The effects of brush fires on vegetation: the Aubréville fire plots after 60 years

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SUMMARY

The oldest African experiment on the dynamics of woody vegetation in relation to brush fires was set up by Aubréville in 1936 at Kokondékro, Cote d'Ivoire. The findings from the most recent assessment show reforestation in the plot protected from fires (117 species present) and a savanna-type development in the plot affected by late fires. Development is variable in the plot affected by early fires, depending on soil fertility. Regeneration of exotic species into the plots has now complicated the picture.

Keywords: Côte d'Ivoire, fires, forest protection, savanna.

INTRODUCTION

Foresters in savanna zones have long observed the disastrous effects of brush fires on forest stands. In the 1930s, they concluded that repeated fires turn forests into less and less wooded grassy savanna. But litle heed was paid to them and "plenty of people are still sceptical about the artifical character of the savanna in the Sénoufo and Mossi regions" [Bégué 1937], because it was their view that the origins of this were soil-related (edaphic). After various phyto-sociological studies carried out in 1931 and 1935 in northern Côte d'Ivoire, Bégué started to wonder if this 'savannization' phenomenon was reversible, "if the evolution of more or less wooded grassy savannas towards closed stands is possible?,.. Our unhesitating reply is that it is, as long as brush fires are radically eliminated..."

In 1953, Aubréville shared Bégué's persuasion that the climax of the Bouaké region is semi-deciduous closed forest, and that fire is the decisive factor in the regression of these forests. To corroborate his convictions, he had to answer two questions:

- is the savanna in central and northern Côte d'Ivoire anthropic or edaphic?
- what role does fire play in the creation of savannas and their continuance?

In 1936, to find these answers, he set up in Côte d'Ivoire a three-part network to examine the impact of fires on woody vegetation. The Kokondékro station, near Bouaké, is the sole remaining one.

SITE CONDITIONS

Kokondékro is situated in a transitional zone between the Sudano-Guinean and forest-Guinean climatic belts, using Aubréville's definitions (1950). The dry season lasts from November to March. The rainy season usually shows two rainfall maxima (June and September), but in some years the short rainy season in July and August fails to materialise. Average annual precipation amounts to 1,086 mm (1974-1990) with marked variations from one year to the next. The average annual temperature is 26ºC. The parent rock is a calco-alkaline granite, with outcrops in places in the lower part of the experimental zone. The upper part of the experimental plots rests on a fossil lateritic slab, while the lower part rests on sloping ground with fine quartzy and ferruginous gravel.

The experiment is situated in the heart of the Kokondékro Forest Reserve, surrounded by natural forests (the upper part of each plot) and planted forest (*Cassia siamea, Gmelina arborea* and *Tectona grandis* planted in the early 1940s).

THE EXPERIMENTAL DESIGN

The experiment consists of three rectangular two-hectare plots (100 x 200 metres) separated by firebreaks ten metres wide. The long axes of the plots run up and down with the slope. Grazing, crop cultivation, and timber extraction in them are forbidden. Every year since 1937 a different treatment system has been applied to each plot:

- plot 1: total fire protection;
- plot 2: "early fires", starting on 15 December at the start of the dry season ;
- plot 3: "late fires" starting at the end of the dry season, during the first half of May.

Before the experiment, a 6-year fallow system

In 1930, on the experimental site, there was a seven-hectare wooded park, with a cotton crop. It had been left fallow from that year on, and burnt every year until 1936. In 1937, for the first inventory, the three plots looked like tree savanna, with a homogeneous flora.

TABLE 1. *Number of stems per hectare by DBH class in each plot in 1937.*

Diameter class	Total protection	Early fires	Late fires
Regeneration < 2cm	631	902	767
≥ 2 and < 5 cm	1858	1956	1747
≥ 5 and ≤ 10 cm	927	635	837
≥ 10 cm	86	56	92
Total	3502	3549	3443

The totally protected plot, with 50 species present, was the poorest from the botanical standpoint. The early and late fire plots had 60 and 62 species respectively. A few large trees had been kept in the cultivated areas and formed the overstorey of the initial stand: these included *Bridelia ferruginea, Cussonia arborea, Ficus sur, Lannea kerstingii, Parkia biglobosa, Piliostigma thonningii, Terminalia glaucescens, Trichilia emetica* and *Vernonia colorata.*

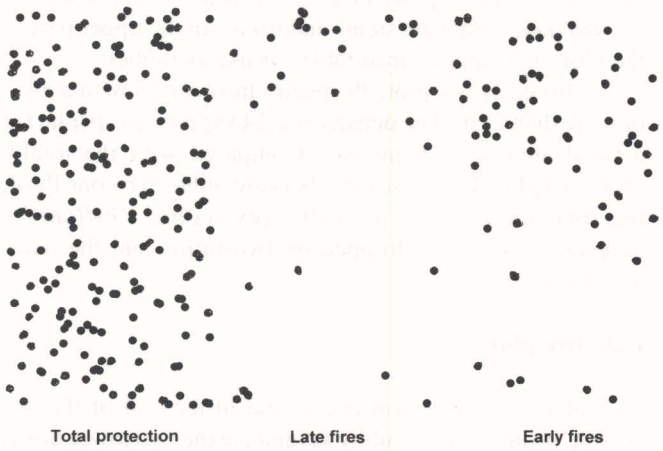

FIGURE 1. *Distribution of trees with a girth of more than 90 cm.*

Experiment monitoring

Since the start of the experiment, there have been seven inventories: in 1937, 1945, 1953, 1961, 1968, 1976 and 1994. The first four included only four diameter classes[1]: 0-2 cm; 3-5 cm; 6-10 cm; 11 cm and more. In 1968, three more classes were added: 11-15 cm; 16-20 cm; and more than 20 cm. The 1976 inventory used successive 2 cm. classes up to 34 cm, a 34-39 cm class, and a last class of 40 cm and more. In 1994, the girth measurements were made for all stems with a girth of 2 cm. and more, and the coordinates of all trees were recorded to the nearest decimetre.

THE VEGETATION AFTER 58 YEARS

In what follows, the description of the development of the vegetation is based on an analysis of the following publications: Aubréville (1953), Dereix and N'Guessan (1976), CFCTI-CI (1969), Mensbruge (de la) and Bergeroo-Campagne (1958), and N'Guessan (1984).

Marked differences in the vegetation can now be observed in the three treatments. Figure 1 shows the distribution of trees of more than 90 cm girth, while Figures 2 and 3 indicate basal areas, in the 1994 inventory.

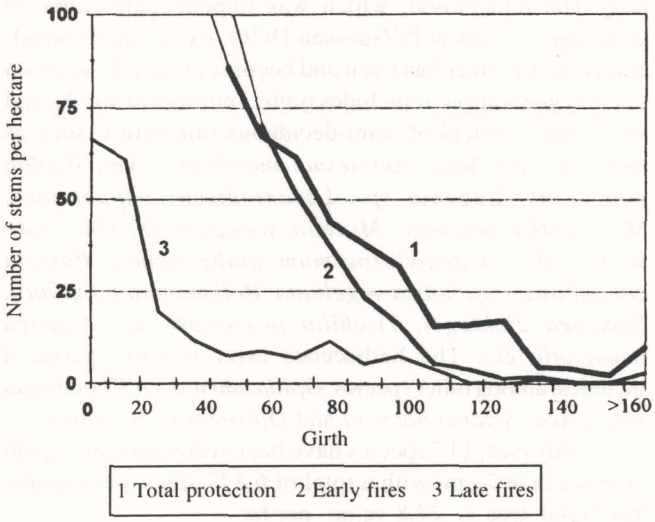

FIGURE 2. *Number of stems per hectare by girth class.*

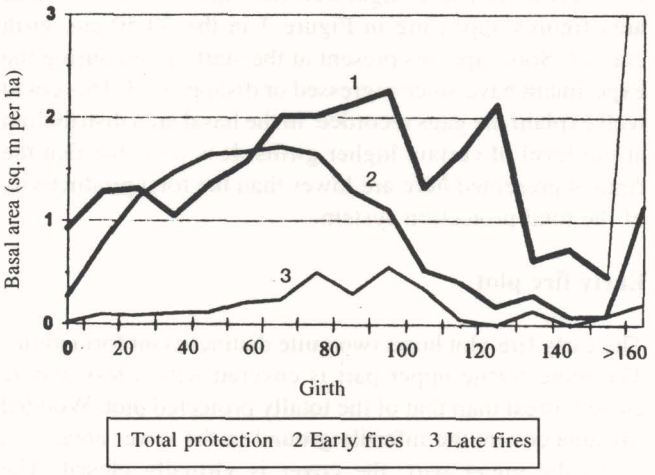

FIGURE 3. *Basal areas (sq. m per ha) by girth class.*

[1] All the girth and diameter measurements were taken at 1.3 metres above ground level.

Total protection plot

After 65 years of fallow, 58 of which have enjoyed total protection, this plot boasts a dense, semi-deciduous forest. The cover is virtually continuous and invaded by creepers and vines. There are various large trees: *Afzelia africana, Antiaris toxicaria, Trilepisium madagascariense, Canarium schweinfurthii, Cassia siamea, Milicia excelsa, Cola cordifolia, Daniellia oliveri, Elaeis guineensis, Gmelina arborea, Khaya grandifoliola.* Among them there are still a few rare savanna species, which have been present since the experiment began. The others are either fast-growing dry closed forest species requiring light, or semi-deciduous species of secondary formations, or lastly very dynamic exotic species. Just a handful of very large specimens of *Ceiba pentandra, Bombax buenopozense, Cassia siamea* and *Canarium schweinfurthii* soar over this forest in the upper part of the plot. The underwood, which was impenetrable some 20 years ago (Dereix & N'Guessan 1976), has thinned considerably as the cover has risen and become closed. In addition to the regeneration, it includes quite a number of shrubs and small trees typical of semi-deciduous rain forest, such as *Aidia genipaeflora, Antidesma membranaceum, Baphia pubescens, Eugenia sp., Lecaniodiscus cupanioides, Malacantha alnifolia, Morelia senegalensis, Olax subscorpioidea, Campylospermum glaberrimum, Pavetta corymbosa, Psychotria vogeliana, Rothmannia longiflora, Samanea dinklagei, Trichilia prieureana* and *Uapaca heudelotii*, etc. The herbaceous layer is very sparse; it includes, among other species, *Opilia amentacea, Thonningia sanguinea, Setaria barbata* and *Oplismenus bormanii.*

In this plot, 117 species have been recorded with a girth of more than 2 cm, with a total of 6,877 stems per hectare. The basal area is 27.8 sq.m. per ha.

Signs of light exploitation for medicinal and herbal purposes (*Olax subscorpioidea, Sarcocephalus latifolius*, etc) and timber (*Cassia siamea, Daniellia oliveri*, etc.) have been recorded. These might well correspond to the low basal area figures appearing in Figure 3 in the 30-50 cm. girth classes. Some species present at the start of and during the experiment have since regressed or disappeared. This could well explain the gaps recorded in the basal area distribution at the level of certain higher girths. It is probable that the figures presented here are lower than the total productivity of the total protection system.

Early fire plot

The early fire plot hosts two quite distinct plant formations. The more fertile upper part is covered with a less mature closed forest than that of the totally protected plot. Wooded savanna covers the infertile ground in the lower area.

In the upper part, the cover is virtually closed. The crowns are starting to be invaded by creepers. In the overstorey we find the following exotic species: *Cassia siamea, Gmelina arborea, Mangifera indica* and *Tectona grandis.* These four species alone represent 39.7% of the basal area of the entire plot. The dominant species also include open woodland/forest and dry closed forest species, and species colonising secondary forest: *Cola cordifolia, Diospyros mespiliformis, Holarrhena floribunda, Lannea barteri* and *Pterocarpus erinaceus.* Some specimens of more typically savanna-related species, such as *Terminalia glaucescens* and *Vitex doniana*, grow among the co-dominant species.

The underwood includes some saplings from large-sized tree species of the semi-deciduous closed rain forest *(Antiaris toxicaria, Canarium schweinfurthii*) and many shrubs and small trees typical of this same formation: *Aidia genipaeflora, Eugenia sp., Lecaniodiscus cupanioides, Malacantha alnifolia, Olax subscorpioidea, Rothmannia longiflora, Trichilia prieureana*, etc. The underbrush is invaded by *Phyllanthus nummularifolia.* Wherever the cover is not yet closed, the underwood forms a dense layer which hampers the development of a continuous herbaceous carpet. The herbaceous species, which are very scattered, include *Euclasta condylotrica, Dioscorea bulbifera* and many young ground creepers.

In the lower part, the stand is very open and invaded by grasses (*Elymandra androphylla, Panicum fragmitoides, Hyparrhenia smithiana, Euclasta condylotrica*) and herbaceous and sub-ligneous dicotyledons *(Aspilia bussei, Cissus rufescens, Lippia rugosa, Tephrosia sp.*, etc). Many sprouts from species in the over-storey are scattered in this herbaceous layer, but the annual fires stop them spreading. The over-storey consists almost exclusively of savanna species: *Bridelia ferruginea, Crossopteryx febrifuga, Cussonia arborea, Daniellia oliveri,, Ficus sur, Piliostigma thonningii, Pseudocedrla kotschyi* and *Terminalia glaucescens.* All these trees bear the after-effects of repeated fires. They are twisted and, unlike the stems and trunks in the upper part of the plot, they appear unsuitable for use as timber.

In this early fire plot, 79 species have stems with a girth of more than 2 cm. The density is 2,244 specimens per ha for a basal area of 15.6 m^2 ha^{-1}. Compared with the totally protected plot, the species numbers are reduced by one third, the total number of specimens (excluding *Phyllanthus nummularifolia*) has dropped by two-thirds and the basal area by 44%.

Late fire plot

This plot has been burnt every year at the end of the dry season. It supports a shrubby savanna in the two lower thirds and a wooded savanna in the upper part. There are two dominant woody species: *Piliostigma thonningii* and *Terminalia glaucescens.* Then one finds *Crossopteryx febrifuga, Cussonia arborea, Lophira lanceolata, Pseudocedrla kotschyi* and *Vitellaria paradox*, with certain specimens with a girth of more than 30 cm. The herbaceous layer includes *Andropogon sp., Imperata cylindrica, Panicum fragmitoides* and *Hyparrhenia smithiana.*

The number of species surviving after 58 years of fires is now not more than 20, with 214 stems per hectare and a basal area of only 3.0 m^2 ha^{-1}.

Exotic species

These appeared at a much later date in the inventories. In 1953 in the case of *Cassia siamea*, and in 1961 *Gmelina arborea* and *Tectona grandis*. With the exception of one or two large specimens already present, *Mangifera indica* also became established as from 1961. These exotic species have been particularly competitive. They have started to invade the total protection and early fire plots, where they now represent 29% and 41% respectively of the basal area. This invasiveness has certainly altered the way natural forest formations have regained the fallow land. Between 1976 and 1994, the regression of a certain number of indigenous species can be definitely ascribed to a lack of competitiveness with the exotic species.

CONCLUSIONS

In the pre-forest Sudano-Guinean zone, the application of different fire systems to fairly homogeneous wooded savanna has led to very contrasting situations after 58 years.

- Without any fires, on two soils of differing fertility, a semi-deciduous closed rain forest re-grows in less than 60 years. The more fertile site is marked in particular by the presence of large trees from the dominant species and by a conspicuous invasion of *Cassia siamea*.
- After a short time, late fires have destroyed pole stage trees. Coppice shoots have not managed to grow and stumps have died off progressively. Adult trees of pyrophilous species still withstand fires and are continuing to grow, but regeneration is no longer guaranteed. After some 40 years, large specimens have started to die back without being replaced by saplings. The cover is thinner and thinner, and fires have become progressively fiercer. Older trees only survive, with difficulty, on the most fertile soils. It is likely that they will soon disappear, giving way to grassy savanna.
- With early fires, soil fertility is decisive. In poor soils, the evolution over the first few years is akin to that of the late fire plot: young specimens are killed off by fire. It would nevertheless seem that some saplings escape - possibly in very wet years which restrict fire intensity. A sort of balance is thus established, which keeps the woody stand stable. There is virtually no timber production. In rich soils, the cover becomes closed in places - probably around old termites' nests. Fire no longer occurs regularly and the cover keeps closing in. Small areas of closed forest have appeared and spread, ending up by becoming joined together. The number of semi-deciduous closed forest species increases, but the young forest thus formed is not immune to running fires which may pass through it in an abnormally dry year.

Thus the recolonisation of fallow land can only be envisaged through total protection on all soil types, or by the use of early fires in the most fertile areas. Late fires should be banned, as should early fires, on the poorest soils. The forester whose goal is to re-develop a closed formation which is productive and sustainable must bear this in mind, especially if he plans to use fire as a management tool. These conclusions confirm and complement those from two other fire exclusion experiments, at Kpong in the Accra Plains in SE Ghana (Swaine *et al.* 1992) and at Olokemeji on the forest boundary in Nigeria (Charter and Keay 1960). After about thirty years, those experiments have produced similar results to the total protection plot at the same age.

ACKNOWLEDGEMENTS

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