Fire in West African Vegetation

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INTRODUCTION

THERE is good evidence that fire in vegetation is a phenomenon of great antiquity, antedating the arrival of man by many millions of years (Harris, 1958). Prior to the appearance of man, natural fires were probably most frequently caused by volcanic eruption and lightning, as indeed they still are today. In those areas of the world subject to the twin conditions of severe dry seasons and the prevalence of so-called "dry" thunderstorms (which include large areas of the African continent), bush and grass fires caused by lightning are by no means uncommon. It may be assumed that such occurrences were as frequent in the past as they are now, and that the pattern and structure of modern plant and animal communities has to some extent been molded thereby. Conditions like these existed over large areas of Africa for many centuries, but it was not until the arrival of man that fire assumed an importance comparable to existing climatic factors in shaping the composition, structure and distribution of plant communities and thereby, the animal populations with which they are inseparably linked.

Stone Age man is known to have used fire no less than a quarter of a million years ago, as is shown by the hearths in the caves of Choukoutien, the home of Pekin Man. His African counterparts were certainly using fire more than 50,000 years ago (Oakley, 1955, 1962) and if we accept Africa as the continental cradle of the human race, as most modern palaeontologists do, possibly earlier than that. However, 50,000 years is quite long enough a time for man-made fires to have exerted a powerful influence on vegetation, and, for our purposes, we may safely accept the figure as it stands.

Man no doubt first obtained fire from natural sources, learned to tend and keep it alive, and then began to use it for a variety of purposes. At some stage, probably while learning to manufacture stone implements, he discovered the art of striking fire from flint and thereby freed himself from the bondage of tending a perpetual flame. From that moment he could not only use, but also make, fire whenever he wished and he has done so with far-reaching results ever since (Oakley, 1956). He had acquired a powerful tool with which he could shape his environment and he continues to use it for this purpose over considerable areas of the world today. The effects on vegetation in some areas, Africa in particular, have been profound.

Fire in African vegetation has attracted the attention of numerous authors from the earliest historical times. The literature on fire and its effects on African vegetation has been reviewed in recent years notably by Phillips (1930, 1936, 1965), Guilloteau (1957) and West (1965) who, between them, have dealt with the whole of Africa south of the Sahara. The literature dealing specifically with fire in West African vegetation has been reviewed by Ramsay and Rose Innes (1963). In the present paper I shall attempt to provide a general picture of the effects of fire on West African vegetation by drawing on my own experience in Ghana and on the work of other authors in various West African territories, including publications which have appeared since the previous review in 1963.

MAJOR PLANT COMMUNITIES IN THE WEST AFRICAN ENVIRONMENT

It is necessary at this point to describe very briefly the structure and pattern of distribution of the major plant communities in the West African environment. West African vegetation is distributed in a number of distinct, though seldom sharply defined, zones lying approximately parallel to one another and to the east-west trend of the coastline. These zones lie at right angles to the climatic gradient which runs through areas of increasing rainfall and humidity southward from the Sahara to the sea, and they are a direct expression of its overall control. The seven major vegetation zones are consecutively, the Saharan desert zone in the far north, followed first by three tree savanna zones[1] (The Sahel, Sudan, and Guinea savannas), then by the forest zone, and finally by the thin discontinuous mangrove swampland zone flanking the coastline in the south. Between the forest and the Guinea savanna to the north of its lies a narrow, partially broken belt of savanna–forest mosiac, the so-called "derived savanna" which represents a fire-induced ecotone between the two (Fig. 1). With the possible exception of two of the vegetation zones,

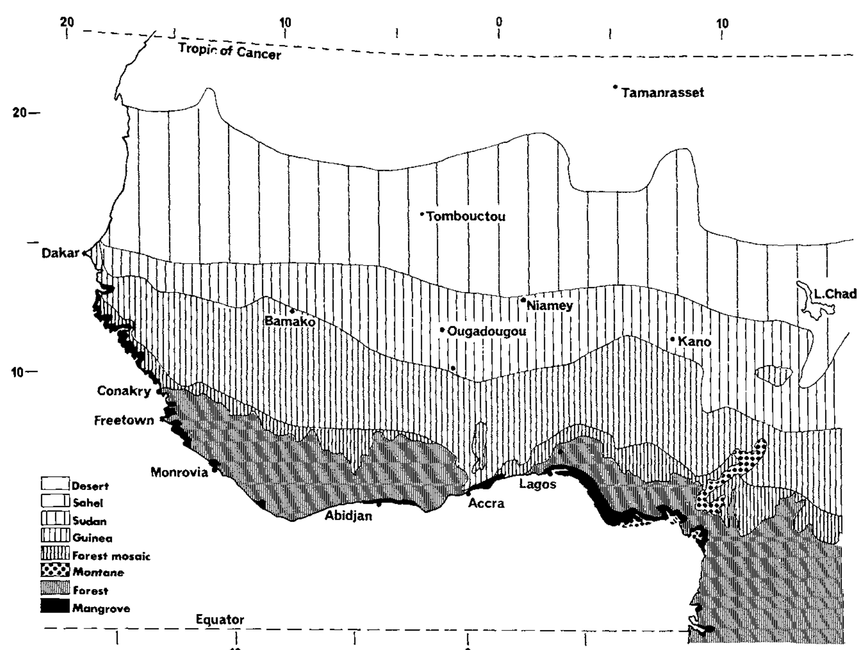

FIG. 1. Vegetation zones of West Africa.

[1] *Tree savanna* (see Boughey, A. S. 1957): a ground cover of grasses in which is distributed a tree population of variable height and density.

the desert zone in the north and the mangrove zone in the south, none of these belts of vegetation may safely be regarded as climax in status. In their relationship to one another, however, and in their response to major shifts in climate, they do resemble an authentic clisere or series of climaxes. For this reason, and making use of Clements' terminology suitably modified, I refer to them individually as proclimaxes [2], collectively as a proclisere. Whatever the vicissitudes of climate may have been, it is unlikely that the spatial relationship of one proclimax to another has changed, though the whole proclisere has undoubtedly migrated north or south, like beads on a moving string, in response to climatic oscillations in the Pleistocene. Fire-using man was in existence at this time and it may be assumed that his influence on the savanna vegetation then was similar (though not so marked) to what it is now but, due to migrations of the proclisere, has not been confined to identical geographical areas.

Unlike the climaxes of North America which are distributed from north to south (and from high to low altitudes) largely in response to the temperature gradient, the proclimax vegetation zones of West Africa are closely linked to rainfall and to its pattern of distribution throughout the year. A comparison of West African climatic and vegetation zones brings out this relationship very clearly (Fig. 2) and is relevant to any examination of fire and its effects on plant communities. The pattern of rainfall distribution throughout the year is probably more important in relation to the structure and distribution of vegetation, and to the influence of fire upon it, than is the more commonly considered average annual volume of rainfall. In West Africa, the longest period of seasonal drought and the lowest average annual rainfall coincide at the desert end of the spectrum, becoming respectively shorter and wetter towards the coast where opposite conditions occur. As we shall see, it is the central savanna zones which are most at risk, where hot rainy seasons followed by prolonged periods of drought not only produce large quantities of highly combustible grassy fuel, but also provide conditions ideal for the spread of fire. These fire-favourable conditions are further

[2] *Proclimax:* any plant community resembling a climax, but gradually replaceable by the true climax when disturbance or other local factors are removed and full climatic control is restored.

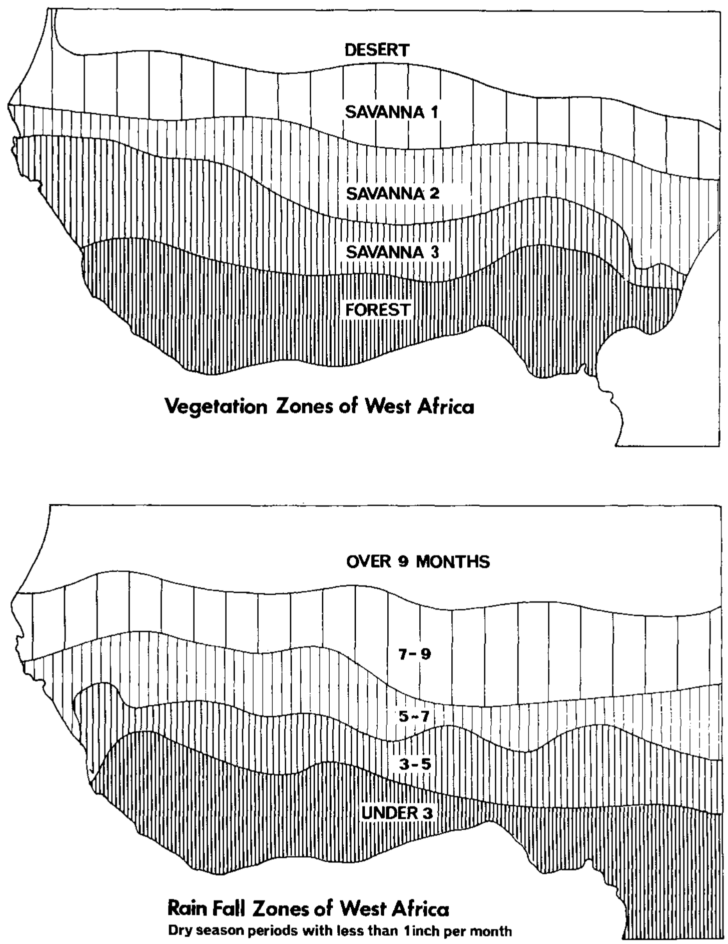

FIG. 2. Comparison of West African vegetation and rainfall zones.

enhanced by the desiccating effects of the harmattan wind blowing out of the desert during every dry season. In such circumstances only a spark is needed to start fires which may burn fiercely for weeks and blacken thousands of square miles of country.

Several zones may be eliminated from further consideration. Fires rarely if ever gain a foothold either in the sparsely scattered, largely ephemeral vegetation of the Saharan zone or in the tidal swamplands of the mangrove zone. They do occur occasionally in certain areas of the southern Sahel zone (Grosmaire, 1958) but, owing to the rather sparse, often ephemeral nature of the herbaceous growth and to the burden of grazing livestock, they are infrequent and cannot be regarded as an environmental factor of any great importance. We are left with the forest, derived savanna and Sudan and Guinea tree savanna zones.

FIRE IN VARIOUS VEGETATION TYPES

The Forest Zone

In the evergreen rain forest near the coast where rainfall exceeds one inch in every month of the year, annual precipitation averages at least 70 inches per annum (often exceeding 100), and the effects of the harmattan are negligible, it is doubtful whether natural (lightning) fires ever occur or, if they do, then only at wide intervals and on the smallest scale. Towards the northern ecotone, however, in a broad belt of semi-deciduous forest, the harmattan exerts a noticeable influence, there is an appreciable dry season, and natural fires have no doubt occasionally occurred. Man-made fires, however, are frequent.

Until recent times fire was one of the very few tools available to the African farmer for clearing land for crops and the practice of burning vegetation has always been, and still is, an inseparable part of the system of shifting cultivation. The trees are felled by axe and/or fire, the debris is burned on site, and the crop planted in the ashes. Seasonal cropping continues until decreasing soil fertility and increasing weed infestation, both reflected in declining yields, force the farmer to repeat the procedure on a fresh area of weed-free fertile forest soil, whilst the process of secondary plant succession restores fertility under forest regrowth on the abandoned farm behind him. The density of the farming population and the availability of land determine the length of the crop–fallow cycle and hence the ultimate fate of the original proclimax plant community.

Except in heavily populated areas, secondary succession in the forest proper is rapid and grass established on abandoned farms is quickly shaded out by pioneering forest trees, rarely surviving long enough to constitute a fire hazard. Consequently, burning associated with shifting cultivation within the forest proper seldom gives rise to destructive runaway fires. On the northern edge of the forest, however, the situation is different.

The Derived Savanna

As in all ecotones, vegetation in the derived savanna is delicately balanced against the combined edaphic and climatic factors of the environment, and is highly susceptible to disturbances, particularly those imposed by man. Such disturbances result in rapid, often persistent, changes in vegetation structure and composition, "higher" vegetation types giving way to "lower" ones. From a forest conservation point of view, it is unfortunate that land in the forest–tree savanna ecotone is especially prized for food crop farming by reason of the fact that rainfall is abundant and dependable, and the area is capable of producing good yields of crops suited to both savanna and forest zones. The process of secondary plant succession is somewhat slower here than in areas of higher rainfall to the south, initial secondary grass communities on abandoned farms tend to last longer, and the invasion of pioneer forest trees may be permanently checked by fires sweeping in from annually burned contiguous tree savannas. The forest is initially breached by fire and shifting cultivation, but maintainance of permanent grassy tree savanna is due to recurrent fires. In these conditions grassy tree savanna encroaches steadily on the forest proper whose boundaries are in slow retreat towards the south. That part of the derived savanna ecotone adjacent to the forest consists of islands of tree savanna embedded in forest whilst the opposite is the case on its other side. North of the forest–savanna mosaic lie the tree savannas of the Guinea and Sudan zones respectively which, of all vegetation zones, are the ones most subject to frequent fires.

Tree Savannas of the Guinea and Sudan Zones

The tree savannas comprise the largest area of West African vegetation, of which the Guinea and Sudan savannas together cover more than three quarters of a million square miles. Of all West African vegetation types, these two are the most subject to recurrent fires which, in this area, constitute a major environmental factor. Guinea and Sudan zones merge gradually across a broad ecotone and the precise position of the boundary between them is still a matter of personal interpretation. At its southern extremity the Guinea savanna consists of a basic ground cover of tall coarse bunch grass in which is distributed a dense population of broad-leaved trees about 50 feet high, whose crowns often touch but do not form a continuous closed canopy (Fig. 3). The stature and density of the tree population decline progressively towards the north in response to diminishing annual rainfall and increasing length of the dry season. At the northern extremity of the Sudan zone, trees approximating 20 feet in height, including an appreciable percentage of fine-leaved drought-resistant species, are widely scattered through an annual–perennial bunch grass mixture of medium height. The entire area has been the home of man for many centuries and is subject to fierce sweeping fires in every dry season.

Lightning has no doubt always been responsible for occasional fires but by far the greatest number are due to the activities of man. Hunters use fire to drive animals out of hiding; cattlemen burn off unpalatable stubble at the end of the growing season to promote early growth of off-season grass; but most runaway fires undoubtedly originate while clearing land for cropping under a system of shifting cultivation. Fires started early in the dry season, when grass stems and leaf bases are still green, are seldom hot and quantities of unburned grass stubble are left standing (Fig. 4). Such residues will not support another fire in the same dry season. Fires occurring late in the dry season, however, burn fiercely in very dry conditions, destroy suckers and seedlings, damage the trunks and branches of larger trees, and expose the soil to insolation and erosion (Fig. 5).

The densest human populations are concentrated in a broad belt beginning near the northern edge of the Guinea savanna and extend across the entire Sudan zone. Heavy population pressure and concomitant intense shifting cultivation (incorporating the use of fire) has caused the emergence of distinctive plant communities through positive selection of useful species and incidental destruction of others. Trees of particular value (e.g. *Butyrospermum* sp. for oil, *Parkia* sp. for fruits, *Acacia albida* for stockfeed and *Adansonia* sp.

FIG. 3. Typical fire-controlled tree savanna of the Guinea savanna zone. Note dense tall grassy ground cover.

for general purposes) are protected during clearing operations and the crops are planted around them. As the selected trees grow and other species slowly disappear under repeated clearing and burning, a "parkland" savanna of widely spaced "super-mature" trees develops over considerable areas (Fig. 6). Well before this stage is reached the cultivation–fallowing cycles become so short that bush fallowing

FIG. 4. Aftermath of a "cool" burn set early in the dry season. Grass foliage has been burned but stems remain; trees are lightly scorched. Residues will not maintain another fire.

FIG. 5. A hot burn, late in the dry season. The ground cover is completely cleared and trees are charred.

FIG. 6. "Parkland" tree savanna resulting from many years of fire and shifting cultivation: Shea Butter trees in annual grassland.

can no longer restore soil fertility, shifting cultivation gives way to sedentary farming, and the selected trees develop under ideal conditions, free of fire and woody competition.

Quite a different type of selection is exerted by fire alone and occurs naturally over enormous areas subject to frequent burning. A number of tree species possessing protective coverings of thick corky bark or reproducing vegetatively by means of suckers from big shallow root systems, have an obvious survival-advantage over species not so equipped. At the other end of the scale are species particularly susceptible to fire damage. Between these two extremes lie the great bulk of species which may be assumed to exhibit every degree of susceptibility to damage by fire. Some quantitative results on selection by fire have been published by Hopkins (1965), Ramsay and Rose Innes (1963), and Charter and Keay (1960). There can be little doubt that the present floristic composition of very large areas of African tree savanna is, to a marked degree, the result of many centuries of selection through frequent man-made fires.

Seedlings and saplings of all species are subject to heavy damage by fire because, as Hopkins points out, they live close to the ground in a sphere subject to the highest fire temperatures and are far more likely to suffer loss of apical buds or destruction of cambium than well grown trees of the same species. He reported that in five consecutive annual fires at Olokemeji in the derived savanna zone, fewer than one quarter of a large number of young trees below three m high survived, whereas only one of 28 trees over eight m high succumbed during the same fires.

As thousands of years of annual burning have no doubt reduced or eliminated an appreciable number of species that would otherwise have populated the present tree savannas, it would be difficult experimentally to demonstrate the nature of the true climax, except in areas (like Olokemeji) close to existing supplies of forest seeds, and then only over long periods of time. Keay (1959) has speculated on the origins of the derived savanna.

The combined effects of fire and farming over many centuries have eliminated the original climax communities. There are, however, small relict communities partially protected for long periods, which indicate the level of potential development (Ramsay and Rose Innes, 1963). These so-called "fetish groves" have usually sprung up on sites of abandoned habitations where the bones of the village ancestors lie buried. It may be assumed that such fetish groves established themselves at a fairly late stage in the exploitation of the land and are much influenced by the burning and selective clearing of the surrounding country, with consequent elimination of sources of seed of climax species. The groves are composed of trees of both fire-tolerant and fire-tender local species whose seeds are dispersed by wind, small mammals including bats, and birds. Below them are scattered shrubs and a sparse grassy ground cover. These relicts indicate quite clearly that the prevailing climate as far north as the Guinea-Sudan ecotone is fully capable of supporting savanna woodland with a partially closed to closed canopy 60 feet in height (Fig. 7). If the surrounding country were protected and depleted soil fertility restored, it is probable that vegetation would develop into closed canopy deciduous forest at about the same height, thereby extending the present forest boundary by over 200 miles. But this will never happen under present social conditions.

FIG. 7. A fetish grove, partially protected from fire, surrounded by heavily farmed land. The trees are about 60 feet high.

Observers are now generally agreed about the gross effects of fire on West African vegetation. It is accepted (a) that fire retards the natural development of vegetation towards a forest or woodland type climax and may hold it more or less permanently in a tree savanna stage; (b) that fierce hot fires occurring late in the dry season are particularly destructive of woody elements, especially seedlings and suckers; (c) that moderate "cool" fires occurring early in the dry season are less destructive and will allow slow development of woody vegetation towards a woodland type climax; (d) that fire is responsible not only for shaping the physiognomic structure of plant communities but exerts a powerful selective influence on floristic composition as well, fire-tolerant species being encouraged and fire-tender ones eliminated; and (e) that fire, properly used, is a powerful tool for shaping vegetation towards chosen objectives. These observations are backed by a few widely scattered but reliable experiments.

EXPERIMENTAL RESULTS

Barely a dozen long-standing experiments in West Africa are capable of yielding reliable quantitative data on the effects of fire on the cover and composition of vegetation, but the results may be applied to a wide area. In addition, recent work has produced information on fuel consumption in late and early burns, on fire temperatures, changes in cover and composition, and specific tolerance to fire (Hopkins, 1963); on the relation between fire and the sprouting of trees and grasses (Hopkins, 1963); and on the practical use of fire in range management (Rains, 1963). The old burning experiments are scattered through various political territories and all the natural tree savanna zones. Selected results representative of several zones are given below.

Forest–Derived Savanna Ecotone

The oldest and best known fire experiments in West Africa were established astride the forest–derived savanna ecotone in the Olokemeji Forest Reserve near Ibadan, Nigeria 42 years ago: an extremely simple design became the prototype of several similar experiments in other territories. Three small plots laid down in open grassy tree savanna in 1929 were enumerated, clear-felled, and then treated annually as follows:

a) burned early in the dry season
b) burned late in the dry season
c) protected from fire and other disturbance

Re-enumerated 28 years later, the protected plot had developed into dense young closed forest rich in fire-tender species derived from

Table 1. Olokemeji: Comparison of Plots After 28 Years of Treatment

	Late Burn		Early Burn		Protected	
	No.	%	No.	%	No.	%
No. of individuals	98	—	163	—	433	—
No. of species						
(a) fire-tolerant	14	87.5	21	63.6	17	39.5
(b) fire-tender	—	—	8	24.2	20	46.5
(c) exotic	2	12.5	4	12.1	6	14.0
Total spp.	16	100.0	33	99.9	43	100.0

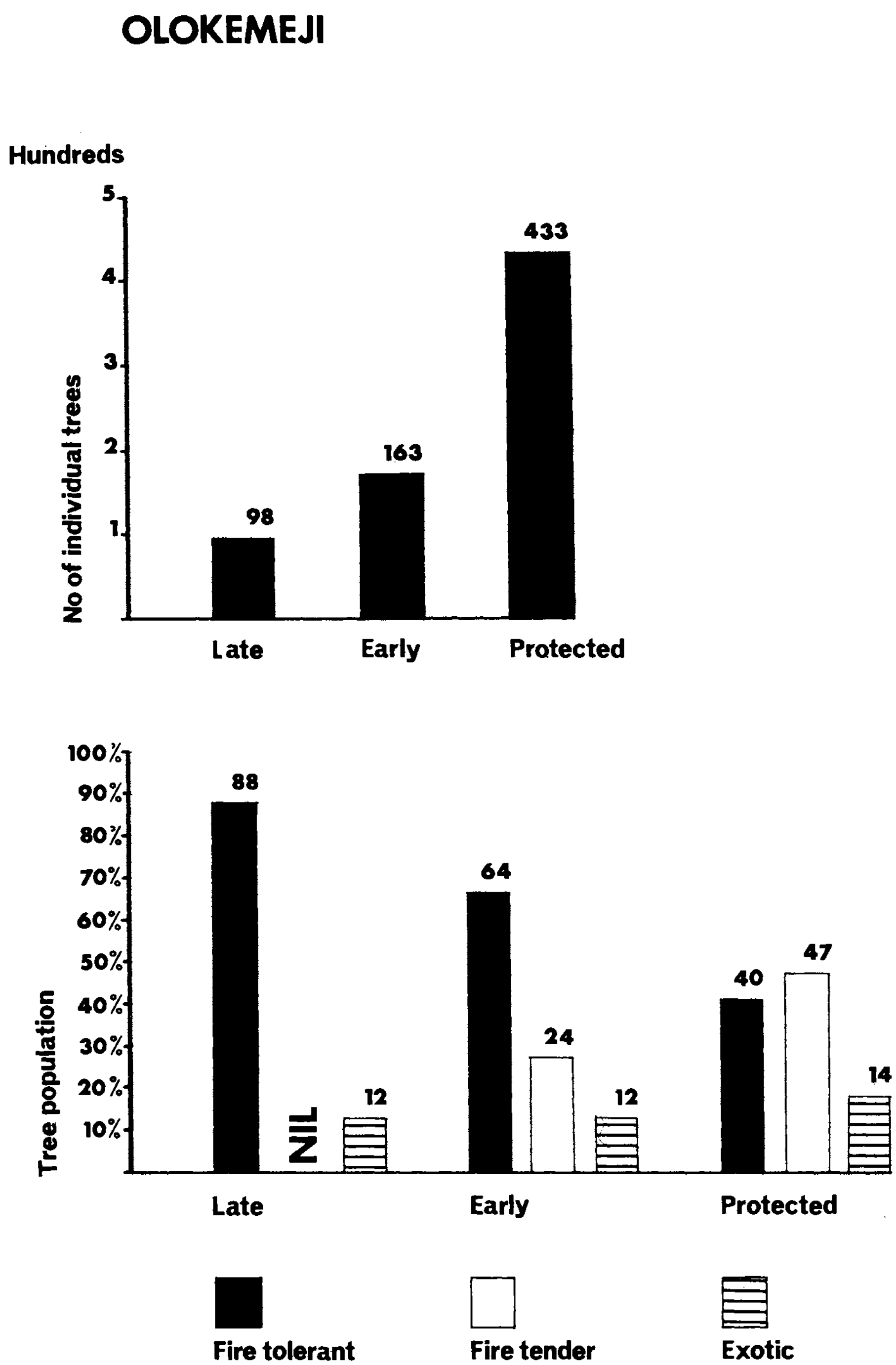

Fig. 8. Results of 28 years of treatment in derived savanna at Olokemeji. Nigeria.

existing forest nearby, the grassy ground cover had almost disappeared, and a species of forest grass was invading. The late burned plot had been held at the open tree savanna stage, and the early burned plot was intermediate between the other two, with patches of dense forest expanding into the grass which was becoming thin and increasingly difficult to burn (Charter and Keay, 1960). Detailed figures are given in Table 1 and the results are expressed graphically in Fig. 8.

Derived Savanna near the Guinea Savanna Zone

A similar experiment was laid down near the northern edge of the derived savanna zone in the Kokondekro Forest Reserve near Bouake in the Ivory Coast 35 years ago. (Mensbruge and Bergeroo-Campagne, 1958; Mensbruge, 1961). The three plots, each two ha in area, were established in secondary grassy tree savanna on an old cotton field. The trees were not felled but treatments were otherwise the same as at Olokemeji. Summarised results shown in Table 2 compare figures from the initial enumeration in 1937 with those from the fourth enumeration 24 years later. By 1961, woody vegetation in the late burned plot, especially seedlings and young trees, had been severely damaged, the total increase in woody growth was less than two percent, and grasses were flourishing. The early burned plot showed an increase in individual trees of 117 percent with greatest gains, as expected, in the smallest tree class; crowns were beginning to merge and grass cover was often too sparse to support a fire. In the protected plot the gain in the number of individual trees since 1937 was 182 percent, including several new species, and the grassy element was sparse and patchy; the greatest gains were in the smallest tree class but significant increases were recorded in all classes. The effects of fire on the youngest classes were obviously catastrophic. Detailed results are given in Table 2, some of which are illustrated in Fig. 9.

Guinea Savanna–Sudan Savanna Ecotone

The last results recorded here come from an experiment laid down on the northern edge of the Guinea savanna in the Red Volta River Forest Reserve of northern Ghana in 1949 (Ramsay and Rose Innes,

Table 2. Kokonedekro: Comparison of Plots After 24 Years of Treatment

		Diameter Classes									
		0–2 cm.		2–5 cm.		5–10 cm.		10 cm.+			Increase (%) over 1937
Treatment	Year	No. of specimens	% of Total	No. of specimens	% of Total	No. of specimens	% of Total	No. of specimens	% of Total	Grand Total	
Late burn	1937	1,535	22.3	3,494	50.7	1,675	24.3	184	2.7	6,888	
	1961	6,293	90.0	191	2.7	222	3.2	284	4.1	6,990	1.5
Early burn	1937	1,805	25.4	3,912	55.1	1,271	17.9	113	1.6	7,101	
	1961	10,582	68.7	2,166	14.1	1,760	11.4	902	5.8	15,410	117.0
Protected	1937	1,262	18.0	3,716	53.0	1,855	26.5	172	2.5	7,005	
	1961	11,788	59.7	4,018	20.3	2,763	14.0	1,187	6.0	19,756	182.0

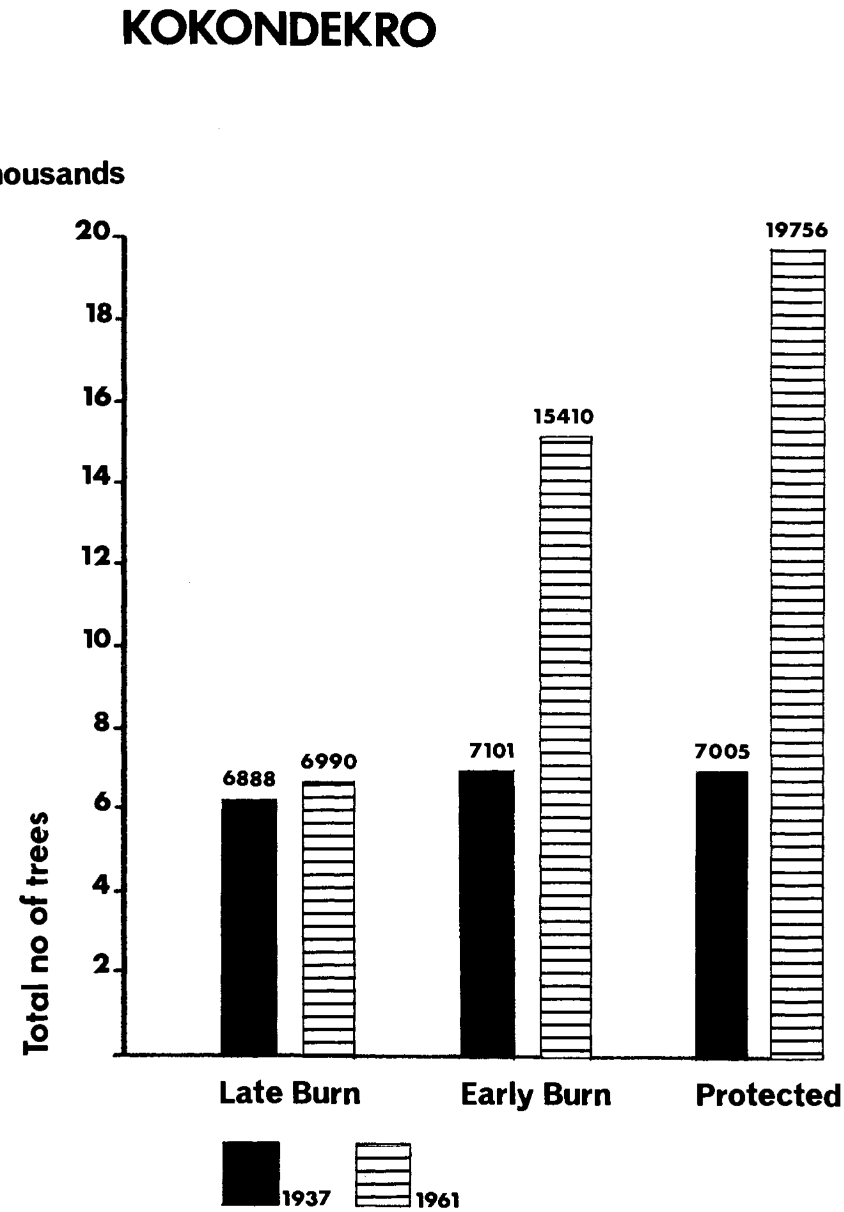

FIG. 9. Results of 24 years of treatment in derived savanna at Kokondekro, Ivory Coast.

FIG. 10. Grassland produced by 11 years of annual hot late-dry-season burns in the Guinea-Sudan savanna ecotone, Red Volta River, Ghana.

1963). The design was identical to the Olokemeji experiment except that the plots were each 10 acres in size. The first 100 percent enumeration of trees and shrubs was carried out in 1950, the second in 1960, at which time the herbaceous components were also analysed.

The late burned plot in 1960 showed an unexpected increase in the tree crop though this may prove to be impermanent. But in general appearance the plot remained an almost open grassland with scattered young trees invading (Fig. 10). The protected and early burned plots (Figs. 11–13) both showed substantial gains in the tree crop which is reflected in the stem counts taken at two enumerations, as shown in Table 3 and Fig. 14.

Fierce fires of the late burns exerted a powerful influence on the composition of the tree population. One sensitive species was reduced from approximately 44 percent to 14 percent of the total crop whilst its place was taken by a comparable percentage of fine-leaved fire-tolerant species: no such change was recorded either under protective or early-burn treatments. Moderate fire-resistance or extreme fire-

FIG. 11. Light open tree savanna produced by 11 years of annual cool early-dry-season burns in the Guinea-Sudan savanna ecotone, Red Volta River, Ghana.

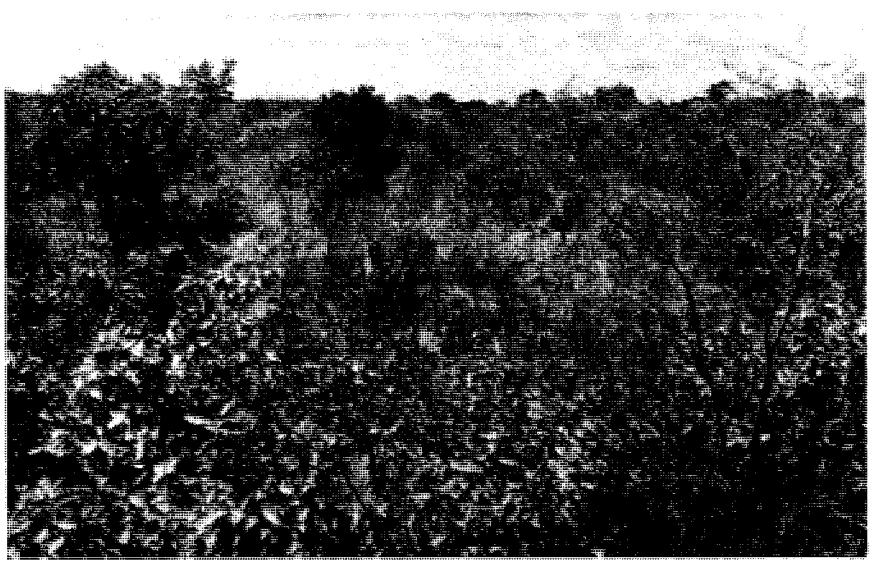

FIG. 12. Dense tree savanna produced by 11 years of protection from all disturbance including fire, in the Guinea-Sudan savanna ecotone, Red Volta River, Ghana.

FIG. 13. Dense rank growth in interior of protected area illustrated in Fig. 12.

sensitivity was noted in detailed results recorded for several other species.

Results for the grassy components derive from a single analysis in 1961 and are therefore less reliable than those for trees. But as vegetation and conditions on all three plots were judged in 1949 to be very similar, obvious differences between them may be accepted as due to treatments applied. The total percentage basal areas for grasses were identical on the two burned plots but 26 percent lower on the protected plot. The difference is believed to be due to strongly increased tree competition on the protected plot which will probably

TABLE 3. RED VOLTA RIVER FOREST RESERVE: TREE STEM COUNTS AT AN INTERVAL OF ELEVEN YEARS

Treatment	Number of stems		Increase (%) since 1950
	1950	1960	
Protected	1,558	6,838	339
Early burnt	1,093	3,197	193
Late burnt	1,148	2,048	78

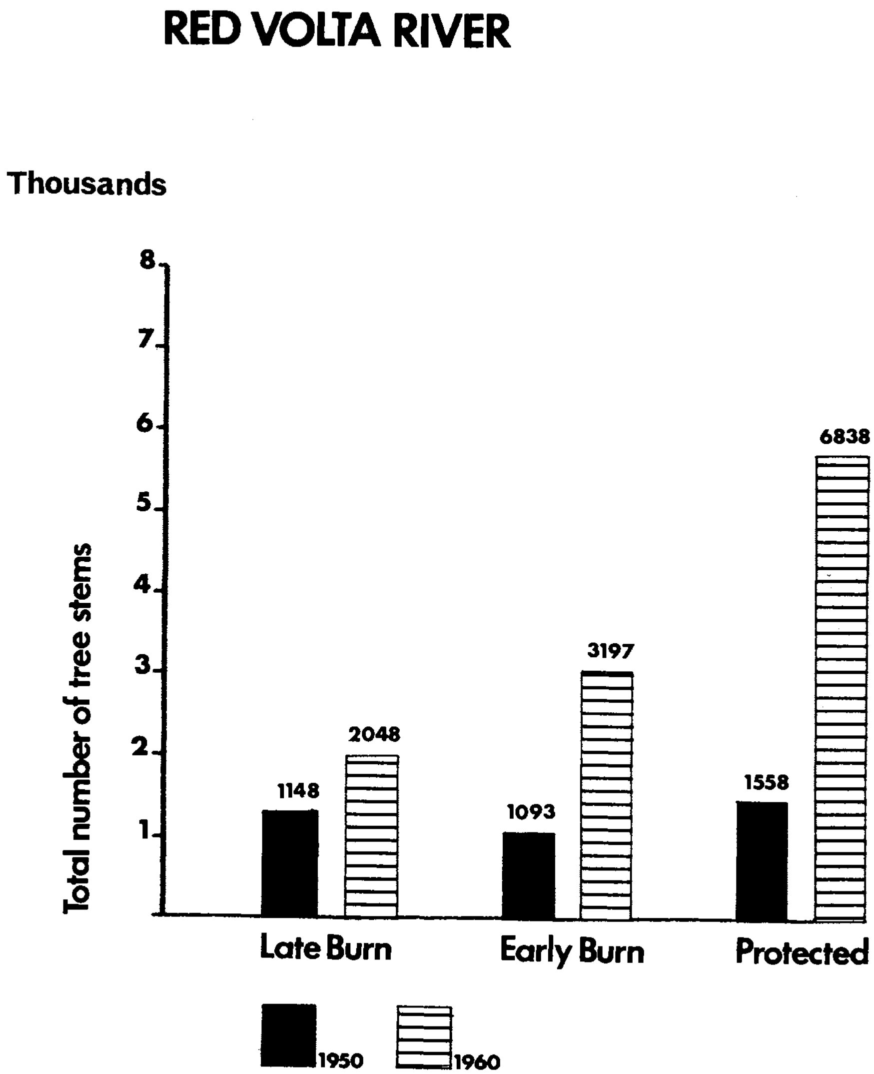

FIG. 14. Results of 11 years of treatment in the Guinea-Sudan ecotone, Red Volta River, Ghana.

also make itself felt on the early burned plot at a later date. Three tall grasses which generally act as a "nursery fringe" to developing woodland showed marked increases in basal cover under increasing degrees of protection: figures for the late burn, early burn and protected plots were 2.6 percent, 13.1 percent and 36.6 percent respectively. This is consistent with the early stages of development towards a woodland type climax but is likely to be reversed as tree competition increases still further. A corresponding difference was noted in the basal area of a group of short grasses which were well represented in the late burned plot but had almost disappeared under protection. Several medium grasses showed an increase in basal area between late and early burns, but a marked decline under complete protection.

Fire Temperatures

In the course of field work at Olokemeji Hopkins (1965) studied the temperatures of fires in derived savanna vegetation that had been subjected to late and early burns for over 30 years, at ground level and at one-meter intervals to a maximum of six m above the surface, by exposing metal strips painted with thermo-sensitive paints. The method allows a large number of observations but results represent ranges of temperature rather than precise temperature figures: the precisely-known lowest temperatures of the ranges recorded were the ones quoted in results. Five paints were used covering a total range from 66°C to 538°C.

Ground level temperatures on both late and early burns invariably exceeded 538°C but fell away above 0.1 m, quite sharply in the case of early burns, more gradually on late burns. Early burns did not generate temperatures of more than 66°C above a height of three m but late burns exceeding 538°C were sometimes recorded up to three m above the ground, and temperatures of over 100°C consistently to heights of more than six m. Wind speed was an important factor in increasing the severity of a fire. The percentage of herbage burned in a fire was taken as a measure of its severity. One exceptionally light (early) fire consumed only 25 percent of available herbage: corresponding figures for late (severe) burns ranged from 64 percent to 96 percent with a mean of 84 percent. The mean dry weight of herbage available at burning was 520 g/m^2.

Hopkins noted that ground fire temperatures under the tall grass at Olokemeji were higher than in the much shorter grass in the Guinea savanna zone near Dakar in Senegal (maximum 90–100°C recorded by Pitot and Masson, 1951), and in the northern Guinea savanna zone near Samaru in Nigeria (maximum 340°C recorded by Rains, 1963). Ground temperatures of 715–850°C were recorded by Masson in the Sudan vegetation zone but the conditions were not noted. At other heights, fire temperatures from Senegal and Olokemeji were comparable. Both Pitot and Masson and Rains noted that grass fires last only a very short time and that high temperatures are maintained for a matter of only a few seconds. These observations agree with those recorded by Cook (1939) at Frankenwald near Johannesburg.

Hopkins (1963) also investigated the relationship between fire and sprouting of trees and grasses. Fire promoted sprouting in three out of four of the commonest trees and both of the grasses studied in the derived savanna at Olokemeji. A significant correlation was found between the dates of burning and subsequent sprouting, and also a fairly constant "period to sprouting" which varied from 6 to 10 days for grasses and from 18 to 30 days for trees. Hopkins postulated that high temperatures either initiate a sprouting promoter or destroy a sprouting inhibitor. He also showed that about two thirds of the energy contained in non-woody aerial shoots and about three quarters of the energy in herbaceous grass shoots is lost to the biological system through annual fires.

Use of Fire in Range Management

Rains (1963), working in the northern Guinea savanna near Samaru, Nigeria is one of very few authors who has recorded results on the positive use of fire in range management in the tree savanna zones of West Africa. He mentions the time-worn controversy over the deliberate use of fire, the general policy of foresters to burn early in the dry season (not from choice but to avoid fiercer, more destructive, fires later in the dry season), and the dilemma of the grazier who would avoid burning altogether if only a practical alternative could be found of controlling bush encroachment, eliminating harsh ungrazed tussocks, and maintaining grass in a permanently vigorous condition.

The basic facts on which range management procedure must be built are concerned with the differential response of various grass and tree species to burning at different times of the year, and the demands of the grazing animal. The basic facts in the Samaru area can probably be used as a guide over large areas of the Guinea savanna and portions of the Sudan Savanna zones. They are (a) that early burning at the end of the growing season tends to damage perennial grasses which are still partially green and have not yet returned all their food reserves from leaves to storage in the roots. Should they be induced by fire to sprout again, out of season, they must do so at the expense of partially replenished root reserves. Finally, if the resulting regrowth is grazed, root reserves are even further depleted and the most vigorous of plants must die in the course of a very few years of such treatment, (b) that burning of dormant grasses early in the dry season causes minimal damage but, if the regrowth is then grazed the plants are seriously weakened; (c) that savanna trees usually sprout well before the grasses and often long before the beginning of the rains: they are most sensitive to fire damage at this time, whereas grasses are still dormant and escape harm; and (d) that effective control of woody growth depends upon the frequency of burning and the severity of each fire which, as we have seen, depends on the amount of grassy fuel available after grazing.

These facts lead one directly to consider the carrying capacity of this type of rangeland under a chosen burning regime, the tonnage of beef that can be produced per square mile, the economics of production and marketing, and hence the area required for viable ranching units. We need not concern ourselves with these aspects except to say that the limiting factor at this stage of development is the amount of grass fuel retained after grazing for control of bush encroachment by fire. Rains estimates that 700–1000 pounds or 1500–2500 pounds of dry matter per acre are required respectively to control woody scrub two to three feet high, or taller scrub and small trees. He also demonstrated that annual fires set early in the growing season, usually just after the first rains (with trees sprouting, but grass still dormant), can effectively reduce uncleared bush to open grassland suitable for grazing within 4 to 5 years (Fig. 15). The same result can be achieved, but in a considerably longer period, if range is burned and grazed in alternate years.

Fig. 15. Grassland produced from uncleared Guinea savanna by annual hot burns early in the rainy season following one inch of rain: Shika, Northern Nigeria.

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The map in Fig. 1 is based on a simplified version of the Vegetation Map of Africa (Keay, R. W. J. et al, 1958) which appears in Plant Life in West Africa (Lawson, G. W., 1966), both published by Oxford University Press; the two sketch maps in Fig. 2 are adapted from those appearing in Man Nature and History (Russell, W. M. S., 1967) published by Aldus Books Ltd, London: I am grateful for permission to reproduce these illustrations modified, as necessary, to suit my needs.

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