MAN ON THE LANDSCAPE

VERNON GILL CARTER

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The Fundamentals of Plant Conservation

BY

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TO ZANESVILLE

One of America's most conservation conscious cities—center of varied official watershed laboratory studies embracing soil and water conservation, reforestation, fish and game management, flood control, and climatic research—pioneer in conservation education, with organized curriculum work in this field since 1937—to the teachers, and all other citizens of Zanesville, this book is dedicated.

A CONTRIBUTION

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ACKNOWLEDGMENTS AND RESPONSIBILITY

I have stated publicly the opinion that no man could, from his own resources alone, successfully write a book on the total relations of man to his environment. There are too many sciences involved. Having, with much travail and the aid of a corps of obstetricians, brought forth the following brain child, I have found no reason to change my mind. It is with deep gratitude that I acknowledge the help of the following men:

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To these men, and to innumerable others whose writings, researches, and remarks have contributed to my still feeble grasp of the complex landscape, I offer thanks for their help.

It must be clearly understood that no one of those mentioned is responsible for statements in this book, except when a direct reference is made. I have not in every instance agreed with their opinions or with their interpretations of data.

No apology is made for laying hold of the most advanced thinking in the relations of man to the landscape. A few phases of those relations may still be controversial. My stand on such questions is deliberate. I choose boldness rather than the extreme caution of the scientific and technical specialists—because I do not believe that modifications resulting from further (and needed) research will make any great difference in the broad social conclusions now apparent.

V.G.C.

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ILLUSTRATIONS

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INTRODUCTION

TO START WITH—

There ought to be a reason why anyone should read this book. Some people have itching brains and will read anything. They are welcome, but in the main we are after more cautious game. To be blunt, we hope to snare those who think plants a fit topic for exercising the intelligence, and fit objects for engaging the muscles.

Thus far, we have as our potential audience the curious citizen, the agriculturist in all his forms, the forester, the home gardener, the feeder of animals both gentle and wild, the sportsman, the nature lover, that considerable body of folk who eat plants on occasion, and in particular, we have the teacher and student of plant life.

Teachers and students of plant science doubtless think the subject important. It is our thesis that it is *more* important than even they claim. The demonstration of this proposition is a task on which we descend with considerable enthusiasm. Assuming that we shall be successful, we must conclude that those among our readers who happen to teach or will some day teach may want to pass on to their students the facts, ideas, and proofs here presented. And so, we cannot refrain from making suggestions on how to do it. However, these suggestions will not be imposed upon those remote from the teaching art, but will be buried in that Potter's field of the penman—an appendix.

If we were to assume anything about our audience, it would be that it has some knowledge of plants—that it knows an oak from a pine. However, we are not going to assume anything in this connection except that it is interested in plants or is willing to become interested. In fact, little will be said about individual plants. We shall proceed quickly to a consideration of plants in the mass.

It is in the mass that plants affect man most strikingly. It is the pasture, the meadow, the range which eventually put the beefsteak on the platter or the rabbit in the game bag. It is the grove, the woodlot, the forest which put the newspaper on the front porch, the vension on the peg. It is when we do not have plants in the mass that trouble starts for man.

AND SO, NATURALLY—

In the chapters which follow we shall discuss many of the troubles of man. We shall see how he has brought them upon himself, and how he can throw them off—by using plants *en masse*. In diagnosing and prescribing for these troubles we must, like the physician, inquire into what may seem unrelated conditions, but which turn out to be fundamentally inseparable. In nature we find wheels within wheels; and, as in a watch, a flaw in one immediately disrupts the proper functioning of the whole instrument. Each wheel is important and worthy of attention, but to the user it is the function of the whole that counts most. It is comparatively simple to become an expert concerning one of nature's wheels, such as soils, or water, or birds, or wildflowers; but, for real understanding we must consider the total landscape. Plants can be only the starting point, certainly not an end.

The functions of plants as society feels them is our concern here. Let us pre-view some of the obvious functions of vegetation, and some not so obvious.

Without plants there could be no people.

Without plants the whole earth would be a desert. Man is a great manufacturer, and through the misapplication of his power he has manufactured well over 50,000 square miles of desert in the United States. He did it by preventing plants from functioning.

Without plants there would be no humus-laden topsoil, no productivity worth mentioning.

Without the continuous service of plants, animals would exhaust the oxygen of the air.

Without plants there would be few reliable springs, few constant streams, few clear rivers, few long lived lakes.

Without plants past and present there would be no great industrial regions depending on freshwater, no cities, no coal, no oil, no gas.

And, let us repeat, without plants there could be no people, no you and I.

We have in these statements considered plants at the zero point. As we move the amount of vegetation upward toward the maximum, the related factors move upward with it, until we have the richest possible natural environment — such as the frontiers man found, and such as formed the basis of this richest of nations. We may go even farther, and on certain areas exceed nature—as by irrigating arid lands or supplying missing soil minerals in certain regions.

Today, the maximum vegetation is only a memory on vast acreages of our country. The headaches of man came thick and fast when it dropped to the fifty per cent mark or thereabout.

A single phrase—plant deficiency—will help answer all the following questions, each of which indicates a flaw in the social order of man.

1. What causes our streams to be muddy?
2. Why do once permanently flowing streams become intermittent streams—with alternate floods and dry beds?
3. What makes people think the climate is getting drier?
4. Why are we forced to spend, above and beyond the natural necessity, hundreds of millions on flood control?
5. Why are new flood crest records being set from time to time?
6. Why do reservoirs for water supply, power, navigation and recreation fill up with mud?

7. Why must millions be spent to keep our harbors from filling with silt?
8. Why do streams wander here and there, far more than they did under virgin land conditions, changing course, altering field patterns and property lines?
9. Why do new industries often avoid many seemingly desirable locations?
10. Why does the fertility of sloping land decrease several times as fast as mere cropping should cause?
11. Why are nutrient minerals, not long ago found near the sur face, now found beyond the reach of roots?
12. Why are millions of acres of once rich soils now gashed, gullied, or skinned down to a whiskery covering of weeds?
13. Why is the humus content of the nation's soils falling?
14. Why is the cost of meat so high?
15. Why do we reclaim arid lands at such high cost?
16. Why do we have so much trouble with weeds, almost none of which the pioneer knew?
17. Why do livestock on a vast total of forage acres now require, per animal, from three to six times the former area for support?
18. Why do great stretches of former hardwood forest areas refuse to produce hardwoods today?
19. Why do we maintain national forests at a cost which is double the value of the harvested timber?
20. Why is the cost of lumber so high?
21. Why does the hunter complain of lack of game?
22. Why does the fisherman moan?
23. Why are marine fish and shellfish scarce and high priced?
24. Why do large areas have only half or a fourth the number of insects, especially bees, necessary for full crop pollination?
25. Why are plant diseases so prevalent and costly?
26. Why are nutritional deficiencies prevalent among domestic animals and the human clan?
27. Why do we have rural slums?

AS WE SHALL DEMONSTRATE—

The answer, in whole or in part, directly or indirectly, to all these questions is: *plant deficiency.* The deficiency is, for most of them, a matter of quantity. Or, the quantity may be adequate for only part of the time, part of the year or period of years. The deficiency may also be one of quality; that is, a deficiency in the amount or number of nutrients composing the plant parts. Very often the quantity of plants cannot be increased without also providing for better quality. Plant quality is of greater importance than most of us realize.

There is no need to labor the point. These questions are momentous, economically, socially, personally. The opportunity for doing something about them and the responsibility of doing something about them rest on the people who have any relation whatever to plants. That is all of us.

But, we must first know precisely what each problem is, and, to the best of present scientific knowledge, what to do. This is in part a task in education, and on those teachers and teachers-to-be, who are concerned with both the natural and social sciences, falls a large share of the burden in saving a civilization from the sure decline which must follow resource destruction. At least the attempt to save it must be made. Otherwise, why teach?

What benefit is it to know a pistil from a stamen if one day there are no pistils or stamens?

When we employ a man we want to know quite a lot about him: his name, race, habits, family background. Those things may influence his fitness for the service we want from him. But, most important, *we want to know what he can do.* Similarly with plants. Their structure, internal processes, name, and classification are pertinent information for certain purposes. But, the great question is: what can they do for us? And, how can we get them to do it?

We certainly do not want to be like the tradition bound Chinese, who (as that former Chief of the U. S. Biological Survey, J. N. Darling, put its) spent so much time worshiping the family tree, talking about the family tree, studying the family tree, that they let their country go to pot unnoticed.

If we are going to inquire into the nature of plants, then by all means let us go all the way and see how they enter into the great, intricately geared machine of soil, water, sunshine, air, men, jobs, health, prosperity and happiness.

TO SUM UP—

The purposes of this book are:

(1) To establish plants *en masse* as a much neglected and exceedingly important factor in the welfare of man.

(2) To identify the social and personal problems arising from deficiencies in the quantity and quality of vegetation.

(3) To reach an understanding of the complex maze of relationships found in the landscape, and how they have developed.

(4) To set forth the principles of landscape management or environmental engineering by which man can ease many of his troubles and avoid others.

(5) To suggest how the younger generation may be made aware of the great part vegetation will play, for good or evil, in its life.

APOLOGY FOR CHAPTER I

The first chapter, "A Global View," is a paradox. It belongs at the end of the book. And yet, it belongs at the beginning. We suspect that it will be disappointing to the reader in its present position. That is because it cannot be understood very well without the background of the chapters to follow. And, on the other hand, those chapters contain a widely ranging array of facts and ideas. They need a unifying preamble, which Chapter I attempts to provide.

The dilemma cannot be solved. The essence of a dozen sciences cannot be distilled and blended into a philosophy of unity in a few minutes. Although it cannot be done, "A Global View" tries. The only reasonable course is to read it again as a final chapter. Such a second reading, backed and sustained by a mosiac of related information, will doubtless be more rewarding.

Chapter I

A GLOBAL VIEW

Before we launch into the details of man's successes and failures in living on the world landscape, let us pause a moment and consider what we are getting into.

Educational experts study such things as the learning process and its handmaid, memory. They have done a great deal of experimenting. They conclude that the best way to begin absorbing, understanding, or memorizing a body of knowledge is first to take an overview of the entire passage to be learned. First, get a general idea of what it is all about. Get an airplane view of the field. Study a map of the whole territory.

In such a general overview, the details are invisible or blurred. But, with such a view fixed in mind, when we later burrow into the details we shall know how they fit into the entire scene. We can see the parts in relation to the whole.

In the field of natural sciences, we are only beginning to fit the parts together so as to make possible a look at the whole. What we see is both discouraging and encouraging. In too many landscapes we find that our past blind misshaping, mishandling of parts and components has produced weird, abnormal scenes. These undernourished, sickly, unbalanced, puny, abnormal landscapes are largely inhabited by abnormal people—people so uniformly abnormal that they think they are normal, and believe that the environment in which they live is normal. It is only recently that these abnormalities have begun to come into the light of general understanding. Science is slowly discovering what is normal for civilized man and the modern landscape. The core of that normality is a robust, timeless, cyclical flow of energy and elements.

This endless flow may be likened to a hydro-power plant on a stream. The stream supplies energy perpetually through the operation of the climatic water cycle. Water is sidetracked over the blades of turbine or waterwheel, then returns to the stream. The energy drawn off is replaced by nature from the immense powerhouse of the sun. The used water is vaporized by sun-born heat and carried by sun-created air currents and winds back to the headwaters of the stream. The compounded mineral elements of the water are the carriers of energy. They must be returned, not dispersed nor destroyed, if the flow of energy is to be maintained. Fortunately, man has been unable to lay violent hands on this phase of the water cycle. It remains as an example of normality. (Fig. 1.)

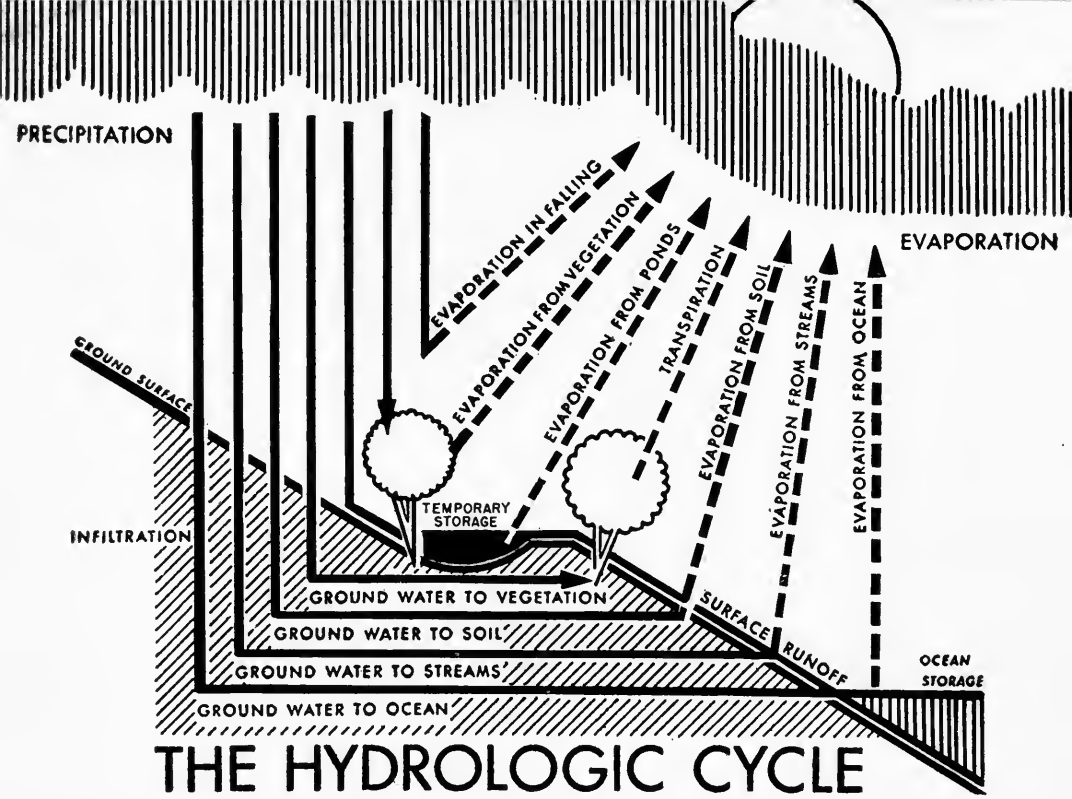

FIG. 1. The hydrologic cycle chart merits careful study. There are two points in the cycle where man alters the natural course: (1) Where the rain strikes the earth, man has decreased the infiltration and increased the runoff, with attendant erosion, lower yields, siltation of storage basins, increase of floods, etc. (2) By excessive pumping of ground water for municipal, industrial, and irrigation use, the water table has in many places fallen so low as to threaten such supplies.

Man, on the whole, has never thought to compare this simple physical cycle to the complex cycle of life. The energy for life is carried by certain elements in soil, water and air. Few men indeed have given attention and thought to the revolving of the proper fraction of these elements from the point of human use back to the soil, so that they maintain a perpetual flow of vigorous plant, animal, and human life.

Not enough men have given penetrating thought to preserving even the soil storehouse itself, a storehouse very easily destroyed and depleted. Nor has man in general considered the intricate, repetitive processes by which the living soil captures, impounds, and transmits to man the complex and varied materials and energies which make him man. These processes are quite delicate in their system of checks and balances, their interdependencies. Man has waded into them, like (if we may draw a caricature) a drunken Cro-Magnon running berserk with a bull-dozer in a watch factory.

Abnormal thinking and actions are rooted in greed, ignorance, misinformation, superstition, fears, and doubtless other unfortunate factors. Civilized man's usage of the landscape usually evolved in just such a mental and emotional climate. The raw truth is that the landscape under civilized occupancy has seldom been allowed or encouraged to function normally.

The channels which thoughts follow are shaped and directed very largely by the personal world we live in. The restricted world most of us live in remains abnormal, and our thinking strongly reflects this fact.

Cities are abnormal in many ways. The ugliness of most houses and business buildings is accepted as normal by 90 per cent or more of city dwellers. The constricted, crowded streets, the lack of parks and playgrounds, the absence of natural scenery, the ignorance of basic production problems and sources of food and clothing, the artificial entertainment, the synthetic stimuli to work and play, the loose standards of conduct—all these are generally abnormal in cities, yet are accepted as normal to city life.

Most American farms, forests, and rangelands are abnormal. The erosion of topsoil, the straight furrow on curving lands, the easy substitution of chemical fertilizers for organic manuring, the exhaustion of humus, the thin, scanty pasture and range, the annihilation cutting of forest and woodlot, the putrid, muddy streams, the scarcity of pollinating insects, the meager populations of birds and other wildlife—these things are abnormal, yet are accepted by a great majority of land owners and land users as normal.

Normal thinking, with a longtime background of abnormal environment, is extremely difficult. It requires search for scientific knowledge. It requires mental labor. It requires social courage. It is not popular. Its conclusions will be resented by many. The forces discouraging normal thinking are great and few will overcome them.

The overview which follows is an attempt to relate man to the landscape, and to point out that the original landscape, and man himself originally, were products of normal forces within the universe. It is a condensed attempt (as is this entire book) to cut through the smoke screens of abnormality and see some of the real modern problems which confront us. That we approach the task from the viewpoint of a particular science is not essential; it is merely a convenient entry into the mazes of the total landscape.

The Organization Behind Life. It is instructive to stop and consider sketchily, what it takes to place a modern mechanical contrivance, say an automobile, at our disposal. We are at least dimly aware of the giant factory with its thousands of workers which fabricate many of the parts and put them together. We may know that many of the parts are made in still other factories. The different metals used are dug out of the earth all over the world. These mining operations are complex procedures involving men and materials. Refining and processing them require mills, and sources of power. Various modes of transportation are involved in moving these earth products to the factories—trucks, railroads, steamships. Many automobile parts are grown on soils—rubber, wool and cotton, soybean plastics—and again many men, animals, machinery, fertilizers, sunshine, rain, processing plants, transportation systems and communication systems are used. The whole universe contributes to the completion of the automobile; and for its operation an extensive industry, petroleum, had to be created; and highway networks had to be built.

It is not too difficult to appreciate the tremendous organization and the resource operations necessary in this instance—because *man* is responsible for most of the manipulative work invloved. We *know* what such effort is.

Living plants are far more complex than any machine. Of the role of the organized universe, the solar and earth factors which are necessary to produce plants, most of us are only vaguely aware. Chemists have found *hundreds* of chemical compounds in leaves alone. Botanists can dissect plants and study their parts, can bring the microscope and test tube to bear on the many kinds of tissues and cells. A master mechanic may know all about how an automobile works. No botanist knows all about how a plant works.

Fortunately the botanist knows some things, and a part of what he knows, everyone ought to know, because that part relates intimately to the quality, satisfaction, and success of human living.

The botanist does not progress very far until he realizes (as does the specialist in any branch of science) that he cannot bottle himself up in an air-tight compartment of knowledge. If he does completely isolate his field of study, he never finds the answers to the great, intricate questions which man asks about life and death.

The most elementary study of a plant (or of an animal, for that matter) immediately brings up three questions: Of what is it made? How does it operate? What is the source of the energy by which it works?

The bio-chemist (we are already knocking on the door of another science) cooks up a plant brew and runs it through his test tubes. He reports that some thirty of the world's ninety-six elements are to be found in a wide range of plants. Fourteen elements, at least, are found in every green plant. Somewhat surprised, he steps next door and asks the physicist to check his findings. The physicist heats plants until the ashes glow. Viewing or photographing through a spectroscope the light rays given off by the white-hot mineral ashes, he confirms the chemist's report and adds another 30 minerals to the list. Each of the sixty elements is identified by the wavelength of its light rays.

So, plants are packets of elements, cunningly arranged and organized. But what are elements? Again the physicist supplies the answer. An element is composed of atoms which are all alike. An atom is an organized and active arrangement of electrons, protons and neutrons. Each of the more than ninety elements has a different number and arrangement of electrons, protons, neutrons. And what are electrons? Negative charges of electricity. Protons? Positive charges of electricity. Neutrons? Neutral charges. And what, the botanist inquires, is electricity? The physicist says it is a form of energy, force, power.

The plant, it appears, is an organized collection of energy. Somewhat timidly, the botanist asks "What is energy?" The physicist can only reply "I am working on that," which is his way of saying, "I don't know much about it, except that it can do work, produce action."

The botanist and his chemist friend go to work. They find that the plant gets its elements from three sources: air, water, and soil. A seed lies in the skin of the earth. It lies in soil, and the soil contains air and water. The plant grows. It takes in elements, and from them constructs itself, according to a certain, largely hereditary, pattern. For something that has no brain, the plant does an amazing architectural job.

Having traced the plant down into the very bowels of atoms, the botanist becomes curious about the air, water and soil—those warehouses of raw stuff from which plants are constructed. The water, he knows, usually comes as rain or snow. In the days of his youth he learned in geography class how the intimate and wonderfully convenient relationship of sun and earth produces weather and climate, how weather turns big rocks into little rocks, even into dust. The effect of sunlight on plants is knowledge which a human can hardly escape. The astronomer tells him that these actions—weather, soil formation, growth—all originated in the energy of the sun.

And so, it becomes clear that the tremendous largeness and precision of the solar system, as well as the unimaginable smallness and precision of atoms, play their parts in the intricate operation of producing a living plant.

Life—the Master Organizer. The solar system is dead. The atoms of mineral elements are dead. With all their clockwork organization they are dead. The air, the waters, the rock dusts, the sunshine are dead. It is these dead things which the chemist and physicist analyze. Yet, out of this death has come life. Life draws upon them all, these simple, natural forms, and transforms them quietly and with ease into such complex living compounds that our greatest scientists are thus far baffled by many of them. If undisturbed, these living organisms grow, reproduce, and die, always enriching that thin zone, enriching that one foot (so far as we know) in all the millions of miles of the solar system's axis which supports life—the topsoil!

This enrichment of soil is an active, energetic process. It is a cumulative process. In it, life overlaps and continues, generation by generation, working over and over the elements life uses, reaching a bit deeper into the rock dust as each century passes, building fertility slowly. As the fertility level rises, the life level inevitably rises. The level of life rises not only in numbers of living things but in complexity of organization. It rises to the ceiling set by the supply and kinds of elements and climate to be found in each region. At the ceiling, each region finally contains the best kinds of life it can support. The final, human triumph is to bring into a region any missing elements and thus raise the ceiling, raise the fertility, raise the level of life there.

The sad story is that man, the acme of life, has generally failed to do this natural, normal duty in enriching his home. He has become a robber of the family goods and a fouler of his own nest. The encouraging story is that in still small but constantly growing number he has realized his error and is correcting it. This reformation is most evident in the agricultural revolution occuring now in the Tennessee Valley, in the Muskingum Valley, in soil conservation districts across the land.

The reformation in land use is based on a belated recognition of the values and lessons of natural organization on the landscape. Nature's system kept the books balanced reasonably well. What life took from the soil, it returned. Water and air were used over and over. They nourished, and seldom injured, life. Each life form, whether plant or animal, drew its substance from the landscape, lived, and when it died its substance went back into the landscape *where it would benefit life to follow.*

Man, the Disorganizer. The organization set up by nature, without benefit of man's technology, was an intricately geared set of cycles. These cycles were intermeshed, driven by power from the sun, and were relatively timeless. They could not run down and stop. Man has, figuratively, straightened out the wheels of this living machine and built a single track, one way road to the sea, the dump, the incinerator, and the cemetery, for the greater part by way of our cities. The substance of the landscape is loosed from its mooring and traded to the cities for money and fabricated goods.

The chief product of the landscape, food, is largely routed through the gullets and alimentary tubes of city people, then through the sewers and down our reeking rivers to the sea. The return phase of the mineral cycle does not operate to any significant extent. The soil is weakened, weakened a little more each year. Minerals are being withdrawn from the soil bank faster than nature can release new supplies from the rocks. Scores of years ago, Victor Hugo warned that the real wealth and strength of France was gushing out to sea through the stone-walled guts of Paris, its sewers. The United States is a younger, stronger land, but already our soils show unmistakable signs of developing mineral shortages. On some 75 million acres the soil itself is gone. If this continues long enough, the last gasp of American civilization may sound remarkably like, may be in fact, the swooshing gurgle of a voracious watercloset. This ingenious device will then sit, in its porcelain and functional beauty, as did its marble prototype in Rome, and wait a thousand years for nature to build a new landscape once again to feed its insatiable maw.

FIG. 2. "Water, instead of nurturing life, destroys it." This Maryland corn needs the water which is escaping. A full yield cannot be secured without it. Not only water and crop growth are being lost, the runoff is heavy with topsoil. Two hundred such episodes—perhaps 30 corn crops—and there will be no topsoil, no corn, no man on this landscape.

And if by chance the watercloset, cold and dry, does not become the symbol of America's decline, it will be because the gully got there first. Erosion is robbing us of soil minerals five or six times as fast as the harvest of crops. Here again, man has placed a heavy hand on the balance scale of nature. Normally, on a mature landscape, weathering and the acid juices of former life eat down into new soil as fast as the surface soil is lost or exhausted. Man, by his choice of row crops for sloping land, by his exposure of bare soil to the power of rain and wind, by his exhaustion of spongy organic matter through continuous year after year cultivation, by harvesting to the last crop remnant, has destroyed the soil cycle. He has, at the same time, by the same acts, short circuited the water cycle; water, instead of soaking in to feed crops, runs away with the soil—water, instead of nurturing life, destroys it. (Fig. 2.) All power may be used for benefit or destruction, according to our management of it. One of the fundamental problems facing the world is the proper use of power. The power of nuclear fission released by a bomb is no more dangerous in the long run than the power of falling raindrops or sweeping wind. (Figs. 3, 4.) Each can play its part in destroying civilization, or enriching it. There may be differences in the speed at which they work, but the result can be the same.

The primary result of man's disruption of the natural cycles of soil minerals, air, water, and organic matter is reduced vegetative production. (Fig. 5.) This brings shortages of food, clothing, housing, and chemurgic products. The shortage of food does not operate like a carefully supervised and balanced reducing diet; the food from

FIG. 3. Atomic power released by nuclear fission in a bomb destroyed this city, this laboriously constructed landscape. How competent is mankind to control this power?

APPLICATIONS OF POWER

FIG. 4. Atomic power originating in the sun operates the earth's water cycle; it is thus the basic force which, guided in this case by an incompetent human mind, destroyed this landscape. Gone are the plantlife, wildlife, and their values to human life. How competent is mankind to control this power?

poor land is usually lacking in nutrient quality—it may not, for instance, provide the proteins needed by the man to produce antibodies; and, human health suffers—resistance to disease decreases.

Abnormal men on an abnormal landscape inevitably engage in abnormal behavior. Aggressive individual fighting and aggressive

FIG. 5. Here man's mismanagement of the power residing in falling rain has disrupted every natural cycle on this landscape. The concentrated minerals of the topsoil are being dispersed; the normal infiltration of water has been disastrously reduced. The hydrologic cycle, perverted from its normal, healthy course, grinds away the foundation of all life.

war are abnormal, regardless of their antiquity. Normal behavior is never wilfully destructive. We could go through a long list of undesirable and destructive behavior traits, which operate in abnormal situations such as deprivation of a completely normal diet, shortages of other necessities to daily living, or even lack of luxuries to which one thinks he is entitled. Inadequate supplies of earth products stimulate fears, suspicions, and aggressive acts between individuals, groups, regions, and nations.

The chaotic state of the world has become chronic over the centuries. It is certainly not a modern phenomenon. Every civilization has eventually exhausted itself, either by wars between nations or by internal war with nature. No one, no group can win a war against nature. The disruption of natural cycles, the doctrine of "take and never repay," is suicidal and never more than temporarily profitable.

There have been and there are islands of normality in the world, where men have learned to live largely in harmony with the landscape. (Fig. 6.) Such a happy status always involves control of the human population by one means or another. (Every kind of life has the capacity to reproduce at a greater rate than the landscape can support.) These tiny islands of sanity in landscape management are probably in some degree accidental. Sufficient scientific knowledge, which would permit a deliberate attempt to establish widespread normal relations between civilized man and nature, has only recently become available.

Man, the Re-Organizer. The natural cycles of life, energy, and matter are a trinity, unified and inseparable. They are a product of the universe. Nature exerts forces to maintain these cycles in operation, and restore then to balance when disturbed. Yet, these balances are so delicate that even a small remnant of the former human population, if it continues destructive practices, can prevent the landscape from recuperating. We see evidence of this on impoverished farms, pastured timberlands, overgrazed rangelands. We see it in once thickly peopled, now largely barren areas in North China, Mesopotamia, North Africa, Greece, Yucatan, Phoenicia, Mexico, South Africa, and others, including the United States of America. Naturally, we should like to prevent such drastic procedures. We should like to see these impoverished areas restored. We should like to see the downward trend stopped on still other areas.

Prevention of slow disaster requires reorganization of man's landscape activities. Where he has been siphoning off energy and substance from the natural cycles without providing for a proper fraction of return, he must provide such return. (Fig. 7.)

Furthermore, science is discovering that the life producing cycles can be enlarged and speeded by feeding into them through the soil (and sometimes through the leaves of plants) certain elements (such as phosphorus and calcium, zinc and copper.) Man found these and other elements lying about in deposits, inert and seemingly useless to *organic* processes. The possibilities for human betterment which lie in such improvements on nature hardly have been touched by the rank and file of land users. Nor has there been a sustained and insistent demand from consumers for rational management of our resources. The job is only well started. The masses sense vaguely and intuitively that such activities will benefit them. But, there is no strong awareness of its full importance.

It is certain that the future security of all peoples is linked with material abundance. People in the mass will never conduct themselves on a purely intellectual and moral plane. Morals, personal or national, are powerfully influenced by the fullness or emptiness of the gut. Hundreds of millions of hungry people (and they are hungry for more than food) are a constant force toward war. America alone cannot feed, clothe, and house them. We can only help them help themselves. They can only help themselves by enriching their own landscapes.

FIG. 6. On this mountainside in Lebanon, man has established normal relationship with Nature, under difficult terms. The laws of the landscape are being observed, and in return for such cosmic citizenship, this mountain has fed, clothed and sheltered the people for 3,000 years.

FIG. 7. This Virginia landscape is slowly being brought toward a state of normalcy. Part of the change has been forced by Nature, as when man was driven, by erosion, from the mountain sides, and the forest now creeps down to reclaim its usurped domain. Another part of the change has been made voluntarily by man, as the strip cropping, enriching of pastures, etc., result from scientific knowledge.

A rich landscape not only provides abundance for a maximum population, but releases workers for industrial production. It provides leisure for the individual and opportunity for self-development. A rich landscape provides surpluses above the bare necessities; it makes possible education, scientific research, art and music, community services and improvements. Social progress rests on the landscape. All things are bound together.

Man's power to reorganize and improve his operations on the landscape increases day by day. The customary lag of 10 to 50 years, between laboratory discovery of basic facts and widespread benefits of their application, must be, is being, shortened. Education at all stages must be alert to absorb at once the rich juices of research bearing on the *fundamentals* of life and living. The technicalities of gadgets are not important to the average citizen or student. He hardly has time to learn the essentials. Careful selection of learning experiences is necessary.

Every citizen of the world has the right to sense, to see, to know the complete unity of which he is a part. He has a right to know the imperfections of his total environment. He has a right to know the causes of these defects. He has the duty to use a portion of his talents to remedy those defects. Otherwise he is a mouse, not a man.

Chapter II

HOW DO WE LIVE AND GROW?

The Powerhouse of Life. Most of the ancients were nature worshipers. Very reasonably, many of them worshiped the sun as the fountainhead of life. Not that it did them any good—but they had a sound idea, the same one that we examined back in high school science courses. From the sun comes the power which activates the life processes of plants, and indirectly of animals. This same powerline of sunlight activates the water cycle, bringing back again and again the moisture by which all living cells function.

Since this sunlight does not reach us at all times because of night, clouds, fog, smoke and rarer reasons, it is fortunate that nature provides means of storing it. Thus life can proceed for a time with the powerline short-circuited, much as an auto can operate for a time on the battery, even if the generator fails. Storage of sun power is found in water, deposited at high points. Such water, on its way to lower levels, releases sun power. Sun power also is stored in plants in the form of carbohydrates, fats, and in proteins. It is released by oxidation, as when it is burned as firewood, or eaten by an animal and transformed into muscular energy. This energy may reappear, for example, as sound produced by vocal apparatus. The screech of a bob-cat is powered by sunlight.

This sun power as stored in plants may be millions of years old. When coal is burned this archaic sun energy is liberated as heat. You may perhaps warm your shins with the regurgitated breakfast of a dinosaur, embalmed in the earth by an overburden of silt and sand, changed by pressure and its heat from carbohydrate into hydrocarbon.

Natural gas and petroleum are hydrocarbons, and are stored sunlight. Whether they are derived from prehistoric plants or from the bodies of animals, or both, is irrelevant here. In either case, since animals are made principally of plant substances, the sun's heat is the thing which has been preserved and which we can use.

These three mineral forms of sun energy are of course fixed in amount. If any are now being formed, the process is so slow that it can have no possible meaning to our present culture. There is considerable controversy as to how long the oil and gas of the United States will last. The most pessimistic estimates give liquid petroleum a life of a decade or two. Then we must use oil-bearing surface sands and shales, which must be mined and distilled. This will probably boost the cost and reduce consumption. Natural gas can be changed into gasoline and oil, but it too is limited. Coal is more plentiful, and gasoline and lubricants can be got from it by hydrogenation. But the high grade, low priced portion of our coal deposits is noticeably shrinking.

When the hydrocarbons do become scarce and expensive, we may be forced to turn to carbohydrates, forced to use sun energy which green plants can imprison from year to year, crop by crop. (This would present a staggering problem because the world's soils today are not even feeding, clothing or sheltering its population decently.) The use of direct sunlight, concentrated by some scientific marvel and changed into a transportable form, offers future possibilities. It also offers almost insuperable practical difficulties. Science will probably be able to use the enormous energies of atoms as a source of controlled power. This could perhaps give us a higher standard of living. Water power cannot supply more than a fraction of our energy needs.

Carbohydrates in the form of starch, sugar, and cellulose, for the powering of the earth's animal population must continue to come from plants. Science to date has not made more than a dent in the problem of duplicating the process which plants use in making carbohydrates. There is at present no glimmer of hope that we shall ever be able to live without plants.

Fats are also energy sources, and are basically carbonaceous. Sugar is their foundation. The energy residing in plant and animal oils is derived from sunlight—sunlight acting through plants on raw materials from atmosphere and water. The oil of the castor bean was used to lubricate airplanes in the First World War. No petroleum product was then good enough. Today better mineral lubricating oils are available. Our machine civilization could operate on plant oils, and may be forced to do so some day. This will mean that vastly more plants will be needed. Instead of gasoline we may find it necessary to use an alcohol, derived from carbohydrates, e.g., from potatoes, grain, wood. And again plants in the mass will be called for. These possibilities, if we may speak parenthetically, offer a very sound argument for conserving and keeping productive every acre of soil in the world. And in order that such a burden be kept from our soils as long as possible, the life of mineral fuel and power supplies should be prolonged by every known means.

Green Food Factories. Of all the physiologic processes which occur, that of photosynthesis is, in a sense, most important. Without it there could be no plants, no animals, no human race. The only logical challenger to the importance of this primary process could be the reverse action, respiration (a form of combustion) which takes place in cells. By respiration, the sun energy concentrated by the green plant into carbohydrate is reconverted again into energy, to appear finally, for one thing, as all the works of man. Toward maintaining these processes all other physiologic activities of plants are pointed.

It is not out of place to review here one of the greatest mysteries confronting man: how green plants make food. If and when science discovers just how chlorophyll does this job, we may know the secret of life. What we know is this: In certain plant cells are bits of matter called chloroplasts. These contain the green chlorophyll—if sunlight, natural or artificial, reaches the cells. (In rare cases already existing sugars may be substituted for direct sunlight). Interfere with the energy supply and the chlorophyll decreases rapidly. Covered sprouts are white. So are the hidden leaves of cabbages, the banked lower stems of celery, the inside leaves of head lettuce—no sunlight, no chlorophyll.

The chlorophyll acts as a catalyst, a promoter of chemical action. It enables the cell to take carbon dioxide (CO_2) from the air, and water (H_2O) from the soil, split their molecules, and recombine the atoms of carbon, hydrogen and oxygen into sugar, (e.g., $C_6H_{12}O_6$).[1] Some oxygen is left over and this is returned to the air, fortunately for us animals. In this process of photosynthesis, the chlorophyll is not consumed. It continues to repeat the same job, as the sugars are carried away to other parts of the plant and new supplies of air and water are admitted to the green manufacturing cells.

What is the significance of this operation? According to Darling,[2] "Chlorophyll . . . plus sunshine has laid down all the topsoil, all the coal, all the oil, and every organic living thing on which mankind has subsisted and must subsist forever. . . Without countless centuries of chlorophyll and sunshine cooperation we could have no food, no fire, no crops, no life, nothing. When we inherited this continent we fell heir to a hundred-million years of cumulative transformation of raw *volcanic rock* to rich loam, grassy plains, primeval forests, a myriad population of fur-bearing animals and waters teeming with fish and other aquatic life—all the product of the *chlorophyll* factory. Don't forget that when this rich endowment is gone its only replenishment must come through that same *small bottleneck of chlorophyll plus sunshine.*

"Can any thoughtful person say that with 80% of our forests already cut down, 75% of our grasslands grazed to a stubble, and millions of acres of underbrush cleared from our hillsides that we have not constricted the bottleneck instead of enlarging it?"[3]

Anyone with a little practice can learn to judge the power potential of a landscape by evaluating the amount of photosynthesis going on there. The more and richer green you can see, the more fuel is being stored. It will be used by both plant and animal life, including man. Of course, we must be familiar with a really fertile countryside

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[1]What happens is that six molecules of carbon dioxide ($6CO_2$) unite, through the influence of active chlorophyll, with six molecules of water ($6H_2O$). In these 12 molecules, there are 6 carbon atoms, 12 hydrogen atoms, and 18 oxygen atoms. When the sugar is formed ($C_6H_{12}O_6$), there are 12 oxygen atoms left over. The chemical equation is expressed in this manner: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$.

[2]Darling, J. N., *Poverty or Conservation,* National Wildlife Federation, Washington, D. C., 1944, p. 11.

[3]Of course it must be realized that Mr. Darling is an artist (as well as a biologist) whose powerful editorial cartoon effects are found in his writings. He uses a broad pen, and makes free use of artistic liberties. We cannot tie him down to complete accuracy of detail, but his protest is basically sound.

in order to judge the degree of chlorophyll activity on one less luxuriant. Such judgment, it must be noted, is of questionable value in determining the nutrient quality of the landscape.

Power Output of Growing Plants. Plants not only store energy useful to lower animals, to man, and to man's mechanical engines, but plants themselves use a part of the incoming sun power to operate themselves. Plants share with animals certain functions. They grow and reproduce. These activities require energy, and the active cells draw on the stored manufactured fuel as needed. This is a point on which the layman is often confused. He mistakenly supposes that plants and animals are purely opposite in function, that plants make fuel, use carbon dioxide and release oxygen; while animals use fuel and oxygen and release carbon dioxide.

It should be emphasized that most plant cells function much as do animal cells, that plants play a dual role, both storing energy and using it. Fortunately, like bees, they store far more than they use.

Albrecht[4] states that a 40 acre field of corn at peak activity consumes as much fuel as a 40 horsepower engine. This represents the power output of all the plant and animal cells which contribute to the growth of the crop. It includes the growing and multiplying cells of the bacteria, the fungi and the animal population in the soil, including protozoa, earthworms, insects and others. The figure is secured by measuring the carbon dioxide released from the soil—a sort of metabolism test of the earth working at high speed with the sun power at full throttle, and supported by release from the soil of accumulated energy of the past.

The Building Blocks of Life. In speaking of carbohydrates and fats, we are dealing with materials compounded almost wholly from atmosphere and moisture. They are quite flimsy in a sense and change back into energy forms with little difficulty. Let us consider proteins. By adding nitrogen and certain other elements to sugar, plants can produce a protein. The catch is that plants cannot use gaseous nitrogen as found in the air. It must be in a different form, as nitrate—something you can get your hands on, something found in soil.

Nitrogen, plus sulphur, and a wide range of other minerals, enable the plant to make proteins, the materials of which living cell parts are constructed. These cells make up the plant itself. Obviously, unless the plant can come into existence, it cannot store energy. The remarkable fact is that plants construct their own building blocks, proteins, out of not less than 23 sub-materials, 23 amino acids. These amino acids are compounded in various proportions from air, water, and a minimum of 10 soil minerals. This construction job has been called biosynthesis, and no specific machinery in the plant for doing it has been discovered.

The amount and number of proteins in a plant depends then on soil fertility. Lime (calcuim) is especially important because of its

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[4]Albrecht, Wm. A., *Why Do Farmers Plow,* American Potash Institute, Inc., Washington, D. C., (no date), p. 2.

relation to nitrogen fixation and cell division. Regardless of the amount of sunlight, if the soil is poor we will not get much protein, nor minerals, nor vitamins. Poor soils primarily produce woody plants, strongly dependent on potassium, topheavy with carbohydrates, and to various degrees indigestible. Try living on sawdust. It is high in fuel value, but not for you. Termites depend on certain protozoa in their digestive tracts to pre-digest wood for them. Even if you could digest it, it would probably not provide sufficient proteins for your body-building needs. It has had to rely on air and water for its bulk, while soil has played a very minor part.

Legumes are plants which indirectly add nitrogen to the soil. This is accomplished by certain bacteria living in nodules on the roots. These bacteria have the ability to change atmospheric nitrogen into protein-like nitrate compounds. The presence of these compounds insures for the legume plant a supply of protein building material. When the plant dies a part of the nitrogen (in the roots) remains in the soil. Crop residues above the surface may add more nitrogen as decay proceeds. Future plants may use them. If a grazing animal eats young, vigorous, growing, leguminous plants, it is guaranteed a good supply of body building protein. (Older, senile plants lose much of their earlier value.) However, legumes, such as clover, alfalfa, and soybeans, must have a generous supply of calcium; and so, great areas of eastern United States must have lime applied to the soil in order to grow them. To put it another way, most of the originally forested area needs lime, and probably other fertilizers, particularly phosphorus, because the woody vegetation itself is evidence of lower fundamental fertility than the grasslands. This is especially true of coniferous forests.

Since animals need from plants both energy factors and growth factors, we must insist on food which supplies both, and in the proper proportion. It is basic that our state of health, nutritionally speaking, depends heavily on the quality and variety of the proteins we consume. We shall have more to say about this later.

Sparkplugs of Life. It was suspected about 1800 and proven around 1905 that no animal can live on a diet consisting only of pure protein, fat, and carbohydrate. In 1885 the Japanese removed beriberi as a devitalizer of their navy by altering the diet of sailors. Specifically, they cut out most of the polished rice, an energy food deficient in vitamin B_1 and other vitamins, replacing it with barley and other foods.

In 1926 vitamin B_1 was isolated, and 10 years later it was manufactured synthetically. Today the study of vitamins is a science in itself.

Feeding vitamins to plants became a public fad a few years ago, and geraniums from coast to coast were dosed with growth stimulators (regulators). As with most such fads there was a scientific basis for it. The only reason, however, for feeding vitamins to plants is that the soil being used is infertile. **Give the plant a soil well stocked with all the necessary minerals in available form, and**

plants will make their own vitamins. It is much cheaper to let the plant do this, and to supply the minerals which may be lacking, than to spoon-feed it with a laboratory product.

Plants do not make vitamins (or incomplete vitamins in some cases) merely to serve the needs of animal nutrition. Plants create them because they are an important factor in plant growth. The fact that animals also need them simply shows our kinship to and dependence on the vegetable world. Vitamins are not directly photosynthetic like sugars; but are biosynthetic, like proteins—a result of mysterious life processes still not understood by man. They are complex chemical compounds and their parts come from air, water, and soil.

It is obvious by now that soil plays an important role in plant production. While the sun is the prime mover and keeps the ball rolling, we cannot have a full quota of chlorophyll, photosynthesis, and biosynthesis unless the soil can provide the proper mineral base to build the necessary bodies of plants. **Thus, any force, or land management practice, which reduces either the necessary depth of topsoil or its fertility results in a waste of available sun power and in a poorer environment.**

Loss of Vitamins: Persistent accelerated erosion, the washing or blowing away of the topsoil itself, usually prevents a full quota of vitamins and minerals from appearing in plants. Exhausting the soil by heavy cropping, with no provision for returning minerals to it, will eventually result in crops which are sick because of deficiencies. The solicitous care which greenhouse men give their soils arises from the fact that a perfect, richly colored plant cannot be produced from an imperfect soil. The plant is a factory powered by solar radiations, but it cannot be expected to produce a high grade product from inferior materials.

Finally, it does an animal little good for plants to produce nutritious food if the nutrients are lost between the field and the gullet. This may occur in canning or cooking by too much heat, stirring air in, contact with metal, too much water, exposure to air, using soda. A recent study shows that cutting an orange with a metal knife destroys by chemical reaction a significant fraction of the Vitamin C. We cannot dwell on these losses here, but they are very important in the use of plants for animal nutrition. Vitamins are often fragile and elusive, and they can be lost from hay as easily as from lettuce.

Vitamin pills, by their huge sales, indicate an intuitive public feeling that modern foods fail properly to feed us. This is in part due to processing the very life out of our crops. Milling and bleaching wheat into white flour, for instance, reduces a nutritious, protein-bearing, mineral- and vitamin-rich natural food to an emasculated, starchy product. A most valuable and complete product of the reactions of sun, plant, and soil is reduced markedly toward that of sunshine alone. For instance, when whole wheat is converted into plain white flour the protein goes down 17%; the riboflavin drops 72%; thiamine falls 90%; niacin fades by 80%; iron decreases 82%; calcium drops 50%.

Conversely, slice for slice of bread, the carbohydrate goes up some 40%.[5]

The advertisers are quite right in calling bread an "energy food," but as handed to us by nature it is the "staff of life," not just a charge of fuel. To overcome this ingenious devitalization, the millers have, at the urging of the medical profession, or because of laws in some 20 states, begun to "enrich" white flour by adding a couple of vitamins and one or two minerals, these to replace some 17, more or less, which were partly or largely removed. Thus we have the vicious circle of one group of industrialists removing many vitamins, a few of which another group then sells to us for replacement. This would not be too bad if we could eventually get all the nutrients we need by this system—but we usually do not.

To Sum Up. Thus far we have perhaps said little that the well-informed citizen does not already know. Plants live and grow by a complex process which is easily and commonly interfered with by man. The fundamental idea to be once and for all time fixed in the mind in this: **With the exception of certain minute plants, chlorophyll is the bottleneck through which all life must pass; there can be little growth or biological activity of any kind without it, no plants, no animals, no human race. Managing the environment to provide the greatest possible amount of active chlorophyll on every acre of the earth should be the basic activity of civilized man.**

(See Appendix B for classroom suggestions.)

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[5]*Foods—Enriched, Restored, Fortified,* Bureau of Human Nutrition and Home Economics, U. S. Dept. of Agriculture, (Publication ASI-39), December, 1945, pp. 3-7.

Chapter III

DO PLANTS HAVE QUALITY?

Succulence vs. Woodiness. As previously stated, plants supplied with adequate calcium (lime) are richer in proteins than when this element is scarce. Calcium, of course, can be effective only if the other nine absolutely necessary nutrient soil minerals are present. Each of these is essential to life, and of course if calcium is lacking in any considerable degree the plant is severely handicapped in utilizing the others. Calcium is stressed because it is the mineral most commonly lacking over the humid half of the country. Another critical mineral is phosphorus. (Phosphorus deficiency is probably the most common mineral lack in animals.) It is essential to the production of a variety of proteins. Like calcium, it is depleted in many soils of the eastern and southeastern states, as well as locally in most states. With a shortage of calcium and phosphorus the nitrogen fixing, protein-rich legumes cannot grow successfully. Those plants which will grow, in spite of such shortages, are forced to depend more on air and water. The cells, heavily charged with carbon, thicken their walls with fibrous cellulose and lignose (sugars) and become woody. Such woody material is not only less digestible, but is relatively poor in minerals, vitamins, and proteins. Thus, **the nutrition of human beings, domestic animals, and wildlife is intimately linked with soil fertility.**

These soil conditions are determined primarily by climate and the mineral composition of the parent rock. Freezing and thawing, the influence of warm season length on the amount and activity of soil biota, winds and evaporation rates, rainfall and leaching—all these influence soil formation, soil structure, and fertility.

On the Great Plains the scanty rainfall has resulted in less weathering; soluble minerals generally have not been carried by leaching beyond the reach of roots. Vegetation is nourishing, able to build much flesh, and so the buffalo, antelope, coyote, prairie chicken, prairie dog and other animals were present in large numbers. Later the steer and pheasant were introduced to replace the decimated buffalo and depleted game birds. Wheat in some areas has been grown, without fertilization, continuously for 30 or 40 years and more, with little drop in yield, testimony to the mineral wealth of the plains soil. Obviously, however, it cannot take this kind of beating indefinitely.

This basic soil situation is reflected in the army figures on rejections of men for service in World War II. The plains states contributed a far higher percentage of men called than our southeastern states. In the latter region, as *one* factor in this situation, the doubled and tripled rainfall coupled with long hot summers have put soluble soil minerals into solution and leached them deep, out of reach of plants. This means they are out of reach of bacteria, insects, livestock, and man. The woodiness of the principal southern crops is well known—pines, corn, cotton, tobacco. Certainly it is reasonable to suspect that these poorly nourishing products would have something in common with most of the vegetation produced there. When it is known that the cotton belt is the nation's greatest consumer of fertilizers, the basic status of its soils is clear. When it is further revealed that soil scientists are bawling for a widespread increase in such soil amendments, plus manures, plus crop rotations, plus diversified farming, plus more permanent pastures, we do not wonder that the collective rural manhood of the region has tended to be susceptible to diseases, plagued by deficiencies, and lacking in stamina. Thus does climate hover over human destiny. Wooden plants make wooden people.

If the southeast listens to the soil scientist—and it is—it may succeed in creating soils good enough to remedy the situation. It is a fact that soil can be improved, and in many cases may be brought to a state of fertility superior to that found by the pioneer settler. Not infrequently it happens that only one or two or three minerals are short, and adding them to a soil makes a remarkable difference in that soil's productivity. It is often like putting gasoline in an empty tank, whereupon the entire machine can go into useful action. Sometimes a considerable variety of soil minerals are lacking or are in such a chemical state that plants cannot get them; then the problem is more complex and difficult.

Three hundred years ago the early tobacco growers of the southern Atlantic Coast discovered something. It was that three years of tobacco (a notorious soil depleter) exhausted the soil so thoroughly that new fields had to be cleared.[1] For this reason the English planters were constantly pestering Charles II for additional grants of land. Thirty thousand acres was considered a reasonable area for staying in business. This was virgin soil. What three hundred years of careless use have done to it may be imagined. But, imagination is not necessary. The facts are available.

If we go on south into the tropical jungles, we find still poorer red clay soils and still less nourishing plants. Most people think the heavy vegetation of the tropics indicates high basic fertility. It does not. It indicates a superficial productivity. The vegetation is mostly woody, and one generation of it is living on the decaying remains of the last. The soil is merely receiving nutrients from one plant and handing them quickly, by swift decay, to another. A high fraction of these limited nutrients is thus saved from leaching by being constantly imprisoned in organic matter. The animal and human population is small, primarily as a result of protein shortage. Only in the higher altitudes of the equatorial region do we find any natively developed civilization, and in climate these areas are not tropical at all. In the low areas, when natives clear a space for gardening they use it two or three years then move; in that short time its fertility has been exhausted.

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[1]It will be argued by some that tobacco had to be discontinued because of diseases. There is considerable evidence that plants growing in a truly complete and fertile soil are not subject to diseases on a scale sufficient to force abandonment of the crop. See *Pay Dirt* by J. I. Rodale, The Devin-Adair Co., New York, p. 165 and chapter 4.

In contrast to woodiness, the protein and mineral rich forage plants are succulent, at least during their youth or prime of life. This is not to say that all succulent plants or succulent parts of plants are rich in proteins and minerals. Species differ. Most young plants are succulent, but in poor soil this stage is often brief; the roots skim the cream off the meagre fertility available to them, and then the plants quickly begin to develop woodiness or toughness.

In the succulent stage cell walls are thin and these units are well filled with water and minerals in solution, giving a crisp quality to the

FIG. 8. Foraging hogs, using some form of basic intelligence unknown to modern man, took the grain from this fertilized sector of a field in preference to the remainder of the 40 acres. (Cliff Love farm, near Warrensburg, Missouri).

tissues so that they pop when broken or chewed. They are easy to eat and digest, in contrast with more woody tissues.

Albrecht[2] reports that farm animals will find and consume first the vegetation on these parts of a field which have received fertilizer. For instance, some Missouri hogs consistently traveled back and forth between a limed and fertilized section of a cornfield and the feeding troughs, ignoring the intervening corn until the fertilized area was exhausted. (Fig. 8.) In another case cattle singled out unerringly the barley in part of a field where a double dose of fertilizer had been accidentally applied. (Fig. 9.) Again, cattle with 190 acres of virgin prairie pasture to roam over confined their early spring grazing to a few acres which had been limed eleven years previously, Albrecht ascribes this selectivity to the greater amounts of nutrients in these plants which the animal detects by taste or smell. However, and we have not seen this idea advanced elsewhere, it may be due to the

[2]Albrecht, Wm. A., "Animals Recognize Good Soil Treatment," *Better Crops With Plant Food Magazine,* Vol. 23 (1939), pp. 20-21.

corollary condition of greater succulence, less laborious chewing. We will take a tender steak anyday before a tough one. This is something the jaws can detect, while a difference in mineral content may elude our taste. In either event, the animal instinct leads it to a sound conclusion. It should be clear that **this selectivity will have a notable effect on the distribution of wildlife, which is free to roam in search of satisfactory food supplies, and probably explains many of the spotty concentrations of upland game found, and not found, by sportsmen and students of wildlife.**

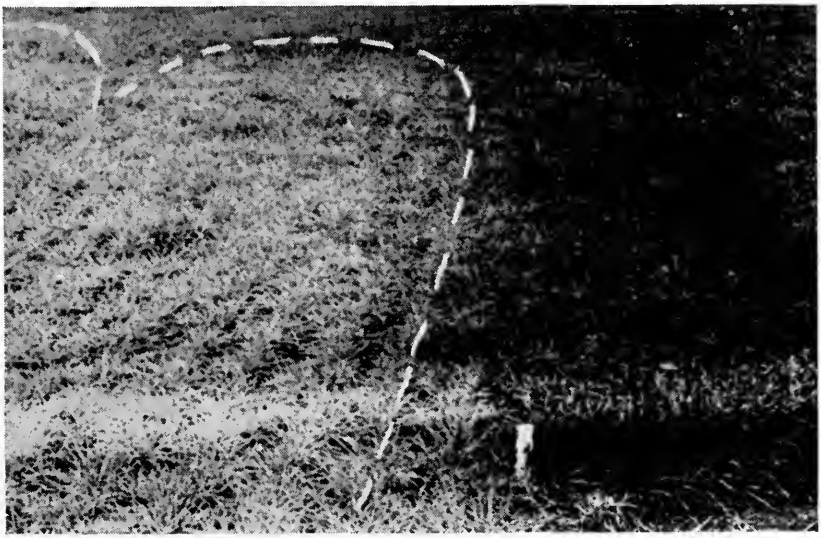

FIG. 9. Cattle grazed thoroughly the outlined corner of this barley field where turning the drill doubled the amount of fertilizer dropped.

Succulence is a trait of the natural vegetation of the world's grasslands. It is a fairly sound guide to soil fertility. The prairies and plains have produced such succulent plants for untold years. When a forest is cleared it usually will not grow grass of prairie quality and (except in certain limey areas) certainly will not grow legumes, unless fertilized. The prairie soils east of the Great Plains differ from the plains in having somewhat less available lime and more phosphorus—*less* lime because of greater rainfall and more leaching. The prairies have somewhat more *available*[3] phosphorus than the high

[3]The significance of the term "available," should be understood. There may be a mineral in the soil, but which plants cannot absorb, because of its chemical state. For instance, phosphorus is found in four groups of compounds. (1) In combination with calcium or magnesium (common in the prairies and plains), the phosphorus is usually used with ease by plants; (2) as part of decaying organic matter it appears to be released to plants, though with some slowness; (3) in combination with aluminum and iron, common in the humid region soils east of the Mississippi, the phosphorus is usually given up so slowly that plants suffer for want of it; (4) in the rock fragment state, the current release of phosphorus by weathering is so slow as to be of little value to plant growth.

plains because the greater rainfall (more carbonic acidity) slowly breaks down this resistant rock. In the drier west the rock decay takes place more slowly. To state it another way: from the foot of the Rockies, calcium (and this is in general true of magnesium, potassium, boron, iron, molybdenum, copper and cobalt) decreases from west to east and southeast, as rainfall increases. From the same point, available phosphorous in the soil increases for several hundred miles eastward and then decreases. (There are many localized exceptions to this general picture. The Great Plains, prairies, and other smaller areas, even small parts of the southeast, originally were blessed with greater phosphorus supplies in the soils than other sections of the United States.)

Calcium and phosphorus are essential in bone and tooth construction, as well as in other important tissues. Thus when cattle begin life on the plains and are fattened and finished off on the prairie corn belt before going to market, we get the best possible product, well charged with minerals and energy. They are far superior to most cattle produced in the eastern and southern states, where, as a rule, both calcium and phosphorus in the topsoil have been leached out or depleted by crops and erosion and are quite limited unless artificially supplied (Fig. 10).

Even a fat cow, like a fat man, can be poorly nourished, tormented by hidden hungers which are never satisfied.

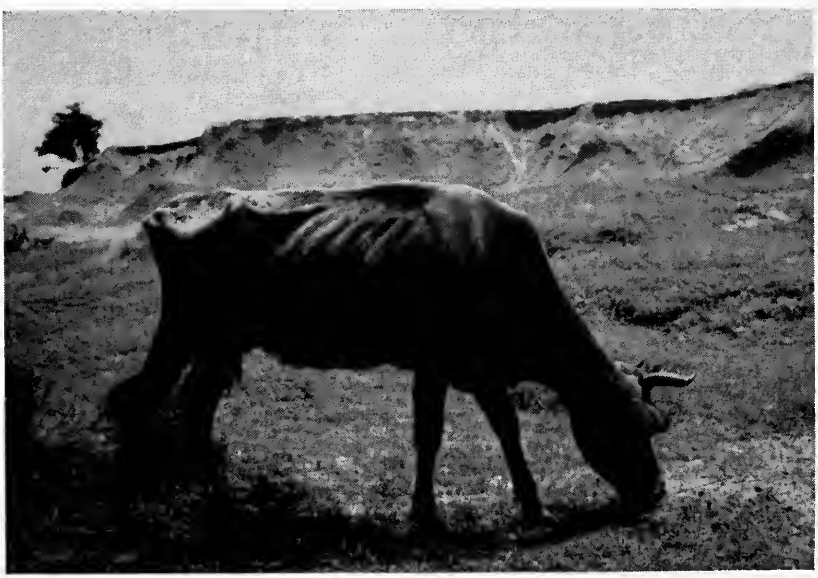

FIG. 10. Cow on the landscape—an example of weird harmony. Soil, vegetation, and animal are a dissonant triad, an affront to nature. This is Mississippi—plenty of rain, long growing season—it is June, it is noon, but look at that empty udder. There is a man over the hill. He is in harmony with this scene, too. Worse yet, so are his children.

We have seen that plants do have quality variations, and had them prior to the coming of the human bungler. Plants act as the intermediary between the physical universe and man. Plants transmit to man (and to all other animals), in proper or improper proportions, those elements of which he is constructed and the energy by which his body and mind operate. Since the earth's surface is not uniform, man is not likely to be uniform. If you have the ill fortune to live in an area where the parent rock of the existing soils was never of high fertility potential (sandstone for example) where climate has not produced a good topsoil, or the sun is obscured during a large part of the time, that is not too bad. Man with his science and his intricate and speedy transportation system should be able to bring to you what you lack: fertilizing materials for your feeble soils so plants can do a good job of feeding you, food plants themselves from areas where the environment is good, sunlamps to give the ultra-violet and the vitamin D, vitamins from laboratories.

Such remedies are possibilities. If we or our children live a hundred years or so, maybe it will all be worked out in fine shape. Or, maybe the United States will follow in the footsteps of Rome, where it was *not* worked out. Let's see what needs to be done in the matter of minerals and vitamins. How do we stand?

Mineral and Vitamin Deficiencies. As mentioned under the topic *Loss of Vitamins,* the acts of processing, preserving, and preparing food may nullify much of nature's work in presenting us with a crop or animal rich in nutrients. This is somebody's business—the press, the home economics teacher, the health, hygiene and physical development teachers, all the science teachers, all the social science teachers. It is also the government's business, because it is the business of all of us.

But, minerals are lost in other ways, too.

By simple arithmetic and not so simple chemistry we can determine the amounts of minerals in the vegetation harvested from a field. We can also measure the soil loss in a year by erosion on that field, and then, by chemical analysis, determine the mineral losses. We can compare the two losses, from harvest and from erosion, and find, for instance, that **on one moderately steep corn field, erosion took away 21 times as much mineral nutrients as went into the corn crop.** For the country as a whole the ratio of minerals lost by erosion to minerals harvested is 6 to 1. Is there anything amazing about the fact that millions upon millions of acres of our sloping, eroding cropland are not providing us with body growing, health maintaining foods? This is somebody's business, too.

Let's take three groups of lambs.[4] We feed one group on forage from an ordinary, much-farmed, untreated field. These lambs gain 9 pounds in two months. The second group gets forage from a near-

[4]Data from University of Missouri, College of Agriculture, reported in *Chemicil and Engineering News,* American Chemical Society, Vol. 21 (1943) p. 221.

by field fertilized with phosphate. These lambs gain 14 pounds. The third field gets phosphate and lime, and the lambs gain 19 pounds. Each lamb in all tests ate the same amount per day. How did the plants function in these three cases? They delivered what was available to deliver, nothing more.

Analysis of carrots from excellent and from poor soils revealed 60 times as much carotene (raw material of Vitamin A) in the plants from the good soil as from the poor.[5]

Wheat grown at Windemere, British Columbia, analyzed at one-sixteenth the iron of wheat grown at Kapiskapsing, Ontario.

According to the U.S.D.A. Marketing Service, wheat in western Kansas averages 60 per cent more protein, with its accompanying minerals and vitamins, than wheat in eastern Kansas. We have not a comparative figure for, say, Alabama, but it must be startling.

Some folk imagine that a plant is like a person, when as long as there is food in the cupboard he is well fed, and when the food gives out, he starves fast. Not so with the plant. Roots in contact with poor soil cannot by any effort overcome the low concentration of nutrients. They are like the American in a Japanese prison camp; no matter how hard he worked the food was inadequate. It simply was not made available fast enough.

How does nature handle soil mineral deficiencies? Plants can stand some variation in nutrient supply. The higher the plant is bred for its usefulness to man the less its tolerance for mineral variations and lacks. Thus, red clover can grow on a mineral diet which would not sustain alfalfa, and other grasses can thrive where red clover cannot. Down near the end of the scale we find, for instance, coniferous trees, and mosses.

When, for any reason, the fertility of a soil decreases, a lower grade, more carbonaceous plant association moves in. The effect of this change on wildlife population and species present can be easily appreciated. They will be forced to change also, and for the worse. The high grade animals (we mean those most used by man) will slowly but surely disappear.

Man, however, is not content with any such program. As long as possible he continues trying to force the sickening land to produce the more profitable vegetation. Normally, when even one essential mineral falls to the point where the more desirable plant is no longer healthy, nature would move in with a species better adapted to the situation. (Fig. 11.) Man tries to prevent this by continuing to plant as before and keeping the competitor away with his hoe. For a time he may succeed in producing a crippled crop which may look near enough normal to get by the purchaser.

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[5]Heiser, Victor, *You're the Doctor,* W. W. Norton and Co., New York, 1939, Chapter 6.

FIG. 11. These three specimens of sweet clover show the influence of two mineral deficiencies, phosphorus and potassium. All three received ample lime, but lime (calcium) alone is not enough. The two specimens on the left are sick with root rot; they were easily pulled from the ground by hand. The healthy roots on the right could not be pulled from the earth.

If this product is processed in any way the ultimate consumer may have no inkling as to its true quality. Eventually this sort of forcing is no longer possible. Something has to happen. Either a lower grade species must be accepted, or the soil must be improved. If the soil is not improved, plant quality may eventually regress to the point of starving practically all animal life off the land. Man must leave long before the field mice do.

Hunger Signs in Plants. The lack of certain minerals and vitamins produce deficiencies in humans; it also affects other animals likewise; and, as might be expected, plants are subject to mineral deficiencies too.

Many of these plants deficiencies may be observed easily.[6] Their diagnosis may require tissue testing in some cases but the informed eye can see that something is wrong. Different species of plants often (but do not necessarily) exhibit the same symptoms for the same disease.

To the untrained eye tobacco plants may look pretty good. The color may be a deep rich green. However a critical look will bring the suspicion that a plant may be too dark a green, with the upper leaves abnormally erect. To the knowing eye this means a shortage of phosphorus. If the terminal bud at the top of the stalk is dead or dying, boron is lacking. If calcium shortage develops, the new leaves become deformed, scalloped, with irregular edges.

Magnesium deficiency puts the chlorophyll out of action, since it is part of chlorophyll. Nitrogen is also a chlorophyll part. As might be expected, lack of either results in loss of greenness—a yellowing.

Lack of potassium or zinc gives a really evil, blotched, diseased appearance to the leaves.

It is not our purpose to make a plant pathologist of anyone, so with a few more illustrations from the garden plants we shall move on. Generally speaking most cases of uniform yellow or light green coloring, coupled with stunted growth, will indicate nitrogen lack.

Onion bulbs may vary from a lemon color to a rich, bright coppery shade according to sulphur content, yet all be reasonably well developed physically.

If snap-beans produce stunted plants and no beans or pods to speak of, there may be boron trouble.

In a root crop such as turnips, beets or radishes, boron lack will appear as dark spots on and in the root, ranging up to severe conditions called brown heart or hollow heart.

Pale yellow carrots are copper starved.

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[6]The following statements are derived from *Hunger Signs in Crops*, published by The American Society of Agronomy and The National Fertilizer Association, Washington, D. C., (no date).

Vegetables short of phosphorus usually develop a reddish purple color on the undersides of leaves.

Potassium shorted leaves become grayish, with edges brownish and wrinkled.

Slow growth is a symptom common to most deficiencies. Drought can duplicate this, of course, since water is necessary for making nutrients available to the roots, and, in cases of stunting due to weather conditions, the nutrient quality may not be impaired.

Obviously, these and scores of unmentioned similar conditions vary from the borderline, almost undetectable cases, to the one-foot-in-the-grave stage. The subject is introduced here merely to confirm the point that **human health rests on plant health**—that, as edible food, **plants do have intrinsic quality ranging from excellent to no-account**—and that in many instances, **plant health depends on soil.**

The Way of the Flesh. There is no disputing the fact that inheritance puts a ceiling over our development. It is generally conceded, however, that very few of us ever reach that ceiling. The environment interposes too many obstacles, too many distractions. Yet the environment in a civilized community is to a great extent our own product. Certainly our ability to alter it is considerable. Equally certain is the fact that we will not alter it for the better unless a powerful reason is presented—because there is a lot of work and expense involved.

If there is anything on earth more desirable than good health, it has been well concealed. Yet, it is probable that there are fewer people with 100 per cent good health then there are people with money wealth. If the connection between good soil, good plants and good health can be proven, then the environmental changes necessary to secure it should be forthcoming. The effort would probably be made. Let's see if the relationship can be further proved by example. (Fig. 12.)

Hidden Hungers in Animals. Borst[7] mentions the not unusual fact that cattle have been observed chewing on bones, suggesting a hunger for phosphorus and calcium. The dog and his bone are commonplace. Livestock swallow wood, bits of iron, hair and other foreign substances; these acts have in many cases been stopped by providing minerals found to be lacking in the diet. The wide use of salt blocks of various compositions in livestock feeding is well known. (Many wild animals find and use salt licks.) Cattle can be routed over the entire range available by moving the salts about at a distance from the water supply, thus insuring more even grazing. Carnivorus animals, dogs and cats for instance, may be seen at times seating various plants, and the question arises whether they are seeking, in many instances, not merely an emetic but to satisfy some instinctive demand for additional mineral nutrients.

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[7]Borst, Dr. Harold, Supervisor, Northwest Appalachian Soils and Water Experiment Station, Zanesville, Ohio, Personal communication.

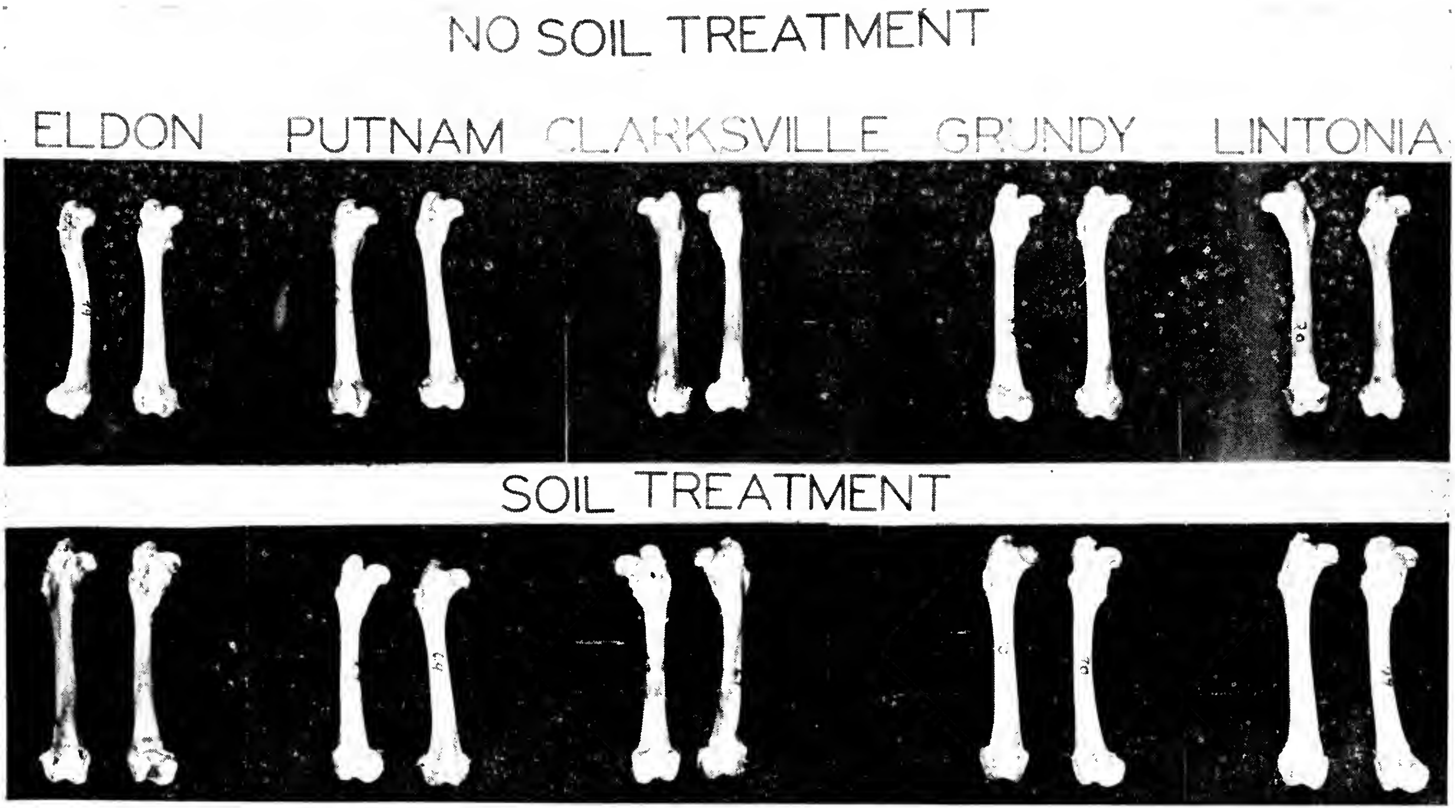

FIG. 12. The effect of soil fertility on body growth and development is shown by these bones from paired animals. Five Missouri soil types were studied; the fertilized Lintonia soil of the southeastern lowlands (Mississippi flood plain) produced the huskiest animals. The photographs do not reveal the density of the bones, but the difference is marked. The reader is advised to measure the length of the upper and lower matching pairs if the variation is not clearly apparent.

Albrecht notes that "Acetonemia in pregnant milk cows, milk fever after calving, pregnancy diseases in sheep, contagious abortion in cattle, rickets in young animals, and numerous other ailments still baffling as to physiological explanation do not occur in June when the animals have had opportunity to get from young grass the more concentrated forms and larger amounts of what we call soil fertility."[8]

Dr. Weston Price, formerly of the American Dental Association's Research Commission, has observed that when primitive women abandon the natural foods on which they were reared and adopt a "civilized" diet they begin to have trouble in childbirth, a difficulty almost unheard of before. Following the change to white flour, sugars, and canned goods by the mothers, many babies die early, or appear with deformities, defective eyes and ears, become susceptible to rheumatism, arthritis and tuberculosis. The results are even worse than among the whites, who perhaps have evolved some degree of adjustment.

The impact of modern foods on the teeth is most remarkable. Primitive Indians, Eskimos, Australian Aborigines, Gaelics, Melanesians, Polynesians, Africans, Moors, Peruvians, when examined in their *isolated* native habitats reveal average dental decay of less than three teeth per hundred. Those of these people who had come in contact with civilization showed decay of 20, 40, and even 60 teeth per hundred. Sometimes parents would move into a "civilized" town, bringing children with perfect teeth. Then, children born later would develop narrow dental arches, misplaced, overlapping, protruding and rotten teeth. The photographs of such family groups are startling. These later siblings do not even appear to belong to the family; such are the facial bone alterations.

These facial alterations also may induce a compression of the lower brain, interfering with the pituitary gland and bringing on physiological and even mental disturbances. Price reports a case (after Ordahl) in which a sixteen year old idiot was restored to normal by widening the upper jaw by means of orthodontal bracing. This relieved pressure on the pituitary, with remarkable results.

Applying his studies to American children, Price surveyed typical communities and found from 25 to 75 per cent showing signs of this same facial alteration—changes unaccountable by heredity, intermarriage, or any reason except a deficiency of bone-forming minerals and vitamins. Teachers are quite familiar with the considerable percentage of pupils who are not bright or healthy, and show it—show it by the dull eye, the sagging jaw, the poor complexion, the bad posture, the inattentive mind, the lack of coordination, etc., etc. Personality problems and the need for mental hygiene result. It is doubtful that their cure can be effected by psychiatry.

For the sceptics, Price suggests a close observation of family groups, particularly where three generations are available. Look for narrow-

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[8]Albrecht, Wm. A., "Soil Fertility and the Human Species," *Chemical and Engineering News,* Feb. 25, 1943, Vol. 21. pp. 225-6.

ing jaws, smaller dental arches, crowded teeth in the youngsters as contrasted with the grandparents. Your own judgment will tell you where such people are most likely to be found.

Our sketchy excerpts from Price do not do him justice and his volume should be consulted for a fuller presentation. One of his conclusions is: "The vitamin and protein content of plants has been shown to be directly related to availability of soil minerals and other nutrients. A program that does not include maintaining this balance between population and soil productivity must inevitably lead to disastrous degeneration." "The most serious problem confronting the coming generation is that nearly insurmountable handicap of depletion of the quality of foods because of depletion of minerals in the soil."[9]

Nutritional studies of livestock have served as outposts in this new science. Next in amount of attention received have been the humans. Third come plants, and at the bottom of the list wildlife. The increase in fur farming has lately focused attention on the feeding problem, because right feeding means a good pelt, and cash to jingle. To see how far astray man can go in feeding, note this: Autopsies on ranch reared and on wild silver foxes revealed 54 times as much vitamin A in the wild animals. Considering the role of Vitamin A in night vision, what chance would the man-fed fox have of catching a field mouse at night? Similarly, if the land were reduced in fertility to the point where it failed to provide plants with pro-vitamin A (carotene) how could the fox population maintain itself when most of its hunting must be done at night when the prey is up and about—that is, such prey as could exist on sick land.

Fecundity is a matter of vital concern to all producers of animals. The certain conception and delivery of healthy young by the female is a prerequisite for successful management of both domestic and wild animals. Dr. Ralph Bogart gives a considered estimate that 40 per cent of Missouri pigs are never weaned. They die. Yet there are instances where effort toward securing feeds from fertile soil has cut this loss to 25 per cent. Sound and vigorous offspring cannot be produced by food consisting of sunlight, air and water alone. Price's observations in the human field corroborate this.

Albrecht has demonstrated that the male rabbit may become sterile when fed forage from a depleted soil; that the addition of phosphate to the soil improved the procreative performance; and that addition of both limestone and phosphate resulted in hay which tended to insure a virile and reliable buck. The doubtful males were markedly rejuvenated by three weeks feeding on the latter, nutritious hay. (Fig. 13.)

Sportsmen who lament the scarcity of cottontail and other game may take the hint and pull mightily for soil conservation and fer-

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[9]Price, Weston, *Nutrition and Physical Degeneration*, published by the author (4th printing, enlarged), Redlands, Calif., 1945, p. 392 and p. 417.

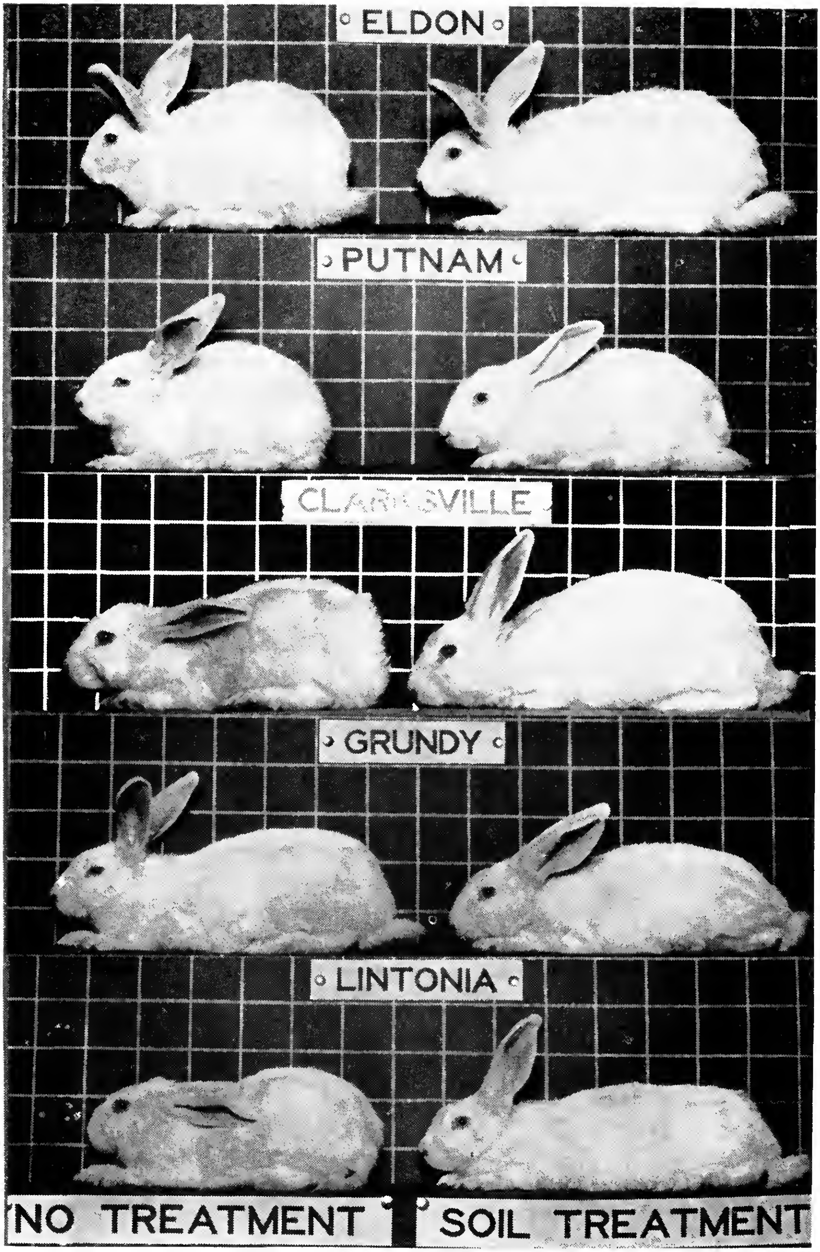

FIG. 13. These rabbits were uniform in size when small. They were fed lespedeza hay from five sections of Missouri. The hay came from paired fields—one fertilized, one not fertilized. The difference in animal growth from the Eldon, Clarksville, and Lintonia soils is startlingly apparent. There are also differences in the other two cases which the scales, close examination, and dissection reveal.

tilizing programs. It is only thus that millions of acres of hunting territory can ever again produce the abundance and quality of game which old timers love to hunt again in memory. The terrain of those memories had not then been exhausted by erosion, and by poor crop and soil management.

We have discussed the production of proteins and vitamins sufficiently to establish a principle of nutrition, which can be applied to any animal—human, domestic or wild: **The life, growth and reproductive potential of plants and animals is largely dependent on complete soil fertility.**

Chapter IV

ARE THERE ENOUGH PLANTS?

The Age of Meagerness. The era of scarcity was a long and arduous one for all primitive peoples, and particularly for those outside the tropic zone. Even when prehistoric man graduated from hunting, fishing and the gathering of wild plants to the more reliable herding and crop growing he still was severely restricted by lack of effective tools and by the depredations of wild animals. All life was pecarious.

With the development of irrigation civilizations along the Nile and in the twin valleys of the Tigris and Euphrates, the common man benefitted little from the comparative plenty of these garden spots of the world. Within sight of the magnificent structures celebrated in history stood the mud huts of the producer. Like a thread, running through the warp of human society is the story of power and wealth drained from the many into the hands of a few. Slavery for the conquered and high taxes for the native kept the rank and file on a near level with the beasts of the fields. Through those later bright spots of human achievement, Palestine, Greece, and Rome, the shadows of poverty, unemployment, disease, and hunger are ever visible.

A thousand years of the Dark Ages, with its feudal system, repeated the pattern of relative plenty for a few and degradation for the many. The production of food was an ever present battle with need, and if the few ate well, the many were lean.

Yet, such improvement in food supply as had been achieved was based on the discovery by some primitive cave dweller that seeds produced plants, that human effort could multiply the number which would grow and mature.

During the medieval period, machinery had its elemental birth, though power was still largely a matter of muscle, mostly man, partly beast.

The Age of Plenty. The beginning of the era of plenty (in Western Civilization) may be dated roughly from the period of exploration, starting with Columbus' discovery of the new world, an area rich with the stored natural energy and materials of millions of years. Almost at once the exporting of American resources to Europe began. First it was gold, but soon it was lumber, and potash from burned forest monarchs, fish, hams, wheat, corn, furs—all the seemingly inexhaustible products of the newly found storehouse.

In payment for these goods, Europe sent back money, the capital which spurred the further exploration and exploitation of America.

The profit motive did the rest. Every man knew that a ready market awaited whatever of human use he could gouge from the earth and get to market. Europe, well populated, had money, (much of it extorted from Central and South American Indians) and a head start in the Industrial Revolution so that manufactured goods were available to trade for American food, cotton, wool, metals and other raw materials.

This country belatedly but with great vigor launched into an industrial program of its own. The poor farm lands of New England poured workers into the factory towns which sprang up at every water power site. To feed these workers, new and better croplands were sought and occupied as fast as the Indians could be driven out and bought out. America began to pour forth its wealth from mine, and forest, and field.

Through it all the personal profit motive drove men to prodigious effort to get resources, to get them first, to get them fastest, to get the best and discard the rest. Rugged individualism reached its peak. It was a procedure not far removed from the law of the jungle.

In the South, cotton plantations with their slave labor duplicated the setup of Rome at its height—and the result was the same. Freemen on the farms could not compete successfully. Most of the slaves had no interest in the land, nor in learning how to use it properly. The effort to teach and force them to work properly was discouraging. The inefficiency of slave labor is well known. It carries on a sustained campaign of impassive resistance and insidious sabotage. All these factors favored a simple agriculture. One cash crop, endlessly repeated, ruined the soil. Erosion came. Washington, Jefferson, Patrick Henry and many other men of perception and vision protested the land use system which was replacing rich fields with gullied wasteland. But, the economic pattern required exploitation if profit was to be made. When prices are determined by a cream-skimming system of supplying the market, the conservative farmer, hunter, or miner is at a disadvantage.

Planning for sustained production often requires a measure of restraint on present profits for the sake of future stability. The pioneer farmer could get new land so cheaply that it did not pay promptly in cash to take care of what he had. Forests were so extensive that any consideration of a future shortage seemed stupid. The problem of the early settler east of the plains was, as he saw it, to get rid of forest, not sustain it.

In the meantime, in this rosy dream of an inexhaustible America, no one considered the egg and the sperm of the human race. In a country of largely good and virgin soils, capable for a time at least of producing proteinaceous, vitamin-rich foods, the growth in population was phenomenal. A constant stream of immigrants plus high human fertility brought mounting census figures. And always there was more and more land to feed the horde. Science and invention multiplied the productivity of man. Surpluses were gobbled up by hungry old world peoples. Then the human wave rolled against the

Pacific boundary and flowed back upon itself. The country had filled up. Yet still, the sperm and egg were at work, ever increasing the demand for food, for houses, barns, fences, clothing, and all other products of the land.

The Age of Adjustment. About 1910, the lack of timber became alarming. Most of the good and easily logged forests had been cut over. In the east and south, soils had been beaten and driven until they lay down to rest, like a starved horse. And like a starved horse, they could not, of their own effort, immediately get up to go again. No longer did everyone have all the good food and all the wood he needed. The government began reserving forest lands against buyers, against exploitation. With the World War came the plowing of the plains for wheat production. High prices, two to three dollars per bushel, caused this raping of the finest natural legume grassland on earth. Here again, nature struck back against man's violation of her laws and rights. The great Dust Bowl, flanked to north and south by smaller satellite dust bowls, was nature's reply.

According to general surveys by the government, over one billion acres of our land has been damaged by erosion.[1] This is more than one half of the United States. A hundred million acres of cropland, more or less, has been ruined for tilled crop production. This is about one-fifth of our normal cropland area. Counting the areas ruined by erosion resulting from fires on forest lands and overgrazing on range-lands, the destroyed area mounts to 282,000,000 acres. These figures mean little until they are compared with some area you know. The state of Ohio has about 27 million acres. Thus, land equal to ten such states has been reduced, virtually to a biological desert. This is difficult for many people to believe. But, if they travel a moderate amount and look for evidence, they will readily accept the estimates of the U.S. Department of Agriculture. (Fig. 14.)

The existence of such total areas of burned, overgrazed, blown, and washed out land has led to questioning the common sense of the human activities which have produced such devastation. Obviously, **a readjustment is called for in our relation as a society to the thin and delicate earth crust which enables us to exist.** It is a simple question of life or death.

Since high grade vegetation is the resource which has, for the most part, disappeared on these problem areas, the obvious conclusion is that it should be restored. This is not an easy task. **The destructive forces unleashed by man not only have destroyed the vegetation; they have damaged the mechanisms which produce useful vegetation.** It takes nature milleniums to construct the sensitively balanced complex of sun, soil, water, weather, plants and animals which climax in a high order of verdure. (Fig. 15.) The wrecking of these climaxes has set such areas back centuries, in many cases thousands of years. (Fig. 16.) The question facing us

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[1]Bennett, H. H., *Soil Conservation,* McGraw-Hill, New York, 1939, p. 60.

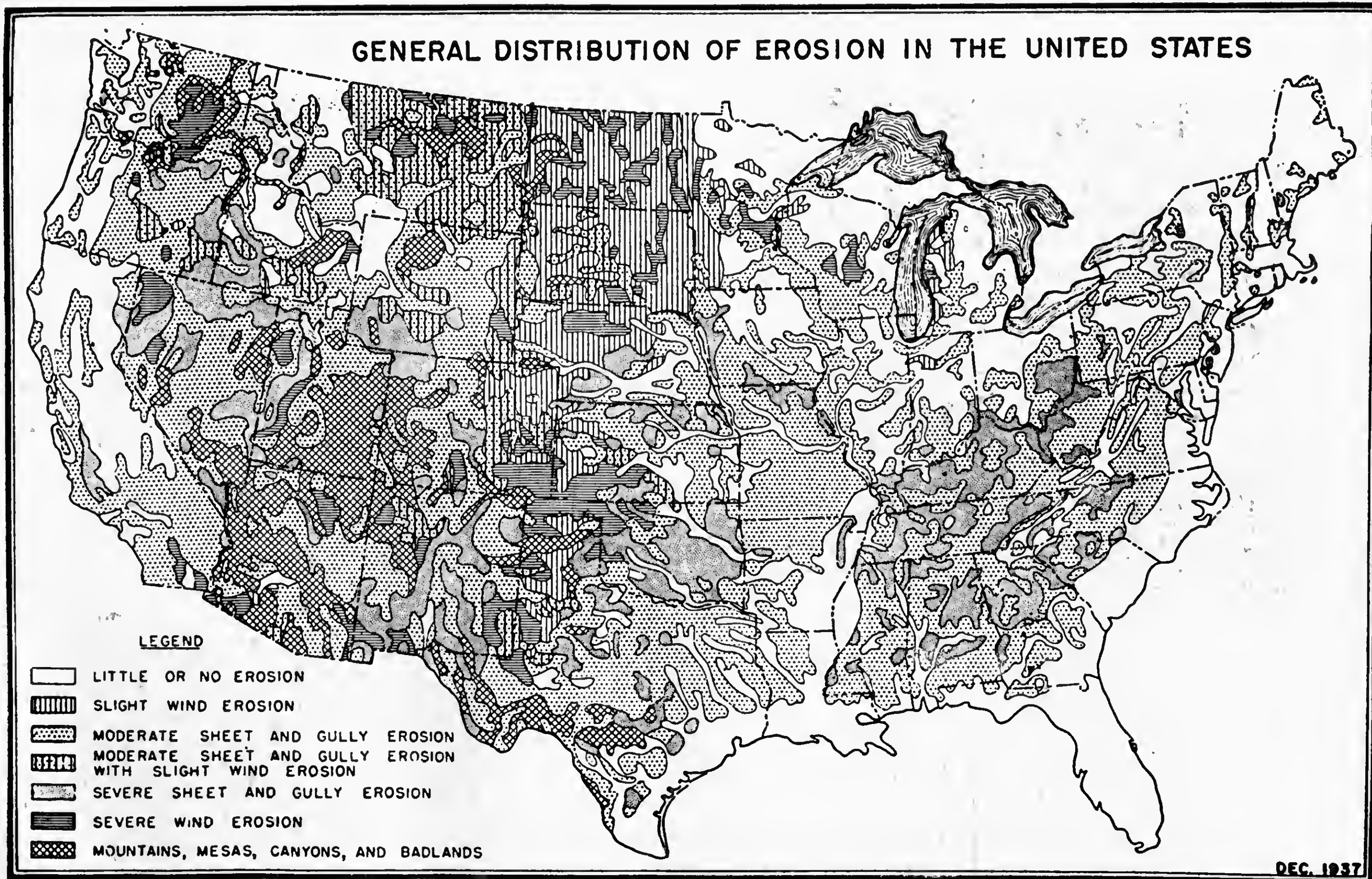

FIG. 14. Slight erosion indicates less than 25% of topsoil lost; moderate, 25% to 75% lost; severe, over 75% lost. Moderate gully erosion indicates gullies more than 100 feet apart; severe, closer than 100 feet. The map keys indicate conditions existing on at least one-fourth of areas shaded.

FIG. 15. This rich soil began as nothing but limestone rock, sterile and lifeless. As the stone weathered into calcium dust, it was flooded from time to time and deposits of mineral-rich silts were added. The roots of plants, and earthworms, mixed the minerals, added organic matter, and in a few thousands of years this soil was built. There are 7 inches of dark topsoil, 5 inches of lighter topsoil, and 13 inches of subsoil. Its product here is lush, living grass—and "all flesh is grass."

is: can science short-cut the leisurely processes of nature in repairing the damage? There is evidence to support a positive answer.

Do We Need More Food? In preceeding paragraphs it has been shown that half of the nation's land is inadequately clothed with vegetation, that one seventh of it has been stripped literally naked, by man. As a result, or as a parallel occurence, erosion is rampant.

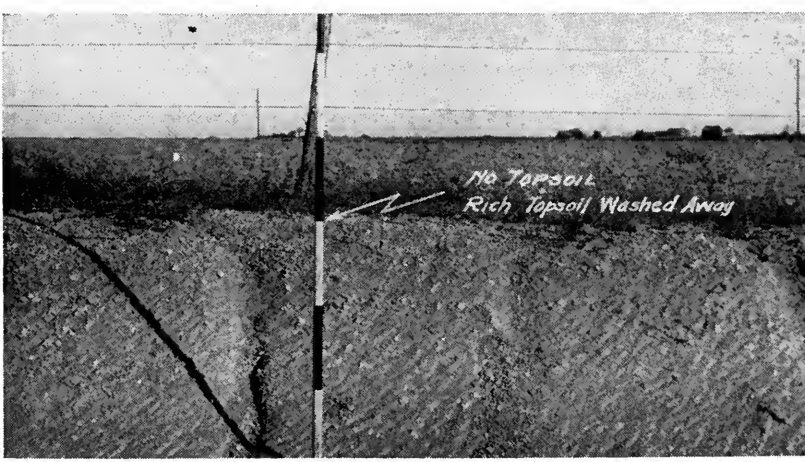

FIG. 16. A Texas case of embezzlement—"secret misappropriation," according to Webster. Here, the sly stealing of topsoil by sheet erosion is finally disclosed. But, it is too late. The wealth is gone; there is not one songbird or gamebird to control insects. The gentle slope was no safeguard for this soil. Scientific protection would have been simple, easy, profitable.

More plants are needed, in the restoration process. This is sufficient reason for more plants.

There is another reason. Numerous surveys have been made of living standards in this country. Dr. Thomas Parran, Chief of the U. S. Public Health Service has said, "Studies of family diets by the Department of Agriculture, in all income groups of the nation, show that one-third of our people are getting food inadequate to maintain good health. . ." The Yearbook of Agriculture, 1939, (p. 42) says, "Those who cannot now afford even an economical fair diet are largely among those with incomes of less than $750 a year. These income classes include 32 per cent of all the families and single individuals in the country." During the war-induced and post-war prosperity, many ate better—temporarily, no doubt.

Without going into a long series of quotations, may we summarize the government's findings? If these submerged millions were to consume a low-cost good diet, our production would need to be increased thus: milk, 10 per cent; butter, 10 per cent; tomatoes and citrus, 10 per cent; leafy, green and yellow vegetables, 80 per cent. This would require an additional 8 to 10 million acres of cropland. If a really good "expensive" diet were available to all of us, an additional 30 to 40 million acres would be needed. (There is a possibility that these increases could be met by increased yields from present acreages.) The surpluses which plagued farmers, before the war, would disappear like frost in the sun.

In other words, as a nation, we need more (and better) plants to eat—directly, or in the form of animal products.

During World War II we produced more food than ever before,[2] and the people had money to buy it. Because we exported a small per cent[3] to our allies, and later to enemy countries also, we experienced shortages at home—proof that our soils *in their present condition* are not capable of supporting even a slightly larger population on a *good* diet level. We cannot be complacent.

II PROBLEMS OF WOOD SUPPLY

Wood Products. Of all the influences which trees exert on our national and individual lives, we are at the moment considering them

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[2]In 1944, the U. S. produced 20% more agricultural products than in 1940 (U.S.D.A., Bureau of Agricultural Economics). This increase, to a great extent, offset (a) the loss of imports due to the war, (b) increased consumption, over civilian rate, of food and fibre by the men and women of the armed forces, (c) Lend-Lease and Relief exports.

[3]The average for 1942-43-44-45 was roughly 8% export of our total agricultural production, for Lend-Lease and United Nations Relief and Rehabilitation Administration uses. For several years before the war, the excess of our agricultural exports over imports of the same types of goods ranged around 2%; in 1928 the excess was about 20%. The drop from 20% to 2% was gradual. No small factor in the decline of normal agricultural exports has been our growth in population. Cropland acreage has changed very little. Population is catching up with food supply.

simply as wood, not as functioning biological units. The commonplace act of purchasing a few boards is today (and was before the war) a major operation on the pocketbook. The purchase of a frame house is and was beyond the financial ability of a large per cent of citizens, or it becomes a life time struggle. To the pioneer east of the Mississippi it was not so. Setting up a home was a minor inconvenience. After reserving what timber he needed for furniture, sheds, tool handles, fences, and fuel, he still had mountains of wood to burn —and he did burn it, to get rid of it, burnt it in huge piles that roared for days.

Today a quick inventory of our daily uses of wood is revealing. Take a look. And if you will calculate the cost of common wood products by the pound, you will be amazed. Wheat can be bought for (let's say) three cents per pound. Hardwood, or even good softwood, will cost two, three, or four times as much. This should not be true of a crop that once grew naturally and easily over nearly half of the country.

Half of our timber harvest becomes lumber; one-fourth is used for fuel. The remainder becomes paper, railway ties, poles, posts, boxes, barrels, veneers, furniture, and thousands of other articles necessary to our way of life.

Forest Destruction. The cutting of forests has been caused by two primary forces: the need for wood, and the need for farmland. Prior to the industrial development most cutting was for land clearing. Then, in a hundred years (1800-1900), it gradually shifted to lumbering operations for wood itself.

Going back in history to early civilizations, we find in Mesopotamia today about one-sixth of the population which flourished in the eastern end of the Fertile Crescent 4000 years ago.[4] The degrading of the country is attributed to invasions by over-populated, nomadic, desert tribes which broke up, time after time, the agricultural system which fed the settled agrarian people. This system was based on irrigation of the flood plains of the Tigris and Euphrates rivers. The canals filled rapidly with silt, requiring a great force of slave labor to keep them cleaned out. The silt came from the uplands, and from the headwaters in Assyria where overgrazing and forest cutting exposed the soil to erosion. Trees have always been scarce in that part of the world, but no provision or thought was ever given (until recently) to a sustained yield forestry plan.

Later, in Palestine, Kings David and Solomon made a deal with King Hiram, of Tyre in Phoenicia to the north, whereby thousands of the Cedars of Lebanon became Solomon's temple and palace. The Phoenicians also sold or traded lumber to the Egyptians, who had little wood. As a result, the mountains of Phoenicia and Syria were denuded. Those four-legged locusts, the goats, searching for every

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[4]Lowdermilk, W. C., *Conquest of the Land,* U. S. Department of Agriculture, Washington, D. C., p. 10.

green thing, prevented revegetation. The soil went into the Persian Gulf and the Mediterranean. Today a more desolate area than the Holy Lands would be hard to find. "Milk and honey" gave way to erosion and hardship.

North China reveals the same story. An increasing population forced the farm front higher and higher into the hills, the forests were cut off, erosion began, silt choked the channel of the great Yellow river on its way to the Yellow sea (appropriate names)—floods, death, crop destruction and famine followed. The stolid Chinese came to accept this as the natural order of life.

The bare, rocky hills of Greece today could not possibly support such a civilization as developed there during the millenium before Christ.

It took Italy a thousand years to recover from the land mismanagement which accompanied the decline of the Roman Empire. Of all lands, hilly forest when converted to agriculture is most difficult to manage for permanent food production, which is not its primary natural use. (Fig. 17.) The mountains and hills of the Italian peninsula were once forest lands. When, as cleared farms, they fell into the hands of rich Romans (absentee owners with no understanding of land) and became slave or serf operated estates, Rome was doomed. The love of the freeman for his land was gone from the hills; and when it went the soil started to go. By 476, when Rome was finished, there were comparatively few people left on the impoverished farms.

Today there is not a forest along the Mediterranean coast anywhere. Many Italians bake bread by using straw for fuel. What small forests exist back in the hills are managed with the care we give our city parks. Each tree is cut under strict supervision, and close to the ground. The citizen lucky enough to be given the privilege of cutting one, carries home every twig and leaf for his oven. Italy has practically no coal or petroleum of her own and fuel is a pressing and distressing problem.

Elsewhere in Europe today forests receive the most careful consideration. As to land destruction following forest clearing, this has not been serious in north and west Europe because of the gentle rains, moderate slopes, and the slowly developed, well adjusted agriculture.

In the United States we find a situation which is alarming except to the uninformed, the selfish, or the stupid citizen. The forests were an important cog in the development of the country. The term "development" as applied to resources by most commercial and industrial interests has been, and in too many instances still is, analagous to your "development" of a Thanksgiving dinner sitting before you on the table.

The U. S. Forest Service states that we are cutting, burning, or otherwise losing trees approximately *twice as fast* as the forests are replacing these losses.

FIG. 17. The challenge of forested hill lands to man has occurred throughout the world. In many places man has won, and the hills serve him. In more places the tormented hills have beaten man down, starved him, impoverished him, and both hills and man are in a sorry state. Here, in Minnesota, man fairly well has adjusted himself and his uses of land to the climate and topography—result: sustained production.

C. H. Guise says that of the large, most valuable trees we cut at five times the rate of growth and that the virgin forest will last only 30 to 40 years at the present rate. He adds the thought that as this high grade lumber becomes scarcer, the price will go up, the market will shrink, and the tree supply will last longer. This is another way of saying that most of us will have to do without some of the lumber products we need. Guise further warns that when the virgin forest is gone there will be a tedious period of waiting before the second growth forests will be able to supply the market at all well.[5]

From the simple standpoint of wood supply, without considering all the other functions of forests and woodlots in the scheme of nature, it is obvious that we do not have, and will not have for a long time, enough trees. There are about 100,000,000 acres of woodland which have been cut over or burned over that are not restocking themselves at all. Professional foresters say that **woodland under good management will produce from two to six times as much good timber as unmanaged areas.** This raises the question of forestry science and what it can do about the situation.

Role of the Forester. Four hundred years ago Europe began to see the need of planning for wood supply. At that time cities held only a minor fraction of the total population, yet the widely forested areas of the continent had slowly given way to farms and to fuel needs, to a point where practical intelligence was brought face to face with a demand for sustained wood supply. The leisurely development of Western Civilization in Europe was geared to nature in a way that we in the United States have never experienced, and for which we are only now beginning to feel a need. We have been so preoccupied with profits that the scientific road to a production and consumption *balanced* against a sustainable raw material supply has been ignored. We are now forced to choose between a continuance of exploitation and the scientific road to a stable and possibly a rising living standard. **If exploitation continues, the standard of living must inevitably go into a decline**, such as the shortages during and following World War II previewed for us.

The science of forestry as developed in Europe made that area self-sustaining in timber at least up until World War II. Just before the turn of the century a pioneer American forester, Gifford Pinchot, found it necessary to go to Europe to gain a training foundation in forest science. He became the first official U. S. Forester. Since that recent date we have been busy adapting continental technics to our problems and evolving our own methods. At the moment a war is on between short-term economics and long-term science as to the fate of American forests and woodlots. Private owners are lined up against public owners. Independent scientists and economists must conciliate the dispute on the basis of what is best for our society as a whole. An educated public must enforce the decision.

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[5]Gustafson, et al, *Conservation in the United States*, Comstock Publishing Co., Ithaca, N. Y., 1940, p. 185.

The small fraction of timber owners who have yielded to scientific principles have found that long term science and long term economics work in perfect harmony. The final result is greater benefit to both the owner and the public. The goal of the operator is shifted from selfish desire for large, quick profits to smaller, sustained profits coupled with social goals of permanent employment, community welfare, and continuing satisfaction of the nation's timber demands. This is citizenship in action.

It is the business of the forester to discover and apply the natural laws which make possible greater production on a given wooded area, greater utilization of the parts of each tree, greater long term benefits to both producer and consumer. It is the consensus of foresters that our present forest acreage *can be managed* so as to produce annually, *forever,* 20 billion board feet of timber, which would be ample for present normal needs.[6] *It is not now so managed.* If demand rises, and it almost surely will, more forest acreage will be needed or more intensive management must then be devised and applied.

Our forests cannot under *present* practices continue to supply our needs. The U. S. Forest Service estimates that we were (before World War II, which aggravated the situation) adding 850,000 acres annually of devastated forest land to the vast area already wrecked. Furthermore, only 5 per cent of cut over land receives any attention leading toward a satisfactory second growth.[7] **The forester, as an agricultural scientist, must have a position of greater influence in private forestry if the nation is to avoid a very unpleasant situation.**

III CHEMURGY AND ITS DEMANDS

What is Chemurgy? Chemurgy is a new word, coined to denote a branch of chemistry at work, processing surplus crops into industrial goods. From soy beans may be made a plastic which is moulded into hundreds of objects formerly made of metal. From soy may be made glue, paper sizing, fireproof paint, gaskets and cloth. Chemurgists are working on a plastic made from alfalfa protein. DuPont uses coal in making nylon, but says farm crops can be used instead. Synthetic rubber from alcohol levies a draft on soil grown carbohydrates, which are fermented to produce the required alcohol. From milk casein is being made paint, glue, sizing, imitation ivory and good cloth much like wool. For years England has used a motor fuel which is 30 per cent alcohol.

> "The deep south has long suffered from lack of industries, overproduced cotton and severe erosion. Dr. Charles Herty, a chemist, found a way to use weedy, five-to-fifteen-year-old slash pine in making both kraft and newsprint. Papermen had said southern pine was too yellow, too gummy. At one blow

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[6]*Ibid.* p. 228.
[7]*Ibid.* pp. 224-25.

Dr. Herty brought industry to the South, switched land from soil-depleting cotton to soil-conserving forests, and saved the remaining world supply of spruce for more enduring uses.

"Chemurgist W. H. Mason looked at sawdust, stumps, chips and other wood waste. Grinding, steam blasting, and hot pressing produced a hard, strong sheet bound together by lignin. Another market for fast growing saplings was found. Trees are becoming a crop. Trees give us paper, cellophane, rayon, photo-film, gun powder, oils, resin, plastics, glue, varnish, germicides, alcohol and lactic acid. Forests become more important every year."[8]

Only a few of the synthetics and direct industrial products which come from crops have been mentioned. Alcohol made from corn and wood goes into scores of subsequent industrial uses. Research in the field goes on constantly. Organized chemurgic activity was born of the agricultural depression of the 1930's, in an effort to find uses for surplus farm crops. The idea was to put urban unemployed people to work processing the unsaleable farm products. Thus purchasing power would be increased, relief rolls reduced, surpluses disposed of. The results were so promising and the chemurgic goods so useful that progress has been cumulative.

An inquiry to the National Farm Chemurgic Council, Columbus, Ohio, brought these statements: It is very difficult to get data on the amounts of organic products going into chemurgic uses. The farmer does not know what proportion of his crops end up in such factories. A careful survey of hundreds of manufacturers would be required to secure a close approximation. The best estimate the Council can arrive at is that 40 million U. S. acres are devoted to growing the raw materials of chemurgy. The demand for such materials is so great and research so successful that by 1955 an additional 50 million acres will be required to satisfy the U. S. market.

Asked where the 50 million acres were to be found, the Council's secretary replied, "all over the world." And what about the rest of the world? The Council has associates in 25 countries, through which an exchange of research goes on.

It is obvious that **as the chemurgic movement grows, all over the industrial world, the levy against the soil and its vegetation will increase markedly.** Plants and more plants will be needed. If certain exhaustible minerals, ores particularly, become scarce, and some are already, the demand for organic substitutes for metals will whip chemurgy along still faster.

Q.E.D. The individual's responsibility as a free citizen does not permit him to be wholly concerned with his own little private world. He may be happy, and doing a useful work in his immediate com-

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[8]Carter, Vernon, *Chemurgy and Conservation*, Personal Growth Leaflet No. 76, National Education Association, Washington, D. C., pp. 12-13.

munity. He may be making a specialized contribution to society as a whole. That is not enough. Neither intelligence, democracy, nor education will admit that it is enough. The citizen has an obligation to sustain, for himself and for the coming generations, the society which gives him the opportunity to be happy and useful. If the society can be improved, he is obliged to improve it. He must attend to all its problems, or the problems will attend to him.

A society is sustained by the natural resources which underlie it. Vegetation is the basic organic resource. Through it all life is channeled. There is not enough vegetation, particularly of the more useful kinds. What there is does not average high in quality. The result is a diseased society. The democratic citizen is obligated to use his influence and a portion of his energy in attaining improvement of the situation.

Chapter V

THE EVOLUTION OF PLANTS

I—THE NATURE OF PLANTS

What is a plant? Thus far, the plants we have mentioned (trees, farm crops, garden vegetables) are obviously plants. For general purposes in defining a plant we might adapt the pattern of the primary teacher whose young pupils were amazed when he called a spider an animal. They were in the habit of thinking of an animal as something with four legs and hair. "Is a spider a plant?" the teacher inquired. "No." "It it a mineral?" "No." "Then what else could it be but an animal?"

Plant-Animal Differences. It is not important here whether slime-mold is plant or animal. The scientists are free to continue their arguments. The Euglena, which takes in food much as an animal does, but also contains chlorophyll and makes some of its own food, is admitted to be both plant and animal. Actually, it is difficult to define a plant. Not all of them contain chlorophyll and make sugar from air and water; yeasts, Indian Pipe, golden dodder, and mushrooms do not, to mention a few. Not all plants have leaves, nor stems, nor even roots. Not all plants are anchored to the earth.
they have, in general, less mobility than animals. The confusion

We can say that plants are more carbohydrates than protein, and down in the lower orders gives strong suggestion that plants and animals may have a common ancestry. When we get out of the microscopic jungle there is less doubt as to whether an animal is an animal, or a plant a plant.

What is life? Plants, we say, are organic; they are alive. Just what life is, again is difficult to define. It apparently is closely linked with chlorophyll, and this is another reason for thinking that animal life may be derived from plant life which logically had to come first. As to the original spark which started life off, we end up with what Dr. H. A. Morgan calls the "creative concept,"[1] which he and most people attribute to God, others to "Nature."

This "creative concept" was brought to bear on the electrical, gaseous void which was to become the elements and the universe. The heavenly bodies took form and developed into the marvelous organization which we slowly have been discovering through science. The

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[1]Morgan, H. A., From a chart published by Tennessee Valley Authority, Knoxville, Tenn., (no date).

elements of the earth entered three storehouses, air, water and land. Energy was stored in and released by the sun, being transferred to the earth by means of light as well as other rays which are invisible. The "creative concept" instituted life and chlorophyll, and the primordial home of life functions, protoplasm. From this beginning all forms of life have developed, carried on and on by reproduction. These life forms draw on the storehouses of air, water and land for physical materials which, when no longer needed by the organism, decompose and return to the three storehouses. For energy, these life forms draw on light, transforming it into heat, sound, chemical, electrical and mechanical (muscular) energy as needed.

Life plus elements plus flowing energy expresses itself not only in reproduction but in growth, movement, sensitivity, and metabolism. Of these five characteristics, metabolism is most constant. Every moment of the cell's active existence is marked by the chemical changes which assure it food and the removal of wastes.

Green and Non-Green Plants. Chlorophyll bearing plants have a unique function which no true animal shares, the manufacture of food. Plants which do not make food, but live on other life forms as parasites, are like animals as far as food source is concerned. Some fungi depend on dead organic matter as a food source; **these saprophytes perform a very useful work in assisting the return of such dead organic materials to the three storehouses of air, water and land, where they again become easily available to new life.** The importance of this cycle in man's welfare cannot be overvalued.

Certain bacterial plants, though lacking chlorophyll, appear to utilize chemical energy from compounds of iron, sulphur, and nitrogen, and to make simple foods.[2] This phenomenon only adds to the confusion as to what is plant, what is animal, and what is life. Of this we are certain: there is an intimate connection between life, the sun, and the earth. It is the details of that intimacy which concern us most in living in today's world.

II EVOLUTION FROM ONE CELL

In trying to understand life today and in trying to achieve something we do not have, a satisfactory adjustment among the many forms of life, it should be helpful to review briefly the development of the plant world as science interprets it.

Natural Selection. Once the geologist discovered that forces both great and small are operating day by day, changing the face and body of the earth, it did not take him long to surmise that these forces had been at work for quite some time. After gaining fairly accurate data on the speed of "uranium-lead" formation in rocks, he began counting backward and came up with some startling figures as to the age of rock formations exposed by river cutting, mountain uplift, or drilling.

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[2]Sears, P. B., *Life and Environment*, Columbia University, Teachers College, Bureau of Publications, New York, 1939, pp. 108-9.

Imbedded in some of these rocks he found signs of once living plants and animals.

These fossils gave rise to the science of paleontology, which in turn has shed much light on the evolution of life forms. The paleontologist found that as the landscape changed in pre-historic times, life changed too. Not only that, but *life itself effected changes in the landscape,* particularly in the soils. It was, and is, a reciprocal, interacting relationship. Also significant in bringing about changes were climatic shifts (notably the coming and going of the several ice sheets), the uplift of mountain ranges which changed wind effects and precipitation patterns, and the shifting relationships of land and water masses which altered weather factors. (The Great Lakes, for instance, so affect climate that many fruits grow as well to the southeast of those waters as they do in southern Tennessee.)

As a result of such changes we find semi-arid land now covering coal which could only have been produced in a swamp, oyster shells in Wyoming, sand of ancient seashores in the Appalachian Plateau, limestone formed from sea animals in the present prairie states.

All through the record of the rocks, life was either adjusted by means of hybridization or mutations to the changes in environment, migrated and found another suitable environment, or became extinct. There are enough examples of such adaptation to prove that life in many instances was adjusted to altering conditions.

One explanation of how it did this was exploded in the face of a "fundamentalist" world by Darwin. His observations, which anyone can verify, were that no two organisms, of the same species, or even sub-species, are exactly alike. These variations range from almost undetectable differences up to marked deviations from the normal. Later studies by other botanists uncovered rather rare but unmistakable cases of radical variations — variations so extreme that they were called mutations, or sports.

Darwin's work (Wallace was on the same trail at the same time[3]) led him to conclude that *in a changing environment,* certain of the ordinary, chance variations would be better able than others to survive such changes in habitat. Some of these survivors would reproduce the new characteristics and so establish new species. This interpretation became known as the theory of evolution by natural selection.

The later studies of mutations, pioneered by DeVries, bolstered the theories of Darwin and Wallace. It was found that remarkable variations and mutations could be caused by unusual temperatures, injuries, certain chemicals, X-rays and other irradations (which in nature might arise from radio-active minerals, cosmic rays, or ultraviolet and infra-red rays). It should be noted that many, even most of these changes in offspring have no relation to survival. They occur constantly; and *if* environment changes, there may accidentally ap-

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[3]Norden Skold, Erik, *History of Biology,* Alfred Knopf, New York, 1928. Part III, pp. 485-88.

pear a variety or mutation which can meet the habitat on its new terms.

Since the fossil record shows a progressive reversion to simplicity in life forms as we travel back through the ages, it is logical to arrive finally at the single cell as the original home of life. Similarly, projecting life forward, we would expect increasing complexity in the future. This complexity may perhaps be of a social rather than an individual nature. **As the total environment becomes more highly developed, life tends to keep pace. If environment regresses, life, too, MUST regress.** There are countless examples of such regression. Look at any wornout farm.

In natural selection the unfit are weeded out by competition or by the development of an unfavorable environment. In human society, science and brotherly love have enabled many of the physically unfit to survive; the competition is now partly economic and social, and the unfit in these fields go to the bottom of the heap. Even this selectivity is being partially overcome by education and by labor organization. The individual is being protected more and more against social and economic discomforts, and great *groups* of people are competing against each other for favored situations. Yet, with all his contention, individually and in groups, **man tends to ignore the great determiner of his well-being, the maintainence of a healthy, well-balanced natural theatre of operations, the landscape.**

That accidental mutations and variations in the plant and animal world have not been unusual is attested by the 300,000 kinds of plants and 1,000,000 kinds of animals (mostly insects) existing today. Add to these the known extinct species and the unknown myriads which have passed from the scene without leaving a yet discovered trace. While there is plenty of argument as to the relation of mutations to survival and as to what effect environment has in bringing them about, it is fairly certain that numberless new varieties of life have perished because they needed a better environment than was available. But as soils, for instance, improved, varieties of plants sooner or later occurred which took advantage of them. In time these became new species. On the earth as a whole there are today probably conditions of topography, soil, and climate which could support most of the forms of life which have ever occurred. In smaller areas, conditions have changed so radically from time to time that many species were wiped out, particularly if their means of dispersal, of migrating into suitable territory, was blocked by topography (a mountain range for instance), or if the migration was too slow to escape the change. We have not the space, nor at the moment any good reason, to explore this subject. If interest warrants, a modern text on botanical evolution may be consulted.

What is more important today than extinction is the fluctuation of quantity and quality in a valuable and useful species according to the way man manages or mis-manages the environment. It is quite true, however, that **valuable species may for all practical pur-**

poses become at least temporarily extinct on limited areas where man's inept hand has been at work. For instance, erosion induced by man has so sorely affected millions of acres of lands that they will not support domestic crops at all; and in many places where hardwood forests formerly grew in grandeur, only lichens, mosses, weeds, wild blackberries, etc., are found today. Once-rich grasslands have given way to weeds and scrub, or have been turned into deserts of bedrock, subsoil, or sand dunes.

Sea and Land Forms of Life. While it is possible that life may have originated on land, evidence favors the seas as its birthplace, certainly as its early home. Water under natural conditions offers a more stable environment and forces less adjustment on its inhabitants. Water temperature changes with weather at about one-fourth the rate at which land heats or cools. The dispersion of mineral salts (washed from the land) in water is more uniform than the occurrence of good topsoil. Sunlight penetrates to a greater depth and with a uniform gradation of intensity. The seas reached a condition early in geologic time which would support life, and have not changed greatly since. Thus life tends to remain at a comparatively low level of organization, though expressed in a great variety of forms. The species which have developed have found their places according to light, pressure, temperature, oxygen, carbon dioxide, and food supply variations. (These are ecological factors which largely determine the biotic complex.)

Fundamentally, life in water is not different from life on land. Chlorophyll and photosynthesis are its basis. Mineral, vitamin, and protein requirements of life demand the presence of soil elements in the water. Plants do not necessarily need roots, only a method of absorbing water and minerals. Aquatic plants must have carbon dioxide the same as their land cousins, and aquatic animals must have oxygen. These gases are not only released by plants and animals themselves, but the overturning action of waves is constantly trapping air. Cool water absorbs oxygen from air, while warm water loses it. Largely for this reason, our greatest fisheries are found in the cooler waters of the earth.

The upper layer of water, both salt and fresh, receives the greatest force of sun energy and thus sustains and activates the greatest amount of chlorophyll, which may be in broad-leaved floating or anchored plants, or in microscopic green forms such as certain of the algae. On microscopic plants feed microscopic animals; the combination of these two is called plankton and is the watery range on which larger aquatic animal forms graze. Commercially and recreationally valuable fish, mollusca, crustaceans, and sponges are thus dependent on plants and sunlight. Whatever the food needs of these animals, however complex the food chain, the terminal link with the earth is plants.

In passing, we should mention that man cuts his own throat by interfering with the fundamental factors. His erosional debris muddies the waters, shutting off the sunlight. His industrial, mining, and municipal wastes either poison aquatic life directly, make the waters chemically uninhabitable, or reduce the oxygen by an excess of decay-producing microbes. Remedying such blunders is a problem for scientists, educators, economists, and statesmen. It is just as much a problem for each individual citizen. The success, or lack of it, in reaching a solution is a good guage of civilization.

Terrestrial plants seem to have evolved along the seacoasts where tides come and go. Certain variant or mutant plants found themselves able to live through the low tide periods. Through the leisurely eons of geologic time, mutation after mutation slowly produced sea weeds which could extract minerals from a thicker mixture of soil and water, endure the greater and more rapid temperature fluctuations of land and air, and conserve moisture between wet periods. The change was not too great because the evolution probably took place in soupy, muddy areas under high atmospheric humidity. Nevertheless, land plants found a much greater complexity and variability of environment and higher order mutations had greater opportunity to survive.

III KINDS OF PLANTS

The plant kingdom may be divided into four great groups. The plants of each group have some factors in common, yet embrace a wide variety of species and sub-species. For the benefit of those who are not familiar with these or to refresh a dim memory we will define them briefly. The four groups, or phyla, are (1) thallus plants, (2) mosses, (3) ferns, and (4) seed producing plants.

Thallophytes. The Thallus, or soft bodied, plants are historically the oldest and simplest. They may have one cell, or more, such as bacteria, algae, fungi. By their simplicity of structure and by adaptation, many of them can live in a wide range of environments. Their original home is the sea and there many of them are found today, either as part of the plankton pasture, on lighted bottoms, on other plants, on animals or on decaying matter. Some thallophytes have made the grade on land, enduring periodic dryness that would kill more highly developed plants. Most of the group are parasites on living forms, or saprophytes on dead ones. They are agencies of disease and decay, both of tremendous importance to man. **We cannot ignore these unspecialized plants without roots, stems or leaves. They are part of the challenge in managing the total environment to sustain a permanent civilization.**

Bacteria and fungi which produce disease in man, other animals, and plants, and which ruin valuable organic property such as food, clothing, and leather goods, must be controlled.

Bacteria and fungi which return humus to soil, break down mineral nutrients for plant use, manufacture nitrates, promote a granular soil, and render other services, must be encouraged. Many present day practices on the land, such as the failure to add organic matter, and the type of mismanagement which produces erosion, discourage these valuable life forms.

Green algae contain chlorophyll, and are useful as fish food, as human food in their large forms, as laboratory culture media (agar), and as household cleaners (diatom fossils). Certain fungi attach themselves to algae and the combinations are found on trees, rocks and raw soils as grayish-green lichens. These lichens are important agents in breaking down rocks into soil by penetration of the rock surfaces and by the acids they produce which dissolve alkaline rocks or alkaline cement in others.

Thallophytes reproduce by the primitive means of spores, tough coated cells which may float in water or on the wind until, perhaps, suitable conditions of food, moisture and temperature are found. Food preservation and disease prevention are practical measures to deal with some of them. On the other hand, to be productive of aquatic life, a pond, lake, or stream must have them, and their number depends in part on the mineral supply or fertility of the water, which in turn depends on the quality, range, and availabilty of minerals in the soil of the drainage area.

Bryophytes. The moss plants and liverworts have a somewhat obscure economic importance. They do play a part in developing the environment for higher plants and for animals. They assist in soil formation, and the sphagnum mosses form deposits of peat in old lakes. These tufted, low growing plants are soft bodied, have a primitive sort of leafy branches, but no true roots. They grow best in damp places, some in water, but others can withstand drying. Reproduction is by spores (which assures wide distribution) and by vegetative propagation (which means they grow and grow, mostly sideways, as far as suitable habitat extends).

Insignificant as we may consider these plants, they have relationships with other plants and with animals which elude the casual eye. They are a step in the evolutionary development of the landscape to a point where it is valuable to man.

Pteridophytes. Ferns and fern-like plants, such as club mosses and horsetails, are similar to those of the carboniferous age when coal measures were laid down. The cold and dryness of Permian glaciation some 240,000,000 years ago wiped out most of them. These plants were more highly organized than the thallus and moss plants. They had stems, leaves, roots and a vascular system enabling the circulation of nutrients and water. They were well adapted to warm humid swamps and grew to tremendous size; but, they were vulnerable to extreme cold through unprotected leaf tips (where growth takes place) and exposed reproductive organs. However, through mutations, some have been able to survive in cold and dry regions. The ferns are the most highly developed of the non-seed-bearing plants, and evidence exists that some of the advanced tree ferns did produce seed. All of the tree ferns associated with coal formation are extinct, although there are a few modern tropical ferns which are of tree size.

Here again, the importance of ferns living today lies not in direct economic value but the part they play in vegetating the earth where

favorable conditions prevail, their role in soil development, and in moisture conservation.

Spermatophytes. Seed bearing plants are the final step (thus far) in the evolution of vegetation. The earliest to make any real progress were low growing evergreens, which bore naked seed and depended on the wind to carry clouds of fertilizing pollen as a prodigal and somewhat inefficient but nevertheless effective means of reproduction. These conifers were hardy specimens and could survive in cold, dry climate and on infertile soil. They were rugged—and still are.

More recent, more specialized, and more dependent on a highly developed and congenial environment are the flowering plants. Reproduction is most efficient, a relation having been established in many cases with insects which do a precise job of pollination, and in return secure nectar and excess pollen. The insect also assures itself (unknowingly, no doubt), of a new supply of food next year by aiding new plants in getting started. There are exceptions; some flowering plants have switched from insect to wind pollination, ragweed for instance, and it will be agreeable to many people if this one changes to some other less extravagant system.

The growing and reproductive parts of the flowering, seed plants are, as a rule, well protected. Through the winter the new plant life is packed into tough, waterproof buds, which in many species open only when daylight of a certain number of hours occurs. Others are indeterminate, and bloom when physically developed. In either case the male cell is protected in a pollen grain and the egg is deep within the flower.

The flowering plants are plastic and adaptable as a whole. They are the most delicately organized, yet so much more efficient than other plants that, like man, they have covered the earth. **These royalty could not exist without the lower forms which help prepare the soil minerals, help maintain the water supply, and dispose of the debris left when life departs.** Each form of life is a wheel in the mechanism of nature and its function is essential to a smoothly working machine. A great deal of man's tinkering with this machine makes us think of the ten-year-old who "adjusted" his mother's wristwatch with an icepick.

Environmental Requirements. The patterns on the landscape assumed by our 300,000 kinds of plants are determined to a large extent by the nature of the plants themselves. In some cases the accident of geographic barriers, such as mountains and oceans, may have its influence. Not all the plants which will grow on a piece of ground will be found there, even in nature undisturbed.

Having evolved in a specific environment, plants may be expected to have some limitations as regards soil fertility, soil acidity or alkalinity, light intensity and duration, growing season, temperature range, ranfall, humidity, drainage, and associate plants and animals.

That they do have such limitations is common knowledge. Just how the plant will react when one of the above factors changes, or the plant is placed in a different setting, is difficult to determine, except by trying it. Some plants are finicky, others flexible. Furthermore, changing one of the environmental factors may result in changes in others. Altering soil acidity by adding lime may increase the fertility for some plants; it may make the soil more granular and absorbent, thus actually increasing the effectiveness of rainfall, and altering the "little climate" in which the plant lives.

Environment is so closely related to life that a knowledge of its development is needed to understand the world today.

FIG. 18. A road cut exposes the earth's rock mantle. The thin layer of topsoil is seen, lying on several feet of subsoil which shades into the parent rock. In your mind, roll the rug of topsoil off the landscape, notch the subsoil with gullies—and you have elemental badlands, barren of all but the simplest forms of life.

Chapter VI

THE EVOLUTION OF ENVIRONMENT

Breaking up the totality of life and environment into fragments has disadvantages. Yet such fragmentation is necessary if proper attention is to be given to the individual factors in the complex. The burden of holding the total picture in mind is placed upon the reader. We shall keep that burden as light as possible, but in doing so a certain amount of repetition of phrases and terms cannot be avoided. Thus, in discussing briefly the evolution of environment we cannot avoid bringing in the role of plants and animals because they are a part of it and contribute to it. The only exception to this is the period before life appeared on earth.

The Home of Life. The mineral earth is the foundation of environment; but no more so than water and air. Of the earth itself, the rock mantle or crust, a variable layer ranging from nothing up to hundreds of feet of thickness, is the most important. Of this crust, **the first few inches of the surface (the topsoil) have come to be the dispensing agent for the mineral salts essential to life** (Fig. 18). The study of these phases of earth science is of course the field of the geologist. Yet he cannot explain his field without calling on other scientists—the astronomer, for instance.

The astronomer reports[1] that the distance of the earth from the sun provides a temperature whose degree and range permit life as we know it. Too little distance would mean more heat and the vaporization of all water. Too much distance would bring permanent ice. In either of these conditions it is difficult to conceive of either plant or animal bodies, since they are composed largely of liquid water. The size of the earth is also favorable for life. The atmosphere is conveniently adjusted by gravitation, providing a density and pressure in which the carbon-oxygen and other gas exchanges can take place in organisms. A smaller planet has not the gravity to hold such an atmosphere. If man ever colonizes the moon, let us say for the purpose of mining uranium or other minerals which he had exhausted on earth, he will be forced to take with him or there manufacture a suitable atmosphere. A planet larger than the earth has atmosphere of such great density as to block insolation (absorption of sun heat at the planet's surface).

The astronomical conditions involving the earth are responsible

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[1]Henderson, Lawrence J., *The Fitness of the Environment*, Macmillan Co., New York, 1913.

for the climate, for water behavior, and consequently for a large part of rock disintegration into soils.

The behavior of water warrants a call on the hydrologist, who adds an explanation of how drainage patterns are formed, the mechanics of natural and man-induced erosion, the movement and deposition of soil materials by water, and the work of streams.

The meteorologist assists in telling of the role of weather and climate in shaping the constantly changing topography of the earth, their influence on soils, plants, and animals.

The physicist details the laws which govern natural forces such as the transporting and eroding power of running water, the kinetic or dynamic energy of falling water, whether it be a raindrop knocking a few soil particles downhill or Niagara whirling great turbines. He explains how contraction and expansion by cold and heat, and the swelling of water as it changes to ice, break down bedrock, cliffs, boulders and smaller fragments into raw soils; how friction and abrasion of moving materials, whether a glacier or a rock particle rolling down a stream bed, are agencies in sand, silt and clay formation.

The chemist helps in gaining knowledge of earth minerals in solution going to the sea or leaching down toward ground water levels in the earth. He speaks of water combining with carbon dioxide from the air and forming carbonic acid which in turn aids in dissolving alkaline minerals in the rocks or rock particles. He delves into the chemical composition and changes in rocks and minerals.

The geologist also has accumulated information concerning various upheavals and subsidences, in which the mountain areas of today were many times under sea or fresh water. Earthquakes have modified the earth's surface, as have volcanoes and hot springs.

All these sciences and more are necessary to explain in detail the preparation by natural forces of a land environment suitable to the simple life forms which followed. (The grievous error in our educational system has been the segmentation of such knowledge so that a very few people have been enabled to see the total environment and grasp the problems involved. A new and promising trend in education is leading toward a break-down of departmental barriers in secondary schools and colleges, to the end that the student may get some idea of the unity of knowledge in its applications to problems of living.)

Life Improves Its Home. The seas and the land had developed into a complex physical and chemical entity before life appeared, although it is possible they occurred coincidentally.[2] It was a mineral and climatic environment of considerable variety, especially on land. Some evidence indicates that life is of electrical origin. (Nuclear physicists have demonstrated that in atomic fission, the disintegration of the atom transforms matter into pure energy). The traditional belief is that spirit was and is involved in the creation of life. Regardless of origin, as soon as life arrived on earth it immediately began to alter its home, even as a house that is lived in reflects the characteristics of the residents. **In general the lower orders of living things tended to improve their habitat (from man's point of view) in the sea and on land. At least they changed it in such a way that other life forms could exist.**

The primitive plants which attached themselves to rocks or rock materials began to exert both physical and chemical forces on the earth, changing it. The green plants stored sun energy and on dying added it to the emerging soil. This started the accumulation of energy in the land which eventually became the reservoir of power and fertility serving the human race. The presence of green plants both living and dead made possible the existence of fungi. which further modified, complicated, and improved the physical and chemical properties of this very thin earth layer.

When rooted plants appeared they penetrated the soil accumulations (and even porous, cracked or cleft rocks) loosening, irrigating and aerating. The roots of dead plants remained at various depths, adding their elements and energy to the soil mantle. As the roots decayed and shrank in size the channels they occupied were invaded by acidified water. This water had become acid by combining with the carbon dioxide of the air and that produced by plant (and later by animal) cells. This acid solution, as noted previously, served as a soil manufacturing agent. Rooted plants also collected minerals from the earth and carried them upward, depositing them, when death came, on or near the surface, thus building fertile topsoil. (Opposed to this was leaching, in which water carried soluble minerals deeper. Which effect was greater depended on the amount of rainfall, temperature, and the porosity of the soil.)

Green plants released surplus oxygen, altering the atmosphere. Food and oxygen being available, animal life appeared, living on and in the soil, or in the waters where soil elements had accumulated through land drainage. These animals formed and released carbon dioxide into the air (or water), which was used by still greater plant populations. During the entire process here described the environment was being enriched in such a fashion that more and more organisms could live in it. This cumulative effect went on and on. Organic matter which had wrested minerals from the soil and put them into first class condition for use by life, returned them to the soil on dying, where they were quickly and easily used by new generations. The hard work was done. **The process had become not only physical and chemical, but biological as well. Rich topsoil was fabricated by life and death.**

By this time, a mature soil, instead of being plain "dirt," or a simple mixture of chemical elements in the form of physical granules or aggregates (clumps), had become an extremely complex, dynamic

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[2]*Soils and Man*, U. S. Department of Agriculture, Washington, D. C., 1938, p. 887.

FIG. 19. In any good community the living and the dead are one. The living are enriched by the contributions of the dead. The more good dead have preceded the living, the better life is, the better the community is—any kind of community, plants, or worms, or men.

organization, crammed with life, energy, proteins, vitamins and raw minerals, all interacting, producing and maintaining a high order environment usable by the organisms involved. (Fig. 19).

Living macroscopic (visible to the naked eye) plants and animals are usually host to micro-organisms. But it is when plants die and help form that part of the soil known as humus, that the micro-organisms have a field day and multiply by the billions in each handful of soil when moisture and temperature are favorable. "So enormous is the total that protein . . . determined in the usual soil analysis, is largely composed of microbic remains."[3] It is such organisms as bacteria, actinomycetes (mold-like), fungi, mycorrhiza (certain molds) protozoa (one-celled animals) and myxomycetes (slime molds) which are largely responsible for high grade soils. **Micro-organisms are fundamental in the creation of a basic environment which will support the higher plants and animals, including ourselves and our civilization. Where these primitive life forms with their slime and their stinking gases are absent, also absent will be the cathedrals, the universities, and country clubs of man.**

In nature the activity of microbial organisms is balanced in some degree against the fertility needs of the larger, green plants.

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[3]*Ibid.*, p. 942.

Weather conditions which favor the growth of large green plants also favor the multiplication and work of the microbes. When man cultivates soil he admits oxygen which stimulates microbial activity, like opening the draft on a furnace. At the same time, the changes in soil conditions resulting from cultivation destroy some of the microbe species, and a new association is established. By over-cultivation, fertility often is made available from the humus faster than it can be used by crops; so that the excess may be lost by leaching or, in the case of nitrates, may escape into the air. **Thus even these microscopic life forms become an object of management by man. If we insist on having a social order such as we have developed, minute and painstaking attention to every detail is imperative if we are to maintain that culture permanently.** The only other road leads back to a primitive environment. As a general rule in nature, until an undisturbed maximum is reached, *life improves its home.* Man, as a part of nature, should logically follow this cue.

Life Changes Forms. As developed briefly in the preceding chapter, a changing environment made possible the survival of many variations and mutations, and their establishment as new species. These new species occupied the various environments as they became available. Usually, when a new species appears in a plant community it affects the vegetation already present. It may be more efficient in extracting water or minerals from the earth and thus starve out nearby species. It may grow tall and provide enough shade to kill shorter plants or prevent their reproduction.

Plants (and animals) do alter the environment, often preparing it for more highly organized life forms. The latter may then make it impossible for their beneficent predecessors to live there.

Life is Interrelated: The various plants and animals are not only adjusted to the conditions of the mineral and climatic environment, they are equally dependent on a friendly community of other species of plants and animals.

Life is marked by both variety and organization. The individual is organized, no matter how simple or complex its structure. Animal species are organized, as to range, feeding areas and habits, reproductive mechanics, etc., some remarkably so, as the bees and the ants.

Equally remarkable relationships exist among plants. Communities of various species, like people, may be compatible or may not. If not, one or more has to go.

The plants in an association have many needs in common, which enable all to live in the same general environment. Yet, many species of the group vary in their needs, and these differentiated needs may be met by other species in the association. Oak and hickory trees, in one association, provide shade for those of the ferns, mosses, and other plants which are intolerant of light. The forest floor holds the abundant moisture needed by many low growing plants, and provides the organic matter required by the numerous fungi. The young trees, growing slowly in the subdued light of the understory, offer no serious competition to their lordly parent trees, yet they stand ready to take over the sun energy when the forest patriarchs crash to earth or die and cast little shade.

This same plant community meets the needs of many animals such as worms, insects, spiders, birds, squirrels, raccoon, deer. Many of these animals in turn render services to the plant community, such as soil improvement, pollination, seed dispersal, and control of injurious life forms. The plant community, by regulating the action of water in and on the soil may maintain permanent springs and streams, which are valuable to both land and aquatic life.

By this overly simplified example we see that at any point in time, *the evolving environment is a complex maze of relationships.*

Life Moves Toward Climax. Though those biologists who are mechanistic will dispute the idea, many philosophers will maintain that life is *driven* toward a climax or peak of development. It is driven by the intrinsic forces and reactions of natural phenomena. The jouney has has its sprint and delays, its detours, its rough going. And once the climax is reached there is no assurance that it can be maintained. Sooner or later some natural force, such as landslide, eruption, erosion, or climatic change, may upset the equilibrium and the area must again start its laborious journey upward from whatever point the disturbance dictates.

Briefly, the development of a climax is this: As a primitive association of plants and animals live in a specific area or habitat, the habitat is changed. Soil structure and composition change; moisture conditions change; sunlight patterns are altered. In general the environment is in time so altered that other associations are enabled to invade the area, in a defined sequence. Finally, if no overwhelming natural force intervenes, a climax balance is established, in which the species present make the most efficient use of the habitat, of minerals. water, air and sunlight. Soil formation equals or exceeds natural erosion. A maximum is reached in every department of life and environment. A relatively few species of plants and animals dominate the area. They determine, by the nature of their activities, which other species can survive there. (Fig. 20.)

Barring a cataclysm, the climax is (probably) perfect and permanent. There is much cooperation and mutual protection between the associated species, but ruthless competition among individuals of a species.

Life Tends to Overpopulate. Potential reproduction in a climax is more than enough to insure maximum biological activity in the area. A reserve army of seeds and spores is ready to recover quickly any portion of the habitat which may be damaged superficially, as by insects, flood, or lightning fire. Yet, excessive reproduction is controlled by natural forces, (Fig. 21) starvation and disease being most common, along with eating of seeds and plants by animals, and mortal combat between animals.

FIG. 20. This virgin forest, dominated by hemlock and beech, is the climax of soil and vegetative evolution for this Pennsylvania area. The cycles of water, soil, and air elements are meshed with the various life cycles of both plants and animals. All these cycles are driven by sun power. There is an annual surplus production which man can draw off without damaging the valuable climax conditions.

FIG. 21. Victim of chestnut blight. The fungus, which has killed nearly all American chestnut trees, attacks the cambium, the living tissues under the bark. The fungus reaches a high population in the tree, ends by completely destroying its own food supply; it dies along with the tree. The million farmers who have fled from farms which they destroyed should appreciate the plight of this fungus.

While nature provides for potential overpopulation, she also provides restraint to prevent it. In Western culture, man has tried birth control, not on a general, organized basis however, and not on a scale sufficient to prevent war, (which is in itself another control). Germany, according to documented reports, tried wholesale civilian murder to reduce population and provide more "living room" for Aryan Germans. In India and China the common controls are starvation and disease, while Japan has malnutrition, hara-kiri, earthquakes, and war. Population controls *must* operate, sooner or later, because of nature's prodigality in seed production.

Man is Part of Environment. Man has managed to insert himself into every plant and animal association on earth which appeared to offer any opportunity for benefit. In some cases, as in equatorial and arctic regions, we suspect that not benefit, but escape from intolerable or dangerous social conditions, led to the migration into such areas.

Up to the point when man ceased to be savage he was simply another animal in the association, perhaps dominating a habitat, but subject to purely natural and adequate, if ruthless, population controls. His contribution to the environment was, roughly speaking, equal to his demands upon it. Developing some minor handicrafts and arts, we say he moved up a notch and became a barbarian. In this stage he did no great damage to his habitat, not having the tools with which to do it; but upon becoming civilized, man adopted the assumption that he was no longer a child of nature but its sworn enemy. **In the role of conquerer man proceeded with ever increasing efficiency to wreck nearly every climax natural community that was sufficiently comfortable for occupation.**

Man thus became the cataclysm which destroyed the perfection and balance of climaxes. (Figs. 22, 23.) It is not the particular species of the climax which we mourn, although they are in general the most prized of the wildlife forms. Rather, **it is the conditions within the environment, which made possible the survival of climax species, that are most valuable. These conditions, where they consist of good soils with high fertility and well developed water control factors, are the most essential assets which man can hold. Without them no opulent and highly developed social order can exist.**

The destruction of these assets was not undertaken in malice, but in ignorance. Man was driven by forces within himself and his culture. These forces ran from hunger and cold through economic pressure to egotism, from simple human needs to vainglorious display of wealth.

The Constructive View. It is perhaps a paradox that in much of his production and construction man has been tearing down. It is as if he wrecked a mansion, intending to build more useful structures with the salvaged materials, but too often ended up with nothing but an outhouse. The evidence of science indicates that, regardless of man's other attributes, he is biologically an animal, though a human animal, and must realize that in his relations to nature he must, if he

FIG. 22. The climax conditions are rapidly going from this Idaho forest area. Fire has destroyed the biotic complex. The water cycle is out of control, is tearing the remaining natural machinery to pieces. Only heroic measures—reseeding of grasses or hand planting of trees—could save this area.

FIG. 23. The end of a Texas climax. It is May, but where are the leaves of the shrubs, the lush and succulent grasses, the fat steers? This is overgrazing carried to its bitter conclusion. Not satisfied with a normal surplus which the climax provides, man has enforced demands which broke the productive cycles. The result is a desert with 25 inches of rain per year.

is to survive, conduct himself as an organism of nature, as a biological unit which must keep to its proper place in the natural community. One glaring fault has been a failure to recognize the absolutely essential role of the lower life forms in preparing and maintaining an environment productive enough to support a satisfactory social order. It is a combination of ignorance and egotism which has led us to assume that lower organisms are insignificant. Man's superior intellect is fully able to comprehend these facts and should permit him to control his powers.

An example of such self-control is found in the agriculture of Western Europe. There the drizzling rains of low eroding power. coupled with originally mediocre forest soils which forced man to build fertility since the Middle Ages, combined to establish a permanent agriculture. An accident, yes, but it enabled Europe to build a thousand year old civilization.

But, wherever the West European farmer migrated he seldom found such an environment. When he applied his ancient system here he got destruction because it did not take note of vicious thunderstorm rains, steeper slopes, the new (to him) soil exposing row crops like corn, cotton, tobacco, and the erodibility of different soils. He also encountered other situations whose dangers were unknown to him or which he ignored, such as insufficient manuring and composting on larger farms, the availability of plenty of good and cheap land, unusual profits for a time from continuous cropping, and later, faster and more extensive plowing with the moldboard plow and the use of other more efficient implements for pulverizing and exposing the soil. The result has been that in a very short time, as civilizations go, **we have in the United States done an almost incalculable damage to the basic landscape resources.** We have, for instance, destroyed more good land than the Japanese ever had. (Fig. 24.)

A constructive principle has been ignored, and it is: **When man disrupts the natural climax association (**e.g., **by removing the forest or the sod) he must substitute a system of agriculture which reproduces or improves the forces and reactions of the original biologic community.** Only thus can the underlying values of soil fertility and water supply be maintained. Which is to say that only thus can we continue to support our population in the manner to which it has become accustomed. And if that population increases (as it is), then it becomes essential not only to preserve what nature so laboriously built, but to improve it. The West Europeans did it. We must do it—and the time has come when we must start.

FIG. 24. California pastureland destroyed by overgrazing and bad management of herds. Cattle trails started these gullies. Man, as a steward of natural resources, is morallly obligated to study the reaction of his land, the nature and habits of his animals, and to devise a system of management for safe, sustained uses.

CHAPTER VII

RELATIONS BETWEEN PLANTS AND ENVIRONMENT

The science which studies the relationships among plants, and their relationships with any part or the whole of environment, is called ecology. Literally, ecology means the study of homes. The physiologic processes of plants, their structure, and their reactions to controlled ecologic factors may be and must be studied in the laboratory; but, how the plant functions in, influences, and reacts to its natural environment can be determined only in the field. (Thus, our whole educational system as it stands is poorly adapted to the study of this extremely important science).

Associations and Communities. In the field the first observation of relationships is likely to be the fact that plants occur in communities or groups. It is rare to find a single plant at any great distance from other plants. Where the soil, moisture and sunlight will support one plant, it will nearly always support more than one. A colony of the same kind of plants exhibits relationships between individuals, between individuals and the environment, and between the group and the environment. There is competition for minerals, water and sunlight. Those individuals which, because of an earlier start or greater inherent vigor, grow taller and secure more sunlight, or establish a larger root system and secure more water and nutrients from the soil, will stunt, deform, and perhaps even starve out others.

This competition within the colony arises from the *similar requirements* of the individuals and the definitely limited supply of one or more of the factors necessary to life.[1] The grower of plants soon learns the importance of proper spacing, if healthy and valuable individuals are to be secured. The forester knows the value of thinning crowded stands of trees in order to promote the growth of the best timber. As far as nature is concerned the tendency is to produce the maximum of vegetation of whatever kinds can establish themselves in a particular environment, but man's demands for useful species requires management. **The total photosynthesis going on in an area must be maintained at a maximum, but it should be channelled through the useful species.** Even so, man must remember that many species not directly useful are necessary to the maintainence of the environment.

The more commonly seen communities of plants, which consist of many species, present another competitive situation, that of

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[1]Clements, F. D., *Plant Succession and Indicators,* The H. W. Wilson Company, New York, 1928, pp. 72-73.

species with species. The destruction of weeds in crop fields by means of cultivation, chemicals, or flame, is required to control such competition. The forester deals with "weed trees," which use nutrients and sunlight without providing man with timber of much value. Forest management suggests their removal, if better trees can use the environment.

In such a community it will also be observed that some species get along quite amiably with others, even to the point of interdependence. This is due to a difference or partial difference in requirements. The relation between legume plants and nitrogen-fixing bacterial plants has been mentioned. The lichen represents a close partnership between algae and fungi. Species may live in intermixture because their roots or their crowns are on different levels. Some species can live in the shade of taller plants, which may live in the shade of still taller plants which may need full sunlight.

The term *association* means those species which, through successive stages of environmental development ending in a relative state of balance, have come to dominate the community, temporarily or permanently. Thus the beech-maple forest actually consists of scores of plant species all dominated by the beech-maple association.

Ecological Factors. Frequent mention has been made of various factors involved in the life processes of plants—such as soil, water, atmosphere, sunlight and temperature. It has been noted that these are altered, so far as plants are concerned, as the environment develops, that these alterations permit the invasion of the habitat by other species, and often result in the disappearance of once established kinds. Insofar as these factors affect the structure and composition of communities they are ecological.

The ecological factors named are all functions of climate, in the final analysis. Temperature, sunlight, and precipitation need no explanation. Atmosphere is put in motion by heat from the sun, and thus distributes water, heat and cold. Unsaturated atmosphere picks up moisture, thus influencing soil humidity. Soil itself is a product of climate working directly on minerals or indirectly through the biologic forces of life and death. The water holding capacity of soil is thus a function of and product of climatic action. There is a lesser dependence on the nature or composition of the parent rock in determining what grows in a specific area. "Vegetation . . . most quickly and strikingly expresses the character of the climate."[2]

In regard to a given species of plant in a given habitat, any one of these factors might be critical. The morning glory is killed early in autumn by frost. Orange groves are often killed by one severe freeze. Lack of water in general keeps forest out of the plains, and Buffalo grass out of the desert. The need for much water keeps

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[2]Sears, P. B., *This Is Our World.* University of Oklahoma Press, Norman, Okla., 1937, p. 180.

willows confined to wet places. Few herbs can survive the dense and year round shade of coniferous forests, and most coniferous seedlings cannot survive without shade. Corn cannot survive the hot, dry winds which are taken in stride by the cactus.

The decision between survival and death may hinge on very slight change in a habitat factor, when it nears the limit of tolerance. Being shaded one hour more per day than a fortunate neighbor may mean that one red oak sapling will die in its youth and its neighbor live. On the other hand young beeches must have deep shade, and an hour too many of direct sunlight per day will kill the exposed seedling.

The evidence indicates that differences in plant growth and ability to survive in a habitat are rarely due to the influence of only one ecological factor, but rather to a complex influence. This can be readily understood. Shade, for instance, reduces temperature of air, leaf, and soil; it reduces, also, evaporation from soil and transpiration from leaf; in effect, shade is equivalent to greater rainfall, in that soil moisture is increased or conserved.

Leaves in shade tend to grow larger because of a need to intercept more light for growth and survival. Shade leaves on a tree may have a very different size and shape from those in the sun drenched top. Plants whose leaves are valuable, such as tobacco, lettuce, kale, chard, etc., may, in some respects, yield better crops if a certain amount of shade is provided. On the other hand, reducing the sunlight may reduce the nutritional quality of some plants; tomatoes, for example, produce vitamin C in proportion to sunlight. Forest nurseries use slatted frames placed on supports to provide the partial shade necessary for the production of healthy seedling trees. Gradually, the light is increased by periodic removal of the shades until the two to four year old transplants are adjusted to full sunlight and ready for planting on even bare eroded hillsides and gullies.

Micro-climates. There is confusion in store for the student who goes out to observe communities of plants. He has been told, let us say, that a certain hilly, humid area comprising several counties, is, or originally was, an oak-hickory forest. He has learned at second-hand that oaks and hickories require a well drained soil and 30 to 50 inches of rain per year. He knows that wet soils in that general climate will probably have an Elm-Willow-Sycamore association on them, that somewhat less wet soils should have Beech-Maple, and that the driest, best drained areas will be dominated by Red Oak-Black Oak. So he goes out, and along the streams, sure enough, he finds elms, willows and sycamores. But up on a dry, bare hillside there are also sycamore seedlings, saplings, or trees. The student scratches his head and wonders. Later he learns that the ecologists have about decided that plenty of light is more essential to the sycamore than lots of water. It needs both, but light seems to be the critical factor.

The student moves on to a gentle slope, and there are the maples, or the beeches, or both. Here and there he sees oaks, or hickories, or both. Up on the hillsides are White oaks, and on the wind dried, sun dried hilltops are Red and Black oaks. Then he discovers, well up on the hill, a colony of maples where apparently they have no business being. All around is well drained sandy soil perfectly fitted to the White oaks he sees. Where is the greater water supply maples are supposed to need? He digs in the soil, and there is the moisture. The geologist explains that ground water seepage is occurring along a strata of impervious shale which out-crops at that point.

The observer has found a micro-climate; in this instance a topographic peculiarity has exerted its influence. When an old forest monarch falls, a small clearing results, with greater sunlight, higher temperature, more evaporation, more air movement. This micro-climate soon develops a small plant world of its own. It is more herbaceous than the shaded forest floor. It is controlled by the environment of the moment, yes, but at once starts a course leading into the climax conditions. In the meantime it will support herb eating animals in greater numbers than will the forest climax. Game managers sometimes make clearings in woodland, make micro-climates for a special purpose—more game. In the future we will likely see more of this.

There are scores of these micro-climates on a single farm. The north side of a tree usually provides one, and there certain life forms may live that could not exist a foot away on the south side of that trunk.

Geography of Plants. It might be expected that wherever on earth similar climates were found, there also would be the same plants and communities. Such is not the case. What we find is very similar appearing vegetation, but the species, in general, differ. What *is* alike, is the *structure* of the plants,[3] and their behavior. Sandy deserts the world over exhibit practically the same characteristics. So do all the deciduous forests, the coniferous forests, the prairies, the plains, the scrub areas.

We have noted that west European farmers on coming to America did not know how to manage the landscape. The Spaniards who moved into the southern California coastal region established themselves very well, because this area has a Mediterranean climate and vegetation types. The transfer of culture was easy. Protestant Germans from the Rhine Palatinate, who have gained fame for their conservation farming in and around Lancaster county, Pennsylvania, ever since colonial days, represent an unusual type of European farmer. Victims of religious persecution, they had moved about Europe in search of tolerance. Weary of wandering, they came to America and with great relief settled down, happy to have permanent homes once more. Many of them were familiar with the Alpine storms, torrents and erosion. They were acquainted with Rhine valley terraces, and so, they had an unusual background for dealing with American crops, climate, and agricultural problems. However, even they were not wholly successful in controlling erosion on their rolling southeastern Pennsylvania farms.

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[3] *Ibid.* p. 184.

The geographical range of plants is almost entirely determined by climate. Climate is a complex which pays no attention to political boundaries, nor even to latitude and longitude in many cases. The tropical Mexican coastal plain is only a hop, skip, and high jump from the temperate inland high plateau. Within the boundaries of a farm, climate and topography usually have directed the construction of numerous environments. One section of the farm may be fit only for forest, another for meadow, another for tilled crops. **Unless consideration is given the fitness of the domestic plant for the environment, neither plant nor environment may be able to sustain itself.** Corn will grow on a fertile hillside, but it is only a matter of ten or twenty corn crops until there is no topsoil left, and no corn. (Fig. 25.)

The Genesis of Succession.[4] Succession has been treated in a symbolic or general way in Chapter 6. Succession is a development of life and habitat toward a climax formation. Succession occurs on every part of the earth's surface where life is possible and where a climax does not exist at the moment. It occurs on land and in the waters. The end result of succession is not only a climax, but it approaches as near as possible a median (mesophytic) condition; that is, a middle status between extremes, of moisture particularly, and temperature. Succession starting in a lake eventually results in filling up the lake with silt and acquatic vegetable matter; followed by an invasion by land herbs, and finally by shrubs and trees. Starting on relatively dry, rocky areas, the succession may end in forest, for instance, where much more moisture is retained than originally. Water is held in the leaf litter, and the now granular and humus laden soil.

Of course, the climax formation is determined by the overall climate: forest in the humid areas, savannah (trees and high grass) in less humid or transitional areas, grasslands in the subhumid climate, short grass or scrub in the semi-arid, and desert vegetation in the arid regions.

What causes succession to get underway? In the beginning of the earth, all places were barren, land and waters alike, and the whole evolutionary process got underway. Today, succession occurs wherever barrenness is produced, or any degree of barrenness short of the climax of the area. The causes of barrenness may be due to man's culture or to natural forces.

Topographic Causes. The fragmented surface of the earth is movable. The removal of earth material from one place must result in its deposition somewhere else. Both actions, except when very slow, result in damage to vegetation. Removal of soil by wind, water, ice, or gravity is called erosion.

The results of water erosion are bare or partially bare gullies, ravines, drains, arroyos, flood plains, stream islands, banks, shores,

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[4]Weaver and Clements, *Plant Ecology,* McGraw-Hill Book Company, 1938, 2nd edition, passim.

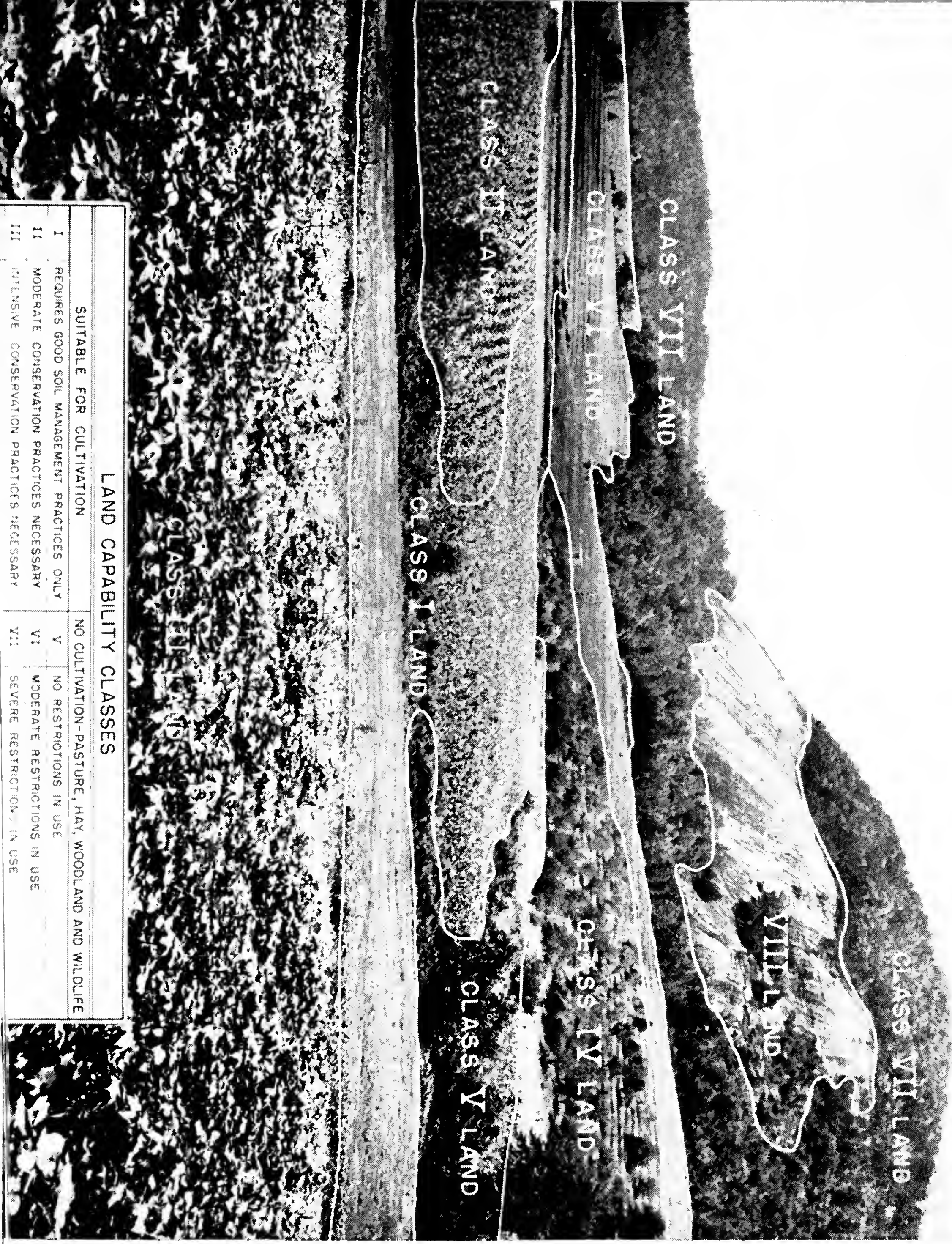

FIG. 25. Classifying land, according to what it can and cannot do, is a job for experts. Anyone, however, can detect blatant misuse after studying this marked landscape.

balds, galls, slopes, bad lands, buttes, scours and bars.

The invasion of such bare areas by pioneer plants depends in considerable part on the type of surface, its stability for a period of time, the water supply, degree of slope, and insolation. Steep slopes in Palestine eroded down to bare rock are very discouraging to life, as are broken cliff faces in the Cascades, and the rocky bottoms of gullies.

Wind erosion creates dunes, sand hills, and blowouts. The fine material is lifted and carried away. The once good loam of the dust bowls has lost its light humus, fine clay, and much of the mineral-rich silt by this process. Of the original topsoil only sand remains over large areas; and it may be on the move, slowly.

Ice denudes narrow strips along streams and lakes, along glacial beds and margins, and leaves bareness where the ice has retreated.

Gravity causes slipping and slumping of wet clay slopes, hill crests, stream banks, shores. Land and snow slides denude the areas involved, cliffs break off, exposing bare surfaces.

Deposits of barren material result from all the above erosional actions, also from volcanic and ground water actions. Surface waters deposit flood plains, deltas, sand bars, reefs, alluvial cones and fans, beaches, spits, and channel deposits. Ground water, rising as springs and geysers, deposits lime, silica, or salts. Wind blown soil deposits are called loess (if fine), or dunes (if sand), or volcanic dust. Glaciers in the past have laid down deposits over vast areas, the materials ranging from great rocks to the finest rock flour or clay. Gravity produces the talus slopes below crumbling cliffs. Volcanoes emit cinders, rocks, lava, dust, ash, mud, sinter. Volcanic lava deposits are very resistant to environmental evolution. Earthquakes, and the possible (but rare) *rapid* uplift or subsidence, may cause bare areas.

In all these cases, a succession of life forms usually begins at once.

Climatic Causes. Destruction of existing vegetation may result from drought, wind, hail, snow, frost, lightning, or evaporation. Drought is most destructive in areas where water is a critical factor, as on the Great Plains. Repeated hailstorms have forced abandonment of certain plains areas. Elsewhere great damage is often done by hail to crops, meadows, broadleaf forest and scrub. Snow damage is serious only in polar and alpine regions. Elsewhere it may benefit vegetation by protecting it from freezing and by serving as a water supply. Lighting as a cause of fire is an important factor in national forests. In unprotected or heavily populated forest regions, fires started by people make lightning a lesser evil, comparatively speaking.

Evaporation, perhaps speeded by wind, may dry up ponds which have an unreliable water supply source. The pond life dies. A land succession begins, only to die in turn if the water returns. Flooding of depressions and lowlands may persist long enough to destroy the vegetation temporarily. Succession may follow the disappearance of the water.

Biotic Causes. Under some conditions plants destroy themselves and their specialized habitat, as when they create conditions favoring the invasion of their home by other species. Animals, particularly man, do much damage, often exiling themselves from an area or region by destroying their own food supply. Ants create bare spots, but their contribution to soil formation makes the damage picayune. Insect plagues can and do destroy all *annual* vegetation and its seed from areas of various sizes, so that invasion is necessary to replace these annuals. The persistent roots and underground stems of perennials may survive. Plant-eating animals confined by man or by natural boundaries to a limited space will, if crowded, denude the landscape. Elk, snowbound in small valleys, may do this. Hogs will make a desert of a small, fenced lot in short order. Prairie-dog towns may present extensive bare areas to view. Beavers build dams and flood small areas, destroying the land vegetation by submersion, and creating a pond temporarily barren, barren at least in comparison to the rich variety of life it may later contain.

Man's principal denuding activities are clearing (whether by ax in the forest or plow on the plains) and burning (whether deliberate or accidental). Lumbering, even the clear cutting so opposed by scientific foresters, need not destroy the climax, unless followed by fire, overgrazing, or erosion. If the operation is conducted with consideration for the seedlings and saplings, the climax is retained.

Succession does not occur unless the climax species are destroyed and the environment set back one or more phases. Some ecologists insist that true succession begins only with complete denudation of an area, and the entrance of pioneer plants from surrounding areas. A severe forest fire followed by erosion usually causes this. A light ground fire usually does not. Even the spectacular crown fire does not necessarily do it in all instances, unless joined by equally severe ground fire. The rapid rise of heat from a crown fire may leave the soil level comparatively cool.

The preparation of a farm field for seeding usually involves the complete destruction of all original vegetation. Certain fumes and gases from smelters, factories, coke ovens, or smouldering coal mine gob piles may result in killing or maiming all vegetation within radii up to several miles. Strip mining creates not only bare areas, but turns over the soil to great depths and leaves a rugged terrain. Dredging and draining create barrens. Canals and ditches, constructed ponds and lakes, create aquatic barrens.

This Changing World. Bare areas as listed in this chapter, are constantly being created on the world landscape. Wherever climate is favorable, migration or invasion begins at once. The outdoor air is never without many forms of life — spores, bacteria, and seeds. These are carried by wind. They are carried, too, by water, birds, mammals, man. Some plant species have migrated across oceans and continents, down thousand mile river valleys or along mountain ranges. But, most invaders of a bare area come from nearby. Migration is limited by mobility, type of carrier agent available, distance, and topography. Not only are spores and seeds distributed, but in other cases the fruit, offshoots, or the entire plant may be transported.

Having invaded the area, the plant must succeed in growing and reproducing if it is to exert any influence. If it does, the next step is increasing its population, and exerting its influences, i.e., modifying the environment. Greater population also gives rise to competition and the establishing, by the most efficient species and individuals, of dominance over the community. As the environment is modified (improved, usually) other invaders come, succeed, establish dominance. This continues through a series of phases, determined by the soil, climate, and available invaders, until a climax is reached. At this point the dominant species do not improve or change the environment further, no other species can take over control of the habitat, and relative stabilization is achieved. This situation remains until and if one or more forces cause a return to complete or relative bareness.

Secondary Succession. Secondary succession is what follows the original succession when its climax is destroyed. A common sequence of events in the dissected Appalachian Plateau and elsewhere will illustrate what occurs when forest is converted to cropland. After the forest is cleared the first few farm crops are phenomenal. How-

FIG. 26. The hill is being rapidly reduced in fertility as topsoil is washed off. The up and down corn rows accelerate the vicious process. The bottom is, in a sense, being enriched at the expense of the hill; but, the excess water runoff from the hill drowns the bottomland crops in spots where it collects. The hill will soon be retired to low grade pasture. If overgrazed, abandonment will follow, and then secondary succession will begin.

ever, fertility drops rapidly as the organic matter is oxidized and leached by exposure to climate, and as erosion gets underway. After a period of cropping, yields drop so far that the land is retired to permanent pasture. (Fig. 26.) The period of cropping may range from five or ten years of continuous row crops, up to fifty or seventy-five years of rotated crops.

The usual procedure in pasturing these lands is to attempt the impossible, that is to make as much money from animals as was once provided by small grains or row crops. In short, these pastures are overgrazed. Erosion continues. The grass cover becomes thinner. Bare land meets the eye in many places. (Fig. 27.) Nature, abhorring nakedness, starts to reclothe the now abandoned land.

Here and there on the raw soil, filamentous mosses appear, along with some micro-algae, and crustlike lichens. (Fig. 28.) These primitive forms partially stop the erosion and begin to rebuild fertility. They increase the chance that invading seeds will find a foothold, instead of being washed off, blown off, or killed by dryness if they sprout.

What kind of seeds can meet the grade? In spite of the humid climate, the high rate of runoff coupled with the lack of absorbent topsoil have changed the soil climate to one of semi-aridity. In short, the soil climate of this onetime Central Hardwood Forest has become the soil climate of the Great Plains. And so it is not surprising that a plains-like grass invades — poverty grass. (Fig. 29.) But, unlike grasses of the plains, poverty grass has about as much nutritional value as excelsior. It has all it can do to keep itself alive, and while it may be somewhat succulent for a brief period in the spring, it provides very little food for steer, lamb, rabbit or field mouse. These animals relish poverty grass approximately in the degree you would relish eating a damp broom. Along with this grass, another much like it in character usually appears—broomsedge. (Fig. 30.)

After poverty grass has contributed its bit to preventing further erosion, has wrested some minerals from their lockers in the poor soil, and has added some humus to the land, the succession proceeds. Running briars move in, particularly dewberry. Dewberry is a low-growing, hardy plant. It produces fruit which is of some value to animals such as rabbits, birds and others. By its shading effect it begins the ousting of the poverty grass and other shorter plants which need full sunlight. (Fig. 31.)

Following dewberry, its taller cousin, blackberry comes into the field. More wildlife is supported and protected. More humus accumulates. Less erosion occurs. More shade is thrown. (Fig. 32.)

Next come low-grade trees, such as sassafras, sumac, and wild crabapple. (Figs. 33, 34, 35.) More roots grasp the soil. More animals can live on the new seeds and fruits. Man is still excluded, however. There is, as yet, little of use to him. As the trees grow, the crabappple outgrows the sumac. Sumac is a no-account weed of a tree, weak and pithy. Birds may eat its seeds, and the outdoorsmen,

EVIDENCE OF SUCCESSION

FIG. 27. Barren area in old field, product of severe erosion.

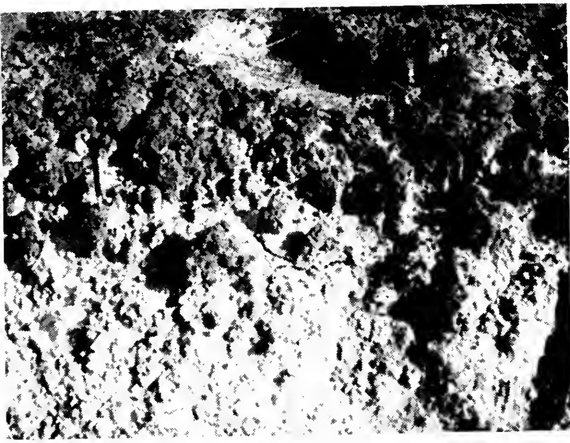

FIG. 28. Lichens on pedestals of soil, resisting further erosion.

FIG. 29. Moss (lower center), soon to be choked out by adjacent poverty grass.

FIG. 30. Broomsedge clump coming into local dominance.

FIG. 31. Dewberry overcoming competition of poverty grass and weeds.

FIG. 32. Blackberry rising above and dominating dewberry and other community plants.

FIG. 33. Sassafras, dogwood, and wild crab-apple competing for dominance.

N OLD ABANDONED FIELDS

FIG. 34. Wild crabapple is common on less eroded parts of field.

FIG. 35. Sumac taking advantage of soil improvement by preceding life.

FIG. 36. Green ash shooting up from rough sod to take over sunlight and soil.

FIGS. 27-37

An old field usually presents many micro-climates, many micro-landscapes, many stages of succession. Present also are many varieties of animal habitat and many orders of animals according to the variations in the landscape.

FIG. 37. Oak overcoming competition of many lower species where soil is good.

wet, cold, hungry and perhaps lost, can start a fire with the peeled branches of sumac. There is not much loss when the crabapple shades out this link in the succession.

By now perhaps twenty, perhaps fifty or seventy-five years have passed since the last scrawny cow grazed the field. The period depends on many factors. After the wild crab comes the ash, the first good harwood invader, and after another fifty years or so the ash has shaded out the crabapple. (Fig. 36.) Then other hardwoods appear, according to ecological conditions—the oaks, hickories, maples, beeches, walnuts—creeping clowly because their seed dispersal is restricted in distance. (Fig. 37.)

And so, maybe, with luck in a hundred and fifty years the climax forest may be well on its way back. Without luck, who knows?; it may take a thousand years.

Animal Succession. Little has been said about animals, but it is obvious that, as environment goes through its developmental phases, food, shelter and moisture conditions favorable to various animals are changing. Usually, successive animal associations proceed along with plant successions, ending in a climax co-terminal with the plant and environmental climaxes. Animals react on the environment in various ways and contribute to its development. Earthworms exert a tremendous influence on soil, when conditions favor their existence. Ants, field mice, shrews, moles, groundhogs, gophers, chipmunks and other burrowing animals aid in soil formation by mixing, aerating, irrigating and fertilizing it. Springtails, snails, centipedes, millipedes, beetles, spiders, ants, mites, termites, bumblebees, etc., are present in surface litter and soil in the magnitude of hundreds of thousands up to millions per acre. Field mice, shrews and moles, with their mazes of subsurface runways, are usually present to the extent of dozens up to a hundred or more per acre. Microscopic animals must be thought of in billions.

Birds and game mammals are present in smaller numbers, but their reaction may be very significant in developing or maintaining the bio-climax. There will probably be, on an acre of average fertility *and suitable vegetation,* one pair of birds, with young. There may be ten pairs of small mammals with ten young per pair. Of other mammals, there might be as many as four or five vegetarian rabbits per acre, one browsing deer to seven acres, one meat eating fox to the square mile. Of game birds, quail may average one, probably less, per acre; pheasants may average one or two per acre, with concentrations on good feeding or watering areas up to 200 per acre at certain times, such as in severe winter weather or drought.

The truth is that dealing with life and environment solely from the viewpoint of plants is an artificial distinction; and, while useful for simplification of the study area, cannot be a wholly true picture of what is encountered in the field. The serious student of life is intellectually obligated to investigate animal ecology, or the combined fields of plant and animal ecology called bio-ecology.

Recapitulation. It should be noted that the pioneer-to-climax succession is very similar to the evolutionary development of the earth's life forms to their present condition. While the over-all evolution must be reckoned in terms of millions of years, the recapitulation of the process may occur on a bare area today in a matter of centuries or even less time. The reason is that all the plant species involved are already in existence and stand by, ready to invade when conditions permit.

Both the above developments are reflected in a general way by the life cycle of the individual plant. Starting with a single fertile cell, it proceeds to establish an increasing intimacy with the environment, and to become progressively more complex in organization as it develops from an embryo to a mature structure. It reacts to the habitat and the habitat reacts to it. **In a stabilized environment, the plant (or animal) or its successors can live indefinitely in its habitat, because it will return to the soil, to the water, and to the air everything it takes from those storehouses, to be used again by its offspring.**

Indicators of Environment.[5] Since plants are products of the environment, they tell a story by their mere presence. The dominant species are most reliable as indicators of living conditions, past and present. Once scientists have, by detailed study of the ecological factors associated with a dominant species, established the habitat pattern, we can then know, whenever we see that species or association, what the pattern is. Much such work has been done. Much remains to be done. Ecology is a young science.

A few examples: Reeds indicate a water table near the surface. Mesquite roots go down for water as much as 50 feet. Beech-Maple forest land is more productive as farms than Oak-Pine. Long-leaf pine uplands will yield profitable corn crops for no more than three years without fertilizer; mixed Short-leaf and Long-leaf pine areas, five to seven years of corn; Short-leaf—Long-leaf—Oak-Hickory land, up to 12 years; Oak—Short-leaf, 12 to 15 years of corn without fertilizing.[6] Short-grass sod growing where it doesn't naturally belong, on the western belt of the tall grass prairies, indicates overgrazing—the climate will support mixed prairie grasses which include much taller ones (wheat grass, for instance) than the short grasses. Wild wheat grass itself indicates land fit for domestic wheat crops. Sage-brush indicates deep, porous, non-salty, farmable soil. Quaking aspen (a low-grade hardwood) dominating northern softwood forest areas indicates past fires. Broomsedge and briars indicate that a former hardwood forest site must be replanted to pines if a forest is wanted, since the original fertility is greatly reduced.

It can be seen that a knowledge of plant indicators, or even knowing that such information exists and can be secured, is valuable

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[5]*Ibid.*, Chap. 17, passim.
[6]Hilgard, E. W., *Soils*, Macmillan, New York, 1911, p. 315.

in any situation involving questions of land use and land improvement.

The relationships between plants and environment are not only important to the individual land owner or user, but must be considered carefully in formulating state and national policies in regard to agriculture, forestry, irrigation, regional and district development plans such as the Tennessee Valley Authority and the Ohio Conservancy [flood control] Districts, soil conservation districts, range management, drainage, and wildlife management.

The acceptance of laissez-faire, hit or miss policies of land use is on its way out. **The increasingly complex social order of the United States today cannot permit guesswork in the management of such vital factors as food supply, organic industrial raw materials, and lumber.**

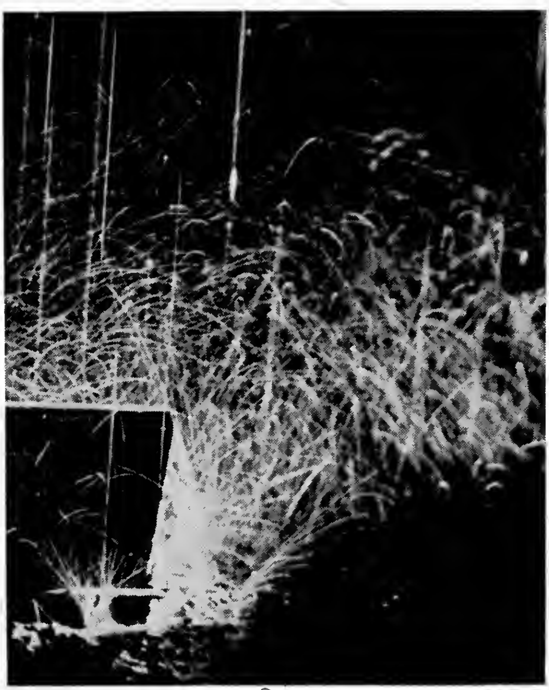

FIG. 38. Artificial raindrops striking bare soil. The greater part of the shattered drops splash within an 18 inch hemisphere, but some splash as far as three feet. The board at lower left guides water and soil into a sunken container for measurement.

Chapter VIII

LIFE AND THE NATURAL LAWS

Physical sciences are based on the discoveries of natural laws and on the interrelationships involved in their operation. In the proving of any new theory or hypothesis, all that is known or is subsequently learned must fit it without contradiction. Otherwise, the hypothesis must be overhauled. The physical and chemical laws have been of great aid in explaining the processes of individual plants and animals. The biologists have sought laws governing organic community behavior, but the intricacy of relationships has made the task difficult. It often happens that we discover a law by disobeying it and reaping the consequences. If a farmer discovers both his income and capital being destroyed by erosion, the experience may be painful enough to cause him to wonder what natural law is operating against him, and why. If the sportsman finds a lack of fish or game where it was formerly plentiful, he may be tempted to support the scientists who can discover the natural laws governing these populations.

The Ruthless Justice of Nature. An outstanding quality of a natural law is its impartiality. Unlike the administration of any man-stated social law, nature provides for no mercy. Nor is there any anger involved, nor revenge. As far as Nature is concerned, neither is there reward or punishment—only cause and effect. It is a well known physical principle that for every action there is an equal reaction. Less well known is the fact that the principle applies to biological forces.

It is fortunate that reactions potentially injurious in both the physical and biological world can often be managed so as to channel them into harmless or even constructive roles. The autoloading shotgun, for example, is constructed in such a fashion that most of the recoil or reaction from the powder explosion is diffused through the shooter's shoulder and body (and partly into the earth); but, in addition, a fraction of the reaction serves to operate a mechanism which ejects the used shell and reloads the gun.

When a draindrop strikes the earth its kinetic energy is released. This energy came from the sun and was acquired when heat evaporated the water, when heat expanded the air and permitted it to absorb water vapor, when heat energy caused a rising air current to carry the vapor aloft. The reaction of the raindrop at the moment of impact may be expended in one sharp, destructive blow if it strikes solidly on bare soil, (Fig. 38) much as the shot or bullet leaving the gun barrel strikes a target. This is the point where most people fail utterly to comprehend the natural force involved in rainfall. In a climate of 40 inches of rain per year, something like 4500 tons of water fall on each acre (an area not much over 200 feet square) each year. Except in the case of drizzles or snow, this enormous weight drops from the skies with a velocity which gives it tremendous striking power. Knowing these facts it is perfectly clear that rain of even average intensity cannot fall without marked effect. An intense rainstorm may in one day skin off a half inch of soil from bare land—soil which was from 100 to 500 years in the making. The reaction may take at least two forms:

(1) Loam soil is granular in structure. This permits the circulation of air, the infiltration of water, and promotes moisture adsorption as a thin film on the soil particle surfaces. These three factors are highly beneficial to plants. The impact of a raindrop breaks up the soil crumbs or aggregates on the surface. The finer materials then clog the soil pores, reducing aeration and infiltration. The total reaction is significant injury to the productive capacity of the land. (Figs. 39, 40, 41.)

(2) The second direct result of drop impact on bare soil occurs on sloping land only. (There is very little land which does not slope.) The raindrop fragments the granules and also dislodges already existing fine particles. These particles adhere to the water of the shattered raindrop, or go into solution with it, and are carried by its splash in all directions. Gravity operates, causing more of the materials (water and soil) to fall downhill than uphill. Thus, without even taking into account the erosion due to running surface water, it is obvious that the soil will be gradually knocked downhill by billions of drop impacts. (Fig. 42.) The farmer eventually will be knocked off the land, economically speaking, and much life directly useful to man on such areas will be diminished toward zero.

Is this unexpected? Is not the raindrop chained to its reaction? Is the soil not obedient to natural law in reacting as it does?

Is there an alternative which corresponds to the shooter's end of the autoloading gun, where natural reactions can be turned to man's benefit? There is. Furthermore, natural processes provide it. Vegetation diffuses the raindrop reaction and prevents destructive effects. It does this most efficiently when the climax vegetation is reached. The raindrop never or seldom strikes bare soil; the resilient canopy and the ground litter prevent it. (Fig. 43.)

When man disrupts natural organization he must be prepared to take the consequences. Or, he must, through intellect and science, provide cushions against the impacts of natural forces.

The Tensions of Unbalance. Life succession on its way toward a climax formation might be compared with a flexible, internally active sphere powered by the sun, rolling uphill. As it rolls, the sphere bulges, now here, now there, but always recovers its internal equilibrium. Let us imagine that as it rolls, it becomes more highly organized internally. Finally it comes to rest at the top of the hill, but still it teeters occasionally, and bulges with an internal disturbance at times; but, in the main it is relatively secure in its high position, and its internal troubles are not serious.

FIG. 39. Three soil samples with coins placed on surface. The setup is similar to a well prepared seedbed.

FIG. 40. After 75 minutes of artificial rain, the splash erosion is clearly evident. The white board behind the pots is six inches away. On sloping land, the splashed soil would fall into the surface flow of water and be carried downhill. The coins illustrate the protective nature of mulch.

FIG. 41. Soil samples covered by a field mulch and subjected to rainfall show very little soil movement from drop impact. Applied or not applied on a nationwide scale, this simple fact may determine whether or not a country can retain a satisfactory standard of living.

FIG. 42. The result of raindrop splash erosion. (The rod is painted in one inch sections.) Where the soil is protected by stone or root or vegetation, erosion is foiled. Here, surface flow had little effect on the soil in place; it did not wash away the pedestals. The churning and digging by the raindrops impact did the damage. Surface flow merely carried away what the drops loosened.

If some abrupt force is directed against the sphere (the natural community organization), it may be ruptured, or thrown back down the hill, or both. These dire effects are the result of destroying the state of balance, external, internal, or both.

It is not easy to draw up an analogy illustrating balance and unbalance in nature. Let us try again. Nature is not balanced like a scale sitting undisturbed in a bankrupt store. It is more like a double platform balance scale which has been turned over to a dozen five year old children for their amusement. The scale will do its best to stay balanced, but what chance will it have, with someone forever stepping up and with a finger tapping one side or the other? At the same time this is going on, a master mechanic is at work on the scale, trying to improve it, making it more complex, more useful to man. When and if he succeeds, the disturbers are still at play. (To complete the picture let us introduce an adult human lunatic who comes in the midst of the procedure and starts kicking the scale around.)

The old truth that "nature abhors a vacuum" can be altered to "nature abhors unbalance," and while the total landscape is hardly ever in exact balance, it is usually somewhere near it, and always subject to forces operating toward balance. There are tensions set up by the ever recurring unbalances. From the viewpoint of power, energy is expended by the community of plants and animals in regaining lost balance. This energy of repair cannot be converted by man to his service without prolonging the unbalance. If nature covers a poor field with weeds, the result is to reduce erosion and replace humus. If man burns these weeds he delays the restorative process.

From a practical angle, man will gain in the long run by putting additional energy into the unbalanced condition, with the purpose of improving it. He can, if science is able to guide him in the procedure, accomplish two ends: the unbalance may be brought nearer to equilibrium, and the climax conditions may be approached. This additional energy might, for instance, consist of laying out a system of strip cropping, or planting trees, or fertilizing, or growing and plowing down a green manure crop, or constructing a compost heap and later applying it to the land.

Propagation of Damage. Physicists perform a demonstration in which several solid balls are hung, by threads, in contact in a straight line. An end ball is swung against one end of the line and the ball on the other end hops out into space. Only the end balls move. The force is transmitted through the intervening balls with little loss of effect.

When damage is done to a climax of life and environment much the same thing happens.

FIG. 43. An epic of survival. This oak, pulsing with life, stands on its island of normality in a sea of California abnormality. Its roots and its self-created protective mulch have held the soil which supports it. The surrounding wasteland was once pasture. Overgrazed, the protective canopy of stems, leaves, and mulch was destroyed by bad management. The weakened fingers of life let go their hold. The hills poured a terrible flood of water and earth onto the farms and towns below.

A severe forest fire creates an unbalance, to put it mildly. One distant result may be that ten years later a truck falls through a bridge 30 miles away—because the tax income for proper maintenance of the bridge went with the forest land value.

Let us follow the trail of the unbalance more closely. After the fire, the soil is exposed because the leaf litter and a large part of the topsoil humus have been burned and nitrogen returned to the air. When rain comes the ashes on the land become a paste which seals the surface. This results in a high per cent of runoff, which, here and there in depressions, concentrates large quantities of flowing surface water. This inevitably starts gully cutting, and is the forerunner of floods. As the ashes are gradually dissolved and washed off by subsequent rains, both sheet and gully erosion proceed more rapidly. In the meantime the strongly alkaline ashes render small streams unfit for aquatic plant and animal life; fish are either killed outright or driven out of the area. (During intense forest fire, fish have actually been boiled alive.)

Fish may not return for several years, because silt will continue to pollute and cloud the water, interfering seriously with aquatic plant growth by reducing photosynthesis. The destruction of vegetation along the stream eliminates shade and the water temperature may rise. (It may, for example, pass that critical 72 degrees which trout cannot endure.) Gone too are the insects, both adult and larval, which once dropped from the shore vegetation to help feed the fish below.

The destruction of organic matter by heat oxidation on and in the soil, and erosion and compaction by rain of the soil itself, mean that its fertility and its ability to absorb water have been markedly decreased. The soil's ability to sustain life has been diminished in proportion to the amount of damage done before the complex process of destruction is stopped. In relation to time, this destruction is very significant to humans, since it is estimated by soil scientists that from 200 to 1,000 years is required by nature to produce an inch of topsoil.

With the soil go the organisms, the small and microscopic plants and animals which are essential to maintaining a fertile topsoil. The reduced shade increases soil temperature and speeds up oxidation of any remaining humus. The larger forms of animal life are driven out of the burned area; some of them doubtless were killed by the fire. They cannot come back immediately because their food and shelter are gone.

By such a fire *and its erosional aftermath* the entire climax community has been destroyed (See Fig. 21.) The area has been rendered bare and succession will set in with the invasion of such pioneer plants and animals as can exist in the denuded area. For a considerable period, the amount of photosynthesis will be small. When enough herbaceous material is present, animals such as rabbits and field mice will come into the territory. They will eat many of the seedling trees and shrubs, and seeds which are blown in. Hawks, foxes, and owls will come to feed on the rodents. The long and arduous trail back to climax begins.

Man suffers—directly in the vicinity, indirectly in all the country. Jobs have vanished, recreational opportunities are gone, ugliness has replaced beauty. The nation is deprived of the raw materials and the finished goods which might have been. Timber is scarcer and prices go higher. The nation's standard of living has been set down a notch.

Surface Symptoms of Unbalance. A forest fire announces its presence at once. Its activity is rapid and the result visible in hours, days, or weeks. There are other forces which bring about unbalance in a slow and subtle manner. The climax environment may be undermined and eased out so slowly that the resident people do not realize what is taking place. Science, and even unlearned close observers, have cataloged many symptoms of such community disease.

Muddy water means erosion. Erosion means a deterioration of the landscape, if it was ever well developed vegetatively. Deterioration of the landscape means loss of fertility and inveitable deterioration of the social order, with accompanying ills in economics, public services, health, living standards.

Broomsedge means lack of essential minerals, particularly phosphorus, which means lower yields, poorer stock, less income, and all the endless chain of causes and effects which follow.

Drying up of formerly copious springs might possibly mean a drier climate; the rainfall record will check this. Nearly always it indicates that the climax conditions are gone. The soil and vegetation are no longer holding the rainfall long enough for adequate infiltration to take place.

Complaints of hunters about lack of game may well mean in some cases that fertility is going, that food and shelter have fallen off.

Gradual increase in the area of pasture or range necessary to support a grazing animal is a reliable sign of landscape regression.

The increasing frequency and height of floods indicates that climax conditions are being lost over large watershed areas.

Decreasing catches of freshwater and marine fish and shellfish may mean overfishing, or more reasonably may mean that the productivity of the environment is being injured. It may mean both.

The recurring need for dredging of harbors means that soil is coming off the farms to fill such harbors with silt. Climax conditions do not provide for any such loss. Apparently the climax has vanished on the harbor's watershed.

These and other symptoms reveal inner disorders which need immediate diagnosis and treatment, or else—

Adjustment Inadequate. Slow as the deterioration of the landscape may be from a human viewpoint, it is a screaming dive to the plants involved. Even man, the most adjustable of all life forms, cannot continue to live and support himself on many areas where

FIG. 44. This is the end result of breaking natural laws on the landscape. The gully will soon claim the house, then the road beyond. But, what good is a house or a road when the people have been exiled from the farm—sentenced by the court of natural justice. And, for how many generations will the children suffer for the incompetence of the father?

once he was prosperous and well fed. Organisms are flexible only in a relative sense and within the critical limits of the fluctuating ecological factors, of sunlight, temperature, moisture, etc.

The tedious and unnoticed decline of a community, whether we think of a plant, a lower animal, a human, or a total community involving the complexity of an entire earth segment — such a decline is an ecological disaster of the first order. (Fig. 44.)

The encouraging fact is that, while Nature is relentless in her justice for those who break the law, for those who unleash destructive forces, Nature is also invariably just to those who have the wit to operate within the law.

It is not always easy for the uninformed to tell whether he is working with Nature or against her. It is a common practice in various parts of this country and others to burn over annually either open field or woodland pastures. The general opinion among herdsmen is that the young, green vegetation which springs up after the burn is much better than the tough, unappetizing plants which were burned. At least it offers improved grazing for a few weeks. The question is whether this is good or bad. What will the verdict of nature be?

From what we know of the slow development of environment (particularly soil fertility which represents energy stored from the expenditures of many generations of plants and animals and from the long weathering effects of climatic forces) we should suspect that the rapid release of the environment's energy by combustion would represent a loss to the landowner out of proportion to the gain.

There are perhaps cases in which practical gain may exceed practical loss, as when the burning of western scrub (shrubs or stunted trees which are of little value for grazing, or anything else) will permit grasses to grow, and provide some return to the human race. Even this is a highly questionable procedure unless carefully controlled, and usually succeeds only if the area is seeded to grass by man.

Careful studies on plots in Kansas, over a six year period, show unburned pasture producing 45 per cent greater yield than from autumn-burned dry plots.[1] The same scientists mention studies showing that burning of bluegrass pasture is harmful, and that burning of chaparral, mesquite, and in some cases sagebrush, soon resulted in increasing the scrub at the expense of the grasses. There are cases in which dominance is shared by scrub and grasses; there, one may be eliminated, leaving the field to the other—for a time at least.

The burning of woodland pasture each year usually dooms the trees. Reproduction is prevented by killing or injuring the seedlings so that they fall prey to insects or fungus attack. Injury to the mature trees shortens their life and reduces their value.

Where the cultural pattern of man touches the basic requirements of life, that pattern must constantly be re-evaluated in the light of new knowledge. Time and again man's culture has threatened and destroyed its own foundation. The great demands which the present huge world population makes on the environment permits of no further errors if civilization is to continue its progress. **The rise and fall of past cultures offers fair warning that Nature reacts with certainty to errors in landscape management.**

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[1]Weaver and Clements, *Plant Ecology*, McGraw-Hill, New York, 1938, p. 29.

FIG. 45. "The grandeur that was Rome." Here a portion of Timgad, Roman city in North Africa (Algeria), has been cleaned up by the French. Observe the perfect harmony between city and landscape—both wrecked.

Chapter IX

THE PROBLEM OF MAINTAINING THE CLIMAX

In previous chapters we have seen how maladjustments arise in *natural* communities due to the fluctuations of climate, the behavior of lower animal populations, or the occasional violence of internal earth forces. We have seen how these unbalances immediately set in motion the natural reactions which, in leisurely but sure fashion, restore the balance and usually the climax. Such maladjustments are not in themselves problems.

A problem can exist only in the consciousness of an intellect capable of perceiving abstract relationships—which is an obstuse way of saying that if we don't know there is a problem, there isn't one.

Is There a Problem? To make certain that there is a point to this discussion, and to supplement casual observation, let us list on a national scale some of the ecological disasters which have befallen us. These disasters, be it noted, are man-induced and man-aggravated. They first should be man-repaired; and in the future, man-prevented. This requires research into, and understanding of, natural law on the landscape, followed as quickly as possible by application of such knowledge. Already, we know much more than we apply. Securing such application is a problem in education and statesmanship.

FIG. 46. Water hauling is a symptom of a diseased landscape. The drying up of springs, and wells, and streams rarely occurs where adequate vegetation covers the land. Such water-lack usually indicates too much runoff, not enough soak-in.

Erosion: There are roughly 2,000,000,000 acres in the United States. Of these, 282,000,000 have been ruined or severely damaged by erosion. Moderately damaged are 775,000,000 acres. Neither of these figures includes mountains, mesas, or badlands. Of our most valuable acres, the croplands, nearly one-half (200,000,000) have lost at least half their topsoil by erosion.[1] For comparison, erosion has cut the living skin off lands which total more than 10 times the size of Ohio.

Floods: We have always had floods, but records show increasing frequency and height. The river gage at Memphis over a 47 year period (1890-1937) has shown a gradual rise of 15 feet in flood crests.[2] The hundreds of millions of dollars these 15 feet have cost is less important than the human suffering. The causes of flood increase are losses of sod, forest, and topsoil with their water holding capacity.[3] Floods and erosion are intimately related. Our annual flood bill averages around $250,000,000.

Water Table: The underground water table of Ohio has been falling an average of one foot per year for some 25 years or more, according to the Ohio Geological Survey. Many industries depending on well water are alarmed. New factories of many types requiring abundant water cannot come into some areas because of the water table situation. Farm springs and wells fail in every dry period in many parts of the country. Many streams and farm ponds dry up periodically, forcing water hauling, (Fig. 46) adding to the cost of livestock production and reducing its quality. The same thing is happening in most eastern states, in the plains region, in California's Central Valley. In the west, artesian wells have rather generally ceased to flow and, motor driven pumps have been installed by the thousands; they draw down and are exhausting some of the great artesian basins fed by mountain waters.[4] The supply is fed in by climate and is limited, but man tends to recognize no limit until forced to do so by threatened bankruptcy. Denuding the watershed by forest destruction and overgrazing encourages surface runoff and floods, and reduces even the natural recharging rate of underground water.

Drainage: Extensive swamp and marsh drainage has destroyed biologic values such as aquatic and terrestrial wildlife, stopped ground water recharging in some cases and stream flow in others. The purpose of such drainage usually has been to provide farm land, but in a large per cent of cases only alkali or acid deserts have resulted. Two-thirds of the 80,000 drained acres of Wisconsin's Great Swamp turned out to be unprofitable for farming. Similar results have

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[1]U. S. Department of Agriculture, *Soils and Men,* Yearbook, 1938, p. 593.

[2]Renner, G. T., *Conservation of National Resources,* John Wiley and Sons, Inc., New York, 1942, p. 91.

[3]Wales and Lathrop, *Conservation of Natural Resources,* Laurel Book Co., Chicago, 1944, p. 226.

[4]Chase, Stuart, *Rich Land, Poor Land,* McGraw-Hill, New York, 1936, pp. 140-142.

FIG. 47. The problem facing Modesto, California, is one which hundreds of other communities must also solve. The home of our civilization, western Europe, long ago cleaned up its streams. America is less civilized in this respect.

occurred in Minnesota and Florida,[5] and on a smaller scale in hundreds of minor areas. The damage is difficult to assess in dollars.

[5]*Ibid.*, p. 144.

FIG. 48. This sign, along the Des Plaines river northwest of Chicago, has an air of permanence which reflects the entrenched position of pollution on the American landscape.

The speculators grow rich; the buyers pay and lose. The public must foot the bill of restoring such areas to their natural state because we need them badly for water control and wildlife.

Pollution: The pollution of inland and coastal waters by commercial and industrial wastes, sewage, and silt has destroyed aquatic life of commercial, recreational, and sanitary value to the amount of about $250,000,000 per year.[6] This loss, if applied to purifying our

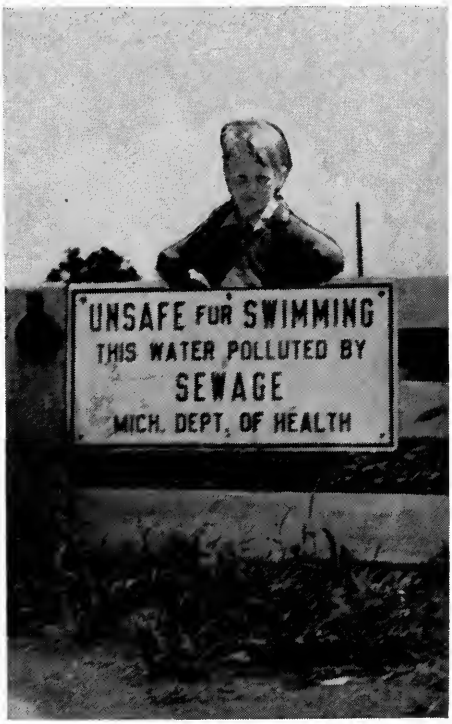

FIG. 49. Michigan, and every other state, has its pollution problems. Sewage is strongly suspected in the spread of "polio," though positive proof is yet lacking.

waters, would accomplish the task in some 15 years. The danger to health is no small one. Thousands of eye, ear, nose and throat cases every year are traced to swimming in polluted water. (Figs. 47, 48, 49.) Physicians uniformly note an increase of such cases with the first warm days of spring, when the magnetism of the ''ole swimmin' hole'' is strong. Coshocton, Ohio, a small city, in the spring of 1936 suffered 2,000 cases of gastro-enteritis because the Tuscarawas river overflowed and its pollution entered the city water supply. Typhoid is an everpresent danger in populated areas of flood. Twenty million city people in this country drink untreated water,[7] and endure periodic epidemics of amoebic dysentery and other diseases.

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[6] Renner, G. T., *op. cit.*, p. 91.
[7] Chase, Stuart, *op. cit.*, p. 140.

FIG. 50. Pollution of the most vicious variety. In this collection of dead fish, many species are represented, carp being most common. When the durable carp dies, the pollution is indeed severe. Most pollution has no such obvious result as this. Usually the better fish move out if they can, or die young, or are unable to reproduce. The water quietly, slowly becomes barren of valuable species.

Toxic chemicals introduced into streams or bodies of water kill or discourage aquatic plant life, which is the basis of aquatic animal life, which is of great value to man. (Fig. 50.)

Siltation: Many water power reservoirs, stock ponds, water conservation pools, navigation pools, and natural or artificial lakes of recreational value have been and are being rapidly filled with silt. This is caused primarily by denudation and erosion of the watersheds, which in turn is caused by ignorance or *carelessness* in the biologic management of the land. The U. S. Department of Agriculture has made a study of 20 power reserviors along the south Appalachian fall line which have filled completely with silt in an average of 30 years each, some in as little as 20 years. (Fig. 51.) The cause was determined to be erroneous land use with its resulting erosion. O'Shaugnessy reservior on the Scioto River above Columbus, Ohio, was reported in the same study to have a use expectancy of 145 years, due to its less hilly and less eroding watershed.[8] Even this situation is far from satisfactory to Columbus since the capacity of this water supply reservior *is* shrinking while the city is growing. This situation

[8]U. S. Department of Agriculture, *Siltation of Reservoirs*, 1940, pp. 139-140.

has forced the planning of an additional reservior, recently completed at a cost of millions.

Forest Destruction: One-third of U. S. forest land has been converted to farms. Not more than half the original forests now carry any commercial timber, even of low quality. Not more than one-third are producing trees large enough to be called saw-logs.[9] The 1944 report of the Chief of the U. S. Forest Service estimated that cutting, forest fires, and disease were, in that year, destroying trees twice as fast as they were growing, and that saw timber was going out five times as fast. (Fig. 52)

Overgrazing: Of our 728,000,000 acres of rangeland, 37 percent is severely depleted; 16 percent is nearly devastated by overgrazing.[10]

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[9]Based on U. S. Forest Services figures, which themselves are approximations.
[10]Renner, G. T., *op. cit.*, p. 124.

FIG. 51. In less than 20 years the Mayfair Mills power reservoir at Spartansburg, S. C., was filled with mud. This is not particularly hilly country, yet the farms in the watershed have contributed a lakeful of soil. The soil was lost; the investment in dam, reservoir, and powerhouse was lost; jobs were lost; recreational values were lost. What was gained? One mudhole.

FIG. 52. Clear cutting is often followed by erosion. There is no natural reseeding here, because no seed trees were left for that purpose. Hundreds of thousands of such non-reproducing forest land acres are added to the National debit each year.

It is highly probable that well over 50 percent of the possible photosynthesis has ceased on such lands, and is greatly reduced on three-fourths of the range. Even where photosynthesis approaches that of the virgin climax, it is, on many ranges, today being channeled through species inferior for livestock feeding. The same statements generally hold true for the nation's farm pastures and meadows, considered as a whole. (Fig. 53)

Wildlife Decline: The wildlife of this country has been subject to increasing pressure ever since the first settlement was founded. Considering the figures and statements given above, there can be no question that *on such injured lands and in such polluted waters* the wild animal population cannot approach what it once was. Commercial hunters in the past have made phenomenal kills of game. It would be very rare for a hunter today to encounter a situation where such kills would be possible, even if the law allowed it. The hauls of commercial fishermen have been fairly well tabulated for many decades. Many preferred fish such as the Atlantic salmon, the shad, the lake herring, have almost disappeared from the nets. There are several reasons, the most basic being the destruction of plant food and shelter.

Some Principles of Conservation. Maintaining the conditions of climax on damaged areas must, of course, await restoration of climax conditions. Assuming that we can restore them in time, and even surpass Nature in some instances, by the application of money, effort, and scientific knowledge, how can these desirable conditions then be maintained? There are five principles which must be applied.

(1) Whenever possible, the loosing of violent natural forces must be prevented.

(2) Reserves of nutrients, moisture and shelter must be maintained. Reserves of breeding stock are essential.

(3) If individual quality is desired, population must be adjusted to resources.

(4) Living standard must be adjusted to resource income.

(5) In altering land use from its natural state, a substitute climax must be used.

Let us consider these five principles:

Avoid Violent Reactions. If the total energy of a reaction can be diffused through a greater mass of matter or over a longer period of time, its violence is reduced; if the cause of the reaction is eliminated, there will, of course, be no reaction.

The violence of a reaction is relative. From the viewpoint of human culture, even the span of a man's life is questionable as the unit of time to be used as a category. Any destructive reaction on the land-

FIG. 53. Insult added to Iowa injury. Among civilized people it is considered poor form to stomp on an opponent when he is down. This field is getting no mercy. The original prairie grasses here were several feet tall, making erosion impossible. The virgin, black soil was among the world's best. Wildlife was plentiful. Today . . . .

scape which is swift enough to be noticeable in a human generation must be classed as very violent.

Violent reactions have been and are even now being brought about by:

(1) Burning of forests, savannahs, grasslands and scrub

(2) Careless lumbering operations which destroy young growth and fail to provide for reseeding

(3) Over-grazing of rangelands and farm pastures

(4) Cultivating steep hillsides or long slopes

(5) Continuous planting of the same crop year after year

(6) Failure to return humus to the soil

(7) Over-hunting and over-fishing

(8) Unnecessary destruction of food and shelter for wildlife

(9) Planned and sustained attacks on certain predatory animals, such as hawks, owls, foxes, pumas.

(10) Concentrating toxins in air and water sufficient to reduce life processes

(11) Interposing light-reducing obstacles between the sun and chlorophyll

(12) Withdrawing ground water faster than it can be replaced

(13) Drainage of sub-marginal lands

(14) Strip-mining

(15) Destroying sod on dry and windy areas

(16) Drawing on fertility faster than it is restored .

The reaction of one or more of the above activities on the landscape is in reality a complex of reactions. The complex involves two or more reactions: on soil, water, light, temperature, air. The reactions on soil, for example, may be classified as they relate to, or alter: (a) the soil formation process, (b) soil structure, (c) soil texture, (d) soil water, (e) soil solutions, (f) soil gases. There are physical, chemical and biologic reactions involved (one or more) in all the changes mentioned. **This highly intricate web of relationships has its weak spots, and these offer opportunity for setting off a chain of reactions, each of which may be minor, but which pile up a cumulative power and violence sufficient to boot man off the landscape.**

Reserves Must Be Maintained. Climate is the long term characteristics of weather. The weather averages commonly quoted are useless in providing a true picture of climate. We must know the daily, monthly, annual and cyclical (if any) ranges of climatic factors in order to understand the nature of such forces as they react on the environment. (We will pass over the grand scale climatic shifts which must be spoken of in terms of geologic time, such as those accompanying continental ice sheets.) Much study has been given to finding some basis for forecasting climatic variations over a period of years. The sunspot theory is current, and seems to offer some correlation. Eleven years appears to be the time unit of cycles in both climatic and sunspot activity. There also seem to be super-cycles, which are poorly understood and which render short cycle forecasting unreliable. One thing we are sure of; the available records and human memory confirm it: notable fluctuations do occur.

A case in point is the Great Plains. The drought of the 1930's drove over 160,000 suffering, bankrupt people out of the dustbowls. In the 1940's many farmers in these same areas harvested bumper crops. The rains came again. The question is: are the short-term benefits an equitable payment for the human misery, the economic distress, and the land damage of the dustbowls?

Under the natural climax vegetation of the plains, blowing is effectively controlled in large degree (but not entirely on the western edge). Nature provides means of maintaining *reserves* of moisture-holding humus, soil-holding roots, wind-retarding stems and leaves. These reserves enable the natural vegetation of the plains to survive the inevitable and recurring droughts.

In nature, fertility loss has never been a problem to a going community. Plants on the whole never exhaust their environment if spared the ministrations of man. They maintain reserves against all but cataclysmic changes. Even fire must be severe and probably wind driven to destroy completely a forest climax. Prairie fires seldom if ever wipe out the climax. Moisture reserves not only aid in protecting perennial roots, but some deep moisture may remain after the fire, to speed their recovery. These statements do not detract from the damage done by fire, especially from man's viewpoint, but do emphasize that destruction of a climax involves a very real violence. Seldom, under natural conditions, do floods or insect plagues succeed in doing more than minor damage as far as the climax is concerned.

Man, in his management of the land and its life must be conservative. **Reserves against the unfavorable extremes of climate are required for a relatively stable and secure existence.** Venture and chance-taking are not ruled out unless losing the gamble with nature will result in long term damage out of proportion to the possible winnings. The odds must be considered—and not from the individual's standpoint, but from that of society. The plains farmer who can salt away $50,000 in three or four favorable years can retire, but if before he quits, he ruins a thousand acres of land for decades to come he has committed a crime against nature and his fellowmen.

The principle of reserves applies to many facets of landscape management. It is a principle well known to businessmen, industrialists, and investors. Safety demands conservative use of funds, the maintenance of reserves for emergencies. The management of biologic investments requires equal conservatism. For instance, some animals must have reserves of number, as in the case of the bobwhite quail.

In areas where severe weather strikes for even a few days, quail may die off by whole coveys. The quail is a gregarious bird. Its life pattern includes the covey for a good reason. In severe weather the covey packs itself into a tight circle. The conservation of body heat by this tactic often means survival. If the group is too small, for any reason (including overshooting of a covey), the circle of mutual protection against cold is too loose to be effective. Thus, the hunter must govern his take from each covey, if he wishes to hunt another year. To reduce a covey below ten birds may wipe out the reserve social strength needed in emergencies.

The extinction of species such as the passenger pigeon, and the heath hen shows what can happen. Long before these birds disappeared from the earth, heroic efforts were made to save them. But, the damage had been done. Their biologic recuperative power fell too low. Their protective reserve included number, and the necessary number finally did not exist. At that point nothing could save the remainder. The trumpeter swan has been hanging on just above this point for several years.

Animals whose nature is non-gregarious do not depend as much upon reserves of number. Of course, they need reserves of food and shelter, as do all animals. In no case can a population, whether plant or animal, be maintained without a certain seed stock or breeding stock. The intelligent management of this factor is complicated by the cyclic rise and fall in population, particularly of wild animals. The muskrat cycle may find only one-tenth as many animals at the low point as at the high. Obviously, the exertion of additional pressures, from human sources, at the cyclic low is dangerous to the species. The regulation of duck hunting in recent years has been a matter of skating as near thin ice as possible. No one knows exactly where the danger point is. The only way of learning would result in extinction of a species, perhaps several species. We cannot afford to find out. To be safe, we must maintain ample reserves of every known factor related to survival.

Population and Resources. We cannot support ten cattle on an acre of meadow for more than a few weeks at most. Following the initial stage of plenty comes persistent hunger and the consumption of the less palatable and ordinarily untouched plants. Then malnourishment proceeds as the animal body consumes itself by utilizing the sugars stored as starch, in fat, and in protein. Starvation ends in death.

Note that overpopulation in the animal world leads to exhaustion of the plant world. When all or part of the animals have died, the plant population will return in proportion to the easement of pressure. Again food is available, and if there is any reproductive power left in the animals their population will also rise again.

Every breeder of animals, or plants, knows that if quality is to be maintained, food and water must be ample. To supply them, management is essential. Competition for them must be restricted.

In nature, competition generally favors the survival of the fittest, The factors which eliminate the less fortunate are disease, accident, starvation, sterility, combat.

In addition to these, man has available several voluntary controls, such as contraception, abortion, infanticide, execution, suicide, murder, sterilization, continence, and war.

War results, in many cases at least, from a failure to exercise the other controls effectively. This mass combat reduces the population to the point where competition is eased for a time. It must be recognized that food is not the only resource for which man will fight, but a good case can be made for the statement that overpopulation is the primary cause of war. We find ourselves constantly dealing with relativities. What is overpopulation in Germany is not necessarily overpopulation in an equal area of India. It is the *unsatisfied demand* for resources which determines the point where overpopulation occurs.

The point at which the available resources cease fully to satisfy the biologic and cultural demands of the population is the point at which population should be stabilized—if destructive competition is to be avoided, and if the accepted quality of the individual is to be maintained.

The plant world sets an absolute ceiling on animal population at any given time. Under a condition in which modern man, with his technical means for altering the landscape, keeps pushing against the food ceiling, the conditions of climax cannot be maintained. India is a good example. The mechanization of agriculture and improved transportation, introduced by the British, increased food production and distribution; and, in an automatic population response, millions of additional Indian mouths appeared. They lived long enough to eat up the increase. The average individual is little or no better fed than before the British came, but the land is being destroyed by erosion and over-grazing faster than ever, due to the greater drain on fertility to feed the additional millions.

Living Standard and Resources. The living standard may be defined as the amount of goods and services which the individual can secure from his environment. The average for a country may be found by dividing the total goods and services available by the population. There are only two ways of raising the average. Produce more per person, or reduce the population without reducing production. We cannot avoid the word "produces," because the supply must be kept coming.

Primitive man existed on a low standard of living because his technology was primitive. He could take from the environment only that which his hands and simple tools could adapt to his use. Iceland today is a democracy in a poorhouse. The people are intelligent; technology is available to them; but the environment offers little to which technology can be applied.

Here are the two ceilings to standard of living: (1) the level of applied science, (2) the supply of resources. In the United States we have a high level of both. Furthermore we have a people who want an ever increasing standard. We have an extraordinary desire for it, nurtured by past experience, advertising, education, and many forms of publicity which keeps constantly before us the alluring possibilities of research and invention. Commerce and industry do their best not to disappoint.

There is a serious question, however. How long can this high level be sustained?

In the case of vegetation there appears to be a definite ceiling on the per acre yield which land can sustain over a long period of time. It is set by the nature of plants and by the practical difficulties of returning fertility to the soil. Periodically, science gives agriculture, forestry, etc., a shot in the arm which should raise the ceiling. But, in practice, these advances usually serve only to offset previous declines.

The history of past cultures has in many cases been this: There was a rise in living standard, which was sustained for a time, even a few centuries perhaps, followed by a disastrous fall. This is the *exploitative cycle.* It has been reproduced on a small time scale in hundreds of American communities. Ghost towns are its evidence, and abandoned logging camps, abandoned farms, abandoned factories.

Sustained yield is the only principle on which a permanent social order can be built. The level of organic consumption may be revised slightly up or down from time to time, up if scientific advances permit, down if deterioration of climax conditions appears.

Altering the Landscape. Man is the dominant life form of the earth; no other can compete with him in a short-term pitched battle. His tools, chemicals, weapons, and intellect make him supreme. Yet, the total environment can out-endure him, out-survive him in a contest. At the end of such a contest man will be gone; but, environment, scarred and wrecked, will remain to lick its wounds and recover. When and if man returns he should be wiser, more friendly, more cooperative. **Environment is man's master, but can be made his partner.**

When man approaches the landscape with the intent of altering it, he should keep a principle in mind:

The maintenance of maximum plant productivity requires that changing the climax vegetation must not debase the fundamental reactions of the environment.

To ignore this dry statement is to deny the cumulative evolutionary progress of millions of years. To ignore it is to assume that Nature, or God, as you please, has been wasting time since the earth's beginning. To ignore it is to say that there is no relationship between the earth and life.

How can such reactions as soil formation, maintenance of fertility, prevention of erosion, and good soil structure be retained? Let us state a few principles.

1—If the climax preserved a year round vegetative or humus cover *on* the soil, man's cropping system must do likewise.

2—If nature returns humus into the soil, man must return humus.

3—If the climax vegetation holds rain where it falls, man's land use system should hold it in like degree.

4—If nature provides sub-surface and surface tillage by animals (such as earthworms) man should employ similar methods.

5—If, by adding certain minerals to the soil, desirable reactions are secured, they should be added.

6—If certain plants bring the desired reactions more efficiently than others, they should be chosen.

One critic, reading the above statements carelessly but with a belligerent eye remarked: "As a corollary, you should also say that if nature causes floods, man should make floods; and if nature kills plants by early frost, man should grow plants killed by early frost." To which we reply that in nature floods have created level and fertile plains, which from time immemorial have best fed the human race. Therefore man might well handle all cultivated land in a way to gain the benefits of levelness and recurrent mineral and human additions. This he can do by such artifices as contour cultivation of sloping lands and by the periodic application of fertility agents. As for growing frost susceptible plants, nature also grows frost resistant plants and if some of these serve man better, then they are the ones to use. If mutations or hybrids can be found or produced which offer man any advantages then the search should go on in laboratory and field and experimental plot.

One point of our argument is that man need not burn the forest to get roast 'possum just because nature does it that way. Because he has some sense, man has found the principles involved in applying heat to flesh for the purpose of achieving a tasty dish. There is no question but that in this instance he has improved on nature; yet has he done anything basically that nature did not do? He has simply controlled the situation for his benefit.

Nature (including man) does some things which by human standards of short term judgment would be called stupid—lightning-caused forest fires for instance. On the other hand, nature does more—*many more*—things which would be judged excellent, from streamlining a fish to mulching a forest or prairie floor. Man should apply his keenest and most cautious scientific judgment as to what should be copied, what should be altered, what should be avoided. In the main, when we consider the management of lands and waters, nature is the experienced teacher from whom we have much to learn.

There is a great variety in the landscape patterns of the world. Many of them are fine examples of what man does *not* want on his farmland—badlands and deserts, for example. And when we observe that man's activities are turning farmlands into badlands, we shudder. On the other hand, some landscapes are (or have been) superior as to their excellence in supporting humanity. They are examples which nature has set. Certainly we shall applaud the type of management which will sustain them forever as such. Moreover, science can study and analyze these superior lands, and how they got that way. Science can strive to understand the complex of their superiority. Then, in scientific triumph, may it not be possible in many areas to take naturally second rate land and manipulate it and augment it and change it into superior land. Much progress has been made in achieving this goal of a new and better climax complex. And when it has been reached beyond doubt, cheers will be in order.

What About Animals? The animal population of a region (from the microscopic to the mammouth) not only is interwoven into the life web, but is of great significance to man in ways economic, recreational, and aesthetic. The larger animal forms are the subject of much legal attention. If laws and regulations affecting wildlife are written with the scientist's counsel and approval they should become progressively more effective.

No law, however, can change the fact that as man alters the pattern of plant communities, by farming or lumbering for instance, the pattern of animal life must also change. Cattle have been substituted for deer in the woodlot and for bison on the plains. Where once the raccoon rambled through the woods, rabbits now run along the fence-rows. Where once the woodcock darted among the trees, the quail roars up from the meadow. Where once the prairie chicken or the now extinct heath hen nested, the imported pheasant has taken over. Man has killed off to a large degree the puma, wolf, coyote and lynx; and, as hunter, has taken over their predatory activities on wildlife. Such predation is in accord with the natural organization of the landscape.

The conclusion of wildlife researchers is that **the population of animals is directly proportionate to food, cover and water;** and that **the size and quality of the animals is directly related to soil fertility.** Climax conditions are necessary to the maximum of animal population and quality. An eroded field, infertile, unable to hold rainfall, populated with woody plants of little nutritional value, cannot possibly support an abundance of animal life, whether it be insects, birds, or man.

The Goal of Management. The maintenance or creation of the values and conditions associated with the richer climax formations —that is the goal of environmental engineering. Through it the maximum energy flow of life can be made available to man and his social order. Through such engineering is conserved the constant and adequate supplies of proteins, fats, minerals, and vitamins without which carbohydrate energy is worthless.

Environmental engineering can maintain that essential state of balance in which the demands of plants and animals seldom exceed and certainly never exhaust the supply of air, water, and soil fertility.

By such engineering the energy and substance of the environment can be made more effective and efficient in the service of man than the natural climax itself. This may be done by channeling the energy and substance through species selected by man as most useful to him. It is entirely possible to create today, on many areas, fertility surpassing that set up by nature.

But, What Has Happened? Environment engineering, or more simply, conservation, in the United States, has been recognized by thinking and social-minded people as a necessity ever since colonial days. No general attempt was made to apply it until recent years. The impression in the public mind that American resources were inexhaustible, coupled with "rugged individualism" and the "get rich quick" motive, led to ignoring conservative management of resources.

The climaxes of forest, prairie and plain were destroyed. The process is graphically and tersely described as "ax, plow, cow, desert." The twin processes of erosion and vegetative deterioration go hand in hand, each encouraging and stimulating the other. Unless man reverses the process, the destruction will, (and has) set the affected areas back decades, and in many cases hundreds of years.

Regardless of degree of damage, problems result. The task of restoring the vast total of injured areas to something near the virgin level of productivity, or above it, is a primary problem of the United States and many other countries. There are special problems related to the total problem, and how they may be solved is another field of study. Our attempt thus far has been to see the need for solving them, to state principles for sustaining the climax when it is restored or created, to suggest how at least further deterioration of the landscape may be prevented and how its restoration must be approached.

"When you hear words that are distasteful to your mind, you must inquire whether they are not right."
—Confucius

Appendix A

EDUCATIONAL IMPLICATIONS

The conclusions, established on a scientific basis, which have been presented in this study have a fundamental significance to the human race which cannot be ignored in any system of general education. We have not invited science to the discussion just for its curiosity value. Science taught as a conversation piece has little place in public education. Physical science taught merely to provide an understanding of the gadgets of civilization is superficial. Biologic science taught as a system of physiologic mechanics and classification is abortive—it falls into the same category as foreign language courses which ostensibly are taught to provide an understanding of the culture of a particular people, but which usually are concluded at about the point where understanding begins to be possible. Such blind alley tactics are rapidly being discredited by educational philosophers.

Science has come into this discussion because it provides facts upon which can be based a broad total view and understanding of man in his relationships to the universal environment. A complete individual knowledge of the many sciences we have invoked is neither possible nor necessary to our purpose. Furthermore, the same or equally significant conclusions will be reached regardless of which basic science serves as a door for entering the study of man and his environment. You say they are not reached. That is because the common approach to a particular science is to study that science for itself alone, not to use it as a highway to citizenship.

Why is public school science thus closed off from its great possibilities in general education? Why does it exhibit every symptom of the narrow, specialized view? Our search for the answer leads us by either of two roads, the teacher or the textbook, directly into the college. The teacher and the text are college products. If the colleges are not giving us the tools with which to construct an adequate general education in the public schools, why not?

Better Teacher Training? The average college of education shows teachers *how* to teach. It does not, in too many cases, tell them *what* to teach. The prospective teacher is sent over to a subject matter specialist in some other department, usually to the college of arts and sciences, to learn something to teach. There the student who aspires to teach a certain subject is shot full of it by an expert. What is the nature of this expert? He holds a doctor's degree or is doing his best to get one. He got *his* training from doctors, or instructors working to become doctors. This is the kernel of the situation. How do these professors get to be experts. They do research. They specialize

The specialist is dominated by his speciality. All his serious thinking is colored by it. His teaching is geared to it. It is only with Christian effort that he can bring himself to admit that other subject fields are important. He becomes suffused with innumerable details of knowledge, each of which is important to him. As he learns more and more about his subject, his students become relatively more ignorant, and he strives harder and harder to impart his vast store of knowledge to them. One of the greatest pleasures of his life is to find students who can lap up his subject matter and yell for more. These he takes to his bosom and proceeds to make research specialists of them.

Eventually, if the specialist, and perhaps his graduate assistants, are any good, they make a contribution to the world's knowledge. The professor writes a book and is acclaimed. His proteges follow in his footsteps. Thus is learning advanced.

As far as the subject department is concerned, the unwritten law is "sort 'em out." The search is for the potential researcher. Where does this leave our prospective public school teacher, the fellow who is there to distill the essence from the subject as it relates to general education, to modern human problems? The answer is that he seldom gets what he needs; and, if he sticks, he is inoculated with specialization; if he shows promise, he is urged to stay out of public school teaching and turn to reseach.

It is a simple statement of almost universal procedure, observable by anyone, and psychologically predictable, that teachers teach what they were taught, as they were taught it. It may be argued that methods courses modify this procedure. They do in detail. But the specialist in methods of teaching a certain subject is himself a product of the same system. Modification will apply to grade levels and content selection for them, but the specialist's approach to subject matter remains.

The textbooks used in public schools have, in the past, been produced by college specialists; and even if a public school teacher is the author, he is a specialist's product.

What is to be done? No one in his right mind would suggest that specialization should be discontinued in favor of general education only. Nor would anyone who knows the present situation in the public schools agree that *it* is good. The present liberal arts curriculum of the colleges is bad for prospective school teachers. When it is shifted down into the high schools it is bad for them, and its badness leaks into the junior high schools, and even into the intermediate grades.

It is the business of the mature democratic citizen (are there not such in the colleges themselves?) to cry out against a system which is not producing well-rounded young citizens who can see the world as an organic whole and have a fair conception of the principles by which its problems must be solved. He must protest an education which sends students running out this lane and then that lane in the forest of knowledge, coming back to start again on new side trips, never able to see very far in any direction, getting biased, restricted notions of the functions of the whole, finally, in a few cases, to settle on one trail with the purpose of exploring it a little further than anyone else ever has, and, not unlikely, to become lost to the world in the process. Why have these students not a map of the whole forest so that they can keep themselves oriented? Why have they not been given an airplane view of the whole before plunging into its mazes? Could they not follow the trails with greater assurance, and with understanding of what was then seen at close range and in detail?

The Genesis of a Trend. To whom shall the protest be directed? Naturally, to the source of the trouble, the institutions for teacher training. Must they farm out their embryonic teachers to another college, to be ruined for public school teaching—without even an apology? The question seems to be: Can a basic course in the liberal arts college serve both the potential researcher and the potential public school teacher? The answer *may* be yes. It may be possible that such a course, revamped for the teacher, would also be better for the budding specialist. It could give the latter one last look at the world before plunging into his lonesome trail. Whether such would be the result or not, it is time for the college of education to climb up out of the basement of the university and exercise more control over the training of its product, particularly over training for the secondary level.

The material here presented purports to be, in a condensed form, the *type* of course content which public school teachers need in the biological field. It is submitted also that, for a liberal arts student taking an elementary course in biological science to broaden his general learning, this type of information would serve the purpose better than a course designed strictly as a prerequisite to advanced work.

Such broad courses are coming into increasing demand, partly because of the conservation education movement, which is rapidly gaining momentum. Various attempts are being made to integrate basic sciences and social studies in order to provide teachers with a foundation for teaching conservation. The Ohio Conservation Laboratory is an outstanding example and prototype. There, the concept is to give in one course a basic survey of plant ecology, animal ecology, geology and soils, nature study, economics, and sociology, as they relate to conservation of natural and human resources. Obviously, this is a big order. Each field is represented by its specialist. Frequent staff meetings are held in an effort to integrate the subject fields. The spirit is willing, and a slow evolutionary progress is being made, but the compartmentalizing specter of specialization hangs over the effort, together with a mild confusion as to just how to relate the subjects to conservation, plus the irritating uncertainty as to what the teacher needs and how he is to use it. Add the time limit of six weeks, and even though all the teacher's time is available, it is little wonder that complete success is not easily achieved.

Additional research efforts are needed, and the type of course here presented, plus appropriate field work, is suggested as worthy of comparative study.

Inservice Training. Teachers now in the public schools are faced with the responsibility of giving adequate coverage to conservation. That they thereby become automatically capable of doing so is of course absurd. Before any intelligent effort can be made toward providing experiences and understandings useful to pupils, the teacher must acquire the basic information and understandings himself.

The Ohio Conservation Education Workshop, 1945, recommended that:

> "Administrators organize a series of faculty and committee meetings dealing with the problems of conservation education, that experts in the conservation of soil, water, forests, wildlife, and minerals be invited to speak, that members report on pertinent articles in periodicals and on investigations of local conservation needs, that field trips, films and recordings be used."[1]

Another recommendation was:

> "That school administrators provide leadership and facilities for gaining first hand experiences in and understandings of the interrelationships of natural resources, and their significance."[1]

The first recommendation, if adopted and put into action without the most careful planning by someone freely conversant with the conservation field, is a perfect opportunity to end up with a highly disorganized study of a highly organized environment. It would seem that study, by everyone concerned, of material such as that herein assembled would prevent much confusion in the teachers' mind. The second recommendation implies that administrators should have at least an elemental knowledge of the field into which they are to lead their staffs.

Mastery of the fundamentals of plant conservation must precede and is prerequisite to an understanding of the special problems, which the student and the public hear most about. These problems will require additional study, but what is read and heard about them will then be understandable and even subject to criticism. Judgment is out of the question without the fundamental knowledge. The teacher should not lay himself open to being used as an unwitting propagandist, as will surely happen on occasion if he is unprepared to recognize biased statements. Conservation of natural resources is a matter of great public concern. Private interests fight progress which affects them adversely, actually or supposedly, and they have the funds and organizations to propagandize their views.

For example: Sportsmen have for years and years demanded that states operate fish hatcheries and periodically place millions of young fish in the streams. The sportsmen's reasoning ran like this:

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[1]From the author's notes.

> "Here is a stream. There are some fish in it. Fish can live in it. There is plenty of water. I fish another stream of the same size. It has three times as many fish. This stream is fished out. The state ought to stock it every year."

He might be right, of course, but when stocking for a year or two brought no improvement, did he question his assumption? Usually not. Streams have been stocked for twenty years in a row, with no improvement. Why did they keep it up? Ignorance.

Any consideration of the environment of the fish, in the light of basic knowledge, would bring an immediate inquiry into food supply, oxygen and carbon dioxide supply, toxins and silt effects, etc. Even without such studies of the environment, we would suspect that the stream, if long established, had reached a state of equilibrium, was supporting all the life possible under present conditions, that the population could not be increased without improving the environment, that the reproductive capacity of fish would quickly restore any decrease due to fishing, that restocking was unnecessary and a waste of money.

In this special problem, all the new information the teacher needs is a few facts about the reproductive powers of fish. These he may have already.

The same pattern will be followed in understanding such problems as erosion control, reforestation, fertility restoration, flood control, drainage, reclamation, irrigation, water table and spring flow restoration, insect control, plant diseases, weed control, upland game management, pollution, stream bank improvement, spoil bank management, waterfowl resoration, songbird activities, etc., etc.

Finally, and most important, having this fundamental knowledge and understanding, the teacher will be better prepared to guide pupils through experiences which will result in better citizenship. This citizenship will arise from the realization that man has the responsibility of maintaining his total natural environment in a state of balance at its highest peak of development, that only then can man, as a species, hope to continue his cultural progress or even retain what he has.

Appendix B

CLASSROOM ACTIVITIES

Suggestions to Teachers. In thousands of classrooms throughout this country there are growing plants. It is a rare school building which is not surrounded by plants. How many pupils graduate from these buildings with any real knowledge of the part plants play in their lives? One of the fundamental aims of pedagogy is that young children must be taught their relationship to the immediate total environment. Nothing else sinks in. Nothing else concerns them intimately. Nothing else is effective in building desirable habits of thinking and acting. First hand experience is the watchword for the primary grades.

At higher levels the use of symbols and vicarious experience, audio and visual, allows the expansion of horizons. Yet, in the intermediate grades the study of geography is a very inefficient process, as any high school geography teacher can testify. The amount of retention is pitiful. In spite of well illustrated texts, the jump into the unknown is too sudden, too complete. Another principle of teaching is that the transition from the known to the unknown must be gradual and closely related. How can a pupil be expected to understand a distant culture when he is almost totally ignorant of his own environment?

Plants offer a simple and convenient entree into knowledge of the natural sciences and their relation to people. From this base of vegetation we can reach out or expand in a great many directions. It is with reluctance that we refrain from chopping into grade levels the suggestions to teachers and other leaders who may have contact with the younger generation. Instead we will, for the moment, leave it to the instructor to convey the information according to the level of his charges.

Nothing so vitalizes learning as direct observation of the real thing. Elementary and secondary education are often cursed by a preoccupation with symbols and abstractions. These intangible entities are for the well developed and experienced mind. Recall which subjects produce failures in wholesale lots when stuffed down the unready mental esophagi of the student body! Are they not the most abstract portions of the curriculum? The great virtue of elementary science is that it lends itself to direct observation. The great virtue of conservation as a vehicle for teaching such science is that the conservation viewpoint makes science significant, to the individual and the community. This significance arises from the fact that conservation deals with current problems which have social repercussions, and which will yield to scientific treatment.

The most direct application of the information and ideas here presented naturally falls on biology and botany classes. The materials may just as logically be placed in general science or science survey courses. They have a valid claim on geographic studies, and certainly on vocational agriculture. Portions, at least, deserve inclusion in health, hygiene, physiology, and nutrition classes. Chemistry teachers are invited to utilize the parts touching on photosynthesis and plant and soil reactions. Social science classes can draw on other excerpts for light on institutional and civic problems. In short, any dissertation on life and habitat must bear on a great variety of academic fields, and we think these fields are obligated to relate themselves intimately to life and habitat.

The suggestions which follow are subject to selection according to the needs of individual teachers and classes. If the entire book were incorporated into a course, then a majority of the activities might well be undertaken, subject to modification according to the local setting. In any event, the type of teacher who has taken the trouble to reach this point, will be the type whose initiative and judgment will assure a sensible and reasonable use of the classroom suggestions.

Chapter II

Pertinent Activities. We are open to the danger of considering demonstrations, experiments, construction activities and field trips as too time consuming. They interfere with the torrent of words. Let it be noted that the saying, "a picture is worth a thousand words," has ample scientific support, and real experiences are even better.

(1) The obvious demonstration of energy storage in plants is to burn some, and let students warm their hands by last summer's sunshine.

(2) Sprout two seeds. Grow one in the dark and the other in the sunlight. After a few weeks, dry and burn both. Which one stored sun energy? Which one would feed a rabbit, a man?

(3) Consider the ashes. Why did they not burn? Are they minerals? Could another plant use them?

(4) If you are a master teacher try this. Mix the ashes in a small bottle of water. Suspend another similar sprout with its roots in the solution. Suspend another like sprout in distilled water. Which grows best?

(5) This is recommended for the "teacher in a thousand." Get three same-sexed, same-weight, young white rats. Feed one on carbohydrate alone (corn syrup or sugar syrup) and water. The second gets carbohydrate (syrup), and protein (boiled egg white, or soybean meal) and water. Number three gets carbohydrate and protein, plus minerals and vitamins (milk and a variety of vegetables). Weigh the rats every week or two for six weeks. Take a good look at the graphs of these weights—and at the rats. The student will never forget the conclusions which will gouge tracks in his brain (as contrasted to the faint and erasible traces left by words alone).

(6) We do not expect anyone to do this. It is too much trouble. But, on the chance that there might be a teacher per state who will, it is included. Find the poorest land in the area, where the vegetation is

scanty and no account. Collect a variety of such green stuff as is there. Collect a similar amount from the most productive soil in the community. Feed these foods, in equal weights, fresh or quick dried, along with water, to a couple of rabbits or guinea pigs for six weeks. Does the quality of soil have anything to do with nutrition?

Very likely, the plant species from the two soils will be different. This, of course, introduces another variable factor into the experiment, so that the conclusion must consider the fact that some species may not be basically as nutritious as others, even on good soil. However, it is a general fact that poor soils cannot produce highly nutritious plants.

Chapter III

(1) Succulence may be demonstrated by comparing the chewing qualities of celery, which is fibrous but still succulent, with a tree twig, which, though also fibrous, is never succulent. Even the wilted or dried celery can be bitten through without difficulty. Try chewing good hay, and straw. The relative values as feed should be apparent. Microscopic examination of the two types of cells will reveal the great difference in cell wall thickness.

(2) Spread a bucketful of alfalfa hay and a similar amount of straw in a dry, warm place. After a few days, when thoroughly dry, weigh generous, *equal* amounts of each. Burn each separately and completely on a piece of sheet metal. The material itself may be ignited, but intense heat should also be applied beneath the metal. Scrape off and weigh the mineral ashes on a delicate laboratory scale (borrowed perhaps from the physics department.)

Try this with celery and wood, particularly wood grown on eroded land.

Which material had the greatest mineral content? What was the percent by weight of the soil's contribution as compared with the contribution of air and water?

(3) Take a field trip. Go to a wornout eroded field. Compare roughly the percentages of succulent and of woody plants. Observe cattle grazing in a pasture. What sort of plants do they ignore? Take a close look at a good hayfield. Ask the land-user what makes it good. What is the percent of woody plants there? Compare the animals on the good and poor land as to appearance and muscular development.

(4) In plants, reproduction requires that the seeds have a supply of starch, fat, proteins, vitamins and minerals to assure continuing life. If you had to live on woody plants, what parts would you eat? Do squirrels, deer, birds know that? Is this why we restrict our eating of corn, wheat, rye, rice, etc., to the seeds? Try burning equal dry weights of wheat grains and wheat straw. Where are the most minerals found? Try the chewing test also.

(5) Collect plant specimens which appear to suffer from mineral deficiencies. Borrow *Hunger Signs in Crops* from your local or state library. It has excellent color plates. Try your hand at diagnosis.

Chapter IV

(1) Why not assemble a history of the vegetative changes in your county? What has happened to the original native plants? How much of the virgin forest or grassland remains? When was the period of its greatest destruction or injury? What were the purposes of that destruction? Was it carried to a point which causes regret today? Why? (Get in touch with your county agricultural agent. He can help with these and following questions.)

(2) Why not make an inventory of the present vegetative resources of your county? How much of its area is covered by forest or native grasses. How much is covered the year round by introduced grasses and other plants? How much is covered only seasonally by cultivated or row crops? How much of your county is affected by erosion? How do the yields from eroded land compare with yields from non-eroded land?

(3) Does the land in your county have enough plants? On the best farms and on the poorest, how many acres are required to support a cow, sheep, or hog? Can you find bare areas, large or small, in fields where plants should be uniformly distributed? Is there any relation between lack of plants, erosion, and living standard of the land user? How much land in your county (or on a certain farm) should be planted to trees or otherwise reforested?

(4) An interesting display may be constructed by arranging specimens of the raw materials of chemurgy and their industrial products. A sheaf of soybeans may be mounted on a panel together with plastic knobs and other gadgets, small bottles of paint, glue, sizing and other soy products. Write to the National Farm Chemurgic Council, North High Street, Columbus, Ohio, for more information.

Chapter V

Educational Suggestions. Discussion without observation being largely sterile, what can be seen that will aid in understanding this material?

(1) An examination of fossil plants and animals is highly desirable, preferably but not necessarily in the field. These are common in limestone and may be found in coal and shale. A check should be made with someone familiar with the geology of the local region to determine the approximate age of the fossils. The implication for the pupil is that the earth has been a long time in developing an environment fit for man, and that he should be wary of destroying it.

(2) A body or stream of water should be examined carefully to observe the variety of life present. Plants will be found which grow

in all sorts of conditions, from cattails in quiet pools to algae on rocks in the swiftest water. Each has its problems, in a sense, of living successfully there, but cannot manage the environment as man can.

(3) The four plants groups or phyla should be observed, if possible, in one place. An exposed rock or cliff may provide the whole picture of algae, lichen, moss, fern, shrub or tree, and grass. The soil conditions will vary from raw rock to several inches of topsoil. The way the various stages of plant succession alter the living conditions may be easily seen by close examination and a little digging with the fingers or a stick. The accumulation of humus, disintegrated rock, and airborne dust not only have built soil but also a capacity for holding water.

Chapter VI

(1) If topsoil is "the dispensing agent for the mineral salts essential to life," and if "topsoil was fabricated by life and death," we would suspect a close relation between the depth of topsoil and the quality and amount of vegetation, dead and alive. While a spade, mattock, or soil auger may be frightening implements to the unitiated, there will be someone about with the lion's heart undoubtedly necessary to tote and wield one of them. Explore the source of the dollar's worth of minerals you are made of. Dig down in the soil to the rocky parent material, the C horizon of the soil profile. Expose the topsoil layer or A horizon, and the subsoil B horizon. The labor will be negligible along a creek bank or road cut. You may find a steam-shovelled excavation ready for your inspection.

But, you have your weapon, so dig on the hilltop; dig on slopes of various degrees; dig in the bottomland. Dig in the woods; dig in the grasslands. Dig where the vegetation is succulent and heavy, and where it is tough and scanty. Dig in virgin soil and in old, mistreated cropland.

When you dig, note the depth and color of the topsoil. Note the amount of raw humus, the size of soil granules. Compare the amount of roots in the topsoil with the amount of the subsoil. Smell the topsoil; smell the subsoil; where is life and death? Then, always judge the correlation between the condition of the topsoil and the vegetation growing on it.

What is the minimum depth of topsoil which supports a good vegetative cover? How many inches of topsoil would you spread on a lawn, built of earth materials from a basement excavation, to insure a good turf? Can commercial fertilizer (N P K—nitrogen, phosphorous, potash) take the place of humus laden topsoil? Why?

If your county has a Soil Conservation District, the conservationist from the U.S. Department of Agriculture assigned thereto can be of great help in learning about local soils. Look him up.

(2) What has water done in shaping your environment? Do you live on the flat limestone floor of an ancient shallow sea, on the sandy

shore of a prehistoric ocean, on stratified silt washed off old mountains, on glacial drift bulldozed down from the north by mile-thick ice? From a high point in your locality, view the drainage pattern developed by thousands (more likely millions) of years of climate. If you live in a region of deciduous trees, be sure to do much of your observing when Nature has her makeup off, when every wrinkle, sag, or bulge is starkly revealed. It is probable that a major part of the relief you see was fashioned before plants exerted any great influence in stabilizing the soil. Would you recommend that the hydraulic power so obviously employed in rearranging the earth's surface be again released, now that man occupies the landscape? If you so recommend, then the next step is to get rid of the vegetation, and the power of climate will be unhindered. If you do not so recommend, what course would you advise concerning vegetation?

(3) The physicist reports that the transporting ability of running water varies as the sixth power of the velocity, that is, $T = V^6$. If water is moving down a more or less bare slope at a velocity or rate of 1 inch per second, then $T = 1 \times 1 \times 1 \times 1 \times 1 \times 1$, or $T = 1$. Let us assume that at this rate some soil will be moved.

If the water were moving twice as fast, 2 inches per second, what would its transporting ability be? How many times as much soil could it move?

Suppose, after a cloudburst, the water were flowing at 100 inches per second (less than 6 miles per hour). What would its transporting power be, compared to the first case? Does this figure explain the dissection or cutting up of the Piedmont, Appalachian, Colorado, Ozark and other plateaus? Water alone could hardly have cut the Grand Canyon. What does the river use for abrasive tools? Would the same principles apply to small gullies in a field? What methods can you suggest to prevent both rapid runoff and abrasive cutting?

(4) If there is opportunity, observe abandoned fields and note the species which occupy them. Are any species invading the area? What evidence can you find that conditions of soil organic matter, soil moisture, soil temperature, and light are changing? As the invaders increase, what changes will they bring about?

Chapter VII

(1) On a field trip, observe how plants grow in colonies. Note parent trees and families of youngsters. See how the forms of some tree crowns are misshapen because of shading by taller neighbors. Find thickets of fiercely competing saplings. Estimate the amount of thinning which would be beneficial. Select crooked, low-grade, sun-hogging "weed" or "wolf" trees which you would remove. Have they any value as wildlife food or den trees? Do they provide needed shade for livestock? Would these questions modify your decision?

(2) On a field trip, observe the four-storied forest: herbs, shrubs, saplings, and mature trees. Note the vines, mosses, ferns, fungi. Where is the greater fraction (on a weight basis) of animal life located. Do not overlook the insects. Where do woody plants concentrate their

nutrients—what parts do the higher-order animals seek? Dig with fingers in the litter of the woodland floor, searching for the runways of rodents. What is there for these animals to eat? Which trees produce abundant seed—the shaded or unshaded?

(3) On a field trip, determine the dominant species of several areas—those plants greatest in number and size. Explain the presence of different associations in terms of ecological factors. How much tolerance toward variations in these factors do you observe; e.g., how far from water are willows found; how far from dry ridges do you find black oaks? (Set up such questions based on your region.)

(4) Locate a variety of micro-climates, where life forms reflect the variation in light, moisture, wind, temperature, soil type. Compare the depth of leaf litter on the windward and lee sides of a wooded hilltop. Observe the edge of a forest or woodlot; what differences are caused by the change from shade to light; where are the greatest concentrations of seedlings found? Can you reach any conclusions about "edge" in relation to wildlife? Compare the height from the ground of leaf bearing branches on trees in the open with trees in a dense stand; (How would this affect browsing animals?) Take temperatures in summer and in winter at these same locations.

(5) Tour a farm, ranch, or plantation. What areas or fields are best suited to trees, to grass, to row crops? Why? Is the land user making any mistakes? Is there any erosion, any unvegetated drainage ways, any grazing in woodland? Ask a soil conservationist to accompany you and discuss proper land use according to the capabilities of various areas.

(6) Locate a pond or lake where dry land slopes gently into marsh, then into shallow water. Note the changes in plant and animal species as you move from one extreme to the other (dry to wet). Is the water area changing to land area?

(7) Find relatively bare areas. Determine their cause. Note the primitive and low grade species present. Find wornout or abandoned fields. Note the species there. What species do conservationists plant on areas in process of reclamation? Are they the climax species? Why? Inquire as to the probable succession of species.

(8) List the plant indicators in your community, and what they indicate. This requires some effort and time, but is worth while since it will help in removing one of the curses of American education: ignorance of the local environment. The best source of information should be the botany department of your state university. Other sources may be the county extension agent, district forester, game and fish management agents, soil conservationist, or nearest agricultural experiment station.

Chapter VIII

(1) To demonstrate raindrop impact, set a jar lid, or saucer, of soil in the center of a large sheet (two or three feet square) of paper or cardboard. Release a few drops of water from a height of several

feet so that they strike the soil. Examine the paper. Do the shattered drops carry soil with them? How far does the splash extend?

(2) Repeat, placing both soil and a new paper at a sharp angle with the floor, simulating a sloping field. Smooth over the soil before releasing the water this second time. Do not permit every drop to strike the same spot or a hole will be dug; this is not what happens during a rain, although such digging demonstrates the hydraulic power of a stream of water. (Do not expect much more than half the splash to fall downhill. The difference is small, but remember the cumulative effect of years of rainfall in this work). Examine the paper for evidence of total average soil movement. Is it downhill?

How do you account for the fact that streams, draining what *appear* to be level farmlands, run muddy after rains?

How do you account for the fact that many gently rounded hilltops of old, dissected plateaus (such as the Piedmont, Ozark, and Appalachian) are severely and more or less uniformly eroded, while the surrounding steep hillsides are perhaps not? As a hint, what use is made of the two types of terrain? (Are there trees on the steep slopes?) Might the same thing happen on rolling prairie or plain?

(3) Place a section of sod covered soil in the container and try the experiment a third time. Do the shattered drops carry soil? Does the splash extend as far as in the case of bare soil?

(4) Now, although the average teacher is already fed up with the inconvenience of setting up such demonstrations, let us, for the benefit of the exceptional teacher, go on. In order to show clearly the very important function of surface litter in preserving a good soil, we shall need two similar shallow boxes or biscuit pans, a sprinkling can or a tin can with a dozen nail holes punched in the bottom, and enough good loam soil to completely fill the boxes. This good loam must have a granular structure. Needed also is enough straw, grass clippings, hay, leaves or other mulching material to cover *one* box so that raindrops will not strike bare soil. Do not cover it yet.

To proceed, drop the artificial rain on the box of bare soil. Try, say, one half inch of rain, evenly distributed (this can be calculated from the area of the box and the fact that there are 231 cu. in. per gallon of water). Observe carefully any changes which occur in the surface soil structure. Are the granules or aggregates broken down? Does the soil surface seal? Compare with the dry box. Does the water infiltrate rapidly—at first—later?

Now cover the second box with a surface mulch. Drop the water. Does it infiltrate better? When the rain is over, carefully remove the litter without disturbing the soil. Compare the two surfaces. On sloping land, which condition would discourage erosion? Which condition would admit air to the soil most freely and continuously? Which would require the most cultivation? Why? What would you recommend in regard to the practice of removing all possible crop remains from fields? What would you recommend in regard to burning off weeds from the fields and leaf litter from woodlots? What now is your reaction to the idea that the ordinary moldboard plow (which buries surface litter and exposes bare soil) may be an instrument of land destruction? Can you suggest a different way of preparing a seed bed?

Chapter IX

(1) The task here suggested cannot be entered into lightly. It cannot be completed in a few hours. Even if it requires a year or two of intermittent effort, it will be worthwhile. That gaping hole in education, particularly urban education (i.e., ignorance of local geography, local biology, local history, local economics, etc.) will be partly filled. It is a disheartening fact that the average student probably knows more about Iceland, Holland and Siam that he does about his own county and state.

Let us then take the local county as a unit of study and learn something about it. While it is well to know the good things about your county, it is more important to know what is wrong with it. And so, having made a start through the activities of Chapter 3, why not complete an inventory of the ecological disasters which have befallen your community. Using the virgin conditions found by your recent ancestors as a basis of comparison, what has happened in regard to:

(a) Erosion and soil productivity
- (1) extent of areas injured by erosion
- (2) degrees of injury by erosion
- (3) decline in fertility and yields
- (4) effect on wildlife
- (5) effects on land users
- (6) effects on business, and public services such as schools and roads

(b) Floods
- (1) record of frequency for past 40 years
- (2) record of heights for past 40 years
- (3) record of damages for past 40 years
- (4) causes of changes in 1, 2, and 3

(c) Water Table
- (1) reliability and amount of spring flow in various areas
- (2) changes in necessary depth of wells
- (3) regularity of stream flow throughout year
- (4) relation of 1, 2, and 3 to soil erosion
- (5) increasing uses of ground water for industry, civic supply, air conditioning, and irrigation (these may affect ground water levels)

(d) Drainage
- (1) successes and failures of drainage projects
- (2) effects on wildlife
- (3) economic consequences

(e) Pollution
- (1) types found
  - (a) chemical
  - (b) physical
  - (c) biological
  - (d) thermal (discharge of hot water by factories)
- (2) sources
  - (a) industrial and commercial
  - (b) domestic
  - (c) agricultural
- (3) where found
  - (a) streams
  - (b) lakes and reservoirs
  - (c) springs and wells
- (4) effects
  - (a) on health (human and livestock)
  - (b) on fish and other wildlife
  - (c) on recreational opportunities
  - (d) on industries, cities
  - (e) on jobs

(f) Siltation
- (1) extent in
  - (a) reservoirs, lakes, ponds
  - (b) harbors
  - (c) streams
- (2) causes
- (3) costs and damages to
  - (a) power production
  - (b) navigation
  - (c) irrigation
  - (d) aquatic plant and animal life
  - (e) recreation

(g) Forest Destruction
- (1) area converted to cropland and pasture
- (2) area needing reforestation
- (3) area needing fire protection
- (4) number and extent of fires reported last year
- (5) effects of 1 and 4 on wildlife
  - (a) species depleted
  - (b) species encouraged
- (6) economic results of all the above

(h) Overgrazing
- (1) evidence and extent
  - (a) changes in carrying capacity of grass lands
- (2) economic effects of overgrazing

(i) Wildlife Decline
- (1) species originally present
- (2) causes of declines
  - (a) changes in food, water, cover

(b) changes in effects of predators
(c) increase of hunting pressure
(3) present status of common species
(a) abundant
(b) scarce
(c) endangered

(j) Strip or Open Cut Mining
(1) extent of denudation
(2) extent of revegetation
(3) effects on wildlife
(4) economic factors—for and against

(2) Which of the 16 "violent reactions" listed in chapter 8 are affecting your county? Record specific evidence.

(3) What remedial measures are underway in regard to Activities 1 and 2? This is a question of much importance, not to be avoided in any study of this nature. It is an essential followup of Activity 1, but may be done simultaneously with each section. From the assembled information a judgment may be made of conservation progress and what remains to be done. It will form a basis for community planning, and such planning should be indulged in by students.

(4) What is the trend of rural population in your county over the past 40 years, more or less? A steady decline from a high point may reveal serious damage to the climax conditions of the landscape, forcing man off the landscape. There may, of course, be other factors bearing on population decline.

(5) We would hardly expect rural people to be unable to support themselves. The land is commonly supposed to be the escape hatch from economic depressions. But, if your county is one where erosion is serious, look up the records of direct relief for the open country folks during the depression of the thirties; if the records are not easily available, inquire of older people who may know.

(6) If there has been a school dental survey in your state, it will be informative and convincing to compare a map showing the average occurrence of defective rural teeth in various counties with an erosion map of the state. City teeth may not reflect poor local soils because of the large percent of foods shipped in.

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Chapters I-IX