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Conceptual Approaches to Human Ecology

by A. Terry Rambo

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ABSTRACT

A number of very different conceptual approaches have been employed in human ecology. This report reviews several of the most important analytic frameworks: environmental determinism and possibilism, cultural ecology, the ecosystem-based model, and the actor-based model. The contributions made by each conceptual approach to increasing understanding of human ecology are described, and their strengths and weaknesses are assessed. Finally, an alternative conceptual approach—the systems model of human ecology—is proposed. In this interactive model, the human social system is seen as being linked to its ecosystem through the interchange of energy, materials, and information.

INTRODUCTION

Human ecology, most broadly defined as the study of human interactions with the environment, has in recent years gained greatly increased attention in all of the social sciences. Despite this, there appears to be little consensus as to what human ecology actually is or should be. In particular, there is continuing vigorous discussion about the suitability of applying several different theoretical approaches in understanding human-environment interactions.

While such diversity of viewpoints within a scientific discipline may indicate youthful vigor, it also can present the nonspecialist with severe obstacles to gaining an understanding of the overall form and direction of the field of study. This problem is made even more acute by the often polemic character of programmatic statements regarding the nature of human ecology. Many writ-

ers approach theoretical discussions as if they are dealing with theology, advocating their own models as the only true and correct ones while dismissing other conceptual approaches as archaic, wrong-headed, or even immoral. Such out-of-hand dismissal may on occasion be deserved but also tends to obscure the existence of legitimate alternative conceptual approaches.

In this report, alternative conceptual models of human relations with the environment are described in the historical order in which they have appeared in the scientific literature. Such a chronological approach helps to illustrate the interplay between research results and the formulation of new theoretical concepts. No superiority is imputed to more recently developed paradigms. In fact, certain currently popular models may be viewed as regressive from the standpoint of the development of social science theory as a whole.

Although largely discredited among social scientists, classical and early modern theories of environmental influence on human affairs (determinism and possibilism) are often employed by historians. Most notable of such historians is Arnold J. Toynbee, who advocates a possibilist stance in his influential *A Study of History.*

The model of cultural ecology proposed by Julian Steward is still the guiding paradigm for many investigators, but in recent years it has been challenged by the ecosystem-based model first proposed by Andrew P. Vayda and Roy A. Rappaport.

The individual decision-making characteristic is the focus of actor-based models of human ecology, and the systems model of human ecology stresses investigation of interactions between human social systems and ecosystems based on their reciprocal exchange of energy, materials, and information.

THE ORIGINS OF HUMAN ECOLOGY

Since ancient times there have been many attempts to explain events in terms of environmental influences on human behavior. Astrology represents one early system of thought relating environmental forces to human actions. Although wholly discredited as a scientific theory by modern astronomy, the belief that the movement of the stars controls human destiny retains a strong hold on the popular imagination, as evidenced by the appearance of astrological advice columns in many daily newspapers.

In a vein more compatible with modern scientific thought, the ancient Greek philosophers recognized that man was both influenced by nature and a force for change in the environment. It was suggested, for example, that the different forms of political organization of the Greek city states and the Eastern empires reflected the influences of climate on the personalities of their citizens. This theme later was developed by Montesquieu and other French writers of the Enlightenment and advocated in recent times by the American geographer Samuel Huntington. Other classical writers commented on the destruction of the natural landscape of Attica and North Africa resulting from deforestation and overgrazing, a theme taken up in the mid-1800s by George P. Marsh, whose book, *Man and Nature, or, Physical Geography as Modified by Human Action* was a precursor of the ecological catastrophe writings so popular recently. These early writings, however, were generally anecdotal rather than presenting a coherent theory of human-environment relationships. It was only with the development of geography and anthropology as scientific disciplines in the latter part of the nineteenth century that human ecology became the subject of systematic study. The first theoretical approach to be tried, however, was that of environmental determinism—a false start that greatly retarded subsequent development of human ecology.

ENVIRONMENTAL DETERMINISM

Around the turn of the century, geographers, notably Friedrich Ratzel in Germany and his American disciple, Ellen C. Semple, espoused the view that humans were completely the product of their environment, a theory that came to be called environmental determinism. Followers of this school, which dominated geographical thought well into the 1920s, asserted that all aspects of human culture and behavior were caused directly by environmental influences (Figure 1). For example, the British were a nation of seafarers *because* they were an island-dwelling race surrounded by seas; the Arabs were monotheistic Muslims *because* living in the vast empty desert turned their minds toward a single God; the Eskimos were primitive nomads *because* the harsh conditions of their arctic habitat forbade their development into a complex civilization. The books of Semple and others were filled with endless listings of seemingly plausible environmental determinants of cultural forms.

Although seductive when first encountered, such claims of causal correlation between environment and culture were easily refuted once given careful consideration. For example, the Tasmanians, who lived on an island not unlike the one inhabited by the English, made no ships; the Arab tribes who had wandered that vast lonely desert for thousands of years before the appearance of Muhammad were believers in a large pantheon of spirits; and the icy wastes once traversed by Eskimo dog sleds are now the scene of snowmobile races alongside giant oil pipelines. There is simply too much variation in human behavior in seemingly similar geographical settings for it to be environmentally determined.

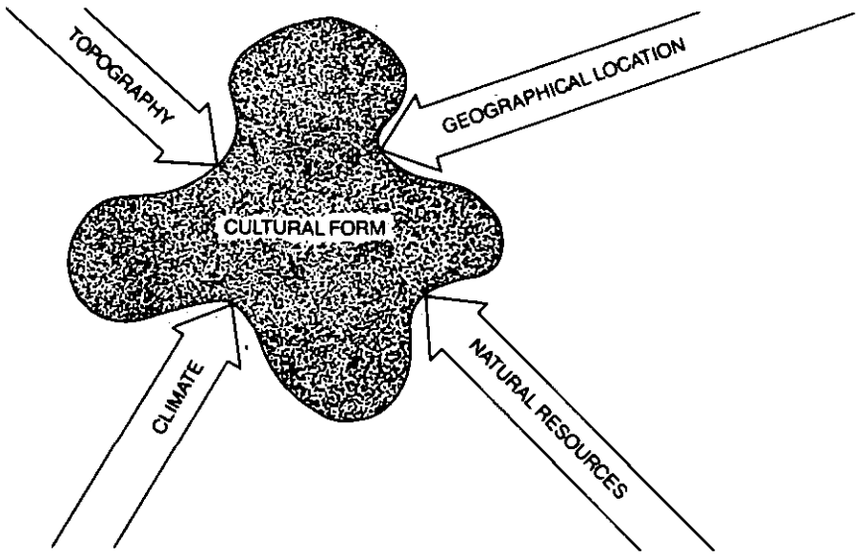

Figure 1. The model of environmental determinism.

ENVIRONMENTAL POSSIBILISM

In place of the discredited determinism, a new theory, called environmental possibilism, was proposed. Its proponents asserted that while the environment did not directly cause specific cultural developments, the presence or absence of specific environmental factors placed limits on such developments by either permitting or forbidding their occurrence (Figure 2). Thus, island peoples could be seafarers, but residents of Inner Mongolia could not be; inhabitants of temperate regions might practice agriculture, but those living in arctic latitudes could not. The value of the possibilist approach was perhaps best demonstrated by the American anthropologist A. L. Kroeber, who showed that the Indians of northwestern North America could not adopt maize agriculture from their southern neighbors because the frost-free growing season in their region was shorter than the four months required for the maize plants to reach maturity. Their environment thus limited the ability of their culture to evolve in an agricultural direction.

A possibilist stance was also taken by the British historian Arnold Toynbee in his multivolumed *A Study of History* (1947), in which he argued that the development of civilizations could be explained in terms of their responses to environmental challenges. Cultures located in the benign tropics failed to evolve because they were not sufficiently challenged by their environment;

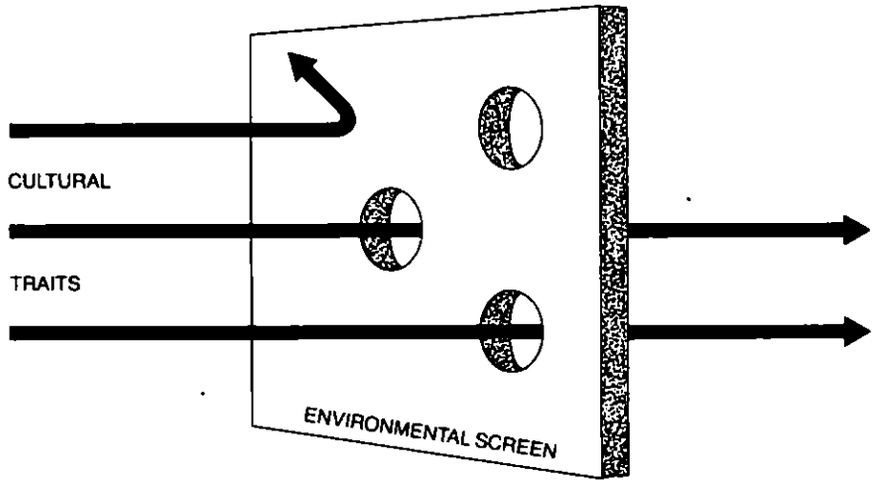

Figure 2. The model of environmental possibilism.

those in extremely harsh habitats such as the Eskimos in the arctic remained forever primitive because simply coping with the demands of their environment sapped all of their creative energies. Only those cultures in environments offering sufficient but not excessive challenges had the possibility of progressing to higher stages of civilization.

Possibilism suffers from one overriding defect as a scientific theory; it lacks any general predictive or explanatory power since it is able to explain only why certain developments could not occur in certain environments. It is totally unable to predict whether or not they would occur under favorable circumstances. For example, the failure of Eskimos to grow corn is explainable, but possibilism cannot explain why the English were great seafarers while the Tasmanians were not. Clearly, the difference in the latter case was due to existence of very different cultural traditions and bodies of technological knowledge rather than reflecting environmental influences. In short, as the British anthropologist Daryll Forde concluded in his book, *Habitat, Economy and Society* (1934), which was perhaps the last major scientific exploration of possibilism, "between the physical environment and human activity there is always a middle term, a collection of specific objectives and values, a body of knowledge and belief: in other words, a cultural pattern."

With this realization, social scientists tended to turn from studying human interactions with the environment, preferring instead to focus on the seemingly more profitable study of the internal structure and functioning of cultural and social systems. Following the French sociologist Emile Durkheim's injunction that "social facts" could be explained only in terms of other social facts, cultural development was explained by the concept of diffusionism—the

historical spread of traits from one culture to others, without reference being made to possible environmental influences on the process. It was not until the 1950s that social scientists, acting under the influences of Julian Steward's concept of cultural ecology, again turned serious attention to the study of human interactions with the environment.

THE CONCEPT OF CULTURAL ECOLOGY

Although his first papers on the subject were published in the early 1930s, it was not until the mid-1950s that Julian Steward's concept of cultural ecology began to exert a significant influence in American anthropology. Although he was trained in the diffusionist school, Steward's experience of field work among the Shoshone hunters and gatherers in the Great Basin of North America *had led him* to recognize that ecological adaptation had played at least as significant a role as diffusion in the formation of Shoshone culture. Drawing on the theoretical methods that biological ecologists were then developing to study the adaptation of animal species, in particular relating specific organs to specific features of the environment, Steward attempted to explain certain structural aspects of Shoshone culture in terms of the resources available in the impoverished semidesert habitat. In what is still one of the finest ethnographies ever published, Steward (1938) made a convincing case that the low density of the Shoshone population, its organization into small family bands with highly dispersed and flexible residence patterns and lack of territoriality, and the lack of powerful permanent leaders all reflected the inability of Shoshone technology to extract a large and stable supply of food from the thinly scattered and sporadically available resources of the arid environment.

It was Steward's view that not all aspects of Shoshone culture could be explained in ecological terms—many traits were present as simply the accidental result of diffusion from neighboring tribes—but that only some elements, which he labeled as "the cultural core," had adaptive significance. In particular, he thought technology, economics, population, and social organization were likely to be part of the core, although he insisted that it was necessary to demonstrate this empirically in each case. He tended to give special emphasis to the relationship between technology and the environment in his model of cultural ecology (Figure 3).*

*It is interesting to note that E. E. Evans-Pritchard, a leading British social anthropologist, suggested a similar ecological approach at almost the same time as Steward although neither man appears to have been influenced by the other's work. Pritchard (1940) related the settlement pattern of the Nuer pastorialists of the Sudan to seasonal changes in resource availability. Despite the acclaim that his monograph met from his colleagues, Pritchard's ecological approach was not emulated by them and British social anthropologists were not to become involved again in human ecology research until much later than the Americans.

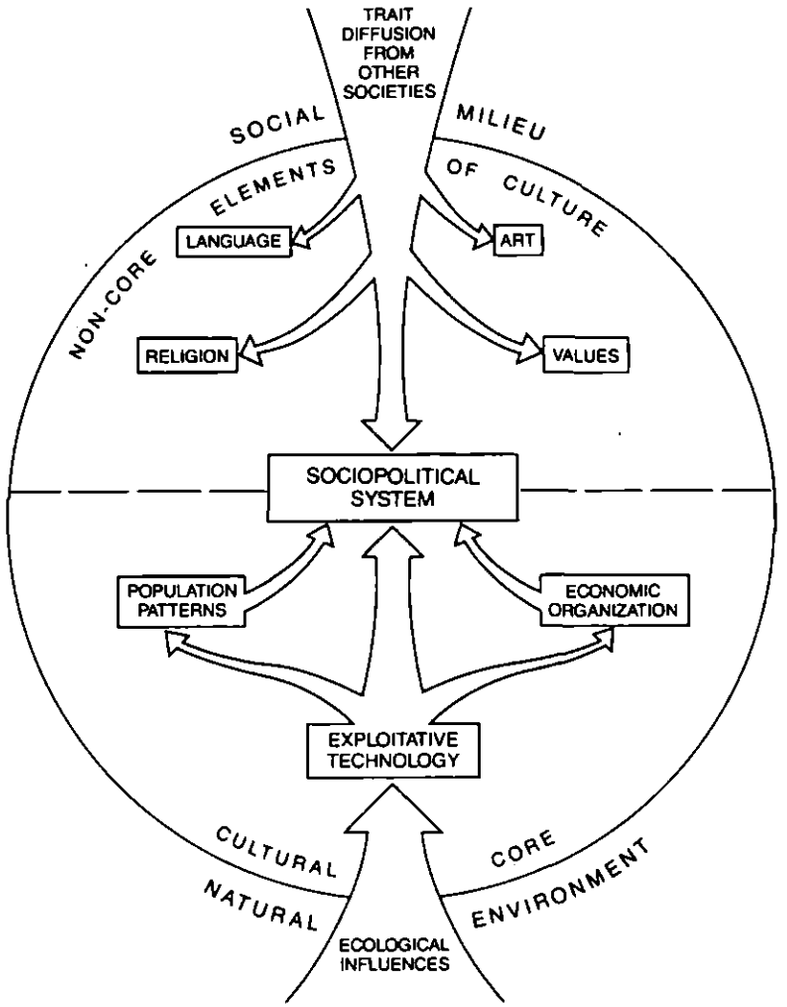

Figure 3. The model of cultural ecology.

The American anthropologist Clifford Geertz (1968) has applied Steward's concept of cultural ecology to explaining the great demographic disparity that exists between Java and the outer islands of Indonesia. Java is one of the most densely populated regions in the world, with an average density of 480 persons per square kilometer (km²) but with more than 2,000 persons/km² in some parts of the island. In marked contrast, most of the outer islands (e.g., Sumatra, Kalimantan, Timor) are characterized by densities of less than 25 persons/km². Geertz has suggested that these various population densities reflect

the differing agricultural adaptations employed in the two regions, which in turn relate to their differing environments (Table 1).

The topography of Java is one of relatively young volcanic mountains surrounded by a series of gently sloping basins, which offer ideal conditions for construction of irrigated fields. The relief of the geologically older outer islands is generally low and irregular, offering few opportunities for development of large, gravity fed irrigation systems. The rivers there also tend to be slow moving, capable of carrying only light sediment loads. In Java, on the other hand, the rivers are short and fast moving, carrying large quantities of nutrient-rich sediments from the fertile young soils of the volcanic slopes down into the paddy fields.

In conformity with these environmental factors, Java is predominantly a region of *sawah* irrigated wet rice agriculture while *ladang* shifting cultivation is the principal technology employed in the outer islands. *Ladang*, or "swidden" agriculture as it is usually called by anthropologists, is a system in which the farmer cuts a plot of land in the forest, allows the vegetation to dry and then burns it before planting a crop. After one or, at most, two harvests, fertility is exhausted and the plot is abandoned and a new field is cleared in the forest. The abandoned plot is gradually reoccupied by forest vegetation, and after ten to fifty years it may again be cleared and farmed. Swiddening represents an effective adaptation to farming the impoverished soils of tropical rain forest areas where most of the available nutrients are stored in the vegetation. It gives high yields with relatively low human labor inputs since most of the work is done by the fire, which simultaneously clears the field, releases the stored nutrients back to the soil in the form of ashes where they are readily available to the growing crops, and kills off pests and weed seeds that would compete with the crops. The major limitation of swidden agriculture is that a large quantity of land is required to support each farmer. An individual farmer requires not only the plot currently under cultivation but also a reserve of forest land adequate for the needs of cultivation until the old plots are again ready for clearing. Swiddening can thus support only populations at densities of fewer than 200 persons/km². If population should increase, it is necessary to shorten the forest fallow cycle, causing rapid destruction of the productive capability of the land due to erosion and nutrient loss.

In contrast to the impermanence and instability of the *ladang* systems, *sawah* agriculture is noted for its stability and durability. Once an irrigated paddy field has been constructed it can be farmed year after year for centuries with little evident loss in productivity. This reflects the fact that it is the supply of water rather than the quality of soil that is the most important factor in growing wet rice. Moreover, the yield is strongly influenced by the amount of human labor put into working the crop—transplanting rather than sowing the seed by broadcasting, more careful and frequent weeding, and cleaning and maintenance of irrigation channels all contribute to a higher yield of rice per

Table 1. Comparison of the Cultural Ecology of Java and the Outer Islands of Indonesia

Region	Population Density	Surface Area Cultivated Each Year	Agricultural Technology	Labor Demand	System Stability	Environmental Characteristics
Java	480 persons/km²	70%	*sawah* irrigated rice	high	high	gently sloping relief
						fast-moving rivers carrying high sediment loads
						recent, nutrient-rich soils
Outer islands	24 persons/km²	4%	*ladang* shifting cultivation	low	low	low-lying, irregular relief
						slow-moving rivers carrying low sediment loads
						old, impoverished soils

hectare. Such a system may encourage population increase, since the more children the parents have, the more hands they have to help work their paddy field. Thus, the existence of these radically different systems of agriculture, reflecting different ecological conditions, may contribute to the demographic disparities between Java and the outer islands.

Steward's concept of cultural ecology has proved to be a powerful and effective strategy for human ecological research, offering new understanding of how traditional societies are effectively adapted to their environments. Its successes have been achieved primarily in studying small-scale, primitive societies, however, especially those where a stable relationship has been established between a static population and an unchanging environment. The concept has been much less applicable to complex modern societies where the actions of large human populations are producing rapid environmental change with consequent need for readaptation of the cultural core. As conceived by Steward and used by others, the cultural ecology model lacks any systematic conceptualization of the environment or of the ways in which human activities impinge on it. Thus, its emphasis is almost exclusively on the human side of the human-environment equation, focusing on the adaptation of culture to nature while ignoring environmental change in response to human intervention.

This fundamental weakness of the concept of cultural ecology is revealed in the work of Marvin Harris, an American anthropologist who has incorporated this approach into studies of what he refers to as "techno-environmental determinism." Operating under the assumption that the technological means of adaptation to the environment is the prime mover of cultural evolution, Harris asserts that the forms taken by all other aspects of culture are determined by the relationship between technology and the environment. In a widely cited paper, "The Cultural Ecology of India's Sacred Cattle" (1966), Harris argues that, contrary to the accepted view that Hindus keep excessive numbers of useless cattle because of their religious belief that cattle are sacred, these cows are actually extremely important to the economic welfare of the poor peasants, helping them to make maximum use of the scarce resources of their environment. Therefore, he concludes, the religious beliefs must have been caused by techno-environmental factors.

According to the conventional view, between one-third and one-half of the 80 million cows in India should be eliminated as economically wasteful animals. Because they are so badly nourished, not more than one cow in two yields any milk, and cattle wander freely around the landscape, damaging crops and interfering with traffic. In some areas cattle actually compete with humans for food, being kept in special bovine old-age care shelters until they die, since the Hindu concept of *ahimsa* that regards all life as sacred forbids their being slaughtered. Hence, it is commonly said that this is an example of

religious ideology interfering with the efficient ecological adaptation of a culture.

Harris claims, however, with some justification, that conventional analyses of the economics of Indian cattle have overlooked numerous benefits that the seemingly excess animals provide to the peasant population. First, he reminds the reader that cows are necessary to produce bullocks, which are the main draft animal on Indian farms. It is only by having large numbers of cows that the demand of the farmers for bullocks can be met. Second, cows yield a steady supply of dung, and cow dung is the main source of fuel for domestic cooking fires in much of South Asia. According to one estimate, the energy value of the 300 million tons of dung burned each year in India is equal to 35 million tons of coal. Much of the rest of the dung is used as manure in the fields. The hides salvaged from deceased cows also provide the basis of a large leather industry, which provides a livelihood for many lower-caste families.

Not only does Harris show that the cows provide many valuable economic benefits to the Indian peasants, he also argues that they do so at minimal cost to the human population. He claims that cows rarely compete directly with people for food since they are not fed grain or fodder grown on land that could otherwise grow food for human consumption, as is the case in Western countries. Instead, the cattle wander grazing freely on whatever grass they can find growing beside roads, around telephone poles, and between the ties on railroad tracks. They also are allowed to graze on the stubble left in grain fields after the harvest. In other words, the cows capture otherwise unutilized energy and nutrients in the environment and convert these into bullocks, milk, dung, and hides—all resources of great value to the peasants. Therefore, Harris concludes, far from the keeping of cows being caused by religious irrationality, the religious tabu on killing cattle exists as an expression of the ecological value of cattle to the Indian human population.

Harris' paper has been subject to severe criticism on empirical and theoretical grounds. It has been pointed out that he tends to overestimate the benefits that people derive from the cows while understating the costs of keeping such large herds. In particular, it has been claimed that 5 percent of the arable land in India is in fact used as pasture and for growing fodder to feed cattle, so these animals do in fact compete directly with humans for food. It has also been argued that a smaller number of better fed animals would provide the same or better level of services to the human population at less economic cost. On the theoretical side, it must be recognized that religious tabus on killing and consuming animals are not necessarily always as adaptive as Harris seems to think. Such practices may, for example, appear to be ecologically rational when they first evolve, as Harris has asserted to be the case with the Muslim prohibition on eating pork since pigs are poorly adapted to the arid environment characteristic of the Arabian peninsula. Once in existence, however, reli-

gious beliefs may take on a life of their own and can be diffused into new environments where they may appear less rational ecologically. Thus, Muslims in Indonesia and Malaysia are forbidden by their religion from eating pork although the pig is ecologically probably the most efficient meat-producing animal that can be raised in the Southeast Asian tropics. Pigs are so important as a source of protein, in Borneo the spread of Islam has been limited to those areas close to the coast where sufficient supplies of fish are available to provide a substitute for pork. Populations on the interior side of what has been called the "pig line" nutritionally *cannot afford* to become Muslims.

The greatest weakness in Harris' argument, however, is that in focusing on the benefits that individual Indian farmers derive from having large numbers of cows, he wholly ignores the destructive impact these animals have on the environment and the consequent lowering of the land's ability to support the total human population at acceptible levels. Overgrazing has stripped most of the upland areas of South Asia of vegetative cover, and the barren soil of the hill slopes has had its structure destroyed by the impact of the cow's hooves and is highly subject to erosion during the brief but intense monsoon rains. The rainwater, which was formerly trapped by tree roots and grasses and then gradually released providing irrigation water to farms on the plains below during the growing season, now pours down the slopes in sheets, carrying away the topsoil and causing great floods in the lowlands. That the environmental degradation in India caused by cows exacts a heavy price in human hunger is clearly shown by the results of an experimental reforestation program at Sukhomajri in the hills north of Chandigar. There, each upland hectare that has been replanted and protected *from grazing* now yields sufficient water to irrigate two hectares of good cropland in the plains during the dry season, more than doubling the supply of food available to the human population.

As the previous discussion of the limitations of the concept of cultural ecology indicates, research on human-environment relations needs a conceptual framework that pays adequate attention to the possibility of environmental change and degradation occurring as a consequence of human activities. Cultural adaptation cannot be seen as static, something that is achieved at the beginning of a culture's history and then maintained unchanging ever afterward. Instead, the relationship between humans and nature is a dynamic one in which both culture and the environment continue to adapt and readapt as each changes in response to the other's influence. It was recognition of the need for a more dynamic model of the environmental side of the relationship that led to formulation of the ecosystem-based model of human ecology.

THE ECOSYSTEM-BASED MODEL OF HUMAN ECOLOGY

Basing their approach on the concept of the ecological system that had been formulated by biological ecologists following World War II, American anthropologists Andrew Vayda and Roy Rappaport suggested that instead of studying how cultures are adapted to the environment attention should be focused on the relationship of specific human populations to specific ecosystems.* In their view, human beings constitute simply another population among the many populations of plant and animal species that interact with each other and with the nonliving components (climate, soil, water) of their local ecosystem. Thus the ecosystem, rather than the culture, constitutes the fundamental unit of analysis in their conceptual framework for human ecology (Figure 4). Cultural traits are of interest only as they can be shown to contribute to the population's survival in the context of the ecosystem.

Such a framework, however attractive it might seem for reintegrating human ecology into general ecological thinking, serves to stand anthropology on its head by emphasizing the biological survival of populations rather than the persistence of the sociocultural systems in which these populations participate. Cultural traits are studied in terms of the possible contribution they make to a population's adaptation to its ecosystem rather than as being part of coherent systems in their own right, the traditional concern of social scientists. Moreover, research following the ecosystem-based model tends to be guided by the unspoken assumption that if a cultural trait exists then it must somehow necessarily serve the adaptive needs of a local population.

The ecosystem-based model of human ecology is exemplified by Roy Rappaport's well-known book, *Pigs for the Ancestors* (1968), in which he attempted to demonstrate how the religious rituals practiced by the Tsembaga tribal group of New Guinea functioned to maintain their population in balance with the available resources of their environment. Religion, an institution that Steward had largely excluded from his concept of the ecologically adaptive cultural core, was seen by Rappaport as playing a key regulatory role in relations between the Tsembaga population and the other components of their ecosystem.

Like many of the tribal groups of the central highlands of New Guinea, the Tsembaga employ a swidden system of farming similar to that described by Geertz for the outer islands of Indonesia. The principal domestic animal raised by these New Guinea tribes is the pig. A continuing puzzle to anthropologists has been their custom of slaughtering animals only on ritual occasions, when hundreds of pigs may be consumed in only a few days, while the

*An ecosystem consists of all the living organisms and nonliving environmental elements (such as soil, water, and climate) that interact with each other within a spatially defined area.

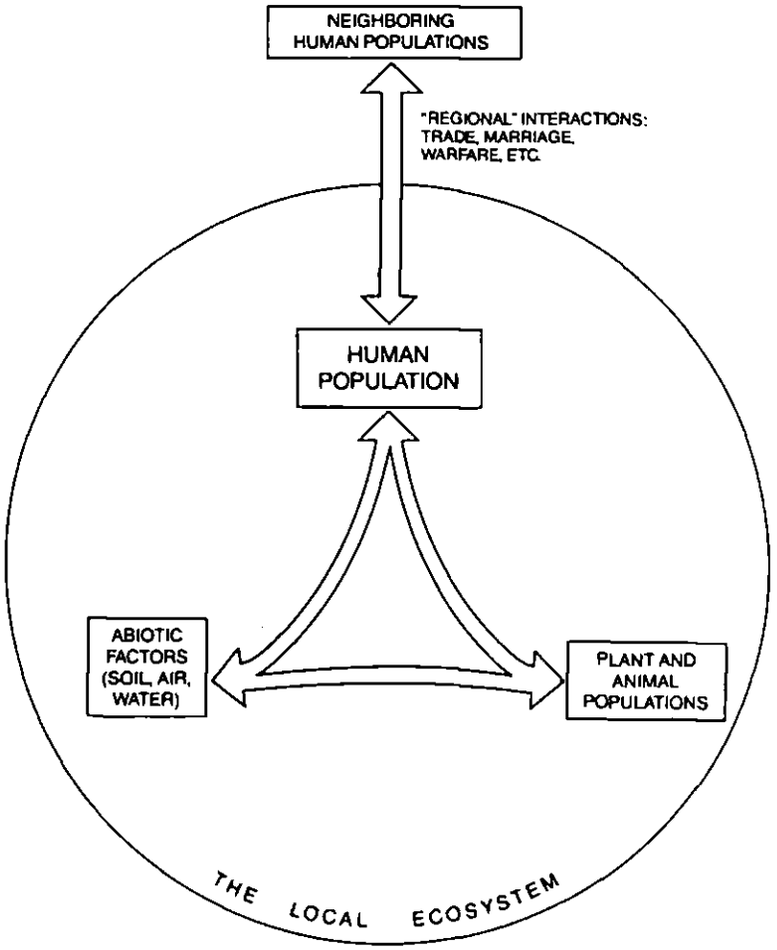

Figure 4. The ecosystem-based model of human ecology.

people go meatless for most of the rest of the time. From a nutritional standpoint, it would seem better to slaughter smaller numbers of animals on a regular basis to ensure more frequent consumption of protein by the human population. The great ritual feasts have therefore often been thought to be an example of a maladaptive cultural trait similar to the sacred cows of India.

After spending fourteen months living among the Tsembaga, Rappaport concluded that, far from being a maladaptive feature of their culture, the ritual regulation of pig killing actually *functions* to better adapt the Tsembaga population to their tropical forest ecosystem. He asserted that the ritual restriction of killing pigs only on certain ceremonial occasions serves to (1) maximize the supply of protein at times when the Tsembaga most need it, and (2) maintain the size of the Tsembaga population in balance with available resources.

According to Rappaport, the Tsembaga are able to raise adequate supplies of carbohydrates in the form of sweet potatoes, taro, and sugar cane in their swidden plots, but they are chronically short of protein, particularly high quality animal protein, which is necessary to ensure good health and resilience in the face of disease and injury. The fact that the limited number of pigs that the Tsembaga are able to raise can be slaughtered only on ritual occasions associated with illness, battle, and the beginning and end of periods of fighting may serve therefore to ensure that protein is available in significant quantities at precisely those times when it is most needed nutritionally.

Illness, injury, wounds, and fear all place the human organism under greater than usual stress with consequent greater physiological demand for protein, the basic building block for bodily tissues. Individuals consuming an inadequate quantity of protein are unable to produce sufficient antibodies to recover quickly from stress effects and are more likely to die from even minor wounds or injuries than are better fed individuals. Even a temporary increase in protein intake can produce dramatic recoveries among such malnourished invalids. Thus, even though the Tsembaga killing of pigs is done for supernatural reasons to appease evil spirits believed to cause sickness and ensure the help of ancestral spirits in fighting, since it occurs at times of illness and war it may allow the human population to derive the maximum nutritional benefit from the small supply of animal protein that their tropical forest ecosystem is capable of producing.

Rappaport not only sees ritual as serving the nutritional best interests of the Tsembaga population; he further claims the ritual cycle functions to maintain the population at a density compatible with the long-term carrying capacity of the ecosystem by regulating the frequency and intensity with which warfare occurs. According to the cultural ground rules followed by the tribes of the New Guinea highlands, war is only permitted during certain limited periods, the beginnings and ends of which are signaled by great ritual pig feasts. No group can go to war, however great the provocation, until a sufficient herd has been assembled to hold a proper feast. Thus, the very ability of the Tsembaga to engage in war is determined by their ability to produce pigs, and their ability to raise pigs is determined by the overall state of their ecosystem.

Warfare of the sort practiced in highland New Guinea until quite recently, while often more of a ritual than a real battle, was on occasion quite a bloody affair with participating groups suffering heavy casualities. When their losses became unacceptable, the contending sides would generally declare a truce. Each side would retreat to its own territory for a special ritual in which virtu-

ally all adult pigs in the community were slaughtered. Some of this meat was eaten by the Tsembaga, but most of it was given to the men from neighboring villages who had served as their allies during the fighting.

During the truce following the pig feast, the Tsembaga were ritually barred from engaging in new fighting. They believed they had not yet repaid their ancestral spirits for the help given to the living during the just-concluded round of fighting and therefore they could not rely on their help again should new fighting begin. It was only after they held a second, larger festival involving the slaughter of hundreds of pigs that their debt would be considered paid and the ancestral spirits again thought willing to help them. At that point warfare would again be ritually permitted. But having slaughtered so many adult pigs when the truce was declared, the Tsembaga would take many years to rebuild their herd to sufficient size to hold the second feast. During those years the human population also had time to rebuild, making up for the losses in warriors *it had suffered* during the previous fighting. Only when both the pig population and the human population had achieved sufficient size *would the* ritual cycle allow fighting to resume. Ritual, although triggered by the growth in the size of the pig herd, thus served to help keep the human population of the Tsembaga in balance with the limited carrying capacity of their ecosystem.

Rappaport's book is widely admired for the ingenious way in which he finds possible links between such diverse elements as nutrition, health, warfare, population size, pigs, and religious ritual within the framework of the Tsembaga ecosystem. Other researchers have raised serious questions, however, both empirical and theoretical, about the validity of his analysis. Margaret McArthur (1974), a leading Australian nutritional anthropologist, has shown, for example, that the Tsembaga are the best nourished of any highland New Guinea population yet studied, with an average daily protein intake well in excess of reasonable minimum daily requirements. She concludes that Rappaport's assumption that the Tsembaga are highly vulnerable to the stress of illness or injury is apparently unfounded. Even if Tsembaga invalids would benefit from a greater intake of protein, Rappaport presents no hard evidence that they in fact receive it from the pigs killed at the curing rituals, according to McArthur. As she notes, the fact that the sick person receives only the liver as his share of the meat does not suggest ingestion of any very great quantity of protein.

The killing of large numbers of pigs on festival occasions is also shown by McArthur to be an extremely inefficient way of using the limited supplies of protein available to the Tsembaga. *During the feasts,* people literally gorge themselves on pork, consuming as much as a kilogram of meat in a single day. Since the human body cannot store protein in excess of its small daily requirement of about 50 grams, the bulk of this intake at festival times is nutritionally wasted, being simply burned as extra calories. Contrary to Rappaport's analysis, McArthur concludes the killing of pigs in smaller numbers at more frequent intervals would be more efficient from a nutritional standpoint. Such regular slaughter would also have greater ecological efficiency since it would remove pigs from the herd as soon as they reached maturity and ceased to be efficient converters of vegetable food to protein. Then the people would not have to support them for many extra unproductive years while waiting for a large enough herd to be assembled to hold the ritual feast. Far from maximizing the flow of energy and nutrients from the ecosystem to the human population, the ritual regulation of Tsembaga pig husbandry thus appears to be highly wasteful and inefficient.

Of course the Tsembaga are not concerned with ecological efficiency; they slaughter pigs for religious and social reasons and not because they are striving to ensure the maximum flow of protein from the ecosystem to themselves. In particular, the mass slaughter of pigs at the end of a truce is intended to display the wealth and power of the tribe to potential friends and enemies alike while ensuring the support of both their ancestoral spirits and their human allies in the next round of fighting. The mass consumption of pork on these occasions, however wasteful it may be *from a nutritional* standpoint, serves the social needs of the Tsembaga by promoting the formation of effective alliances with needed allies in the coming war. The efficacy of the ritual slaughter should therefore be assessed, not as Rappaport has done in terms of the interaction of the Tsembaga population with their local ecosystem, but in terms of the adaptation of the tribal society to the conflict-ridden social environment of the New Guinea highlands.

From the latter perspective, it is particularly ironic that the Tsembaga had fallen victim to the forces of their larger social environment, having been defeated in battle in 1953, driven off their ancestral lands, and forced to take refuge among their allies. As Rappaport himself reports, "the Tsembaga ceased to exist as a group after their defeat, and, if it were not for the agents of the newly arrived Australian government who offered to protect them, it is unlikely that they would as a group have returned to their territory" (1968). Such a group hardly seems an appropriate choice to illustrate a theory of the role that ritual plays in maintaining homeostatic balance between a local human population and its ecosystem. To the extent that balance is maintained, it would appear to be between human society in the highlands as a whole and the regional ecosystem, not between transitory local populations like the Tsembaga and the small territories they exploit directly.

Despite the many serious criticisms of Rappaport's study, it remains a valuable contribution to human ecology. Perhaps its greatest impact has been to *focus attention* on the adaptive significance or ideology, an aspect of culture that Steward had largely excluded from consideration as *affecting human* interactions with the environment. By suggesting plausible ways in which religious ritual might regulate Tsembaga relations with other components of their ecosystem Rappaport opened the eyes of social scientists concerned with ecol-

ogy to a new area of study. That his particular model of the interactions between ritual, human population, and other ecosystem components may not be a valid one is a reflection on the specific conceptual approach that he employed, not a rejection of his more fundamental insight that religious ritual could be just as significant ecologically as the technological aspects of culture that Steward emphasized.

The professional debates that followed publication of Rappaport's book also have focused attention on what remains the greatest theoretical problem in human ecological studies—that of identification of the unit of human adaptation to the environment. While some critics, of whom the present author is one, feel Rappaport erred in thinking too small and focusing on a local population rather than the larger social system of the highlands as his unit of analysis, others take the position that adaptation occurs primarily at the level of the individual rather than at the level of groups, populations, or social systems. It is on the basis of the latter conviction that what has been called the actor-based model of human ecology has been formulated.

THE ACTOR-BASED MODEL OF HUMAN ECOLOGY

In the face of severe empirical problems in defining the social unit of ecological adaptation, it has been suggested that adaptation occurs at the level of individuals rather than of cultures or populations. This actor-based model of human ecology, as Orlove (1980) has labeled it, has become the major new wave in human ecology. The model reflects both anthropologists' general concern with individual decision-making processes and evolutionary biologists' current preoccupation with showing that natural selection operates exclusively at the level of the individual organism. From this perspective, any higher levels of organization, whether communities, ecosystems, or human social systems, exist only as the fortuitous outcome of interactions among many individual organisms.

In the case of human society, therefore, environmental adaptation is seen as occurring not as the result of natural selection on the cultural or social system level but rather as the result of the outcome of thousands of individual decisions about how best to interact with the environment. Individuals are assumed to be making choices constantly about how to exploit available resources while coping with environmental hazards. Those who make the "correct" choices will survive and prosper; those who choose less wisely will be selected against. Over time, the more successful adaptive strategies will become institutionalized as cultural norms. Such norms, however, are no more than the statistical outcome of individual choices and have no independent reality of their own as has been the usual conception of social scientists (Figure 5).

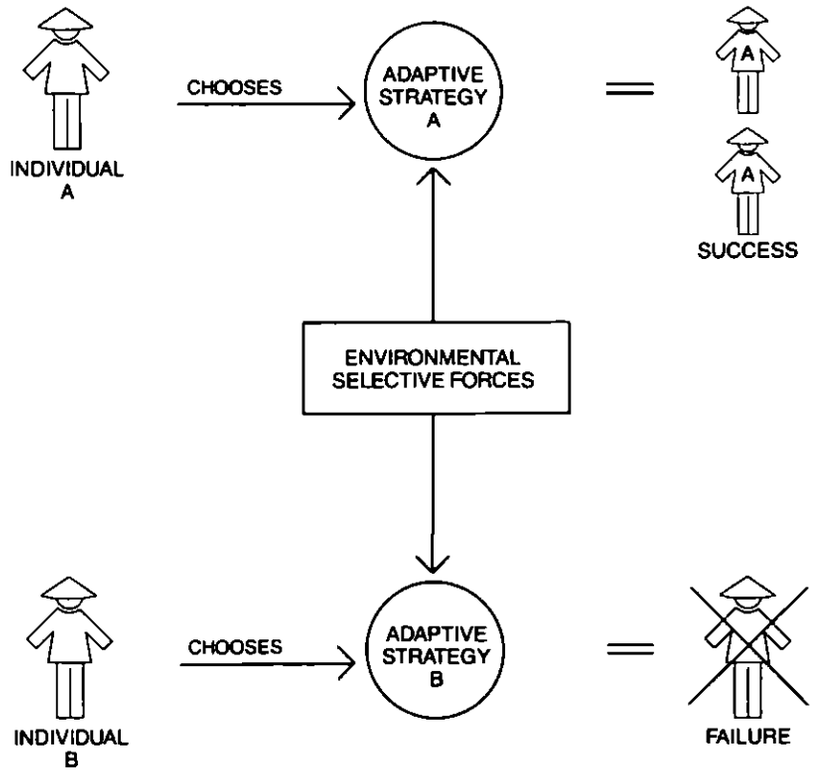

Figure 5. The actor-based model of human ecology.

For example, an actor-based analysis of the Tsembaga might explain the ritual cycle of pig killing described by Rappaport as simply the accidental outcome of hundreds of separate decisions by individual tribesmen about how to best maximize the use of the limited resources available in order to achieve power and prestige within their society. Thus, while the success of the feast from the societal viewpoint is measured by the total number of pigs that are sacrificed, the status of each individual Tsembaga male is enhanced only in direct relationship to the number of pigs that he contributes. The larger the number of animals he can kill, the greater the number of guests he can entertain and the larger the portions of meat he is able to present to his guests, thus placing them under greater obligation to assist him in the future. Each Tsembaga male therefore will seek to build up the largest herd that his family's labor force can support. Only when he reaches that limit will he want to hold the feast and only when a sufficient number of men have achieved the desired number of pigs will the community as a whole agree that it is time for the ceremonial slaughter. It may be, as Rappaport claims, that this happens before the

carrying capacity of the ecosystem is exceeded and its future productivity degraded but, from the perspective of the actor-based model of decision making, this happy result is no more than the summed outcome of many separate individual decisions.

The actor-based model, with its emphasis on the processes by which people make decisions about how to interact with their environment, is a valuable approach for understanding how change occurs in social systems in response to environmental perturbations. The approach is particularly useful for the insight it gives into why traditional farmers accept or reject agricultural innovations. A study by Michael Moerman (1968) has, for example, helped to explain why peasant rice farmers in northern Thailand have adopted tractors under certain environmental circumstances while they continue to rely on water buffalo under other circumstances. Similarly, Michael Calavan (1977) has shown how willingness of Thai farmers to plant improved rice varieties reflects rational consideration of environmental forces affecting crop yields.

These and other studies of individual decision making have shown convincingly that Asian peasants are far from being the tradition-bound creatures of the economic development textbooks. Instead, they are shown to be highly rational decision makers who carefully assess agricultural innovations in terms of potential benefits and costs. Despite their promise of higher yields, "modern" cropping methods are often rejected because such innovations may require high inputs of fertilizer, pesticides, and water. These inputs are unavailable to the poorer farmers, and modern cropping methods are also much more vulnerable to environmental hazards such as floods, droughts, and insect and disease outbreaks.

Poor marginal farmers, who are barely able to eke out a living with existing technology, simply cannot afford to take the greater risks of failure associated with innovative means of production. Rather than take big risks to maximize income, the farmer who has only 1 hectare (ha) or less of land must always seek to minimize risks. For him it is better to obtain a harvest of 1,000 kilograms of padi every year without fail than it is to harvest 3,000 kilograms in favorable years and nothing in years when environmental conditions are less favorable. From this perspective, it is easy to understand why Vietnamese peasants from the Red River Delta, who were notoriously conservative in their farming methods there, proved to be extremely receptive to agricultural innovations after their resettlement in the Mekong Delta in 1955. These peasants had not miraculously become more "rational" and less "tradition-bound" simply by moving from north to south; they had increased their average landholdings from .1 ha to 5 ha per family. They could now afford to take the risks of experimenting on part of their land with "miracle rice" from the International Rice Research Institute (IRRI), with fertilizers, insecticides, and even tractors, because failure no longer meant starvation. Under new

environmental conditions, these formerly conservative peasants quickly became among the most innovative farmers in Vietnam.

Although the actor-based model of human ecology has been usefully employed in explaining peasant choices about environmental relations, it relies upon a set of questionable assumptions about humans and society. The fact that Thai peasants are capable of choosing which of two rice varieties will give optimum yields under local environmental conditions cannot be taken as evidence that humans in general always or even usually make correct decisions about their interactions with the environment. In its assumption that humans always behave rationally, the actor-based model bears many resemblances to the "free-market" model of the classical economists who conceived of countless independent individual decisions to buy or sell as operating to produce optimal prices in any particular supply and demand situation. Modern economists have largely abandoned this free-market model, aware as they are of the imperfections of consumer knowledge and the deliberate manipulations by monopolistic corporate bodies, which distort the free market. Advocates of the actor-based model of human ecology, however, appear to be embracing uncritically such an "Adam Smith" conceptual approach with the implicit assumption that individual farmers normally make their decisions in an ecologically rational way. Andrew Vayda (Vayda and McCoy, 1975), in particular, having disavowed his earlier theoretical view that it is local populations that are adapted to ecosystems, now appears to take the position that individuals in traditional societies generally make "correct" decisions about the use of natural resources so that the sum of these decisions promotes stable environmental relationships.

While no anthropologist doubts that traditional peoples often have accurate and detailed environmental knowledge, which can allow them to make rational decisions about resource use and coping with natural hazards, it must be strongly emphasized that there is no inherent requirement that such an end will result. In many situations, such as "the tragedy of the commons" described by Garrett Hardin (1968), the summed effect of individual decisions, all of which are rational from the perspective of each actor, is to destroy the carrying capacity of the environment, thus lowering the welfare of the whole community.*

*The tragedy of the commons refers to a situation where a number of individuals share unlimited access to a limited degradable resource such as a communal pasture. It is in each individual's short-term self-interest to graze as many animals as possible on the pasture, thus ensuring personal maximum gains. This quickly leads to overgrazing, which, if continued unchecked, results in the degradation of productivity of the pasture, as has occurred in much of India. Everyone loses, but those individuals who keep the most animals on the deteriorating range still maximize their share of the declining communal resource so that overgrazing is likely to continue until the pasture is destroyed. Such a process can be observed currently in many upland areas in Asia.

It is not even valid to assume that individuals always make rational adaptive choices in terms of their short-run self-interest. Recent world history provides abundant examples of people making wrong choices for their own survival. How, for example, is it possible for anyone to assert that humans are rational decision makers in the face of evidence that during World War II several million Jews in Europe went quietly and with virtually no resistance to the Nazi extermination camps? When the Secret Police (SS) or Gestapo knocked at the door each of these individuals made the decision to accept fate and go along peacefully—a wrong decision that repeated millions of times resulted in the near extermination of a people. Given the overwhelming military power possessed by the Nazis, it might have made no difference to the ultimate outcome if the Jews had decided to resist, as they finally did in the Warsaw Ghetto uprising, but it is a fact that such resistance was never even considered because use of physical force was not condoned by Jewish culture as it had evolved in the ghettos of Europe. The "good man" was one who was peaceful and accommodating in the face of force, not one who was violent and offered resistance to authority. Since individuals must make decisions within the context of their particular culture, all choices are ultimately value statements—the expression of a preference for one way of life over another. Such values are, however, a property of the social system, not of the individual actors within the system.

An individual Tsembaga tries to raise the largest possible pig herd, not because that is the optimum strategy for adapting to the New Guinea environment but because that is the way in which he can gain status within Tsembaga society; a Thai farmer chooses to grow rice variety A instead of rice variety B because he believes that it will give him a higher yield from his land and a higher yield will allow him to live in the style that Thai culture considers good. Their decisions may or may not be correct ones within the context of their cultural values, but they as individuals did not create these values. Instead, the values are a pre-existing aspect of the social systems into which these individuals were born. As children they were socialized to accept these values as correct, and as adults they make their choices about interactions with the environment in terms of those values. The Thai farmer does not try to accumulate a large herd of pigs and the Tsembaga people do not try to raise a rice crop, however suitable such a strategy might be from an ecological standpoint, because such decisions are not even options with the frameworks of their respective cultures.

A Tsembaga is concerned with raising pigs and a Thai with growing padi not because of any choice made by these individuals but because their respective cultures channel their interests in these directions. Both the nature of the game and the rules by which it is played are set by the social system, with the individual actor being able only to choose his specific moves. Thus, the Tsembaga may strive to raise a larger or smaller herd of pigs and the Thai may

plant miracle rice seed instead of the traditional variety—the social systems "allow" the individual that much freedom of choice. But the larger issues of life are not matters of choice. Hamlet may agonize about being and nonbeing, but most individuals simply accept their existence within an ongoing social system as given. They may try to better their situation, but they normally do not seek to rewrite the fundamental rules of the game as they are prescribed by their culture.

The actor-based model of human ecology is thus one of limited applicability. It can reveal a great deal about why individuals within a particular social system make the particular choices about interactions with the environment that they do, but it cannot explain why their social system presents them with the particular choices it does. An explanation of the character of a social system as a system cannot be achieved by looking at the characteristics of the individuals that compose the social system. Instead, it is necessary to focus on the characteristics unique to the higher order system itself as it interacts with its environment. This approach is called the systems model of human ecology.

THE SYSTEMS MODEL OF HUMAN ECOLOGY

A major scientific development in recent years has been the formulation of "general systems theory," which is concerned with the general properties of the structures and functions of systems as such, rather than with their specific contents. According to this theoretical approach, atoms, cells, organisms, ecosystems, societies, and even the universe as a whole all share the common properties of being self-organizing systems and can therefore be studied in terms of a common theoretical perspective. Biological ecologists have long been aware of the systemic qualities of the natural world, as their use of the term ecosystem reveals. Among social scientists, the recognition that human societies constitute organized systems is also an old one, dating back at least to the work of the French sociologist Emile Durkheim. His writings, particularly *The Elementary Forms of Religious Life* (1915), provided the basis for the development of the structural-functional social systems model that has been the dominant paradigm of British and American anthropology and sociology since the 1930s.

Structural-functionalism, as first theoretically articulated by A. R. Radcliffe-Brown (1965) and Bronislaw Malinowski (1922), and as developed empirically by E. E. Evans-Pritchard (1940) and especially Sir Raymond Firth (1936), saw all of the diverse institutions of society as being organized into an integrated system, where each institution fits harmoniously with every other one, and where change in any single institution would ramify into complementary change in all of the other institutions with which it was functionally connected.

The structural-functional model, with its conception of societies as systems,

proved to be of great value operationally, producing many new insights into the ways in which societies were organized. Numerous formerly inexplicable customs suddenly became intelligible in the light of their functional relations with other institutions. The payment of "bride price" in tribal societies, for example, became comprehensible when it was perceived that it served to strengthen marriage bonds by making divorce more difficult and that such strengthening was important since marriages served politically to unite otherwise autonomous clans. Thus, what had earlier been perceived as a quaint, "savage" custom was now recognized as serving important functions in the maintenance of tribal social solidarity.

The ethnographic works of the structural-functionalists give many more examples of such functional relationships. To read Evans-Pritchard's monograph on the Nuer of the Sudan (1940) or Raymond Firth's several works (1936) on the Tikopians of Polynesia is to gain a strong conviction that these societies were integrated systems. Certainly most Western social scientists became convinced of this and thus the structural-functional model rapidly became the dominant theoretical perspective in anthropology and sociology. Soon, however, criticisms began to be heard that the structural-functional model was a static one, unable to explain the occurrence of change within the social system.* If, as the theory asserted, every institution was integrated perfectly with every other institution, what force could cause change to occur?

The problem with the social system concept as developed by the structural-functionalists was not their postulation of integration among system components but their failure to conceive of the system as an open one. Following the lead of Durkheim (1938), it was argued that "social facts" must be explained only in terms of other "social facts"; one could not seek the causes of social change outside the boundaries of the social system itself. This limitation of the field of inquiry—originally conceived as a way to prevent the resort to reductionist psychological or physiological explanations of social systems such as "explaining" the development of Nazi Germany in terms of Hitler's pathological personality or "explaining" the incest tabu in terms of man's instinctual horror of interbreeding—became an obstacle to understanding the process of systems change. The development of human ecology can be seen as an attempt to escape this theoretical impasse by treating social systems as open rather than closed systems. Beginning with Julian Steward's concept of cultural ecology (1955, 1968), it was recognized that "social facts" might be explained not only in terms of other "social facts" but also in terms of "ecological facts."

*Acceptance of the view that social institutions have a tendency toward integration need not imply acceptance of the view that social systems are naturally homeostatic and stable. The Marxist conceptual model, for example, certainly recognizes the role played by conflict in social evolution yet at the same time holds that technology, social and political institutions, and ideology are highly integrated phenomena at any particular stage of economic growth.

Unfortunately, the new enthusiasm for explaining social and cultural institutions in terms of environmental influences caused some analysts to lose sight of the systemic character of society. Rather than seeking to understand how one open system (the social system) interacted with another open system (the ecosystem), they focused their attention on trying to explain how particular institutions (e.g., sacred cows, pig feasts) might be explained in relation to particular environmental conditions. That this research strategy produced valuable insights is without question, but it could not lead to a comprehensive understanding of society-environment interactions.

An alternative approach, the "systems model of human ecology," describes social systems as they interact with ecological systems. Adaptation is assumed to occur, not at the level of discrete cultural traits or social institutions—as in the model of cultural ecology—or in terms of specific human populations—as in the ecosystem-based model of human ecology—or in terms of specific individual decision makers—as in the actor-based model of human ecology—but at the level of the total social system as a system. Cultural traits, therefore, do not necessarily function to ensure the welfare of either individuals or local populations but instead serve primarily to ensure the survival of the social system itself. From this perspective, the ritually regulated warfare of the Tsembaga is not seen as directly benefiting either most individual Tsembaga or the Tsembaga local population as a whole. In just one battle eighteen died and the people were defeated and driven from their territory, hardly what can be labeled an adaptive outcome either for the individual casualties or the dispossessed survivors. Instead, such endemic conflict is considered essential for maintaining the type of social system characteristic of the New Guinea highlands. Individuals, or even the whole Tsembaga local population could be destroyed, but the larger social system endured.

In the systems model of human ecology both the social system and the ecosystem with which it interacts retain their integrity as systems, with each changing its structural configuration according to its internal dynamics. At the same time, however, it is recognized that each system receives energy, material, and information from the other, and these inputs also influence its structure and functioning. Each system, of course, is also open to influence from other systems of the same kind so that a social system may be altered by inputs received from a neighboring social system (the processes anthropologists call diffusion and acculturation) just as an ecosystem may be changed by inputs from other ecosystems (e.g., migration and colonization). Causality in the systems model of human ecology is thus extremely complex with no primacy being assigned *a priori* to any element or force in the total system. Figure 6 is a simplified diagram of the basic structural and functional relationships involved in the systems model of human ecology. This model emphasizes four relational aspects:

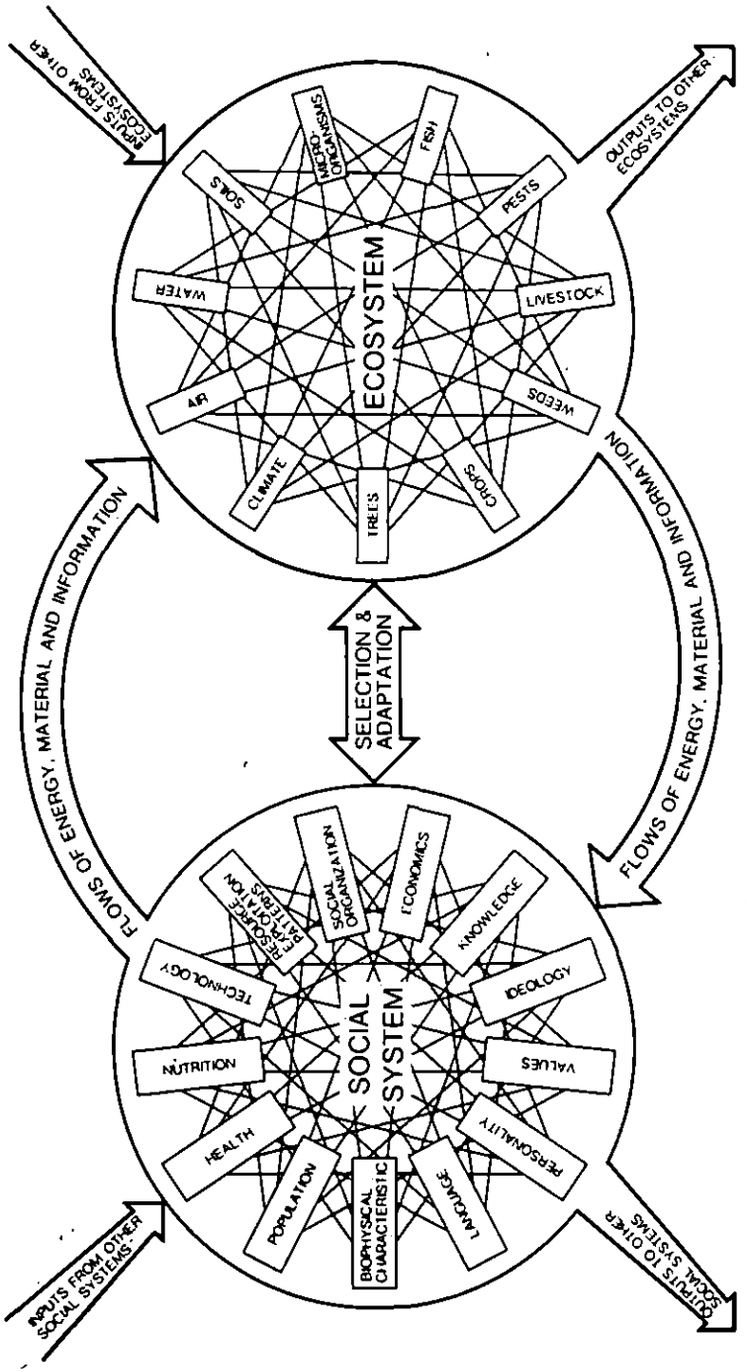

Figure 6. Social system–ecosystem interactions.

1. Inputs from the ecosystem into the social system—These inputs can be in the form of flows of energy (e.g., food, petroleum), materials (e.g., protein, construction materials), or information (e.g., sounds, visual stimuli).
2. Inputs from the social system into the ecosystem—Again, these can take the form of flows of energy, materials, or information generated by human activities.
3. Change in the institutions making up the social system in response to inputs from the ecosystem—Such change may be either primary, as when an increase in the death rate due to environmentally transmitted diseases changes the population structure of a society, or secondary, as other social system institutions change in response to environmentally generated primary change in one institution. Social system changes in response to inputs from the ecosystem may be and often are adaptive, that is, they contribute to the continuing survival of the social system under changed environmental conditions. They need not, however, result in a better or happier way of life for individual human participants. In other words, it is the social system itself, rather than the people who are involved in it, that is the unit of natural selection and adaptation.
4. Changes in the ecosystem in response to inputs from the social system—Just as human society changes in response to environmental influences, so does the ecosystem change in response to human influences. Such change may be either primary, the direct impact of a human activity on an ecosystem component such as the killing off of a particular animal species by overhunting, or secondary, alterations in other ecosystem components caused by anthropogenic primary change in one component.

As a brief and somewhat hypothetical example of how the systems model of human ecology works, the problem of deforestation in South Asia may be examined. In recent years hill slopes in northern India have been deforested (ecosystems change) by overgrazing by animals and by cutting of trees and bushes by people for domestic cooking fuel. This has resulted in a severe shortage of fuel (flow of energy from the ecosystem to the social system). Peasant households have responded to this energy crisis by using their children to scavenge any available twigs, agricultural litter, and especially, cow dung (change in resource exploitation pattern). This activity enhances the economic value of children to the household, leading parents to have more children (change in population). Consequent increased population results in increased human pressure on the productivity of the ecosystem. Intensive collection of cow dung (flow of energy and material from the ecosystem to the social system) has, however, reduced the supply of manure in the farm fields (change in soil component of the ecosystem) with consequent lowering of crop yields (change in plant component of the ecosystem). Yields have been reduced further by the

decreased dry-season flow of irrigation water from the deforested hills and the clogging of irrigation canals by soil eroded from the denuded hill slopes (secondary changes in ecosystem components). These reduced yields are reflected in a decreased flow of food energy and materials to the human population with consequent negative consequences for nutritional status and health (changes within social system institutions).

If government extension agents introduce biogas generators (change in technology of the social system resulting from diffusion from another social system), concentrated organic residues are again available for use as manure in the fields (change in flow of material from the social system to the ecosystem) with a consequent increase in crop yields (change in plant component of the ecosystem). The solution of the domestic fuel problem could lead to reduced fuel collection in the uplands (change in flow of energy from the ecosystem to the social system), which allows regeneration of vegetative cover, resulting in better water and soil retention (changes in the ecosystem), which improves the supply of irrigation water to the fields leading to increased supply of foods for the peasants, and so on.

Whether or not such ecological benefits actually are obtained from introduction of the new technology, however, will be strongly influenced by social structural factors. If biogas plants are sold to individual households, only the wealthier peasant families will be able to afford them. Poorer peasants are likely to end up collecting dung to sell to the biogas plant owners for cash. The biogas plant owners will thus gain differential control of both energy and fertilizer supplies with consequent widening of the gap between well-off and poorer farmers in the village. More reliable supplies of irrigation water also are likely to benefit differentially the owners of larger plots lying within the command area, again serving to increase economic inequality within the community. Poorer households, having no vested interest in maintaining the renewed watershed, may even deliberately seek to sabotage the working of the irrigation system. This has in fact happened in the case of the Chandigar project referred to previously.

The point of this discussion is that the relationship between the social system and the ecosystem is both complex and dynamic. The virtue of the systems model of human ecology is that it focuses attention on the processes of change and adaptation rather than emphasizes the static structural characteristics of the social and ecological systems. Moreover, this approach avoids any necessity for specification of any universal "prime mover" for change: neither environmental nor social factors have any *a priori* primacy because impulses for change may flow in either direction. The systems model therefore overcomes to a large extent the limitations of the model of cultural ecology with its lack of provision for dealing with environmental change caused by human activity. The systems model also, by its careful specification of the parameters of the social and ecological systems as integral independent systems, avoids many of

the boundary definition problems inherent in the ecosystem-based model of human ecology.

There is no inherent contradiction between the systems model and the actor-based model of human ecology. The latter approach is simply one among many that can be incorporated within the larger social systems framework. Certainly, decision making by individual participants affects both the character of the social system and its interactions with the ecosystem, but, as has already been discussed, all such decisions are made within the context of these systems.

Perhaps the greatest virtue of the systems model of human ecology is that it offers specific guidelines for doing research on human interactions with the environment. Rather than simply starting with the idea that environmental influences must somehow affect humans or that human actions must somehow influence the environment, it focuses attention on the significant areas of interaction between human social systems and ecological systems—the flow and counterflow of energy, material, and information. Such specification provides an essential framework for carrying out comparative research. Lacking such a systematic model, human ecology can continue to produce only the sort of *ad hoc* results that have essentially characterized the field to date.

CONCLUSION

It must be emphasised that while the systems model provides a framework for analysis of human interactions with the environment, it is not intended to be and should never be used as an operational research model. That is, no investigator should simply use the model as the basis for making a holistic description of any specific community's interactions with its ecosystem. Such a total description would be as useless as it would be undoable in practice given the immense complexity of even the simplest social and ecological systems.

Instead of describing systems for description's sake, it is much more rewarding to start work with a specific problem as the focus of the research.* To return to the earlier example of deforestation in India, one could ask: "Why do Indian peasants cut down too many trees?" One could equally well start with the question of: "How can soil fertility be restored?" or "How can the supply of irrigation water be increased?" or "What are the likely social and ecological impacts of introducing biogas generators to rural communities?" The choice of the question is likely to reflect the initial problem orientation of the investigator (e.g., the forester will probably initially be concerned with the

*Carol Colfer and Andrew Vayda have recently advocated use of a problem-oriented rather than a community-oriented approach in human ecology research, referring to this strategy as "contextual analysis" (Colfer 1981).

cutting of trees). Employing the systems model as the research framework, however, may help him to perceive that the solution to his problem may lie outside the boundaries of the forest, requiring the provision of alternative sources of energy to the villagers before reforestation may be feasible.

The real value of human ecology lies in helping humans to see previously unrecognized relationships between what people do and the environment in which they do it. Many important insights have already been provided, changing in profound ways how people think about the world and their place within it. Systematic research on human ecology has only really just begun, however, and areas of ignorance far exceed areas of understanding. But that is why the field is such an intellectually exciting one in which to work.

BIBLIOGRAPHIC NOTE

Useful reviews of the development of human ecology as a field are provided by Anderson (1973), Bates (1953), Bennett (1976), Grossman (1977), Helm (1962), Netting (1971, 1977), Orlove (1980), Sahlins (1964), Vayda and Rappaport (1968), and Young (1974).

Prescientific period thought on human-nature relations is described by Thomas (1925). Environmental determinism is expounded by Semple (1911), while the theory is critically reviewed by Platt (1948) and Sprout and Sprout (1965). C. Daryll Ford (1934) provided the most detailed presentation of the possibilist approach. The example of the distribution of maize agriculture in North America being limited by climate is from A. L. Kroeber's monumental *Cultural and Natural Areas of Native North America* (1939).

The articles collected in Steward (1955), particularly Chapter 2, "The Concept and Method of Cultural Ecology," as well as his later article (1968), offer clear statements of the model of cultural ecology. Steward's monograph, *Basin-Plateau Aboriginal Socio-political Groups* (1938), remains one of the best examples of the empirical application of this model. Evans-Pritchard's monograph on the Nuer (1940) represents a parallel, but independent, effort. Geertz (1963) applies the cultural ecological approach to analysis of Indonesian agriculture. The sacred cows of India are discussed from the standpoint of cultural ecology by Marvin Harris (1966, 1975), and Odend'hal's empirical study (1972) of the energetics of Indian cattle supports Harris' view that they efficiently convert environmental resources into forms useful to man. R. O. Whyte (1968) offers a much less favorable assessment of the role of cattle in India. Diener, Nonini, and Robkin (1978) document the extensive ecological degradation resulting from overgrazing. The existence of the "pig line" as a bar to the spread of Islam in Borneo is reported by J. M. Bolton (1972). Information on the effects of reforestation at Chandigar on irrigation water supplies was provided by P. R. Mishra in personal communication. The Chandigar project is described in detail in a paper by David Seckler (1979).

The ecosystem-based model was formulated by A. P. Vayda and R. A. Rappaport (1968) under the label of "general ecology." Rappaport (1968, 1971) presents additional theoretical discussions of this approach, while his monograph, *Pigs for the Ancestors* (1968), is the major empirical employment of the model. Margaret MacArthur (1974) raises serious objections, however, to his interpretation of nutritional data while Anderson (1973) questions the suitability of the local population as the unit of ecological analysis.

B. S. Orlove (1980) presents the clearest discussion of the actor-based model of human ecology and the label itself was suggested by him. A. P. Vayda and B. J. McCay (1975) also assert that the proper focus of human ecology should be on individual decision making regarding adaptation to environmental hazards, a view given theoretical support from the standpoint of current

perspectives in biological evolutionary theory by P. J. Richerson (1977). A. W. Johnson (1972) states the case for the importance of individual decision making with regard to agricultural innovation, while M. Moerman (1968) and M. M. Calavan (1977) present empirical case studies demonstrating the "rationality" with which Thai peasants make decisions. Observations regarding Northern Vietnamese resettled in the Mekong Delta are from the author's unpublished field notes. G. Hardin's (1968) paper, "The Tragedy of the Commons," points out that individual decisions often in sum lead to environmental disaster. That individuals may make erroneous choices is documented in chilling detail in Raul Hilberg's monograph, *The Destruction of the European Jews* (1961). That there is a real distinction between survival of the individual or populations of individuals and the survival of whole cultural systems is a point clearly made in P. Diener's (1974) essay on the Hutterites.

There is no adequate single treatment of the systems model of human ecology. L. Von Bertalanffy (1968) remains the basic work on general systems theory while E. Laszlo (1972) offers one of the more readable introductions to an often jargon-laden school of thought. E. P. Odum (1971, 1977) presents a systems view of ecology with particular emphasis on the integrity of the ecosystem as an analytic unit, an integrity that is questioned by P. A. Colinvaux (1973). E. Durkheim (1915) is the precursor of structural-functional approaches to society. That social facts can be explained only in terms of other social facts is the theme of his *Rules of Sociological Method* (1938). A. R. Radcliffe-Brown's collected essays (1965) present the structural-functional approach as developed by social anthropologists. Leslie White (1975) advances the thesis that adaptation occurs at the level of the social or cultural system rather than at the individual level. James Dow (1976) presents mathematical models for analyzing the flow of energy, materials, and information between social and ecological systems while the present author (Rambo 1982) explores more qualitative applications of the systems model of human ecology to research on Southeast Asian agricultural societies.

REFERENCES

Anderson, J. N.
1974 Ecological anthropology and anthropological ecology. In J. J. Honigmann (ed.) *Handbook of Social and Cultural Anthropology,* 477-97. Chicago: Rand McNally & Co.

Bates, M.
1953 Human ecology. In A. L. Kroeber (ed.) *Anthropology Today,* 700-13. Chicago: University of Chicago Press.

Bennett, J. W.
1976 *The Ecological Transition: Cultural Anthropology and Human Adaptation.* New York: Pergamon Press Inc.

Bolton, J. M.
1972 Food taboos among the Orang Asli in West Malaysia: A potential nutritional hazard. *American Journal of Clinic Nutrition* 25:789-99.

Calavan, M. M.
1977 *Decisions Against Nature: An Anthropological Study of Agriculture in Northern Thailand.* Special Reports No. 15. Normal Northern Illinois University Center for Southeast Asian Studies.

Colfer, C. J. P.
1981 Women, men, and time in the forests of East Kalimantan. *Borneo Research Bulletin* 13(2):75-85.

Colinvaux, P. A.
1973 *Introduction to Ecology.* New York: John Wiley and Sons.

Diener, P.
1974 Ecology or evolution? The Hutterite case. *American Ethnologist* 1, 1974:601-18.

Diener, P., Nonini, D. and E. E. Robkin
1978 The dialectics of the sacred cow: ecological adaptation versus political appropriation in the origins of India's cattle complex. *Dialectical Anthropology* 3(3):221-41.

Dow, James
1976 Systems models of cultural ecology. *Social Science Information* 15(6): 953-76.

Durkheim, E.
1915 *The Elementary Forms of Religious Life.* London: G. Allen and Unwin, Ltd. (orig. 1912).

———.
1938 *The Rules of Sociological Method.* New York: Free Press (orig. 1895).

Evans-Pritchard, E. E.
1940 *The Nuer.* New York: Oxford University Press.

Firth, R.
1936 *We, the Tikopia: A Sociological Study of Kinshop in Primitive Polynesia.* London: G. Allen and Unwin, Ltd.

Forde, C. D.
1934 *Habitat, Economy and Society.* London: Methuen & Co. Ltd.

Geertz, C.
1968 *Agricultural Involution: The Process of Ecological Change in Indonesia.* Berkeley: University of California Press.

Grossman, L.
1977 Man-environment relationships in anthropology and geography. *Annals of the Association of American Geographers* 67(1):126-44.

Hardin, G.
1968 The tragedy of the commons. *Science* 162, 13 Dec:1243-48.

Harris, M.
1966 The cultural ecology of India's sacred cattle. *Current Anthropology* 7: 51-59.

———.
1975 *Cows, Pigs, Wars and Witches: The Riddles of Culture.* London: Hutchinson.

Helm, J.
1961 The ecological approach in anthropology. *American Journal of Sociology* 67:630-39.

Hilberg, R.
1961 *The Destruction of the European Jews.* London: W. H. Allen & Co. Ltd.

Johnson, A. W.
1972 Individuality and experimentation in traditional agriculture. *Human Ecology* 1(2):149-59.

Kroeber, A. L.
1939 *Cultural and Natural Areas of Native North America.* Berkeley: University of California Publications in American Archaeology and Ethnology, Vol. 38.

Laszlo, E.
1972 *The Systems View of the World.* New York: George Braziller Inc.

McArthur, M.
1974 Pigs for the ancestors: a review article. *Oceania* 45(2):87-123.

Malinowski, B.
1922 *Argonauts of the Western Pacific.* London: Routledge and Sons, Ltd.; New York: E. P. Dutton and Co.

Marsh, G. P.
1965 *Man and Nature.* Cambridge: Belknap Press (orig. 1864).

Moerman, M.
1968 *Agricultural Change and Peasant Choice in a Thai Village.* Berkeley: University of California Press.

Netting, R. McC.
1971 *The Ecological Approach in Cultural Study.* New York: Addison-Wesley Modular Publication No. 6.

———.
1977 *Cultural Ecology.* Menlo Park, California: Cummings.

Odend'hal, S.
1972 Energetics of Indian cattle in their environment. *Human Ecology* 1(1):3-22.

Odum, E. P.
1971 *Fundamentals of Ecology,* 3rd edition. Philadelphia: W. B. Saunders Co.

———.
The emergence of ecology as a new integrative discipline. *Science* 195:1289-93.

Orlove, B. S.
1980 Ecological anthropology. *Annual Review of Anthropology* 9:234-73.

Platt, R. S.
1948 Environmentalism versus geography. *American Journal of Sociology* 53:351-58.

Radcliffe-Brown, A. R.
1965 *Structure and Function in Primitive Society.* New York: Free Press.

Rambo, A. Terry
1982 Human ecology research on tropical agroecosystems in Southeast Asia. *Singapore Journal of Tropical Geography* 3(1):86-99.

Rappaport, R. A.
1968 *Pigs for the Ancestors: Ritual in the Ecology of a New Guinea People.* New Haven: Yale University Press.

———.
1969 Some suggestions concerning concept and method in ecological anthropology. In D. Damas (ed.) *Contributions to Anthropology: Ecological Essays.* Ottawa: National Museums of Canada, Bulletin 230, Anthropological Series No. 86:184-88.

———.
1971 Nature, culture and ecological anthropology. In H. L. Shapiro (ed.) *Man, Culture, and Society,* 237-67. Revised Edition. London: Oxford University Press.

Richerson, P. J.
1977 Ecology and human ecology: A comparison of theories in the biological and social sciencies. *American Ethnologist* 4:1-26.

Sahlins, M. D.
1964 Culture and environment: the study of cultural ecology. In S. Tax (ed.) *Horizons in Anthropology,* 132-47. Chicago: Aldine Publishing Co.

Seckler, D.
1979 Sukhomajri: A rural development program in India. Unpublished staff seminar paper, Ford Foundation, New Delhi (mimeographed).

Semple, E. C.
1911 *Influences of Geographic Environment: On the Basis of Ratzel's System of Anthropo-Geography.* New York: Henry Holt.

Sprout, H., and M. Sprout
1965 *The Ecological Perspective on Human Affairs.* Princeton, New Jersey: Princeton University Press.

Steward, J. H.
1938 *Basin-Plateau Aboriginal Sociopolitical Groups.* Washington, D.C.: Smithsonian Institution, Bureau of American Ethnology Bulletin 120.

———.
1955 *Theory of Culture Change.* Urbana: University of Illinois Press.

———.
1968 Ecology: culture ecology. In *International Encyclopedia of the Social Sciences* 4:337-44.

———.
1977 *Evolution and Ecology: Essays on Social Transformation.* Urbana: University of Illinois.

Thomas, F.
1925 *The Environmental Basis of Society: A Study in the History of Sociological Theory.* New York: The Century Co.

Toynbee, A. J.
1947 *A Study of History* (Abridgement of vol. I-VI). New York: Oxford University Press.

Vayda, A. P. and B. J. McCay
1975 New directions in ecology and ecological anthropology. *Annual Review of Anthropology* 4:293-306.

Vayda, A. P. and R. A. Rappaport
1968 Ecology: culture and non-cultural. In J. A. Clifton (ed.) *Introduction to Cultural Anthropology,* 476-97. Boston: Houghton Mifflin Co.

Von Bertalanffy, L.
1968 *General Systems Theory.* New York: George Braziller Inc.

White, L. A.
1975 *The Concept of Cultural Systems: A Key to Understanding Tribes and Nations.* New York: Columbia University Press.

Whyte, R. O.
1968 *Land, Livestock and Human Nutrition in India.* New York: Praeger Publishers.

Young, G. L.
1974 Human ecology as an interdisciplinary concept: A critical inquiry. In A. Macfadyen (ed.) *Advances in Ecological Research* Vol. 8, 1-105. London: Academic Press Inc.

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