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Tropical silviculture in dense African forest (Part 1)

Photo 1.
A natural stand of Okoumé growing in a former African crop field. La Mondah near Libreville (Gabon).
Photo Heitz.

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R. Catinot, I. Bossanyi (trans.)

RÉSUMÉ

Sylviculture tropicale en forêt dense africaine (partie 1)

Cet article représente la première partie d'une étude réalisée par l'auteur sur le développement des méthodes de la sylviculture appliquée aux forêts denses humides d'Afrique. L'étude compare les résultats obtenus par chaque méthode. Les articles suivants exposeront les aboutissements des recherches en foresterie menées ces dernières années, incluant une discussion à la lumière des résultats de ces recherches sur les méthodes utilisées au moment de la rédaction de l'article. L'auteur décrit aussi une nouvelle méthode rendant compte des expériences passées et de nouvelles idées. L'article apporte des éléments essentiels à l'heure où les gouvernements africains promeuvent des programmes de reforestation et de restauration forestière dans les forêts tropicales humides. Cela est désormais primordial en raison de l'augmentation et l'extension de l'exploitation forestière en Afrique, nécessaire pour stimuler les économies africaines, mais épuisant indéniablement le capital forestier.

Mots-clés : sylviculture, méthode, exploitation forestière, restauration forestière, plantation, productivité, forêt tropicale dense humide, Afrique.

ABSTRACT

Tropicale silviculture in dense African forest (Part 1)

This is the first part of a study by the author on the development of forestry methods for humid African forests, with a comparison of the results obtained in each case. The subsequent articles deal with the results achieved in forestry research in recent years, and include a discussion, in the light of research results, of the forestry methods in use at the time of writing. The author also describes a new method that takes account of past experience as well as recent ideas. We felt it would be of interest to publish this study today, at a time when African governments are planning to promote reforestation or rehabilitation programmes in humid forests. This has become essential as a result of the steadily increasing extent of logging in African forests, which is necessary to boost African economies but is undeniably depleting their forest capital.

Keywords: forestry, method, logging, forest restoration, plantation, productivity, humid tropical forest, Africa.

RESUMEN

Silvicultura tropical en bosque espeso de África (Parte 1)

Esta es la primera parte de un estudio realizado por el autor sobre el desarrollo de métodos forestales para bosques africanos húmedos, con una comparación de los resultados obtenidos en cada caso. Los artículos subsiguientes tratan los resultados obtenidos en investigación forestal durante los últimos años, e incluyen un estudio, a la luz de los resultados de la investigación, de los métodos forestales utilizados en el momento de escribirse. El autor también describe un nuevo método que combina la experiencia pasada con ideas más recientes. Pensamos que sería interesante publicar este estudio ahora, en un momento en que los gobiernos de África están planeando promover programas de reforestación o rehabilitación en bosques húmedos. Resulta esencial a causa del incremento constante de la extensión de las explotaciones forestales en los bosques africanos, que es necesario para impulsar las economías africanas, pero que indudablemente está mermando su capital forestal.

Palabras clave: silvicultura, método, explotación forestal, restauración forestal, plantación, productividad, bosque húmedo tropical, África.

As soon as they arrived in tropical Africa, the forestry engineers responsible for managing its dense forests embarked on efforts to regenerate them.

However, one the one hand their arrival was relatively recent (1900-1905 in Nigeria; 1925-1930 in other African countries), and on the other hand, the authorities were not convinced that forest regeneration was useful: the first explorers, loggers and forest administrators were often deluded by the exuberant growth of these dense forests – "*when one tree falls, ten new ones grow in its place!*" – and the presence of a few very large trees led to the mistaken belief that the forest would produce very large volumes of timber, although we now know that actual volumes rarely exceed 300 cubic metres per hectare, which is far less than in managed temperate forests. Their initial observations thus led to the belief that dense tropical forests were inexhaustible and would regenerate naturally with no need for human intervention.

The complexity of the problems immediately raised by these regeneration goals should also be strongly underlined: the 200-300 species concerned had to be identified beforehand and their respective temperaments, needs and silvicultural properties had to be studied, which required years of observations in difficult conditions. But since we have begun to understand these forests as biological entities, it has become clear that we cannot count on Nature alone to ensure their regeneration.

Finally, it has to be acknowledged that the very long time over which forestry investments would be needed could be a disincentive explaining why even the most favourably disposed Governments have never provided foresters with means suited to the scale of the problems they face: even the most deserving trials and studies have been conducted in no particular order, depending on the availability of time and funding. Because forestry trials are slow to produce results and need to be repeated and verified in different stations, the tendency has been to generalise too quickly and to try to steal a march over time by immediately seeking a single method that can be universally applied. This has led to often over-hasty conclusions, which, defended with enthusiasm and entirely understandable obstinacy, are reflected in positions that can only be called dogmatic. Ideas on the subject have come to crystallise around two opposing principles that are as old as forestry itself: natural versus artificial regeneration. However, their partisans have often taken positions so intransigent that any discussion inevitably ends in an atmosphere of politely mutual incomprehension - as in the words of a British forester, TAYLOR, who reported somewhat humorously that he had witnessed the birth of a "schism" at the Forestry Conference in Abidjan.

These opposing ideas have produced two different silvicultural methods:

1- Silvicultural methods involving natural regeneration

These claim to enrich dense forests in valuable tree species by encouraging seeding, and especially the growth, of pre-existing trees by applying cultivation techniques, usually at the same time as felling. Essentially, the idea is to gradually increase the amount of daylight reaching the ground in order to trigger the germination of fallen seeds and stimulate the growth of pre-existing seedlings that are struggling under the canopy. This is done by removing lianas, thinning and poisoning unwanted species before, during and after felling. The idea is basically a slow and cautious destruction of the canopy to gradually bring daylight down to seedlings of all ages of the species to be encouraged.

Many methods have been derived from these ideas, often differing in their detail, which we will describe and discuss below: these include improving Okoumé[1] stands in Gabon, top-down conformation and standardisation in Congo-Léopoldville[2], improving natural forest stands in Côte d'Ivoire, selective management in Ghana and the Tropical Shelterwood System in Nigeria.

2- Silvicultural methods involving artificial regeneration

These methods are based on the opposite claim that it is more reliable and ultimately cheaper to help Nature along throughout by transplanting noble species produced in tree nurseries into forests that have been exhausted by logging.

1 *Aucoumea klaineana* Pierre.
2 Now the Democratic Republic of Congo.

Photo 2.
Natural silviculture in Côte d'Ivoire (part of the dominant storey is poisoned to allow light to reach the forest floor).
Photo Lepître.

The idea is therefore to create a new and entirely man-made forest. But again, the pre-existing forest has to be destroyed to give the new seedlings enough light for them to grow. The canopy destruction principle provides the basis for a simple classification of the different techniques involving artificial regeneration:

a) The Taungya Technique

This involves giving farmers, to whom portions of forest are temporarily handed over to plant crops, responsibility for destroying the canopy by ancestral African methods (slash-and-burn, girdling, etc.). Crop plants and forest seedlings or saplings are then planted in alternating rows and receive full sunlight from the start. This method therefore reconciles the interests of both farmers and foresters.

b) The Okoumé-Limba[3] Technique

This involves destroying at least 75 % of the canopy within six months of seeding or planting to cater for these particularly light-loving species; the rest of the canopy disappears during the following year. This process, in which the trees are widely spaced (4 m x 4 m; 6 m x 6 m; 12 m x 12 m; 14 m x 14 m) also relies on secondary regrowth to "educate" the young trees (straight stems, self-pruning, etc.). Canopy destruction is drastic: trees less than or equal to 30 cm in diameter are cut down manually or uprooted with a bulldozer, and the others are poisoned or girdled.

c) The Martineau Technique

Also known as "underplanting": this is similar to the previous method, but spread over time. The understorey is destroyed at the time of planting and the dominant storey gradually suppressed by girdling. Only small-scale trials were conducted in Côte d'Ivoire, from 1930-1932, using close-planted saplings around which all regrowth was carefully removed.

d) The Narrow Deforested Strips Technique

Developed by Professor AUBRÉVILLE, this is an extensive method in which saplings of noble species are planted in narrow strips opened up vertically into the natural forest, with the necessary daylight brought in by gradually destroying the forest canopy between the strips. These are evenly spaced every 10 m, 20 m or sometimes 25 m, and the number of saplings planted is therefore quite small (200 on average), which is why this is sometimes referred to as an "enrichment" technique, unlike the closely spaced planting in the Taungya or Martineau techniques. This is obviously simply a matter of vocabulary.

e) The Evenly Spaced Planting Spot Technique

Developed by M. DONIS and Dr MAUDOUX in Congo-Léopoldville, this is derived from the Anderson technique. It involves planting saplings of the species to be regenerated in spots distributed uniformly within the forest, initially providing no daylight but very slowly and gradually removing the pre-existing forest canopy. The idea is to maintain the natural forest ambience as far as possible and considerably reduce the cost of plantations.

Photo 3.
Artificial silviculture in Congo-Léopoldville (a 4-year-old Limba plantation among banana trees).
Photo Falize - INEAC.

Tropical forestry can therefore apply a wide range of silvicultural techniques that draw on two radically different conceptions that are both classically used by foresters across the world: natural regeneration, which relies on Nature above all and to which foresters trained in the English tradition are especially attached, and artificial regeneration, which is mainly the preserve of foresters trained in the French tradition, while Belgian foresters have advocates from both schools.

Much could be said about the tendencies that have determined these choices: in particular, it may seem surprising that the French foresters, who were the heirs to a centuries-old tradition that made them fierce champions of natural regeneration, should have turned, in Africa, into champions of artificial regeneration. But I believe that the reasons lie in circumstance, in those "turns of Fate" in which the hand of Man can be so hard to discern: it is surely worth noting that the first English foresters, who laid the foundations of silviculture in Nigeria, were trained in Asia, in Burma or Malaya: H. N. THOMPSON, the first to arrive, in 1903, came from Burma; MAC GREGOR and KENNEDY were sent to India and Burma in 1925; G. M. SOMERVILLE who, in 1943, conducted the first large-scale operations that would lead to the Tropical Shelterwood System, was an officer of the Malay Forestry Service. On their arrival in the dense forests of West Africa,

[3] Okmoué: *Aucoumea klaineana* Pierre; Limba: *Terminalia superba* Engl. & Diels.

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Photo 4.
A stand of Okoumé improved by thinning. Lake Youbi (Congo-Brazzaville).
Photo Aubréville.

they spontaneously applied the rules of natural regeneration that had proved so effective in Malaya, where a great many species were established to supply the very large local timber market, resulting in felling of sufficient intensity to allow light-demanding species to regenerate naturally. Barely 1,000 km away from Nigeria, on the same West African coast where forestry was still in its infancy, the reactions of the first French foresters coming to Côte d'Ivoire from 1924 to 1930 were the exact opposite: they also attempted to work with natural regeneration as a priority, but they very quickly abandoned the idea, considering that the local natural and economic conditions were totally unsuitable: because there was no local timber market, only a few "noble species", none of them common in the forest, were felled for export, which resulted in a kind of selection in reverse by removing the seed trees of species of interest and leaving all others standing, while felling only about 3 trees per hectare could not open the canopy enough to warrant regeneration cutting.

French foresters in Côte d'Ivoire, like MARTINEAU, AUBRÉVILLE and BÉGUÉ, therefore focused their efforts on artificial regeneration and post-felling "enrichment" with valuable species. The reactions of French foresters in Cameroon and Equatorial Africa were exactly the same: as we will see, even for invasive light-demanding species like Limba and Okoumé, they abandoned natural regeneration methods as they seemed far less reliable and ultimately far more costly than artificial plantings.

We therefore feel quite justified in arguing that the choice between natural and artificial regeneration methods was dictated either by local circumstances and conditions or by the training received by foresters, and was not necessarily the outcome of systematic and comparative research.

Therefore, we now have several very different silvicultural techniques to choose from, of which we only partially understand the advantages and disadvantages because there have been no systematic comparisons and often no practical applications on a large scale: the few inter-African forestry conferences that have been organised have not produced the necessary syntheses and critical studies, and the initial positions have not changed.

At a time when some African countries are becoming aware of the absolute necessity of regenerating their forests, we felt it would be useful to review current knowledge on a subject of such great importance for the future of forestry in Africa, to attempt a comparison between the different methods and to identify their practical limitations, to discuss the results of recent research, to propose improvements to current methods and set out a research programme, and to describe the main lines of a new method based on the lessons that can be drawn from experience and trials conducted in the last 30 years.

Description of known methods
Methods involving natural regeneration

The techniques we have put into this category in fact fall into two groups:

1. Improvement techniques where natural regeneration is not the immediate aim

These techniques apply cultivation techniques to obtain a gradual transformation of non-uniform stands with more or less abundant valuable species into a more productive and more organised stand that will therefore regenerate more easily.

2. Techniques aiming for and using natural regeneration

In some ways, it can be considered that these techniques deliberately ignore the previous stage that consists of taming and organising a natural forest in order to obtain natural regeneration directly.

Techniques to improve stands of timber

1- improvement of Okoumé stands

a. Aim

The aim here, in Gabon, is to facilitate the growth, at any age, of the best specimens in natural Okoumé stands that have formed spontaneously in the clearings made in dense forest by African farmers to grow their crops (cassava, bananas, taro, etc.). To the Gabon forestry service, it was essential to undertake improvements to these sub-spontaneous spots of Okoumé, which occupy about 120,000 ha of forest and where Okoumé specimens of all ages can be found at highly variable distances from each other, by clearing the surrounding vegetation to obtain better organised stands.

The aim is for these natural Okoumé stands to reach maximum productivity in the shortest possible time.

b. The technique

This involves the following technical operations:

1. Cutting transects of diminishing grid size (1 km x 1 km, then 200 m x 100 m, then 100 m x 100 m) to produce a map showing not only the topography, but also, with simple conventional symbols, the position and extent of patches of Okoumé, the average diameter of the trees and their density per hectare.

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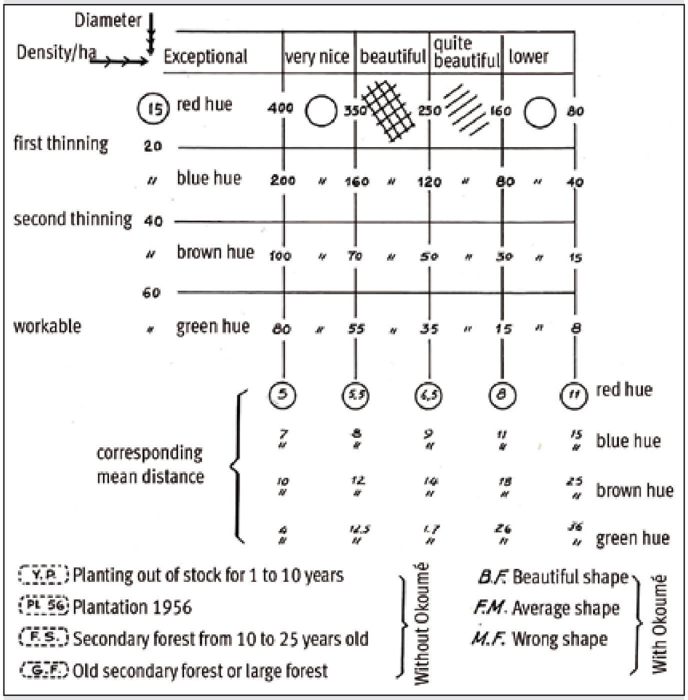

Figure 1.
Improvement of Okoumé stands.

2. Silvicultural work and inventories: forestry teams count usable Okoumé trees along 100m survey transects while conducting silvicultural operations as follows:

- Stands 0 ‹ ∅ ‹ 10 cm: thinning down.
- Stands 10 ‹ ∅ ‹ 20 cm: thinning to a density of 400/ha and removal of various dominant trees.
- Stands 20 ‹ ∅ ‹ 40 cm: thinning to a density of 80 trees/ha in a maximum of two operations, also removing overtopped and dominated Okoumé and other trees to promote the growth of a diversified understorey.
- Stands 40 ‹ ∅ ‹ 60 cm: no thinning, but miscellaneous dominant trees should be cleared and Okoumé trees with no future commercial value should be removed.
- Stands ∅ › 60 cm: inventory of exploitable Okoumé trees, removal of lianas, no silvicultural work.

Trees are removed by felling, and girdling when the diameter is larger than ∅ › 30 cm.

c. Results

By using tariff tables based empirically on the diameter and shape of trees and yield coefficients at the time of felling, it was possible to determine the extractable volume for the entire managed stand and the number of stems in each diameter category expected to reach felling diameter. These calculations were done by “Brigades” comprising two forestry or works engineers, 5 or 6 forest rangers and 30-35 workmen, at a cost of about 100 F CFA/t in 1958.

The work covered nearly 100,000 ha of forest and produced results of considerable interest in that several hundred thousand Okoumé trees were saved that were either growing too close together or overtopped by more fast-growing species. It is estimated that the Okoumé stands treated in this way represent a potential of 3,000,000 tonnes.

Figure 2.
Diagram showing improvement work in a stand of Okoumé (hatched) 0 ‹ ∅ ‹ 20 cm:
thinning in patches of Okoumé and suppressing unwanted trees by girdling (dotted lines).

2- Top-down homogenisation

a. Aim

This technique refers to all the work aiming to gradually convert an uneven aged natural forest into a high even-aged stand in order to improve productivity.

According to M. DONIS, one of the promoters of this method, the idea was to reduce the age range between the upper and lower felling limits by allowing daylight to reach the most well represented recruitment classes. The aim was to encourage tree classes of average size and high production potential by simultaneously suppressing the competing vegetation in each storey. This meant removing any vegetation not able to produce woody material and intercepting sunlight to the detriment of timber species present as saplings and juvenile or adult trees.

b. The technique

After a detailed forest inventory, the technique involves removing lianas, bushes and non-commercial tree species (about 250 trees/ha) competing with the pre-existing trees to be encouraged, and felling commercially valuable trees larger than the most well represented recruitment classes.

The first inventories after five years of forestry work showed a smooth transition from one class to the next. However, the trees were still growing quite slowly (0.5 cm to 0.7 cm/year in diameter), but the Belgian forestry service thought this could be increased by improving the technique used to poison the species to be suppressed.

Further trials had aimed to suppress all non-commercial species larger than 7 cm in diameter, and once the secondary species that would become established in the gaps thus created had formed a high enough canopy, work could begin to regenerate the valuable species left in place.

c. Results

In theory, top-down homogenisation was expected to produce the following results:
- no large trees except those of high commercial value;
- average sized trees of different ages;
- more light reaching the ground more uniformly to encourage natural regeneration.

The labour required was estimated at about 15 man-days/ha, with a high level of technical supervision.

This method was applied in a few thousand hectares of the Mayumbe forest in 1949-1952 and was no doubt abandoned as a result of the political events that broke out in Congo-Léopoldville.

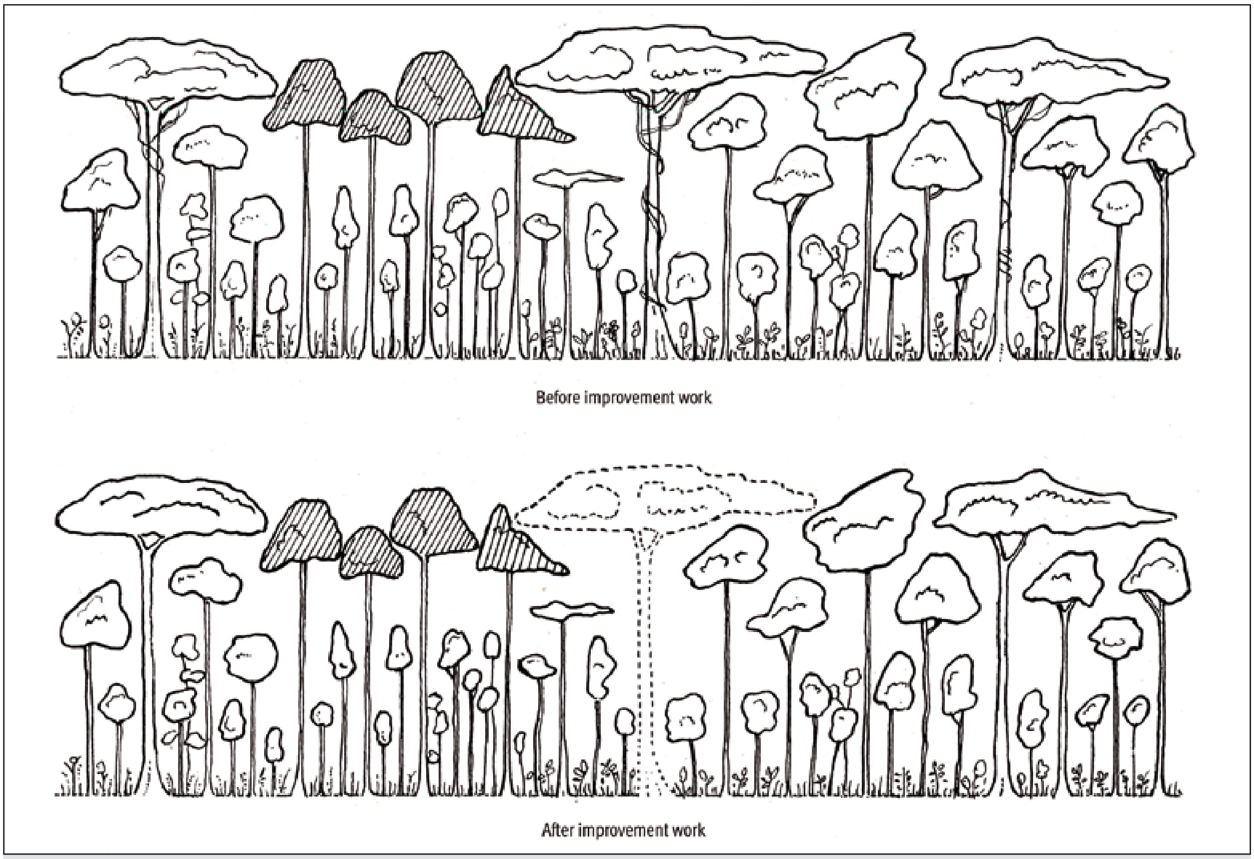

Figure 3.
Diagram showing improvement work in a stand of Okoumé (hatched) (20 ‹ ∅ ‹ 40 cm): suppressing unwanted trees by girdling (dotted lines).

3- Standardisation

This method was developed in an attempt to perfect the selection management system in forests clearly dominated by one or two species that are particularly apt to regenerate naturally (*Brachystegia laurentii* (De Wild.) Louis ex Hoyle, *Gilbertiodendron dewevrei* (De Wild.) J. Léonard, *Cynometra alexandri* C. H. Wright, *Julbernardia seretii* (De Wild.) Troupin).

The Belgian forestry service took a particular interest in this method in 1955-1960 after plotting a graph, based on an inventory, of the distribution of tree diameters, from which it deduced the work to be undertaken: brush clearing and removal of lianas, followed by felling of surplus mature trees. The latter operation proved to be the most problematical, because the gaps left after felling were very large.

Neither of these two methods seems to have been taken beyond the trial stage.

Methods aiming for natural regeneration

Three of these methods have been used at full scale. In tropical Africa: "selective management" in Ghana, the A.P.N. method (*Amélioration des Peuplements Naturels*, or Natural Stand Improvement) in Côte d'Ivoire, and the T.S.S. method (Tropical Shelterwood System) in Nigeria and Western Cameroon. Although the three techniques are often confused, they differ in that the first does not aim to promote seeding of the right species by opening up the canopy, but instead, on the grounds that seeding occurs spontaneously and naturally and in sufficient abundance, simply helps out pre-existing trees more than 10 cm in diameter by clearing and thinning; the second aims to encourage natural seeding after an identical phase of clearing and thinning, while the third clearly aims to promote natural regeneration by means of seeding cuts.

1- Selective management

This method was mainly used in Ghana: as its name implies, it is also a forest management system where the overriding aim of sustained production is sought by attempting to combine felling and regeneration. Based on that principle, its users have to modulate the intensity of their work according to available financial resources, which has brought them to the conclusion that the shorter the felling cycle, the more money is available. But they nevertheless have to admit that there is a limiting factor in this context, which is the timber volume actually available at the time of felling, and that this makes it difficult to consider a felling cycle of less than 15 years.

This method can be broken down into two main operations: selective cutting and improvement thinning.

Selective cutting

For the reasons given above, the forest is logged over every 15 years or so.

Each felling operation is preceded by an inventory of exploitable trees and trees with a slightly smaller diameter, which are numbered and plotted onto a map to the scale of 1:2,500. With the help of this document, the forestry service

Figure 4.
Diagram showing top-down homogenisation: the commercially valuable trees are hatched.

marks the trees to be preserved, aiming above all to maintain the right distribution of valuable seed trees, and provides the logging companies with a "logging map" and the list of numbered trees that may be felled, which means that the felling operation to follow will indeed be "selective".

Improvement thinning

This takes place in the same year as felling and involves:
a) removing lianas;
b) clearing around useful species of 10 ‹ ∅ ‹ 50 cm ;
c) coppicing young trees of useful species that were wounded during the felling operation.

No provision is made for saplings of ∅ ‹ 10 cm, or indeed to encourage regeneration, which, according to the technicians, is usually quite sufficient without intervention.

Improvement thinning is done by teams of 20-25 workmen supervised by 4 forest rangers and directed by a chief ranger; each team is assigned 5 to 8 ha/day, which represents about 3-4 man-days/ha.

Thinning is done by cutting and poisoning, at an estimated cost of 15 shillings/ha in 1958.

This method works on the assumption that there is a fairly large proportion of useful species from the outset. This, however, rests on an idea that has been criticised by H. G. DAWKINS: because of the damage caused by felling, a system based on several cuts in each cycle cannot increase standing timber by more than 1.4 m^3/ha/year, which puts severe limitations on the acceptable costs of the work as no improvements can be counted on until the timber yielded by clearing and thinning can be put on the market.

J. W. C. MOONEY, on the other hand, claims that with a single cut per cycle, any useful trees left standing (10 cm ‹ ∅ ‹ 50 cm) can suffer serious harm from their sudden isolation and that in any case, they would need to be felled before the end of the cycle, failing which the damage they could cause to young recruits would be simply unacceptable. We will go into these arguments in the general discussion on methods.

Photo 5.
Top-down homogenisation near Luki (Congo-Léopoldville).
Initial work (liana removal and girdling): note the large girdled tree on the right.
Photo Falize - INEAC.

2- Improving natural stands

a. Aim of the operation

In 1950, the Côte d'Ivoire forestry service, which, with the benefit of hindsight, had already conducted a review of the silvicultural methods used in that country since 1930, found the initial published results of the Tropical Shelterwood System, recently developed in Nigeria by English foresters, so persuasive that they decided to abandon the "Narrow Deforested Strips" method used until then in favour of a technique based on the T.S.S. and described as the A.P.N. technique (improvement of natural stands). The technique was promoted by the forest administrator M. BONNET, who laid down the main management principles for obtaining high even-aged stands by successive felling. The reasons for making such a radical change were as follows:

- In terms of economics, BONNET was impressed by the development of sawmills for the local market, whose annual demand for logs looked set to increase from 50 000 to 200 000 m^3 within a few years, by their geographic distribution and by the increasingly broad range of tree species they used; for example, the value of Mahogany, for which prices were dropping even on the export market, was also diminishing as a pilot species for reforestation. Economic conditions, together with the geographical dispersion of forestry worksites, thus seemed to dictate a wider variety of species to be regenerated: according to the new principles, the few large reforestation sites established in the vicinity of ports and concentrating on two or three valuable export species would need to be replaced by much smaller sites (upwards of 1,000 ha) in locations scattered across Côte d'Ivoire, in accordance with local demand and processing all valuable forest species on the spot.
- Technically, the constraints of maintaining the 13,000 ha enriched By the Narrow Deforested Strip technique (5,000 to 6,000 ha per year from 1945 to 1949) were so great and were raising so many doubts as to the effectiveness of the work conducted (letting in the right amounts of light and the constant battle against encroaching lianas) that supervisors and workmen were losing interest. Furthermore, for some naturally abundant species, such as Niangon and Avodiré, there were grounds for wondering whether such efforts were really worthwhile when Nature herself seemed so bountiful and well disposed.

Photo 6.
Improvement of natural stands in Côte d'Ivoire. Opening up the canopy by poisoning trees: note those already dead.
Photo Lepître.

Photo 7.
Improvement of natural stands in Côte d'Ivoire. A Niangon sapling growing in the light let in by improvement work.
Photo Lepître.

b. Technique and cost of operations

To save time, the choice of forests to be managed would have to favour average-aged secondary formations that were already being logged but contained a large number of pre-existing trees of interest. The second phase would focus on older formations that were usually intact, and primarily on natural regeneration involving a much longer work cycle.

Work would begin with a very thorough inventory based on grid squares of diminishing size (100 ha, then 20 ha, then 1 ha) to determine the number of specimens of each commercial species, which were grouped into diameter classes and into two categories of commercial value (cost = 2-3 man-days/ha). The next phase would suppress all lianas (cost = 8 man-days/ha), which would usually wither within 1 month. Next would come canopy opening operations to eliminate seed trees of unwanted species and to allow light to reach the stand: this would be done by means of two poisoning operations at six month intervals using phytohormones (cost = 5 man-days/ha and 30-45 l of phytohormones).

A forest treated in this way takes on a managed aspect, thinned down, lighter and airier with very little secondary regrowth, but where young specimens of commercial species are guided and protected from lianas as they grow up the "shafts" thus created.

Finally, maintenance would involve keeping the narrow deforested strips, both narrow and wide, permanently clear, while further clearing and liana removal would be planned in principle every three years for ten years (cost = 15 à 18 man-days/ha).

Finally, the progress of natural regeneration would be monitored by means of a 1% inventory.

The total labour costs for these operations were estimated at 46 man-days/ha, rounded up to 50 man-days/ha.

c. Results

While it is not easy, even for a practised eye, to give a fair appraisal of the results of an even-aged plantation in dense tropical forest without a detailed study, it is almost impossible to form an opinion, from a tour in that environment, as to the results of applying a natural regeneration method. This is a managed forest technique in the broadest sense, and management means clearings, but whereas in a pine forest, each clearing can be seen from the next so that it is possible to get an overall picture, in dense tropical forests all that meets the eye are one or two young Niangon trees in a shaft of light (sometimes even sunlight), and depending on the twists and turns of the forest track and on the guide's sense of direction, finding the next one can take anything from a minute to a quarter of an hour. Assessing the density of pre-existing trees of commercial interest is an incomparably greater challenge – and no map can provide such detail. The forestry research section for Côte d'Ivoire therefore had to organise statistical surveys based on 10 m x 5 m sampling units on either side of certain transects in the basic grid layout (as noted by the Forests Administrator de LA MENSBRUGE in 1957). However, the results, when extrapolated to large units, did not seem to provide enough detail to give a fair rendering of their irregularity. It was therefore decided to establish permanent sample plots no more than 10 m in width and surrounded by wire fencing, in order to monitor the growth of individual specimens established or encouraged by regeneration cutting.

In 1960, I was able to visit several forest zones treated in this way. As far as it is possible to give an objective opinion, my first impressions were not favourable:

a) an overall impression of disorder, often bordering on the chaotic and, at least to the naked eye, of manifestly poor results (many saplings established in clearings were already overtopped for lack of sufficient clearing around them).

b) to a visitor, the complexity was worsened by the fact that the 25 m wide interstrips, separating the old plantations into narrow deforested strips, were treated by this natural regeneration method.

c) an often striking abundance of "cloaking" liana growth: it does seem that there is no better environment to encourage their proliferation than these dense forest stands with large clearings at regular intervals, which provide the lianas with the abundant light and supporting stems that allow them to thrive.

In fact, this method was abandoned in Côte d'Ivoire in about 1960, because it seemed difficult to assess its results and also caused efforts to be dispersed in both space and time, at least as much as with the previous methods.

3- The tropical shelterwood system (T.S.S.)

a. Aim and Background

This method has been very well described by the English foresters who developed and applied it, especially LANCASTER, ROSEVEAR and TAYLOR, and in order to follow the reasoning that brought them to develop the T.S.S., we need to give a brief account of the history of the Nigeria Forest Service.

The service was created in practice in 1903, with the arrival of H. N. THOMPSON, a forestry officer trained in Burma. Until the end of the First World War, he sought the best technical solutions among all the different regulations that other tropical forestry services would later introduce: the obligation on all loggers to establish replacement plantations (24 saplings for each tree felled) and to clear around the patches of natural seedlings that emerged in clearings; clearing and thinning to be conducted by foresters during their tours of duty; introduction of a reforestation tax due at the time of felling or export. At the time, it was generally assumed that these plantations would be artificial, but numerous problems rapidly appeared (borer attacks on Mahogany, irregular growth), so that until 1927, and despite the creation of a research section, the forestry service proceeded by trial and error as regards techniques and regulations. At that time, two forestry officers trained in Burma and India, J. D. KENNEDY and W. E. MAC GREGOR, returned to Nigeria and began numerous trials for artificial plantations (after crops, in narrow deforested strips) and natural regeneration by gradually opening up the canopy by felling and poisoning (KENNEDY's "Uniform System" clearly bears the stamp of the forestry methods used in Burma and Malaya). Unfortunately, due to the unpredictability of colonial postings and the war of 1939-1944, the trials were discontinued in 1944.

Photo 8.
Tropical Shelterwood System: natural regeneration (in the 7th year) in a forest parcel; successful regeneration of *Khaya ivorensis* and *Entandrophragma angolense*
Photo Taylor.

But in that year, following additional trials conducted in Nigeria in 1943 by another forester trained in Malaya, G. W. SOMMERVILLE, on possibilities for the natural regeneration of Meliaceae (Mahogany, Sipo, Sapelli, Tiama), the value of the Uniform System seemed to become clearer and the English foresters, taking "a leap in the dark", as ROSEVEAR and LANCASTER put it, decided to create a new method that a conference of five forest officers developed in 1944: this was the Tropical Shelterwood System, soon to be referred to by its acronym T.S.S.

The ultimate goal sought was to promote an economic revival by gradually opening up the canopy to establish numerous well formed saplings under the cover of large trees before felling.

b. The technique

One of the main concerns of the promoters of the T.S.S. was to "automate" forestry work as far as possible to allow for the lack of experience of forestry workers and the extreme diversity of the forest parcels to be managed: they deliberately sought to achieve only a reasonable average result, which seemed the only possible way of avoiding work on each individual tree. The aim was to obtain, by regeneration, a minimum of 100 saplings/ha, 1 m in height, within an estimated time of five years.

Managed in this way, the forest could only be logged as from the sixth year. The year after that would be devoted to clearing around saplings more or less covered by felling residues and coppicing trees that had sustained felling damage. Finally, clearing, and thinning if necessary, would be done 5, 10 and 15 years later. Altogether, forestry work would therefore be needed for 20 years.

The operations were as follows:

▪ Year 1: cutting lianas and young trees of ∅ ‹ 5 cm with no economic value; these initial cuts would often suffice to trigger regeneration by allowing light to reach the forest floor.
▪ Year 2: applying sodium arsenite to kill trees of no economic value in the middle and lower stories, thus making the first large openings in the canopy (two applications of poison in the year); cutting liana regrowth and counting the new tree generation obtained.
▪ Year 3: clearing around seedlings of valuable species.
▪ Year 4: clearing around seedlings of valuable species and counting the regenerating trees.
▪ Year 5: clearing around seedlings.
▪ Year 6: felling.
▪ Year 7: clearing, coppicing, thinning seedlings.
▪ Year 11: clearing, coppicing, thinning seedlings.
▪ Year 16: thinning.
▪ Year 21: final thinning.

This technique therefore draws directly on the old natural regeneration techniques used in temperate countries, with substantial modifications to allow for the particular conditions in tropical forests: seeding cuts are replaced by poisoning of trees that cut out light as most have no commercial value; logging, however, removes only part of the dominant storey to avoid disrupting the balance of the biological forest environment and triggering an explosive proliferation of lianas caused by suddenly letting light reach the forest floor.

Little more can be said about this method, other than the fact that after a period of hope and euphoria, its users seem to have succumbed to doubt and paused for a time, because:

▪ as with the A.P.N. method, it was very difficult to verify results over large areas because the worksites were so widely scattered;
▪ it was very difficult to let in the right amount of light for the trees to grow well without triggering a profusion of lianas;
▪ spreading the work over 20 years tended to disperse efforts after a few years and to increase the surface areas to an extent that would become unmanageable in dense African forests.

Having been applied over large areas in Nigeria and Ghana (several tens of thousands of hectares), the method now seems to be regressing and is even being abandoned in Ghana.

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Figure 5.
Diagram of the Tropical Shelterwood System. After felling the commercially valuable trees (hatched), large trees of other species were girdled. Note natural regeneration on the forest floor.