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[1] C.T.F.T. : Centre Technique Forestier Tropical. The C.T.F.T. was incorporated into the CIRAD as a forestry department in 1984.
[2] Bois et Forêts des Tropiques

Tropical silviculture in dense African forest (Part 5)

Photo 1.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. The New Growth method: manual preparation of the terrain by cutting down small trees to a height of about 50 cm.
Photo Leroy-Deval.

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RÉSUMÉ

Sylviculture tropicale en forêt dense africaine (partie 5)

L'article présente la dernière partie de l'étude sur la sylviculture en forêt dense africaine. L'auteur y décrit une nouvelle méthode, appelée la méthode « Nouvelle croissance » que le Centre technique forestier tropical a pu développer au Gabon depuis 1958. L'objectif est de donner le plus de lumière possible aux jeunes arbres plantés tout en maintenant une ambiance forestière acceptable par le soin et l'entretien en faveur d'une nouvelle croissance des espèces d'ombrage. Dans la conclusion, il compare les coûts et les rendements des différentes méthodes sylvicoles employées dans les forêts tropicales humides, et il fait le point sur la situation actuelle et les perspectives d'avenir.

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

ABSTRACT

Tropical silviculture in dense African forest (Part 5)

This article presents the final section of a study on tropical silviculture in dense African forests. The author describes a new method, called the "New growth" method, which the Centre Technique Forestier Tropical had been developing in Gabon since 1958. This method aimed to give planted saplings as much light as possible while maintaining an acceptable forest ambience through care and maintenance for newly growing shade species. In the concluding section, the author compares the costs and yields of the different forestry methods employed in humid tropical forests and takes stock of the current situation and future prospects.

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

RESUMEN

Silvicultura tropical en bosque espeso de África (Parte 5)

Este artículo es la última parte sobre silvicultura tropical en bosques espesos de África. Aquí el autor describe un nuevo método, llamado método del «Nuevo crecimiento», que el Centro Técnico Forestal Tropical está desarrollando en Gabón desde 1958. Su objetivo es proporcionar a los pimpollos plantados tanta luz como sea posible manteniendo un ambiente forestal aceptable mediante el cuidado y mantenimiento a favor de un nuevo crecimiento de las especies de sombra. En las conclusiones compara los costes y producciones de los diferentes métodos forestales empleados en los bosques húmedos tropicales y evalúa la situación actual y las perspectivas de futuro.

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

The "New Growth" method

Development of this method began in Gabon in 1958. It is the outcome of trials that began there in 1956, on preparing the ground for plantations by poisoning the dense forest. The aim at the time was to try to improve the Okoumé plantation method by applying poisoning techniques that would entirely destroy the pre-existing forest. The purpose was, on the one hand, to reduce the cost price of deforestation and on the other hand, to dispense with the use of tractors, because it had become apparent that the removal of the topsoil that this involved encouraged the establishment of umbrella trees, whose proliferation was a significant problem for the maintenance of Okoumé plantations.

The method adopted following these trials was applied in the Ikoy Bandja forestry station in Gabon for plantations of the main commercial dense forest species, and proved to be highly promising in the majority of cases.

A. Aim

The aims sought were:

1. To provide planted saplings with as much light as possible by entirely destroying the pre-existing forest canopy; this was to be done by manual felling of the understory, and poisoning of the dominant story. Depending on the temperament of the planted species, they could either be rapidly exposed to full light, or gradually over several years. The trials seemed to show that in most cases, the young saplings should be exposed to the maximum amount of light as soon as possible, which meant poisoning the entire dominant story from the outset.
2. To ensure excellent protection of the soil to be planted by cutting the understory down to only 40 to 50 cm from the ground: the resulting vigorous coppice shoots and the brash left to decompose without burning produced new closely growing soil cover and thus maintained a forest microclimate and preserved the pre-existing humus and microbial life in the soil. The carpet of dead leaves falling from the poisoned dominant story also helped to protect and enrich the topsoil.
3. To prevent, as far as possible, the establishment of umbrella trees (*Musanga cecropioides R. Br.)* thanks to the carpet of new growth that not only prevented umbrella tree seeds from reaching the ground, but also screened out light to prevent the growth of seedlings from any seeds that succeeded in germinating. This is only an effective deterrent to umbrella trees in the first two years after preparing the ground, as they then become established in the gaps in the new growth created by the fall of poisoned trees. But the fact that the planted saplings do not have to compete with umbrella trees in their first two years of life is essential, as this is the period when they are most likely to be overtopped by the surrounding regrowth.
4. To "educate" the planted saplings by shrouding them in new growth that maintains a forest ambience around them (temperature and humidity) and forces them to grow straight and drop their lower branches by self pruning.

The originality of this method therefore lies in maintaining vigorous new growth of shade species that preserve both soil fertility and the forest ambience and cause the saplings to grow in accordance with one of the oldest rules of cultivation: "with their feet in the shade and their crown in the sun". This is the essential difference with the Limba and Okoumé methods, which are based on total destruction of the natural understory (with bulldozers or by burning) to clear the ground entirely, and on the saplings becoming shrouded by the regrowth of secondary species (Musanga, Macaranga, Croton, etc.) that become established following the destruction of the shade species in the natural understory.

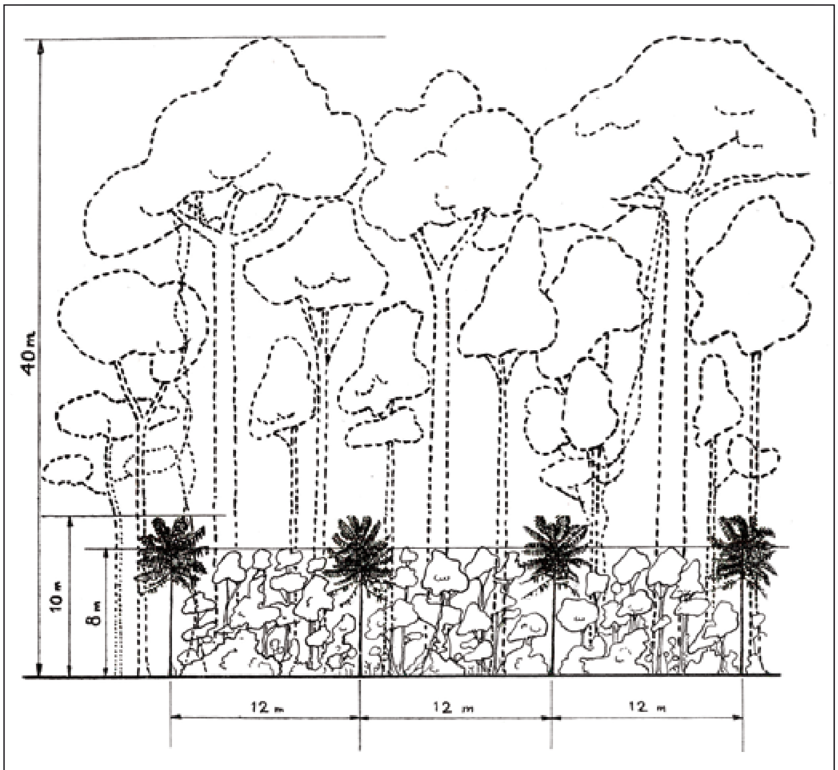

Figure 1.
New Growth method.

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Photo 2.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. A pair of prototype Borrel solar meters set up on open ground to check their operation. Note their robust appearance.
Photo Leroy-Deval.

Photo 3.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. New Growth method. A 5-year-old plantation of Sipo in 1960, after cutting back the vegetation between the plantation rows.
Photo Leroy-Deval.

B. Technique

This method involves the following operations:

1. Reconnaissance, grid plotting and mapping of the terrain

These are the same operations as those conducted to prepare the ground for Limba and Okoumé plantations (deforested strips running north to south and east to west, mapping topographic accidents, etc.).

2. Destruction of the pre-existing forest

This is done in two stages:

▪ First stage, manual clearing (with machetes and axes) of shrubs and trees less than 15 to 20 cm in diameter; the vegetation is cut down to knee height and the brash left on the ground without burning. This operation has to be done as simply as possible and experience shows that cutting up the brash and pushing it into windrows is unnecessary and expensive because after a few weeks, the leaves and twigs dry out enough to allow easy access.

The 15-20 cm maximum felling diameter was chosen following the trials for four reasons:

▪ manual clearing is imperative because machines would strip the topsoil, which is to be avoided above all;

▪ however, manual work is costly and must be kept to a minimum: this is why only small diameter trees are cleared as cutting them only requires a few blows of the axe or machete;

▪ trees cleared in this way must not be allowed to obstruct the ground too much because, as they are not to be burned, they would need to be topped and cut into logs to make space for planting and even for access; instead, they are left on the ground, and when the leaves and twigs have dried out after a few weeks, it is easy to prepare the plantation rows, as long as the felled volume is not too large;

▪ the number of trees left standing and poisoned should not be so great as to destroy a large proportion of saplings when they fall. However, experience has shown that when poisoned trees fall, only those larger than 30 to 35 cm in diameter are a real danger because those smaller in size have a smaller crown and small branches that do not cause much damage as they fall. The 15-20 cm diameter was only established through a trial and error approach covering all these aspects.

It should be noted that this method of preparation is very different to that for the Limba method, which is also manual but involves felling trees up to 40 to 45 cm in diameter. These considerably obstruct the ground to be planted, and therefore have to be cut into sections and topped, which in turn increases the costs of the operation (see the tables comparing the different methods).

▪ Second stage, poisoning by the Malay slash method of all or part of the trees left standing, depending on whether the saplings are to be planted in full or partial light. Poisoning with phytohormones or sodium arsenite is a matter of circumstance, but phytohormones are usually preferred as they are easier to handle.

These two deforestation operations should preferably be conducted during the dry season before planting to ensure that enough light is available at the right time: it is estimated that six months after poisoning, the soil prepared for planting will be receiving about 50% of the light reaching open ground.

3. Deforesting and marking out strips

This is done by using machetes to open up narrow strips into the new growth developing from the coppice stumps. Spacing will be about 4-6 m between saplings, which is often one third or one half of the final spacing. As there are no plans at present to use thinnings from species other than Okoumé, this initial spacing leaves enough margin for the choice of final spacing, taking the percentage of destruction caused by the fall of poisoned trees into consideration (25 to 30% of the planted saplings).

4. Planting the saplings

This is done with the method that maximises the initial growth of each species (1-1.50 m stumps for Sipo, 1.50-2 m seedlings for Niangon, 1.50-1.75 m stumps for Framiré, etc.). The aim is that the saplings should overtop the new growth as quickly as possible, while preserving as much as possible of the latter during planting.

5. Maintenance

This is done with machetes, the constant aim being to keep the new vegetation growing as closely as possible to the saplings, but keeping it down below their tips so that they remain in full light. To maintain the vigour of the new growth, clearing often needs to be "stepped" (see sketch). It is important to keep a close eye on the umbrella trees that will inevitably become established, and to poison them as soon as they reach 1 to 2 inches in diameter.

Maintenance work, which is inexpensive during the first two years (mainly liana removal), would need to be conducted for 5 to 8 years, depending on how fast the species grow.

C. Cost of the method

This is expressed in man-days per hectare (MD/ha) for a plantation with 5m x 5m spacing (table I).

Comments

1. It is obvious that the cost of the method will essentially depend on the rate of growth of the forest species planted: with Okoumé, for example, nursery costs are only 4-5 MD/ha, the costs of opening up gaps and planting only 2-3 MD/ha and clearing operations amount to about 20 MD/ha, bringing the total plantation costs to about 70-75 MD/ha.
2. One difficulty with this method is the transport and handling of 120-130 l of diesel/hectare. An improvement could be made by girdling the smaller trees instead of poisoning them: for trees up to 30 to 40 cm in diameter, making the Malay slashes and applying the poison takes almost as long as girdling. We therefore propose to check, at the research stage, the cost of girdling trees up to $\Phi = 40$ cm and the resulting savings in diesel and phytohormones. As a first approximation, we assume that the cost of girdling would be higher by 1 to 2 MD/ha, but this would be offset by savings on the costs of purchasing and handling 60-70 l of diesel and 1 l to 1.5 l of poison. The result would be entirely positive without unduly complicating the organisation of the work to be carried out.

D. Results

The results are still too recent and fragmentary to guarantee the success of the method: the trials that began in 1958 in Gabon (Ikoy-Bandja Station) were repeated in Côte d'Ivoire in 1961, but only over small areas. Nevertheless, they are very promising: much faster growth rates were obtained for Niangon (*Tarrietia utilis*) and Sipo (*Entandrophragma utile*) than with the conventional methods, and the growth rates for Framiré (*Terminalia ivorensis*), Bilinga (*Nauclea diderrichii*) and African mahogany (*Khaya ivorensis*) were equal to those obtained for the same species with the Taungya method. In today's conditions, there is every reason for optimism, although there may be some concern that competition on the ground from the abundant regrowth preserved around the saplings could hinder their growth: the competition is undeniable, but it may be hoped that it will be compensated by the favourable microclimate maintained on the ground, and by the persistence of intact microbial life and its enrichment.

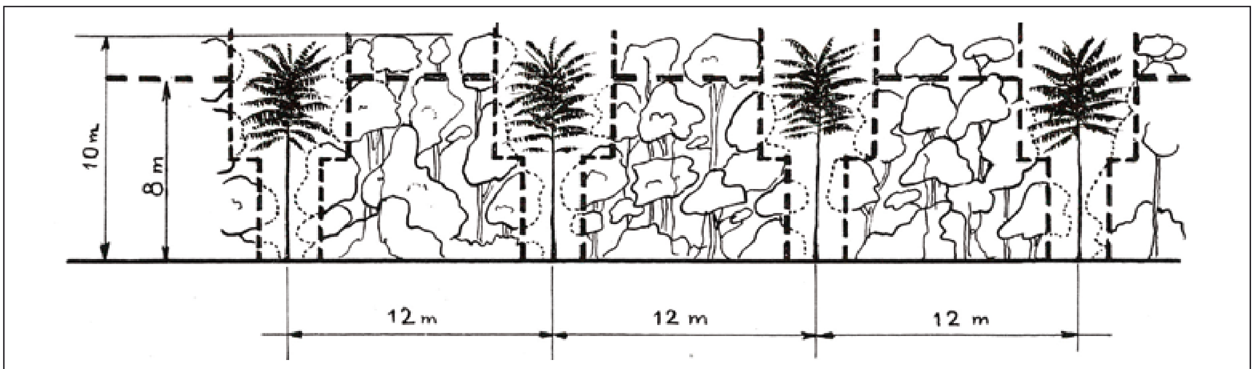

Figure 2.
New Growth method: stepped clearing.

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Table I.
Estimated costs of the “New Growth” method.

Operations	Number of MD/ha*	Observations
Identifying parcels, prospecting	2	
Clearing, poisoning	20 to 22	and 130 l of diesel + phytohormones depending on the age of the plants
Deforesting narrow plantation strips	1	
Nurseries (400 saplings/ha)	14 to 18	
Opening up gaps	8	
Plantation	10	
Clearing Year 1	3	
Clearing Year 2	3	
Clearing Year 3	7	
Clearing Year 4	7	
Clearing Year 5	6	
Clearing Year 6	6	
Total	87-93	

* MD/ha: man-days per hectare.

Photo 4.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. New Growth method. A 5-year-old plantation of Sipo in 1960, after clearing.
Photo Leroy-Deval.

Finally, it is quite likely that maintaining dense new growth up to the tips of the young saplings will help to prevent the dispersal of insect pathogens (Khaya Borers). In any case, maintaining new growth comprising a wide diversity of species should allay concerns over pure plantations of the same species over large areas, since the method produces the most varied kind of forest stand imaginable: a result far removed from the pure conifer plantations that are a constant source of worry to foresters.

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Comparison between the methods

We believe it to be of interest to summarise, for each method, the successive forestry operations over time, and their costs in man-days, machine hours and litres of poisoning substance per hectare: the summary is given in table II below. We do not mention the labour costs of general overheads (opening up and maintaining forests roads, maintaining logging camps, etc.) as the amount varies with the location and organisation of worksites (subcontracting, accommodation for workers or not, etc.). The total can however be estimated at 10-15 MD/ha. The layout and some of the figures require some comment:

a. Natural (NS) and artificial (AS) silviculture methods are grouped into the same table.
b. Only one natural silvicultural method, the Tropical Shelterwood System (T.S.S.), is mentioned, as it is highly representative and, as far as we know, the most recently used.
c. A fourth year of maintenance is given for Okoumé, as experience has shown this to be essential.
d. We have deliberately omitted thinning work because the first operations conducted in this area are too recent to provide reliable cost figures.

Table II.

Type of work	Conventional Tropical Shelterwood System	Modified Tropical Shelterwood System	Taungya	Limba	Okoumé	Conventional Narrow Deforested Strips method	Modified Narrow Deforested Strips method	New Growth method
Parcel identification; prospecting	2	2	2	2	2	2	2	2
Year 1								
NS: clearing lianas, poisoning	10	20 and 100 l of diesel	32 - 36	69	29 and 4-5 h bulldozer	25 - 35	28 - 39 and 130 l diesel	56 - 62 and 130 l diesel
AS: clearing								
Year 2								
NS: liana poisoning	6 and 30 l diesel							
AS: clearing		4	-	8	12	2	3 - 4	3
Year 3								
NS: clearing or logging	4	4						
AS: clearing			-	10	12	5	3 - 4	7
Year 4								
NS: clearing	3	3						
AS: clearing			3	9	8	3	3 - 4	7
Year 5								
NS: clearing	3	4						
AS: clearing			3	7	-	5	3 - 4	6
Year 6								
NS: clearing, logging	6	3						
AS: clearing			-	9	-	3	3 - 4	6
Year 7								
NS: clearing	3	3						
AS: clearing			-	-	-	5	3 - 4	-
Year 8								
NS: clearing	3	-						
AS: clearing			-	-	-	3	-	-
Year 9								
clearing	3	-	-	-	-	5	-	-
Year 10								
clearing	3	-	-	-	-	3		
Total	46, and 30 l diesel	43 and 100 l diesel	40-44	114	63 and 4-5 h bulldozer	61-71	48-59 and 130 l diesel	87-93 and 130 l diesel

Table III.

Methods	Cost of work	Duration	Number of trees Initial plantation	Final	Volume (m^3/ha)	Growth rate	Rotation (years)
T.S.S.	40 MD + 30 l diesel	10	100	25-50	75-200	mediocre	75-100
Modified T.S.S.	43 MD + 100 l diesel	7	100	25-50	75-200	good (?)	75-100
Taungya	40-44 MD	5	400	60-100	200-400	excellent	40-60
Limba	114 MD	6	60-65	60-65	200-400	excellent	40
Okoumé	63 MD + 4-5 h machines	4	500	60-65	200-400	excellent	60
Conventional Narrow Deforested Strips	61-71 MD	10	130 à 200	25-50	75-200	mediocre	75-100
Modified Narrow Deforested Strips	48-59 MD + 130 l diesel	7	130 à 200	25-50	75-200	good (?)	60-75
New Growth	87-93 MD + 130 l diesel	6	400	60-100	200-400	excellent (?)	40-60

* MD: Man-Days; T.S.S.: Topical Shelterwood System.

Table IV.

Species	Felling diameter	ΔØ/Year	Log volume /tree	Rotation (years)	Volume/ha	Volume m^3/ha/year
Limba	0.65 m	1.6	4.5	40	270	6.75
Okoumé	0.80 m	1.3	6.5	60	390	6.5

The following aspects of the methods should be compared:

1. Cost of work: this criterion is clearly to the advantage of natural silvicultural methods, the Taungya method and the modified Narrow Deforested Strips method (assumption); in second place are the conventional Narrow Deforested Strips method and the Limba, Okoumé and New Growth methods (the Limba technique does not require thinning, and the cost is therefore the same as for the others).
2. Duration of maintenance work: with this criterion, the methods are ranked exactly in the reverse order (except the Taungya method).
3. Number of saplings produced: while the T.S.S. and the Narrow Deforested Strips method seek to produce only 100 to 150 saplings per hectare initially and 25 to 40 as the final result, the other methods should produce a final result of 60 to 100 trees/ha. It is important to translate these figures into timber volumes produced per hectare at the end of the rotation: we should in fact be even more accurate and estimate the proportions of "premium quality" logs (for veneer, planking, etc.) and second-class timber. But this is not yet possible without major risks of uncertainty and we have therefore used a broad range by estimating that the volume per log of an exploitable tree in a plantation will vary from 3 to 6 m³ depending on the species. On this basis, the volume to be expected per hectare should range from 75 to 200 m^3/ha with the T.S.S. and Narrow Deforested Strips methods, and from 200 to 400 m^3/ha with the other methods.
4. Growth rate: it is difficult to be rigorously objective on this point, but we believe nevertheless that the Taungya, Limba, Okoumé and New Growth techniques have produced much better results than the T.S.S. and Narrow Deforested Strips methods.

The relevant data are summarised in table III.

To compare the methods, their yields would need to be determined in m^3/ha/year. However, this is not possible on the basis of current knowledge, in part because we have very few data for the natural silvicultural methods, and in part because very little is known about the diameter to age ratio, except for Okoumé and Limba. For these two species, we have estimated that plantation productivity will be as indicated in table IV.

In both cases, a yield of 6 m^3/ha/year is obtained. With natural silviculture methods, it is likely that yields would range from 75 m^3/60-75 years to 200 m^3/60-75 years, or 1 to 2.5 m^3/ha/year.

The only one conclusion to be drawn from these figures is that there is no miracle solution: among the conventional methods, we must either choose a natural silviculture method or the Narrow Deforested Strips method, which is

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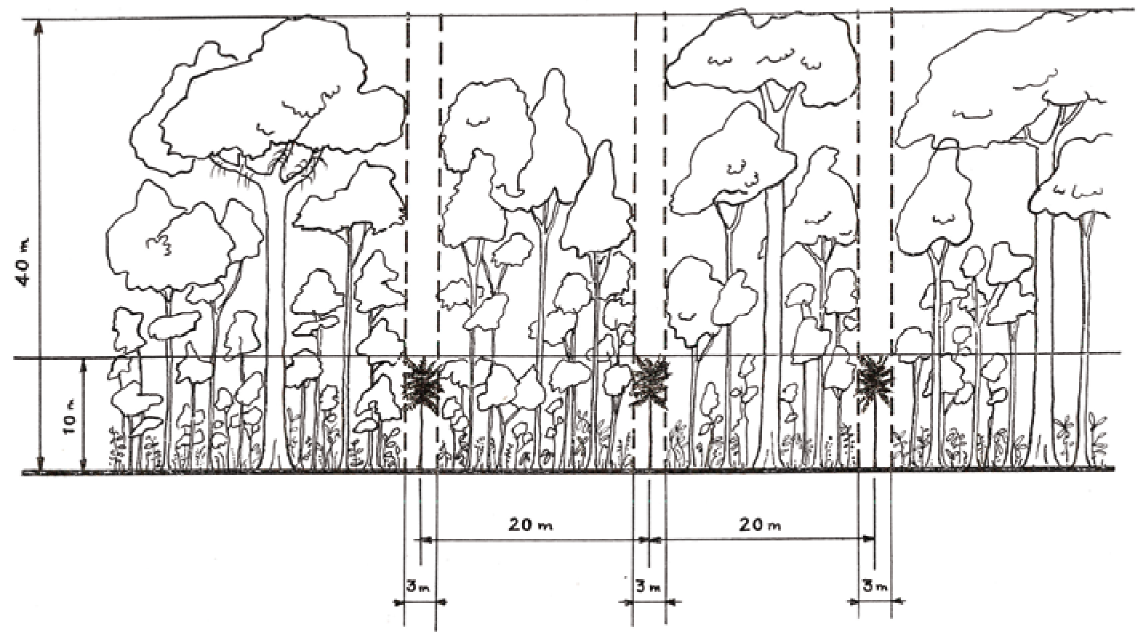

Figure 3.
Narrow Deforested Strips method.

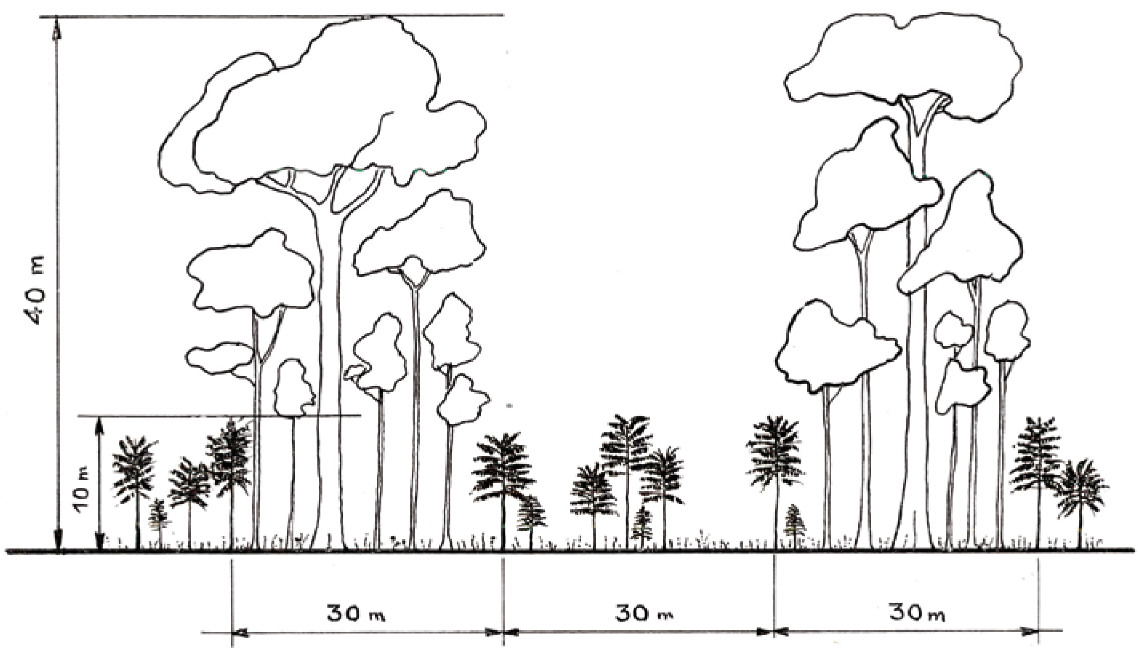

Figure 4.
Tropical Shelterwood System (T.S.S.).

cheaper (40-50 MD/year) but requires a much longer rotation that produces only 1 m^3 to 2.5 m^3/ha/year, or choose an artificial plantation method, which will be more costly (80 to 95 MD/ha) but will require a shorter rotation to produce a far higher yield of around 6-6.6 m^3/ha/year.

The choice will depend on circumstances, on the quality and quantity of available labour and on the goals to be achieved, in particular as regards the choice of species to be regenerated as a priority. This will be based in part on local ecological conditions and in part on the silvicultural properties of species of commercial interest. We have attempted to summarise the characteristics of the main species in table V.

Table V.

Latin name	Trade name	Rainfall (mm/year)	Technical properties	Transplanting method	Temperament	ΔØ/Year	Parasites
Triplochiton scleroxylon	Obeche, Ayous, Samba	1,400-1,200	Veneer	0.7-1 m saplings with apical whorl	Light-demanding	1.5-2 cm	
Terminalia superba	Fraké, Limba	1,400-1,200	-	0.80-1.75 m Stumps	-	1.5-2 cm	
Aucoumea klaineana	Okoumé	1,600-3,000	Veneer, paper pulp	Seedlings, root balls, stumps	-	1.25-1.75 cm	Psyllids, Pestallozia
Khaya ivorensis	African Mahogany	-	Veneer, saw-wood	0.75 m/1 m saplings, bare roots, root balls,	Light-demanding	1.5-2 cm	Borer
Khaya grandifoliola anthoteca	-	1,200-1,600	Saw-wood, veneer	-	-	-	-
Entandrophragma utile	Sipo	1,400-2,500	Veneer, saw-wood	0.75-1 m stumps, saplings with apical whorl	-	1-1.5 cm	
Entandrophragma angolense	Tiama	-	-	-	-	1.50 cm	
Entandrophragma cylindricum	Sapelli	1,400-2,500	Peeler logs, saw-wood, veneer	0.75 m to 1 m saplings with apical whorl	Semi-shade to light-demanding	1 cm	Borer
Pycnanthus angolense	Ilomba	1,500-3,000	Veneer, saw-wood	1.50 m saplings with apical whorl	Light-demanding	1.5-2 cm	
Terminalia ivorenis	Framiré	1,400-2,500	Veneer, saw-wood	1.50-1.75 m stumps	-	2-2.5 cm	? dieback
Afzelia bipindensis	Doussié	1,600-3,000	Saw-wood, roofing timber	0.5-1 m stumps	-	1-1.5 cm	
Tarrietia utilis diversifolia	Niangon	-	-	1.50-1.75 m saplings with apical whorl	-	1 cm	Borer (Gabon)
Lovoa trichilioides	Dibétou	-	Veneer, saw-wood	0.50-1 m saplings	Light-demanding to semi-shade	1.5-2 cm	Borer
Chlorophora excelsa	Iroko	1,400-2,000	Saw-wood	0.50-0.75 m saplings with root ball or apical whorl	-	-	Phytolimalata
Nauclea diderrichii	Bilinga	1,600-3,000	Saw-wood, roofing timber, telegraph poles	Root balls, short stumps, apical whorl, 0.50-1 m	-	1.5-1.75 cm	Borer
Cedrella mexicana	Cedar	1,200-2,000	Veneer, saw-wood	Direct seeding, saplings with apical whorl or root ball	Taungya	2 cm	No Borers in Africa, Bark beetles?

N. B.: Saplings with apical whorl: sapling with all leaves removed except the apical whorl.

Conclusions

Silviculture

This study will surely have demonstrated both the complexity of silvicultural problems in dense tropical forests and the inadequacy of current knowledge on this subject.

The expatriate foresters who, up to now, have made up the majority of forest administrators in tropical Africa, must have found it very difficult to suddenly start applying the techniques of temperate countries in such fundamentally different natural conditions: it was not possible to regenerate or plant forests on bare soil, partly because logged forests are not clear-felled, and partly because the risks of soil damage due to the severe climatic factors would be too great (except with the Taungya method over small areas).

The foresters therefore had to look into replacing natural logged, but practically intact, forest with artificial forests that would produce high yields without too much

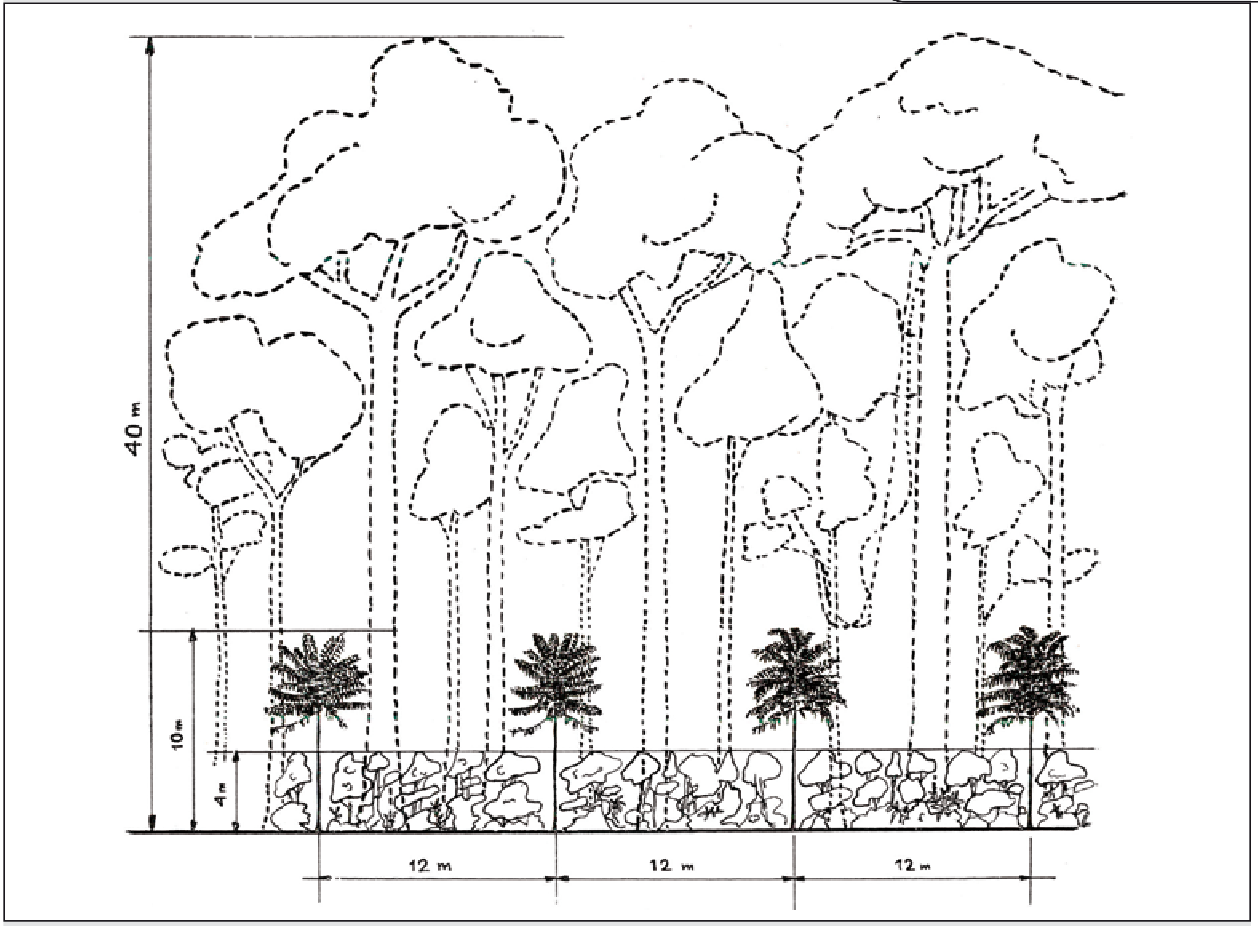

Figure 5.
Limba-Okoumé method.

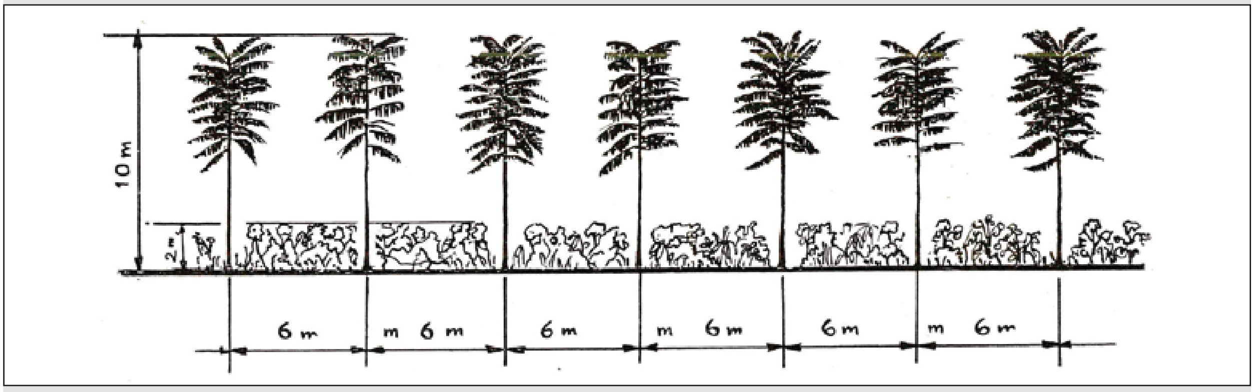

Figure 6.
Taungya method.

disturbance to the biological environment. The idea was to substitute the natural forest, but this had to be achieved at least cost – a requirement that obviously prompted the use of natural silviculture techniques, which seemed to be perfectly suited to the aims sought.

However, because a great many trees left standing after logging had to be felled to encourage regeneration, and because the regenerating saplings grew very slowly, many foresters abandoned the technique and turned to artificial regeneration, or plantations.

The latter, in turn, soon demonstrated their limitations: foresters either aimed to encourage sapling growth in full light on tilled (and therefore bare) soil (Taungya method), which resulted in parasite attacks and poor self-pruning, or to raise the saplings in a forest ambience that had to be maintained (Martineau method, Narrow Deforested Strips method), and which raised the same intractable problem of slow growth due to insufficient light as with natural silvicultural methods.

Photo 5.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. A 7-year-old Framiré plantation (1958).
Photo Leroy-Deval.

Photo 6.
C.T.F.T., Gabon. Ikoy-Bandja Forestry Station. A 5-year-old *Khaya ivorensis* plantation, in 1960.
Photo Leroy-Deval.

The Limba and Okoumé methods brought an initial solution: it soon became apparent that these hyper sun-loving species could be planted on open ground, and that most of the vigorous new growth of secondary species under these natural conditions had to be maintained as it had a beneficial effect on sapling conformation and self-pruning and helped to maintain a forest ambience. But although these two fast-growing species were able to hold their own against the competing regrowth, most of the other species could not do so without the help of a prohibitive number of clearing operations.

Another solution is being attempted, with the "New Growth" method, which maintains new growth of much slower-growing shade species for as long as possible around the saplings and allows most planted species to compete successfully with the new growth without excessive needs for maintenance in a forest environment conducive to their development – the one difficulty with the method being the need to maintain all plants at the same rate of growth. Furthermore, the possibility of varying the amount of light by more or less entirely destroying the dominant canopy should allow any species to be planted, regardless of temperament, which in effect makes this a general-purpose method.

Finally, a third solution is being sought by modifying the different conventional methods to substantially improve the growth rate of saplings by considerably increasing the amount of light available to them. This is done as follows with:

- the Tropical Shelterwood System (T.S.S.): by suppressing all non-commercial tree species in all stories[1];
- the Narrow Deforested Strips method: by destroying the entire dominant story between the plantation strips and the new growth of shade species between the saplings planted in the strips;
- the Martineau method: by quickly destroying the entire dominant story and the new growth of shade species between the saplings; thus modified, it becomes the "New Growth" method;
- the Taungya method: by maintaining as much new growth as possible between the saplings, so as to form a forest.

It can be seen that these methods are actually very similar: they all aim to place saplings, whether planted or naturally seeded, in the best possible light conditions, while "educating" and maintaining them in a forest ambience provided either by the understory of the surrounding natural forest (Narrow Deforested Strips method), or by the new growth of secondary species that develop as light reaches the ground (Limba and Okoumé methods), or again by the new growth of shade species deliberately left as soil cover (the other methods).

What is certain is that there will be few differences, in silvicultural terms, between the T.S.S. and the New Growth method, if the latter is used with semi-shade species, of which some trees from the dominant story would need to be left standing. However, in our view, these will all be useful because once the optimum amounts of light required by the main species have been determined, they can be treated by applying one method or another: the New Growth method for those demanding the most light and the Narrow Deforested Strips or T.S.S. method for less light-demanding species.

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1 If these are too few in number, a few trees of each of the species can be kept in an even distribution across the plantation to avoid over-large gaps.

Management

In view of current results, and from the conclusions of this study, it might be tempting to simply abandon natural regeneration techniques in favour of artificial plantations. This would not only be overhasty, but also unacceptable, because it would ignore planning constraints. There are two aims in tropical forestry: on the one hand, to maintain or increase forest potential depleted by logging, and for this purpose, foresters will often need to look to plantations with the highest yields. But on the other hand, they are responsible for maintaining forest growth and for managing often very large areas of natural forest, and for this purpose, given the means currently available, they can only resort to more extensive techniques, up to and including natural silviculture methods: it would be unthinkable to replace several million hectares of forest with plantations when it is feasible, through forestry operations generally costing half as much, to obtain appreciable and sustained yields over large areas. Of course it is always possible to hand an economically lifeless forest back to Nature, such as a logged-over forest that will never regenerate unaided but would preserve a wooded environment; but the only way of preventing such forests from being taken over by a population seeking ever more land to cultivate is to manage it over the largest possible area.

Unfortunately, this would appear to be very difficult with current natural silviculture techniques because of the excessive duration of the necessary regeneration operations, which will eventually choke off any major work programme. This is the reason why we have considered improving these techniques by attempting to increase the growth rate of species to be regenerated by providing them with a great deal more light and thereby reducing the duration of maintenance work. We believe that this is a research priority and that any improvement in this area could have major repercussions for the future of dense tropical forests.

But especially, we believe that the Narrow Deforested Strips method, for which we have discussed improvements based on the same considerations, could in many cases, thanks to its extensive nature and modest cost price, be used as a relay for natural regeneration, as it would always have the classic plantation advantages over the latter: the vigour and selection of nursery-raised saplings, the choice of suitable species of interest and regular planting schemes that greatly facilitate both ongoing maintenance work and supervision and forestry planning for the future.

We hope that the modifications we have suggested will lead to improvements in the silvicultural value of this method and make it possible to obtain 30 to 50 fine trees per hectare, representing 100 to 250 m³ of timber, at a cost of around 50 MD/ha.

In our view, it would then become the most appropriate silvicultural technique to serve as a basis for the extensive management we have considered as a complement to dense, high yield plantations.

General conclusions

Through this study, we have attempted to review current knowledge on tropical silviculture: while some will feel we have been too severe, others will believe we have been over-optimistic. Our aim was simply to discuss, honestly and without bias, the available information, which we believe may be summarised as follows:

- Many different methods have been attempted, usually in too much haste, and there have been many failures.
- Some methods are well proven and producing good results every day, others could reach this point in the near future if some effort is made to improve them.
- In the current context, priority must be given to research, to which the necessary means must be devoted.
- Resolving the problem is a matter of urgency, and what is at stake is no less than the future of Africa's dense forests and of the forest economy in each of the countries concerned.

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