Fire and Vegetation Of Arid Lands*

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It was John F. V. Phillips (1936), writing in the *Journal of South African Botany*, who titled his paper "Fire in Vegetation: A Bad Master, a Good Servant, and a National Problem." "A Bad Master, a Good Servant" is the problem we are dealing with here and as with most questions there are two sides to be analyzed.

George R. Stewart (1948) wrote a novel "Fire" which tells in dramatic fashion the explosive nature of fire in western forests and its ugly aftermath. The oft-told story of the Tillamook Burn in Oregon leaves no doubt in the mind of the average person concerning the devastating effects of fire on the forest. People working up enthusiasm for the prevention of forest fires have plenty of material for their propaganda machines.

In a recent number of *Science* there was an article by Robert Cushman Murphy (1962) on Antarctic Conservation. While this article is not concerned with fire it does illustrate some of the factors that I want to consider here. In addition to placing man as the main despoiler of the almost virgin Antarctic lands he indicates that the contact need not be too close to place conditions on the environment that are disastrous. As Murphy says, "A penguin colony cannot be a human playground—not if it is to remain a penguin colony." He goes on to show that actual vandalism is less to be feared than ignorant trespass. The

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heedless maneuverings of airplanes and helicopters can do more to upset the behavior of these colonies than actual killings by man. Later on in this article he shows how altruistic motives can upset nature's balances. He cites the case of the gulls that feast on the eggs and young of penguins. This rivalry between the gulls and the penguins over the centuries has resulted in established balances that keep the various inhabitants of this inhospitable land under control. Many of the personnel coming to Antarctica by ship and plane, during the recent activity in the region, have aroused, in their inexperienced minds, a desire to kill the gulls to save the penguin young. As Murphy says "from an objective point of view, this relationship between the gull and penguin is neither to be condemned nor condoned but merely to be accepted." Can't we look at fire in this light?

Climax vegetation is the result of a given environment and the vegetation of any given area in approximate balance with the soil, weather and biological factors, including man during the last few thousand years. If this is taken for our premise, it might be well to see just what we are going to consider as the set of factors that together make up the environment. Rainfall (be it snow or rain), temperature, edaphic factors, and interrelationships of biologic things are easily worked into the climatic complex. But fire, which seems to have been long associated with man, is often either ignored or overlooked.

The ability to use language, tools, and fires has distinguished man from other living things and fire seems to have been one of the first of these and most closely associated with mankind. Walter Hough (1926) in his work on early civilizations, gives considerable space to a discussion of the various ways in which man is associated with fire. That fire has been a definite factor in the development of early man seems to be little doubted by most anthropologists. Carbonized artifacts are found with the remains of man in the earliest sites. Pekin Man was closely associated with fire some one-quarter to one-half million years ago. The burning of vegetation, either purposely or accidentally, appears to be almost a universal custom among primitive people. Anthropologists seem to recognize this fact

more readily than ecologists. A sound understanding of the present-day distribution of plants on the earth's surface has to accept fire as part of the environment.

If man has always been closely associated with fire, isn't it reasonable to assume that man was able to care for fire and use it to his advantage as needed. While fire is usually thought of as a "household" article, early man did not confine his fire to the cave or shelter but used it indiscriminately as it benefited his well-being.

Omer C. Stewart (1955) in one of several papers on fire and the American Indian, claims that he has evidence of almost every tribe in the western United States using fire to modify its vegetational environment. One of the main factors overlooked, because of the lack of definite evidence, is the fact that fires were an almost constant factor in the climate of the forests and grasslands. As a matter of fact, wherever there was an accumulation of inflammable material there were bound to be fires, either from natural causes or set by man himself.

Data on the constant recurrence of fires especially in the past of any given area are not too abundant. There are, however, many studies that have set patterns that show fires occurring at rather frequent intervals.

Show and Kotok (1924), in a paper on fires in the California pine forests, give a list that is not excessive and is probably like many other areas of similar vegetation. They list fire years over the last three centuries as occurring in 1685, 1690, 1702, 1708, 1719, 1726, 1735, 1743, 1747, 1750, 1766, 1786, 1796, 1804, 1815, 1822, 1829, 1837, 1843, 1851, 1856, 1865, 1870, 1879, 1889. This is a compilation from a large area, and not every acre was burned, but they concluded by the number of fire scars on trees that in this area as a whole the above years were active fire years.

F. P. Keen (1937), in a study on climatic cycles in Oregon's Watkins Butte area, found fires occurred in 1824, 1838, 1843, 1863, 1883 and 1888. In another study by Keen (1940), one tree had an early scar dating from 1481, and, when the tree

was cut in 1936, it had weathered twenty-five fires at approximately eighteen-year intervals.

E. Fritz (1932) found the Redwoods recording four fires a century for over one thousand years.

Harold Weaver (1951), in the Arizona Ponderosa Pine forests of the Apache Reservation, found fire records in tree-rings dating as far back as 1708. Between this date and the most recent scar in 1943 the average interval for all trees was 7.3 years.

Robert Humphrey (1953), working on the desert grasslands of southern Arizona, examined 32 trees of mesquite; seventeen were 12 inches or less in diameter and fifteen were from 12 to 30 inches in diameter. Only one of the smaller trees showed any signs of a fire scar. Sixty-nine per cent of those 14 inches or larger bore unmistakable fire scars. This was on the Santa Rita Range Reserve and shows evidence of old fires on this area which has been protected since early in the 20th Century.

It seems, then, that fires are to be treated as a part of the environment in any area where there is organic material enough to burn and where conditions, at least at times, render the material easily combustible. Rainfall, snowfall, evaporation, wind, frost, temperature, etc., have been recorded, analyzed and charted and have become an essential part of the habitat of most vegetational studies, but fire is only mentioned briefly, if at all.

That fires are part of the environment even in habitats of rather moist situation is easily seen in the southern part of Florida. The Everglades, a swamp to most people, has had terrific fires even before man's drainage efforts. One of the most severe fires I have ever encountered was in the middle of the Big Cypress Swamp in southern Florida.

If you accept the fact that fires should be considered part of the natural environment in both the distant past and near past, I would like to turn my attention to fires as they occur in arid lands.

In order to have fires, combustible material must be present. Fires on open sand dunes are impossible. As the vegetation gets more abundant, and covers more of the ground, we

have, eventually, a situation where there is enough combustible material to burn more than an individual plant. At some time in this process of a thickening vegetation we reach the stage where the vegetation is thick enough to carry a running fire. In the desert proper these areas that can carry fire are remote and not extensive. Early reports of fires in our southwestern desert region were largely confined to burning of tobosa swales and broad desert washes that have considerable vegetation from extra water along the occasional streams.

In the basin and range country of Arizona, and other parts of the Southwest, the valleys are covered with a sparse vegetation except for the grassy swales, but as one goes up the mountain sides the vegetation becomes thicker in response to the increased rainfall of higher altitudes. The tops of some of the higher mountains receive enough rainfall to produce a well-developed pine forest, or in some places spruce and fir. On the lower slopes of the mountains and at elevations in southern Arizona of 2500 feet or above one encounters the so-called grasslands. These grasslands and the higher chaparral and pine forests are fire areas that at present are undergoing changes because of fire control.

It is in these grasslands that the present mesquite problem exists in southern Arizona, New Mexico, and Texas. Formerly in these grasslands mesquite was absent or at least confined to the washes. Since the appearance of man and the introduction of cattle and sheep noticeable changes are evident. Pictures of the Santa Rita Range Reserve taken early in this century show an open grassland with only an occasional shrub. Later pictures show more and more shrubs and trees invading the area until at present some of the former grassy areas have little grass and are mostly covered with shrubs and desert trees, notably mesquite. It has been estimated that over half of the area now occupied by mesquite has been invaded since the introduction of livestock (Parker and Martin, 1952).

It has been rather convenient to assign this change from grass to shrub to overgrazing and, undoubtedly, overgrazing is in the picture. However, it seems hardly correct to assign this

factor of overgrazing as the only contributing factor. At one time I was asked when I thought the overgrazing commenced in our desert grasslands. My answer was to the effect that the minute the early settlers drove the first cow into our country we were bound to have trouble. I still believe that this is true. However, the arrival of cattle was merely one of a series of events that all occurred about the same time.

In the ecotone between the desert vegetation and the grasslands of southern Arizona you have an area that is in very delicate balance. Only a slight change of any kind can tip the scales in one direction or another. One cow is enough to create a new and drastic upset and unless other processes are brought into play severe changes will result.

Once mesquite is established perennial grasses disappear under the trees and eventually in the spaces between trees. Mesquite must be classed as an aggressive invader and a persistent competitor. Once established, eradication is not an easy matter. Dormant buds just below the soil surface sprout if the tops are damaged, and the root systems are deep and widespread. Seeds are long lived and germinate easily even after passage through the digestive tract (Glendening and Paulsen, 1955).

Originally mesquite was confined to the margins of the washes and drainage ways. Here one still finds the largest trees, but slowly, during the late 1800's and in the present century, mesquite has taken over much of the former desert grassland. There is evidence of past fires in this grassland (Humphrey, 1953), and with the advent of domestic livestock fires were controlled. Unlike the Southeast the burning of this grassland was not necessary to remove excess forage. The removal of organic material by cattle and the spread of seed in the dropping of cattle set up a system that was very favorable for the aggressive mesquite.

As the inflammable material lessened, fires were no longer able to burn out the young seedlings and even during the rare favorable years for grass production local fires only top-killed the mesquite and left the roots to sprout from extensive, well-developed root systems. With constant grazing and dry years

the carpet of vegetation has not been present to carry fire so that at present even experimental burns are hard to get. The change is merely a shifting of the ecotone from grass to the desert shrubs.

Let me quote a paragraph from an early paper by one of our outstanding naturalists, Aldo Leopold (1924):

> Previous to the settlement of the country, fires started by lightning and Indians kept the brush thin, kept the juniper and other woodland species decimated, and gave the grass the upper hand with respect to possession of the soil. In spite of periodic fires, this grass prevented erosion. Then came the settlers with their great herds of stock. These ranges had never been grazed and they grazed them to death, thus removing the grass and automatically checking the possibilities of widespread fires. The removal of the grass relieved the brush species of root competition and of fire damage and thereby caused them to spread and "take the country." The removal of the grass-root competition and of fire damage brought in the reproduction. In brief, the climax type is and always has been woodland. The thick grass and thin brush of presettlement days represented a temporary type. The substitution of grazing for fire brought on a transition of thin grass and thick brush. This transition type is now reverting to climax type—woodland.

In northern Arizona a similar situation occurs with another woody plant, juniper, which at present is spreading out into the grasslands of this region.

Let me quote a paragraph from a book by my colleague, Robert R. Humphrey (1962, in press):

> However, the combined evidence appears conclusive that grassland fires in the desert grassland, as perhaps in grassland areas the world over, have been instrumental in preventing the establishment of wood species. This control has operated in many ways, not the least of which is the difference in length of time required for grasses as contrasted with most desert-grassland woody plants to mature sufficiently to produce seed. Some half-shrubs, such as burroweed and snakeweed, that are exceptions to this, may mature in one or two years. The dominant invading shrubs, on the other hand, of which mesquite is outstanding, will normally not produce seed for several years. Fires occurring at intervals

> more frequent than this and killing the plants or burning them to the ground would continue to keep them suppressed. Although ground fires may leave the majority of mesquites alive, periodically recurring burns will kill the young plants and even mature trees back to the ground. Plants that are killed tend to stump sprout, sending up several shoots where there may have been only one before. As a consequence, no single stem develops to the extent that one might expect. This delays the age at which flowering and seed setting may be expected.

I spent two years on the edge of the Gobi Desert in northern China in Shansi. This region would have been a wonderful area for watching the results of fires if large populations had not appeared in the country thousands of years ago. In this semi-arid region the combustible material was carefully gathered and used as fuel and fodder so that little was left on even the most remote mountainous areas. The grasses and shrubs, (including lilacs) were still present in the area especially around sacred temples that were somewhat protected. In these areas limited grasses are found along with pines, cedars and other shrubs. People in this desert area have removed the cause of fires by their constant demands for even the flimsiest of fuel and fodder. The older writings of this area, however, do mention fires as part of the picture and in some areas in remote Shansi records tell of annual burnings to "clean the grass."

In 1954 and 1955 I was fortunate enough to spend a year in another arid area where again fire was an important part of the picture. During a stay in Adelaide I was able to visit parts of southern Australia, Queensland, and western Australia, as well as the arid central part of Australia about Alice Springs. One is impressed with the Eucalyptus forests and their great diversity of species. Probably it would be incorrect to draw too many conclusions from this short visit to a vegetation as variable as one finds in this "land down under," but the effects of fire on the landscape were noticeable and much experimental work is being done in the region on fire as a factor in the development of the vegetation.

In the Queensland area Mulga (*Acacia aneura*) is an im-

portant browse plant that is used heavily to supplement feeding during periods of drought (Everist, 1949). That Mulga occupies areas where the original grass cover has been removed by overgrazing seems to be an admitted fact and by removing the Mulga and restricting grazing the grass can be brought back. However, Mulga is used extensively as a browse during the long irregular drought periods when grasses are not available. The general practice, during periods of drought when feed is in low supply, is to lop off the higher branches and make them available to sheep. Thus we have a case here where a shrub invading a grassland is useful during unfavorable periods. This same idea has been advanced in the southwest of mesquite, but in the case of mesquite trees fire is not a factor in eliminating the trees as they stump sprout easily. Mulga on the other hand is killed by fires.

The coastal Eucalyptus forests of the Queensland area in general character are much like the Ponderosa Pine forests of our western states. They are open forests with a grass cover and devoid of shrubbery undergrowth when fires are allowed to run through the forests periodically. However, in recent years with fires being controlled more shrubs are appearing and now when fires are started the burn is more severe and more damage is done to both the forest and the grass cover.

One of the facets of experimental vegetation control, that had been carried to a fine point in some of the Australian areas, is the application of minor elements needed in plant growth. This work has been carried on in many areas of Australia under different types of vegetation and a complete story of this work is out of place here. However, to show the results, an example can be drawn from work south of Adelaide some eighty miles, about the town of Keith in the Ninety-mile Desert region.

Here by extensive work large areas of shrubby land have been reclaimed and are now growing good grasses by the application of ounces per acre of various minor elements such as zinc, copper and cobalt. Experimental plots in this area with application of a single element show little results. However, combinations of two or three of these minor elements can change

the vegetation from shrubs to grasses in very short periods of time.

R. L. Specht and his coworkers (Specht *et al.*, 1958), in the sixth paper on this region, give some interesting data on the fate of certain minor chemical elements during the development of this so-called "Heath Vegetation."

To illustrate the effects of minor elements on the mineral-poor soil of this area let us look at zinc as reported by Specht. During a twenty-five year period the amount of zinc tied up by roots of the plants changed from less than 100 grams/acre in the early stages to over 400 grams/acre after twenty-five years. His figures for magnesium, copper, and manganese showed similar though less impressive changes over the same time span. He analyzed roots, litter, and tops of the several species present and although variable (manganese increases more in the tops) they all showed that these trace elements were increasingly tied up in living plants during the twenty-five year period. He concludes that "degradation of the stand must inevitably occur to restore much of the 'working capital' of nutrients so bound to the ecosystem."

The work being done in Australia may point to some ideas that could be followed out in this country. The shrubby climax vegetation is evidently in very delicate balance with the present climatic conditions. By the application of these minor elements the scale is tipped in the direction of grasses which can then compete on a favorable basis with the shrubs. I have had the impression in regard to mesquite in our Southwest that some micronutrient might control the mesquite-grass ratio, but no work has been done to find the elements or the levels needed to tip the balance in the mesquite country in the United States.

In the Keith area the shrubs are usually bulldozed into windrows and then burned. After the burned area is fertilized with the proper minor elements grasses can compete. Three years later this area shows a grassy cover that is hard to believe. This type treatment is not confined to this area as the same spectacular results are seen in Queensland and Western Australia as

well as many other areas in South Australia. Usually a clover is seeded for its nitrogen effect.

The center of Australia is a flat level plateau of low elevation. It is extremely monotonous as far as geological features go and the soils are rather uniform. However, one is impressed traveling over this area at the diversity of the vegetation. A large area of one community of plants changes to another type with no obvious reasons for the change. Climate is the same, soils are the same, and no geologic features are noted. Recent work in this area (Perry, 1961: pers. comm.) indicates that these differences are mainly the results of fires. A fire that occurs during the cool season results in one type of vegetation coming into being while a fire in the warm season will bring on an entirely different set of plants. Once started these communities of plants exist until another fire brings further change. There is also evidence of the intensity of a given fire resulting in different seeds being brought to the germination phase. Certainly one is impressed with the lack of man's knowledge of the total effects of fires and the need for a more complete understanding of the picture before fire is condemned as a tool in the manipulation of vegetation and its handling for the best use of all concerned.

A brief mention of fires as a factor in the management of the grasslands of South Africa is needed to complete my story of fires in arid lands. The African veld has long been subjected to fires by both the natives and the Europeans. There is much literature on this area, and many excellent experimental plots have been set up for the specific study of the effects of fires on vegetation (Shantz, 1947). One draws from these papers that at least occasional fires are needed to maintain these valuable grazing areas, but the manner and time of burning seem to be still unsettled. Much of the experimental work being done in South Africa aims to reach a balance between fires and grazing as well as, in certain areas, the maintenance of the native life. The delegation from South Africa at the Sixth International Grasslands Congress were keenly aware of fire as a factor in the

vegetation of their country and eagerly sought ideas from others as to procedures.

In summing up: fires have periodically swept through the vegetation of virtually every square mile on this earth that had anything to burn. These fires, both ancient and modern, have helped shape the present day patterns of vegetation. Civilized man has had a tendency to regard fires as the ultimate disaster to vegetation, and by and large tried to eliminate it as a factor in the environmental complex. So well has this disaster aspect taken that in some of our present day forests, fires can be catastrophic.

Everywhere man is found he has early mastered fire and used it for domestic purposes but has not been too careful to keep fire under control. Certainly he did not worry about the fires he used in corralling big game (Sauer, 1944). Later man was not careful with the fires he used to clear farmlands. Despite a changing attitude about fires from early man to the present, fires still are to be reckoned with.

Here's a quote from Stewart's novel "Fire":

> "So from the ancient past, fire has been at once comforter but mischief-maker, blessed but baleful, preserver of life but its destroyer, purifier but annihilator. It gives and it takes away."

To go back to a statement at the beginning of this talk. Fire, "A Bad Master, a Good Servant," is still to be mastered so that it can best serve modern civilization.

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