A Biotic View of Land [1939]

This is one of Leopold's landmark papers, delivered as a plenary address to a joint meeting of the Society of American Foresters and the Ecological Society of America on June 21, 1939, in Milwaukee, Wisconsin. It was subsequently published in the *Journal of Forestry*. From the most recent contemporaneous ecological theory it abstracts an emerging new portrait of nature—the biotic or ecosystemic concept. Like "The Conservation Ethic," the essay represents a milepost on Leopold's intellectual pilgrimage, and substantial portions of it were incorporated in *Sand County Almanac's* "The Land Ethic."

In pioneering times wild plants and animals were tolerated, ignored, or fought, the attitude depending on the utility of the species.

Conservation introduced the idea that the more useful wild species could be managed as crops, but the less useful ones were ignored and the predaceous ones fought, just as in pioneering days. Conservation lowered the threshold of toleration for wildlife, but utility was still the criterion of policy, and utility attached to species rather than to any collective total of wild things. Species were known to compete with each other and to cooperate with each other, but the cooperations and competitions were regarded as separate and distinct; utility as susceptible of quantitative evaluation by research. For proof of this we need look no further than the bony framework of any campus or capitol: department of economic entomology, division of economic mammalogy, chief of food habits research, professor of economic ornithology. These agencies were set up to tell us whether the red-tailed hawk, the gray gopher, the lady beetle, and the meadowlark are useful, harmless, or injurious to man.

Ecology is a new fusion point for all the natural sciences. It has been built up partly by ecologists, but partly also by the collective efforts of the men charged with the economic evaluation of species. The emergence of ecology has placed the economic biologist in a peculiar dilemma: with one hand he points out the accumulated findings of his search for utility, or lack

of utility, in this or that species; with the other he lifts the veil from a biota so complex, so conditioned by interwoven cooperations and competitions, that no man can say where utility begins or ends. No species can be "rated" without the tongue in the cheek; the old categories of "useful" and "harmful" have validity only as conditioned by time, place, and circumstance. The only sure conclusion is that the biota as a whole is useful, and biota includes not only plants and animals, but soils and waters as well.

In short, economic biology assumed that the biotic function and economic utility of a species was partly known and the rest could shortly be found out. That assumption no longer holds good; the process of finding out added new questions faster than new answers. The function of species is largely inscrutable, and may remain so.

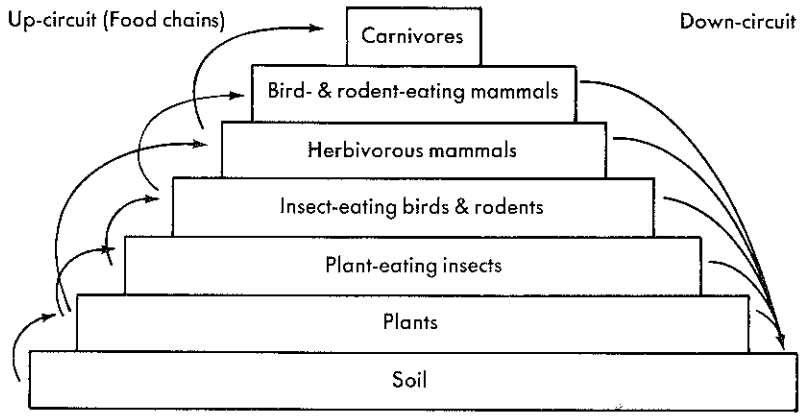
When the human mind deals with any concept too large to be easily visualized, it substitutes some familiar object which seems to have similar properties. The "balance of nature" is a mental image for land and life which grew up before and during the transition to ecological thought. It is commonly employed in describing the biota to laymen, but ecologists among each other accept it only with reservations, and its acceptance by laymen seems to depend more on convenience than on conviction. Thus "nature lovers" accept it, but sportsmen and farmers are skeptical ("the balance was upset long ago; the only way to restore it is to give the country back to the Indians"). There is more than a suspicion that the dispute over predation determines these attitudes, rather than vice versa.

To the lay mind, balance of nature probably conveys an actual image of the familiar weighing scale. There may even be danger that the layman imputes to the biota properties which exist only on the grocer's counter.

To the ecological mind, balance of nature has merits and also defects. Its merits are that it conceives of a collective total, that it imputes some utility to all species, and that it implies oscillations when balance is disturbed. Its defects are that there is only one point at which balance occurs, and that balance is normally static.

If we must use a mental image for land instead of thinking about it directly, why not employ the image commonly used in ecology, namely the biotic pyramid? With certain additions hereinafter developed it presents a truer picture of the biota. With a truer picture of the biota, the scientist might take his tongue out of his cheek, the layman might be less insistent on utility as a prerequisite for conservation, more hospitable to the "useless" cohabitants of the earth, more tolerant of values over and above profit, food, sport, or tourist-bait. Moreover, we might get better advice from economists and philosophers if we gave them a truer picture of the biotic mechanism.

I will first sketch the pyramid as a symbol of land, and later develop some of its implications in terms of land use.



A rendering of Leopold's drawing of the biotic pyramid which appeared in the *Journal of Forestry*. The drawing depicts the plant and animal community as an energy circuit.

Plants absorb energy from the sun. This energy flows through a circuit called the biota. It may be represented by the layers of a pyramid. The bottom layer is the soil. A plant layer rests on the soil, an insect layer on the plants, and so on up through various groups of fish, reptiles, birds, and mammals. At the top are predators.

The species of a layer are alike not in where they came from, nor in what they look like, but rather in what they eat. Each successive layer depends on those below for food and often for other services, and each in turn furnishes food and services to those above. Each successive layer decreases in abundance; for every predator there are hundreds of his prey, thousands of their prey, millions of insects, uncountable plants.

The lines of dependency for food and other services are called food chains. Each species, including ourselves, is a link in many food chains. Thus the bobwhite quail eats a thousand kinds of plants and animals, i.e., he is a link in a thousand chains. The pyramid is a tangle of chains so complex as to seem disorderly, but when carefully examined the tangle is seen to be a highly organized structure. Its functioning depends on the cooperation and competition of all its diverse links.

In the beginning, the pyramid of life was low and squat; the food chains short and simple. Evolution has added layer after layer, link after link. Man is one of thousands of accretions to the height and complexity of the pyramid. Science has given us many doubts, but it has given us at least one certainty; the trend of evolution is to elaborate the biota.

Land, then, is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants, and animals. Food chains are the living channels which conduct energy upward; death and decay return it to the soil. The

circuit is not closed; some energy is dissipated in decay, some is added by absorption, some is stored in soils, peats, and forests, but it is a sustained circuit, like a slowly augmented revolving fund of life.

The upward flow of energy depends on the complex structure of the plant and animal community, much as the upward flow of sap in a tree depends on its complex cellular organization. Without this complexity normal circulation would not occur. Structure means the characteristic numbers, as well as the characteristic kinds and functions of the species.

This interdependence between the complex structure of land and its smooth functioning as an energy circuit is one of its basic attributes.

When a change occurs in one part of the circuit, many other parts must adjust themselves to it. Change does not necessarily obstruct the flow of energy; evolution is a long series of self-induced changes, the net result of which has been probably to accelerate the flow; certainly to lengthen the circuit.

Evolutionary changes, however, are usually slow and local. Man's invention of tools has enabled him to make changes of unprecedented violence, rapidity, and scope.

One change is in the composition of floras and faunas. The larger predators are lopped off the cap of the pyramid; food chains, for the first time in history, are made shorter rather than longer. Domesticated species are substituted for wild ones, and wild ones moved to new habitats. In this world-wide pooling of faunas and floras, some species get out of bounds as pests and diseases, others are extinguished. Such effects are seldom intended or foreseen; they represent unpredicted and often untraceable readjustments in the structure. Agricultural science is largely a race between the emergence of new pests and the emergence of new techniques for their control.

Another change affects the flow of energy through plants and animals, and its return to the soil. Fertility is the ability of soil to receive, store, and return energy. Agriculture, by overdrafts on the soil, or by too radical a substitution of domestic for native species in the superstructure, may clog the channels of flow or deplete storage. Soils depleted of their stores wash away faster than they form. This is erosion.

Waters, like soils, are part of the energy circuit. Industry, by polluting waters, excludes the plants and animals necessary to keep energy in circulation.

Transportation brings about another basic change: the plants or animals grown in one region are consumed and return to the soil in another. Thus the formerly localized and self-contained circuits are pooled on a world-wide scale.

The process of altering the pyramid for human occupation releases stored energy, and this often gives rise, during the pioneering period, to a

deceptive exuberance of plant and animal life, both wild and tame. These releases of biotic capital tend to becloud or delay the penalties of violence.

This thumbnail sketch of land as an energy circuit conveys three ideas more or less lacking from the balance of nature concept:

(1) That land is not merely soil.

(2) That the native plants and animals kept the energy circuit open; others may or may not.

(3) That man-made changes are of a different order than evolutionary changes, and have effects more comprehensive than is intended or foreseen.

These ideas, collectively, raise two basic issues: Can the land adjust itself to the new order? Can violence be reduced?

Biotas seem to differ in their capacity to sustain violence. Western Europe, for example, carries a far different pyramid than Caesar found there. Some large animals are lost; many new plants and animals are introduced, some of which escape as pests; the remaining natives are greatly changed in distribution and abundance. Yet the soil is still fertile, the waters flow normally, the new structure seems to function and to persist. There is no visible stoppage of the circuit.

Western Europe, then, has a resistant biota. Its processes are tough, elastic, resistant to strain. No matter how violent the alterations, the pyramid, so far, has developed some new *modus vivendi* which preserves its habitability for man and for most of the other natives.

The semiarid parts of both Asia and America display a different reaction. In many spots there is no longer any soil fit to support a complex pyramid, or to absorb the energy returning from such as remains. A cumulative process of wastage has set in. This wastage in the biotic organism is similar to disease in an animal, except that it does not culminate in absolute death. The organism recovers, but at a low level of complexity and human habitability. We attempt to offset the wastage by reclamation, but where the regimen of soils and waters is disturbed it is only too evident that the prospective longevity of reclamation projects is short.

The combined evidence of history and ecology seems to support one general deduction: the less violent the man-made changes, the greater the probability of successful readjustment in the pyramid. Violence, in turn, would seem to vary with human population density; a dense population requires a more violent conversion of land. In this respect, America has a better chance for nonviolent human dominance than Europe.

It is worth noting that this deduction runs counter to pioneering philosophy, which assumes that because a small increase in density enriched human life, that an indefinite increase will enrich it indefinitely. Ecology knows of no density relationship which holds within wide limits, and sociology seems to be finding evidence that this one is subject to a law of diminishing returns.

Whatever may be the equation for men and land, it is improbable that we as yet know all its terms. The recent discoveries in mineral and vitamin nutrition reveal unsuspected dependencies in the up-circuit; incredibly minute quantities of certain substances determine the value of soils to plants, of plants to animals. What of the down-circuit? What of the vanishing species, the preservation of which we now regard as an aesthetic luxury? They helped build the soil; in what unsuspected ways may they be essential to its maintenance? Professor Weaver proposes that we use prairie flowers to reflocculate the wasting soils of the dust bowl; who knows for what purpose cranes and condors, otters and grizzlies may some day be used?

Can the violence be reduced? I think that it can be, and that most of the present dissensions among conservationists may be regarded as the first gropings toward a nonviolent land use.

For example, the fight over predator control is no mere conflict of interest between field-glass hunters and gun-hunters. It is a fight between those who see utility and beauty in the biota as a whole, and those who see utility and beauty only in pheasants or trout. It grows clearer year by year that violent reductions in raptorial and carnivorous species as a means of raising game and fish are necessary only where highly artificial (i.e., violent) methods of management are used. Wild-raised game does not require hawkless coverts, and the biotically educated sportsman gets no pleasure from them.

Forestry is a turmoil of naturalistic movements.

Thus the Germans, who taught the world to plant trees like cabbages, have scrapped their own teachings and gone back to mixed woods of native species, selectively cut and naturally reproduced (*Dauerwald*). The "cabbage brand" of silviculture, at first seemingly profitable, was found by experience to carry unforeseen biotic penalties: insect epidemics, soil sickness, declining yields, foodless deer, impoverished flora, distorted bird population. In their new Dauerwald the hard-headed Germans are now propagating owls, woodpeckers, titmice, goshawks, and other useless wildlife.

In America, the protests against radical "timber stand improvement" by the C.C.C. and against the purging of beech, white cedar, and tamarack from silvicultural plans are on all fours with Dauerwald as a return to nonviolent forestry. So is the growing skepticism about the ultimate utility of exotic plantations. So is the growing alarm about the epidemic of new Kaibabs, the growing realization that only wolves and lions can insure the forest against destruction by deer and insure the deer against self-destruction.

We have a whole group of discontents about the sacrifice of rare species:

condors and grizzlies, prairie flora and bog flora. These, on their face, are protests against biotic violence. Some have gone beyond the protest stage: witness the Audubon researches for methods of restoring the ivory-billed woodpecker and the desert bighorn; the researches at Vassar and Wisconsin for methods of managing wildflowers.

The wilderness movement, the Ecological Society's campaign for natural areas, the German *Naturschutz*, and the international committees for wildlife protection all seek to preserve samples of original biota as standards against which to measure the effects of violence.

Agriculture, the most important land use, shows the least evidence of discontent with pioneering concepts. Conservation, among agricultural thinkers, still means conservation of the soil, rather than of the biota including the soil. The farmer must by the nature of his operations modify the biota more radically than the forester or the wildlife manager; he must change the ratios in the pyramid and exclude the larger predators and herbivores. This much difference is unavoidable. Nevertheless it remains true that the exclusions are always more radical than necessary; that the substitution of tame for wild plants and the annual renewal of the plant succession creates a rich habitat for wildlife which has never been consciously utilized except for game management and forestry. Modern "clean farming," despite its name, sends a large portion of its energy into wild plants; a glance at the aftermath of any stubble will prove this. But the animal pyramid is so simplified that this energy is not carried upward; it either spills back directly into the soil, or at best passes through insects, rodents, and small birds. The recent evidence that rodents increase on abused soils (animal weed theory) shows, I think, a simple dearth of higher animal layers, an unnatural downward deflection of the energy circuit at the rodent layer. Biotic farming (if I may coin such a term) would consciously carry this energy to higher levels before returning it to the soil. To this end it would employ all native wild species not actually incompatible with tame ones. These species would include not merely game, but rather the largest possible diversity of flora and fauna.

Biotic farming, in short, would include wild plants and animals with tame ones as expressions of fertility. To accomplish such a revolution in the landscape, there must of course be a corresponding revolution in the landholder. The farmer who now seeks merely to preserve the soil must take account of the superstructure as well; a good farm must be one where the wild fauna and flora has lost acreage without losing its existence.

It is easy, of course, to wish for better kinds of conservation, but what good does it do when on private lands we have very little of any kind? This is the basic puzzle for which I have no solution.

It seems possible, though, that prevailing failure of economic self-interest as a motive for better private land use has some connection with the failure of the social and natural sciences to agree with each other, and with the landholder, on a common concept of land. This may not be it, but ecology, as the fusion point of sciences and all the land uses, seems to me the place to look.