Human Impact on Ancient Environments

Charles L. Redman

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form of racism within our own country, with the ills of environmental degradation being born most heavily by already disadvantaged segments of our population.

This brings us to a very big issue that has no resolution but should be considered by every individual contemplating the condition of the environment and action to *preserve* it. What is an *ideal* environment, or even, what can be done to *improve* the environment are certainly not questions that would be answered the same way by all people. Our perception of the environment is conditioned by our attitude toward it, and our attitudes are influenced by many of the ideas discussed in this chapter and by many factors in an individual's own life. How important are long-term issues to us when they conflict with more immediate needs? What do we consider beauty, value, and meaning in the world around us? These are very personal issues and lead to attitudes as diverse as the people who hold them. Natural landscapes and pristine habitats are of immeasurable beauty to many of us, but what actually constitutes a *natural* landscape or a *pristine* habitat? What about the beauty in wheat fields or hills covered with grapevines or an endless highway? These issues have no simple answers, but they are at the very core of our environmental future. They are not new issues, and in some form they must have been faced repeatedly throughout human history. Hence we will revisit them many times in this volume.

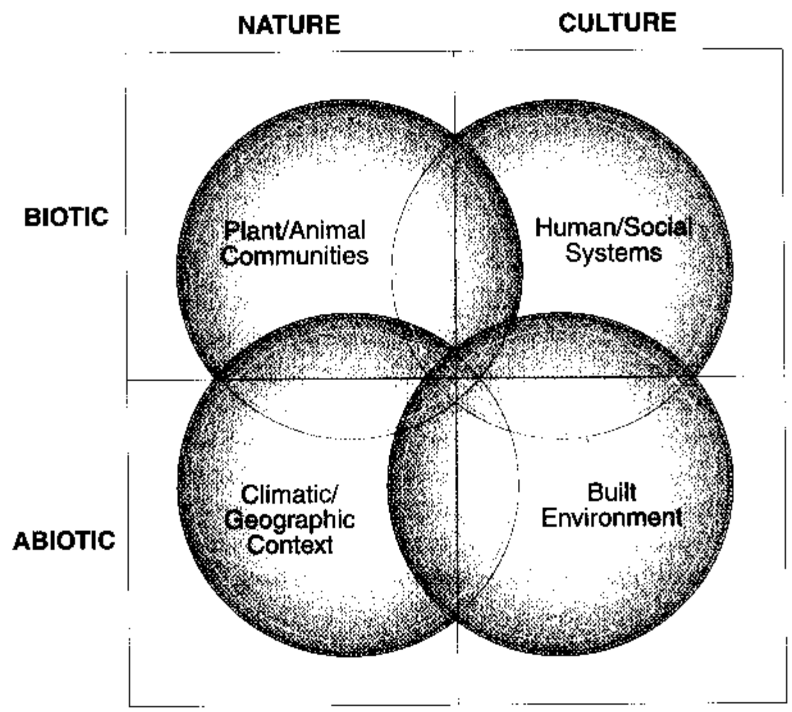
3
Concepts That Organize Our Thoughts

Just as we must recognize that attitudes shape the way we view a problem, we should also be aware that to understand and solve a problem, we must employ concepts to organize the complexity of the real world into manageable units. These concepts not only simplify and give names to the intricacies of nature, but also incorporate some of the basic means by which the world operates. This chapter defines concepts that allow us to better communicate about the environment and explains some of the basic operating principles of nature.

Who are the participants in this drama of human-environmental interactions that this volume is dedicated to elucidating? At the most basic level, one can divide the world into abiotic (nonliving) and biotic (living) components (fig. 3.1). Abiotic aspects are commonly called the physical environment and are made up of entities and forces such as soil, water, air, climate, topography, etc. In keeping with our objective of integrating human activities into our thinking, it is useful to add a second component to the physical environment — the "built environment." Biotic aspects of the world are its living organisms: plants and animals. Although we recognize people as members of the more general animal kingdom, it is useful once again to separate specifically human activities from the remainder of biotic elements.

The biotic components of the world comprise a dazzling array of organisms. At the broadest level, the *biosphere* encompasses all of the earth's living organisms and the physical environment with which they interact. At the smallest level, all biotic components are made up of cells, genes, and strands of DNA, but our interest begins at the basic level of integration, the *organism*. An organism is a coherent living entity that on its own or with the help of other similar entities is able to survive for varying lengths of time and to reproduce progeny of similar characteristics. A *population* comprises

Figure 3.1
Conceptual model relating aspects of the environment.



groups of individuals of one species, that is, one kind of organism. Since populations are composed of aggregates of the same species, they tend to exploit resources in a specific manner. This pattern of resource exploitation of a species is referred to as its *niche,* and although it often coincides with a physical space, the niche should be distinguished as a set of relationships rather than a particular habitat. In fact, the niche represents the relationship of the individual to all aspects of its environment, complete with the range of conditions and resource qualities within which the individual can survive. Hence, ecologists often think of the niche as the occupation of a population of organisms and the habitat as their current address (Butzer 1982:15).

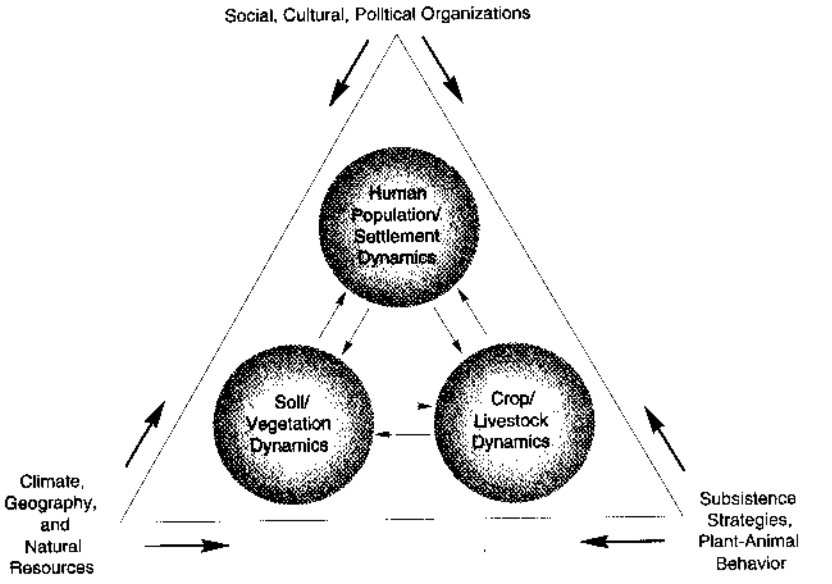
All the populations of various species, both plant and animal, that occupy a given area are called a *community.* The biotic community of an area and the abiotic environment in which it lies are together considered an *ecosystem.* A famous ecologist, Eugene Odum, defined an ecosystem as all of the

organisms in a given area interacting with the biotic and physical environment. An ecosystem is characterized by energy flows, food chains, biotic diversity, and cycling of materials (1963). Entities within the ecosystem that affect each other through one or more of these processes are said to have a *functional relationship.* The central issues addressed in this book involve the functional relationships among participants in particular ecosystems, especially the relationships involving human populations. Because of this, it is most useful to follow the lead of many scholars who refer to ecosystems in which humans play a substantial role as human or anthropogenic ecosystems. Specific, regionally bounded, anthropogenic ecosystems are the basic unit of discussion and analysis in this book. Yet, even a single ecosystem is extremely complex for a complete empirical study. The fact that the case studies presented are all in the past makes elucidation even more difficult. Hence, the ecosystem concept will be used as a paradigm to organize the facts about each case, but most descriptions and analyses will involve functional parts of the ecosystem, such as soil/vegetation dynamics, crops/livestock dynamics, or human population/settlement dynamics (fig. 3.2). The interplay of all of these components takes place in the context of a climate, a geography, a social system, and subsistence technology. In the following chapters, case studies will be used to describe these components as they occurred in the past, and an attempt will be made to delineate as many interrelationships as possible.

The variability across the earth's land masses can be classified into a limited number of major regions, each with distinctive plant and animal groupings. Ecologists have divided the world into zones or biomes in various ways, but seven categories are commonly used: tropical forest, temperate deciduous forest, temperate coniferous forest, grasslands, desert, tundra, and mountains. In one type of biome located in two widely separated regions (perhaps even continents), the component species of the communities may be quite different, but they occupy analogous niches and function within the biome in similar ways. For example, the bison of North American savanna biome (a type of grassland) might be considered as analogous to the wildebeest of the African savanna. In this volume I will draw on archaeological case studies from widely separated locations and time ranges, each with its own resources and strategies. However, because of the functional similarity of communities and populations within even widely separated ecosystems of the same biome, it will be possible to recognize similar situations and responses.

The human-environmental interactions in the case studies in the following chapters can be looked at in terms of how stability and change affect the overall system—more particularly, the human ecosystem of the region. A

Figure 3.2
Influences that affect the components of an ecosystem.



system is a group of elements that are bound together by a set of relations such that a change in one element will cause changes in all others. A human ecosystem comprises an assemblage of different species of organisms—including humans and their nonbiotic environment—all bound together by regular interactions.

These interactions are defined by the movement of energy, matter, and information, and are regulated by feedback relationships in which the outcome of each change affects subsequent inputs. Feedback relationships that act to dampen potential changes are referred to as negative feedback, whereas those that enhance changes are termed positive feedback. Change is always taking place in an ecosystem, but what is important is whether the change is of sufficient magnitude to permanently alter it. Crossing this type of limit, or *threshold,* distinguishes the repeated alternations that constitute cycles, such as those that reoccur on a seasonal pattern, from the cumulative changes that define a real transformation. Because its constituent elements are subject to change, an ecosystem continually changes through time.

Most natural and human systems, at any point in time, appear to be primarily governed by *negative feedback*, which allows the system's values to oscillate but keeps them within limits so that the basic nature of the system remains stable. Three very important characteristics of human ecosystems are their *predictability, resistance* and *resilience* (fig. 3.3). The key aspect of predictability is the extent to which the impact of forces acting on the system can be anticipated, and hence predicted, based on past experience. The resistance of a system is its ability to resist or accommodate external pressures without seriously transforming itself. The resilience of a system is its ability to return to close to its predisturbance state. All ecosystems are exposed to continual external and internal pressures, and the ability of the system to maintain stability will depend on its structural resistance, its resilience, and whether impacts to the system are predictable enough to be effectively assimilated.

Most of the activities within an ecosystem involve the exchange of material and energy (the ability to do work) between two entities or between one entity and the physical environment (fig. 3.4). Energy exists in many forms, but the three fundamental varieties for our consideration are *radiant, mechanical,* and *chemical.* The source of all radiant energy entering our biosphere is the sun, and this energy is captured and exchanged by both abiotic and biotic mechanisms. Mechanical energy comes from the external force of gravity of the moon and sun, and rotational forces of the spin of the earth. In addition, organisms can use the earth's gravitational pull by taking

Figure 3.3
Model of changing system state (after Nancy Grimm, personal communication).

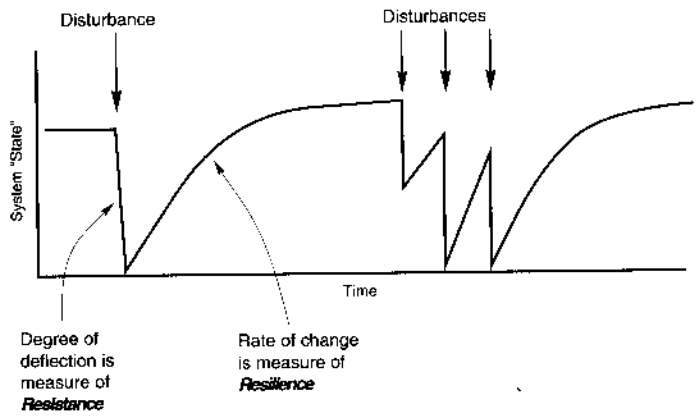
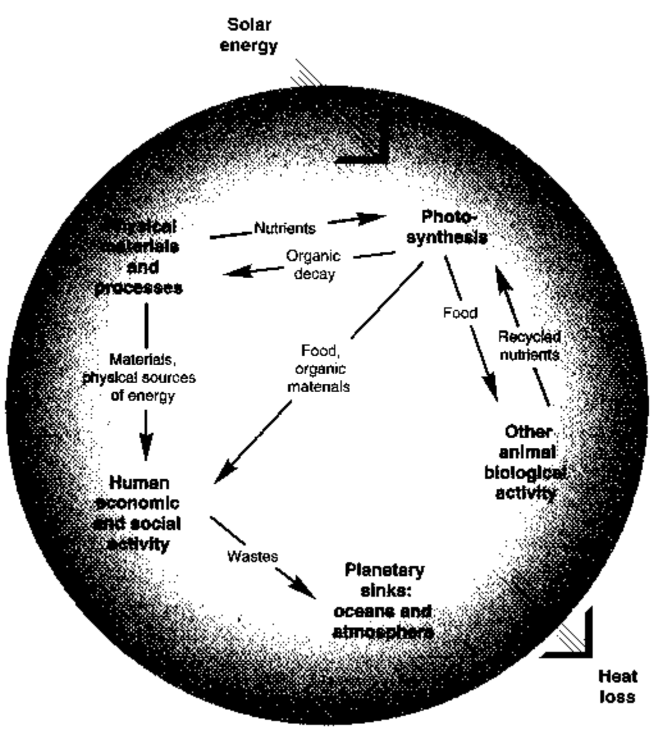


Figure 3.4
Exchanges among the components of the environment.



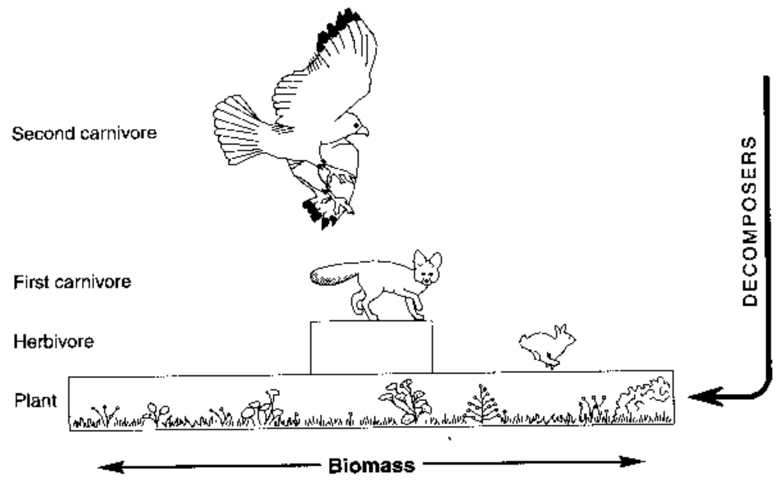
advantage of differing potentials or heights. Chemical energy derives from various chemical reactions that capture or emit energy, most often in the form of heat. Fire is probably the most commonly recognized form of extra somatic energy release. *Photosynthesis*, which takes place in plants, is the fundamental source of stored chemical energy in living organisms (in the form of sugars). Animals release this energy for their own use through *metabolism* of the plant-produced material or of other animal material that already ingested plant material.

There is a crucial relationship between the existence of life forms and the transfer of energy. According to the second law of thermodynamics, we live in a universe that with every interaction is tending toward greater disorder, yet life requires an enormous degree of orderliness. The creation and maintenance of life forms can only be achieved at a very high cost of

energy consumed. The transfer of this chemical energy, usually as food, from one life form to another is fundamental to all our thinking about ecosystemic behavior and, more specifically, to all human-environmental interactions. In reality, it is a very complex process, but it can be thought of as a *food chain* with many links and simply represented as a *trophic pyramid of energy* (Ricklefs 1993:104; Little and Moren 1976:7). At the base of this pyramid are green plants, which are the primary producers, providing all food for higher level organisms (see fig. 3.5). Above the primary producers are consumers of various levels: herbivores, carnivores, and omnivores. Decomposers break down the remains of organisms at all levels into constituent compounds that can once again be used by primary producers.

At each successively higher level of the pyramid, much of the available chemical energy is lost on maintaining the lower level organisms and the basic inefficiency of biological energy transfers. Hence, less and less energy is produced as one progresses up the trophic pyramid, which usually translates to fewer and fewer organisms. Therefore, the primary production of plants must be enormous in order to support a large biomass of herbivores, and it takes many herbivores to support a few carnivores. The ratio of production on one trophic level to that on the level below it is defined as the *ecological efficiency* of that link in the food chain. Several variables must be specified to

Figure 3.5
Schematic diagram of a trophic pyramid.



allow an accurate measurement of this ratio, but as a general guideline, it has been estimated that the conversion of food biomass into consumer's biomass involves an efficiency of about 10% (Diamond 1997:169).

The enormously important implication of this ratio for omnivores (such as humans), who are able to choose their source of food, is that eating primary producer plants is a more efficient use of available food resources than depending on herbivores, who themselves consume the plant material. Put simply, a vegetarian diet could potentially support significantly more people than a diet that consists of large quantities of meat from domestic animals. But the issue is far more complex than this statement or the simple diagram in figure 3.5. Plants, animals, and humans are not related in a simple linear pyramid flow, but by a series of complex and changing food chains that can be best represented by a multidimensional "web." Many creatures on intermediate levels of the pyramid are able to digest, and convert to useable energy sources, foods that those at the higher levels (especially humans) can not consume due to limitations of their digestive system and selective tastes. Therefore, the food chain humans depend upon does have inefficiencies due to our reliance on meat from animals that dissipate plant energy in supporting themselves, but at the same time, these animals extend our reach to sources of plant energy we would never be able to ingest ourselves. (Food chains will be discussed in greater detail in chapter 4.)

Human Decision-Making

Although it is convenient to use ecosystem concepts as formulated by biologists, it is essential to recognize that human-dominated ecosystems differ in fundamental ways from other biological systems: information, technology, economics, and social organization play inordinately greater roles (Butzer 1982:32). This difference takes the form of purposeful behavior and the ability to evaluate potential outcomes without actually attempting them.

The actual state, or condition, of a human ecosystem is the cumulative result of previous conditions being influenced by both *driving* and *mitigating forces*. Driving and mitigating forces are another way of conceptualizing the various elements and influences that affect an ecosystem (see fig. 3.2). Driving forces themselves are conditioned by a variety of influences, which can be separated into four categories: demographic, economic/technological, social/political, and environmental. These drivers do not work in isolation, but usually interact with each other and are limited by a series of mitigating forces. The human population of a system can grow through both

fertility and immigration, but the increase in numbers is ultimately limited by resources needed to sustain itself, increased disease, higher social tension, and many other mitigating forces. By understanding the nature of driving and mitigating forces that affect a particular system, it is possible to model the factors that have led to the current condition or state of the system.

If all of these forces and the processes that influence them remained constant, our study would be more straightforward. But change, as well as stability, characterizes human and nonhuman systems. What is unique about human-dominated systems is that many of these changes give rise to a *stress* that is recognized and consciously acted upon. In the normal course of events, humans continually find themselves in situations where they can choose how to adjust to the effects of a stress. Hence, humans play an active role in shaping the future state of their ecosystem through rational processes of defining alternatives and choosing among them based on past experience or knowledge gained from others. Taking their lead from biological evolutionists, anthropologists have focused on the term *human adaptation* as the strategies adopted by people to enhance their chance of survival and reproduction. *Adaptability* is a term used to indicate the capacity of a cultural system or groups within it to adjust to stresses. *Stresses* can take many forms, each posing a different kind of threat to the system and prompting differing responses. Archaeologists have long recognized that *climatic stresses*, such as changing temperature, rainfall, or seasonal variations, can cause tremendous problems for human survival. In most of these cases the climatic change is seen as external and uncontrollable, and the human response is the dependent variable. There are, however, other types of stress that may be affected by external factors, such as climate, but are more actively influenced by human actions. These would include *nutritional stress*, *disease stress*, *demographic stress*, and *stress caused by competition from other human groups* (Little and Moren 1976:29–45).

Responses to stresses can take many forms, the most basic being a *genetic* change in the organisms themselves. This is a long-term response that does not relieve the pressure for numerous generations and simultaneously acts to decrease the potential flexibility of the organism by focusing on specific adaptations. Although genetic changes are constantly occurring in all populations, it is not apparent that this type of change has had significant impact on human populations as a result of the types of stresses described in this book nor over the time span discussed. The second basic category of response is *physiological*, which involves actual bodily changes in the organism. Physiological changes can often help organisms cope with stresses and mitigate the need for genetic changes to occur for an organism to survive and