tribal groups simultaneously called on traditional myths to legitimate their role as temporary stewards of communal land (Worster 1992). Myths operate at various scales: national myths (such as the manifest destiny), community myths (a timber town's story of how and why it was founded), and clan myths (a family's story of its early matriarchs). Myths are difficult, but not impossible, to measure: festivals, symbols, and legends all are indicators of myth supply. A change in myth (such as reduced perception of community self-reliance) can impact social institutions (such as faith) and a variety of social norms as well as resource use (such as wilderness).

Social Institutions → soluciones colectivas para necesidades o desafíos universales

Health (medicine). The health care institution encompasses the full range of organizations and activities that deal with the health needs of a human ecosystem. Health care in modern industrial societies is relatively complex, including primary care (personal and family health maintenance, outpatient activities by general practitioners), secondary care (such as services of specialists), and tertiary care (such as hospital procedures involving surgery [Rodwin 1984]). Health care institutions often are measured by capacity (the number of doctors or hospitals per 1,000 population) or outcomes (such as infant mortality rates). In rural communities, primary care often is available locally; secondary and tertiary care often are provided on a regional basis. Hence, relatively small changes in the health institution (a doctor's retirement, the closing of a pharmacy) may have direct and indirect effects that ripple through the social system.

Justice (law). The collective problem of justice faces all human social systems; its role in human ecosystems is critical. Two forms are central: distributive justice (who should get what, such as property rights [Rawls 1971]) and corrective justice (how formal norms should be enforced, such as rules for punishment [Runciman 1966]). The legal system can be measured both by its practitioners (such as the number of lawyers or judges/1,000 population) and its performance (number of trials or convictions). The contemporary legal system plays an important role in ecosystem management—the courts influencing distributive justice through timber sale appeals and injunctions, and meting punishment for resource crimes (such as poaching). Changes in legal institutions, such as new procedures for appeal or new laws (the revision of the Endangered Species Act is an example) can dramatically and directly impact the use of natural resources, the development of capital, and other components of the human ecosystem.

Faith (religion). To the human ecologist, religion as an institution has two components: (1) its social function as a system of organizations and rituals that bind people together into social groups (Durkheim 1938) and (2) a coherent system of beliefs and myths (Weber 1930). Both are critical to human ecosystem functioning. Religion, like other social institutions, can be measured by diversity (range of religious practices), capacity (number of churches), or participation (percentage of the population claiming membership). Religion impacts the social system in many ways, altering social cycles (religious holidays), providing identity for both caste and clan, and influencing beliefs and myths. A change in faith (such as increased demands after a natural disaster) can have significant bearing on how effectively social systems will adapt to new ecological and socioeconomic conditions.

Commerce (business and industry). All societies require a system for exchanging goods and services, and the institution of commerce is central to this exchange (Durkheim 1933). Commerce includes not only the exchange medium, but the organizations that manage exchange such as banks, markets, warehouses, and retail outlets. Modern industrialized societies (including their rural regions) rely on a mix of exchange styles; the typical U.S. rural community usually conducts its commerce through a mix of cash, credit, and barter (Machlis and Burch 1983). Commerce can be measured as capacity (such as the percentage of production capacity utilized, or the number of banks) or as a flow (the number of transactions, or the dollar value of a gross regional or local product). Commerce in rural areas, particularly in the West, is largely dependent on local natural resources (be it water, energy, timber, scenic or other values [West 1982]). A change in commerce can create a cascading set of impacts on other social institutions (such as sustenance), the social order (shifts in wealth or power), social cycles (as in a recession), and critical resources (such as land or labor).

Education (schools). Individual *Homo sapiens* are born into the world sorely lacking in the knowledge needed to survive, adapt, and interact with others. Hence, education (the transmission of knowledge) is a ubiquitous collective challenge: We must educate our young. While significant learning takes place in the home and on