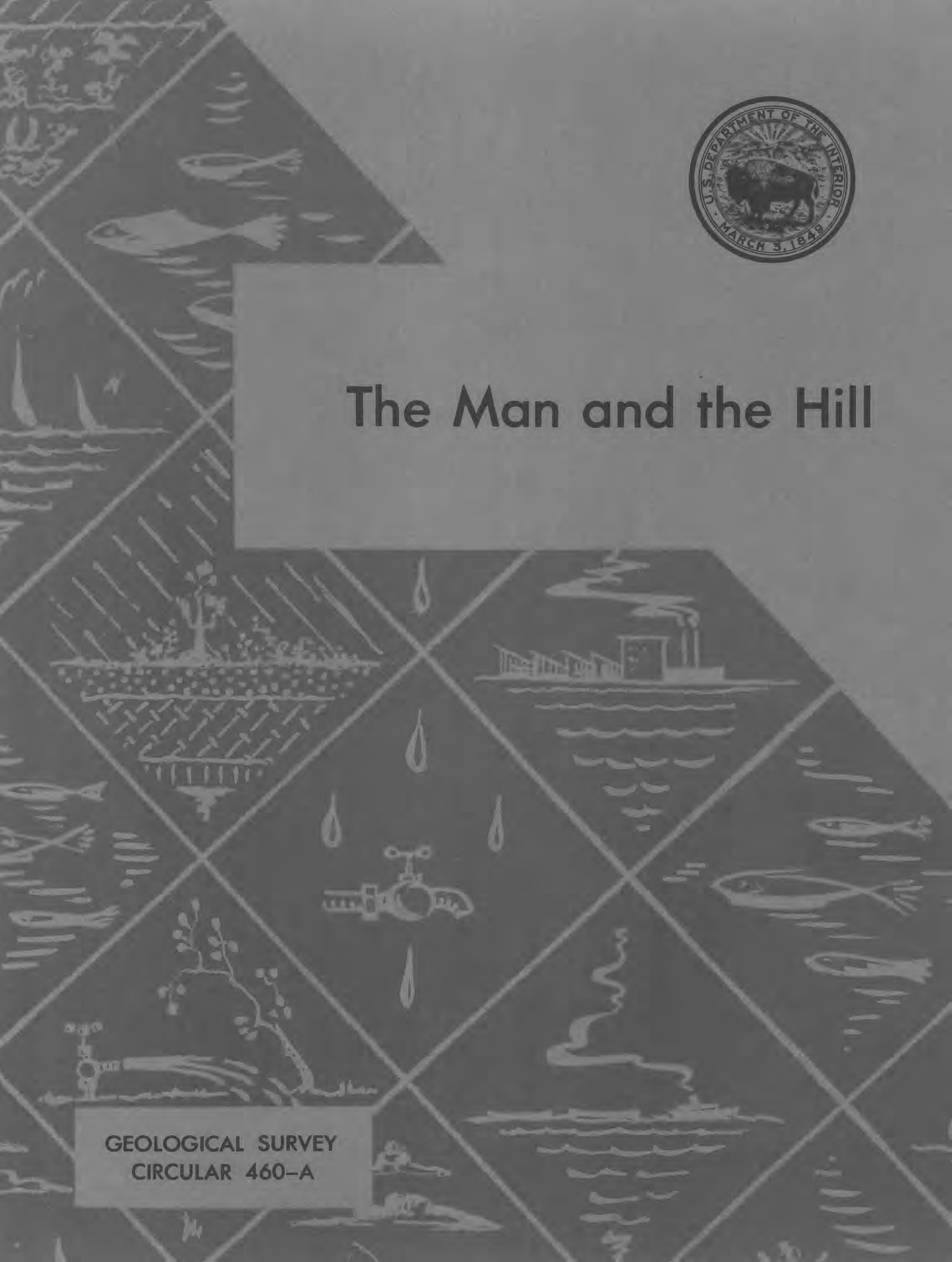

The Man and the Hill

GEOLOGICAL SURVEY
CIRCULAR 460-A

Part A

The Man and the Hill

By Luna B. Leopold

CONSERVATION NETWORKS

GEOLOGICAL SURVEY CIRCULAR 460-A

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CONSERVATION NETWORKS

PART A

The Man and the Hill

By Luna B. Leopold

Opening address to the Symposium on Climatic Change, United Nations Educational, Scientific and Cultural Organization and World Meteorological Organization, Rome, October 1961.

He was sitting on a large slab of rock. As he looked at the cloud of dust hanging hazily on the horizon, the piece of antler and the block of flint he held in his hand hung as if they were suspended from their previous rapid motion. The man gazed intently across the swaying grass which rose in wave-like billows across the distant hills. What was that dust—a herd of buffalo, a band of hunters, or were coyotes chasing the antelope again? After watching for a while he started again to chip the flint with a rapid twisting motion of the bone in his right hand. The little chips of flint fell in the grass before him.

It is the same hill but the scene has changed. Seated on the same rock, holding the reins of a saddle horse, a man dressed in buckskin took the fur cap off his head and wiped his brow. He was looking intently across a brown and desolate landscape at a cloud of dust on the far horizon. Was it the hostile tribe of Indians? It could be buffalo. Nervously he kicked at the ground with the deerhide moccasin, pushing the flint chips out of the way. He wiped the dust from his long rifle. What a terrible place—no water, practically no grass, everything bare and brown.

Now at sunset, slanting across the hills green with springtime, a cowman sits on a big rock, pushes his sombrero back on his head, and looks across the valley at a large but quiet herd of stock, moving slowly as each steer walks from one lush patch of grass to another, nibbling. Suddenly he stood up. Far on the horizon some dark objects were moving. Is it the sheepmen? Could it be the stage coach from Baggs to the Sweetwater Crossing?

Same hill—a gray truck was grinding slowly toward the summit. It pulled up near a small fenced enclosure where there were some instruments painted a bright silver color. A man stepped out of the truck and turned to his younger companion, "You've never found an arrowhead? Maybe you have never thought about it correctly. If you want to find where an Indian camped long ago, put yourself in his place. Where would he sit to chip flint? He would take some high hill above a grassy valley where the breeze would cool him and where he could look across the country, watching for game or for enemies. If I were an Indian, that's what I would do. You change the chart of the rain gage and I am going to walk up to the place where I think he might have sat." He walked over to the crest of the hill and, near a large slab of sandstone, started to pick up pieces of flint.

This is an oft-repeated story. A given hill is repeatedly visited, used, loved or hated, protected or marred, by successive generations of men. All these men had characteristics in common. They had a job to do, a livelihood to make; they had their own plans, their own fears, but they were in one way or another connected with the land.

But the land itself was not static—it changed in time from season to season, year to year, and century to century. The soil and chips of rock, beaten by the elements, the hooves of beasts, and the feet of men, move gradually but inexorably down the slope. Each succeeding generation of men left some mark on the hill. That mark is usually erased with time but under certain circumstances the sequence of events can be reconstructed with considerable assurance. And I think it would be true to say that the hill also left some mark on the men. This mark may be only a passing memory, but many men have grown up on many hills, and the hills have, at least to some extent, conditioned man's attitude and his view of the environment in which he lives.

Now we are engaged in a great struggle with those hills, more intense than at any other period in the earth's history. The expanding population requires ever-increasing supplies of the natural resources which are found on or in these hills—the grass, the soil, the water, the minerals, and the timber. By extracting these, man's mark on the environment becomes ever deeper, his effects ever more indelible. But his ability to obtain or to manage these resources depends on an ever more sophisticated understanding of the characteristics of the resources, their mode of occurrence, and their response to management. Particularly in the renewable resources, the response to management is often not clearly separable from the response to slow and subtle changes in the natural environment. The most pervasive and probably the most important of these slow and subtle natural changes result directly or indirectly from variations in climate. Over a shorter or longer period of time the variations in climate affect the type and characteristics of the soil profile. Its ability to take in and store moisture and the supply of water is simultaneously governed by the same climatic factors. In response to the changes in moisture and conditions of soil, the vegetative association also tends to change. New combinations of species, having different types of interaction with soil and moisture, move in and displace the previous species. The insects, the animals, the bacteria are similarly influenced by this interdependent complex, and they change also.

With variations in climate come new conditions of equilibrium. Particularly in arid climates is there a sensitive balance between the erosive effects of water and gravity and the ability of the vegetation to hold the soil and mitigate the erosive effects of running water. It is an axiom in ecology that the climatic factors, soil, and the biota interact in such a way as to promote a quasi-equilibrium, notwithstanding the long-term geologic effects of gradual degradation of the continents by solution and by the processes of erosion.

Interestingly, many of the effects of man's action on this complex and on the conditions of quasi-equilibrium are similar to the effects of the long-term variations in climate. Man's utilization of the vegetation for grazing, for lumber, or for agriculture tends to alter the relation between hill slopes, vegetation, and water. An overgrazed range is characterized by the decrease in volume growth, by the gradual replacement of some species by others, particularly the replacement of perennials by annuals, a general simplification of the biota, and a short-cutting of food chains. These same reactions of the landscape are those which would result from a change toward greater aridity. The decrease of volume growth and density of grasses under conditions of excessive grazing results in a deterioration of soil tilth, a reduction in infiltration capacity, increased susceptibility to erosion, and usually increased erosive potential of the available surface runoff. A change in climate through its effect on vegetation, and thus on rainfall-runoff relationships, can be remarkably similar to the effects of man's use.

We have produced a machine, the bulldozer, with remarkable efficiency for doing geologic work. But we have only begun to study how resources can be managed for optimum production and for social advancement. In the field of water development and in the field of agricultural production, full development is in sight at least in some drainage basins, even within the present generation. Optimum management is going to depend greatly on an understanding of the natural relations which produce the quasi-equilibrium that characterized the landscape before the advent of man. A principal object of present-day research in the field of natural resources is to unravel these complexities that govern the natural quasi-equilibrium.

It therefore becomes a matter of practical concern, as well as a matter of intellectual interest, that the specific causes of given observed effects be identified and that the chain of events—the linkage of interrelated factors—be known in far more detail than is possible at present. Specifically, the ecologist, the geologist, the botanist, the zoologist, the sociologist, and a host of others find themselves unable to link cause and effect because they cannot dissociate the direct and indirect effects of man's use from the similar effects which are brought about by the natural variations in climatic factors.

If, then, it seems abstruse or unimportant that we gather here to discuss the nature, the causes, and the tools by which we study climatic variation, let us disabuse the mind of such a casual observer of this misconception. On the contrary, in the field of water resources—the field I know best—management is becoming increasingly dependent on an improved basic understanding of the interrelations between the atmosphere, the biota, and the land as they affect the hydrologic cycle. To gain a workable understanding of these interrelations it is imperative that we know more than we do at present about the nature of, and the effects emanating from, climatic changes.

This problem is of greater concern in the arid areas of the earth than it is in the more humid ones. First, the arid areas are characterized by an inherent variability, particularly in climatic factors. This variability is reflected in the biota. Secondly, in an arid climate the climatic controls are somewhat more direct than they are in areas where water is not a limiting factor. The responses, even to relatively minor climatic variations, are more specific and more prompt.

A subject of the highest priority in arid-zone research should be the mechanics and processes in the hydrologic cycle wherein the natural changes resulting from climatic variation are confounded and confused with the changes caused by man's activities.

Many of us have been associated over the past several years with a concerted effort to focus attention on the problems of the arid zones. We have organized and attended meetings and symposia, we have formed committees, we have instigated research laboratories and student training programs—a myriad of activities. Important as are these activities in stimulating an interest and knowledge of the arid zone, they often deal with relatively distant and abstruse aspects of the total problem. Further, few of these are of such nature that they involve many people in many countries. There are other immediate, practical, and inexpensive ways of achieving some of our objectives, particularly the acquisition of new and vitally needed information. Such information has educational value in promoting a greater public understanding of the nature of arid-zone problems. One such specific is the following.

Vitally needed now is an international system of observations on small watersheds of the principal hydrologic and landscape factors. Field observations of the same kind in many places would improve our understanding of the hydrologic and the biologic aspects of the interrelation between the man and the hill. I hereby call, therefore, for the establishment of an international network of observation points to collect data on some of the basic parameters governing the relation between man and the landscape in arid zones. The network of observation areas I visualize might consist of the following.

A small watershed would be chosen, the size of which might be from one to ten square miles. It would be chosen to represent a typical area in the general region—that is, typical in its general geology, vegetation, slopes, topography, and land use. At the mouth of the drainage basin some very simple observations would be made intermittently. The major flows in the stream channel would be observed by means of an extremely simple instrument devised in our country which we call the crest stage gage. This is merely a perforated pipe standing near the stream channel within which is contained a wooden measuring stick and at the bottom of which is dumped some burnt cork. When the water rises in the channel the cork floats up and clings as a high-water mark to the stick inside the pipe. At some later time the observer comes to the crest stage gage, pulls the stick out of the pipe, observes the position of the cork which is the high-water mark of the most recent flow, and records its vertical position.

Another observation which can be made very easily is the cross-sectional shape of the channel at the point of observation. A cross section can be surveyed, tying it at each end to permanent monuments. These monuments or markers might be as simple as a cross chipped in local rock at each end of the channel. Where rock is not available, an iron pipe can be driven into the ground, which will not be disturbed by ordinary activities of man or beast. Such cross sections could be resurveyed seasonally, or even once a year. The changing cross section over a period of years would give a quantitative idea of whether the channel is aggrading or degrading.

As many of you probably know, in most field situations it is practically impossible even for the expert to look at a stream channel and tell whether the channel is presently in a period of gradual aggradation or gradual degradation.

Obviously, in the measurement locality there should be a long-term storage rain gage. These instruments are now available cheaply and have been shown to give good results. A gage buried in the ground and containing a few drops of oil or other material to reduce evaporation can give a very usable record of the seasonal precipitation. Rain gages do require some sort of a fence or barricade to protect them from passing stock, but such protection can be furnished at very low cost. If a small enclosure is built to hold a rain gage there is then the possibility of having a trap for obtaining samples of windblown pollen and windblown dust. At the same place one may collect samples of rain to measure its content of dissolved chemical salts.

Apart from these measurements which are made seasonally or annually at the mouth of the watershed, each watershed should have a cursory description of its soil, geology, topography, and vegetation. Quadrants, transects, or some other simple means of describing the vegetation are necessary in order to give quantitative estimates of the gradual change, if any, in plant growth or species distribution.

As an initial step in our part of the suggested network, we in the United States are proposing a series of small watersheds be chosen along a line or transect stretching in an east-west direction between the major mountain masses in the North American Continent. Later we hope also to have a similar series of watersheds in a north-south line through the central part of the United States where the topography is relatively flat. The north-south transect, then, would give a representation of the effect of latitude uninfluenced by major differences in topography.

One might ask why it is necessary to suggest that this hydrologic network of bench mark areas be formulated on an international basis. To me the answer seems quite clear. Not all the possible conditions of vegetation, soils, climate, and use are represented even in a very large country. The first purpose of having such an international network is, therefore, to get a sampling of diverse types of landscape in different parts of the world. The second reason why this program should be of an international nature is that many of the climatic and use factors have a distribution dependent partly on continentality, on relation to major bodies of water, and on other characteristics of aspect and position. To obtain such a range in conditions, the observations should be on various continents.

What I suggest is practical in terms of the types of instruments and observations which are required. Standardization, even of very simple observations, can give a large amount of very useful information, and has the advantage of offering the possibility for immediate installation. Observations that require very specialized equipment, highly trained manpower, or considerable cash outlay are difficult to initiate. The suggestion made here, on the contrary, has actually been tested in the field; the instruments are of the simplest sort; the time schedule for observations is not critical; and the long-term results of such observations have already proven their great usefulness.

Allow me to propose that this network of simple observational areas be called the *Vigil Network.* A vigil is a watch, an observation over time, if you will. It comes from the Latin, *vigilo,* to watch. We will watch the changes that occur with time in the vegetation, the channels, the biota, and the landscape. If one considers the name *Vigil* is not specific enough, let it abbreviate a more formal designation: Veglia Idrologica, Globale e Internazionale di Luoghi d' Osservazione— Hydrologic Vigil at Comprehensive International Sites.

In proposing, then, an international network of landscape observations on small drainage basins, I hope we will begin a trend toward true international cooperation even of relatively simple nature, within the practical limitations of manpower and money. Too long have we devoted most of our major attention to the establishment of costly and complicated programs which take years to initiate. What I am suggesting is within the reach of even the smallest countries; the amount of initial effort for installation is very small; the possibility of having uniform methods adopted by various countries is good; and the program can be started by any scientist regardless of his particular background or training.

I hope that the present symposium will bring out in the papers examples of the principle which I have stated—that the interaction of the effects of man and the effects of climatic change can be separated only by research. I hope further that there might be some response to this suggestion for the installation of an international network of observation areas. If I seem to see interest in this proposal, I wish to transmit to Prof. Tison of the International Association of Scientific Hydrology and to the World Meteorological Organization suggested specifications for the choice of the drainage basins in such a network, a description of the type, operation, and availability of the simple instruments necessary for the observational program. I hope that those of you who find this proposal of interest will write to Prof. Tison and obtain copies of the suggested plan.

The Vigil Network might well become the nucleus of an even broader program of international cooperation in hydrology—the proposed International Water Decade being considered at Athens this month by the International Association of Scientific Hydrology.

The problem of climatic change, particularly in the arid zones, is that it alters the interrelationship between man and his natural environment. But it also affects the relationship between *a* man and that small segment of the earth where he lives. The problem of climatic change, insofar as it affects the use of natural resources, therefore affects *each* man on *his* hill. In making a suggestion, therefore, for a simple, practical, and inexpensive series of observations which may in some small measure further the cause of research in the arid zones, I would make a general plea to simplify and generalize the other aspects of arid-zone research activity with which we are all concerned. International programs often concentrate on means that are indirect, costly, and sufficiently abstruse that they do not seem to bring to *a* man on *his* hill any idea of his relation to the environment. We may do well to direct our attention to more widespread, simple, and inexpensive forms of communication to reach more quickly more men and more hills.

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