PRE-PROJECT STUDY ON ENRICHMENT PLANTING

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Before tackling a study, one should make sure that the technical language is understood by all. Thus the terminology used should be clearly stated or widely-known common definitions should be referred to. Here, we are interested in vegetation formations in tropical Africa. The latter were itemized and defined at a meeting of experts in Yangambi (Zaire) in 1956.

We shall briefly describe the formations concerned by the enrichment work undertaken in various countries in West and Central Africa, whose definitions are given in the <u>Manual of Forest Botany</u> by R. LETOUZEY (CTFT, 1969). Dense forests are closed formations, whose tree and shrub crowns touch. The existence of such formations depends principally on the climate. They are as follows:

- Forests of low and medium altitudes:

+ Dense, moist forest (rain forest)

"Closed formation with trees and shrubs reaching varying heights; no Gramineae on the forest floor, but often suffrutescent plants and less often herbaceous plants with big leaves not belonging to the Gramineae family ".

The following can be specified:

* Evergreen, dense moist forest, (or true rain forest), the majority of whose trees are in leaf the wole year round (Fig. 1)

* Semi-deciduous, dense moist forest, a large proportion of whose trees remain without leaves for a part of the year. (Fig. 2)

+ Dense, dry forest (Fig. 3)

"Closed formation with trees and shrubs reaching varying heights (but in general, not as tall as those of dense, moist forests); the majority of the tall trees lose their leaves for a part of the year (exceptionally, they remain evergreen: dry, evergreen forest); the undergrowth is made up of shrubs either evergreen or deciduous, and on the forest floor there are tufts of Gramineae in places".

These forests are also characterized by the quality of their floral composition, as well as by varying quantitative aspects related to their commercial potential.

A concrete example in the Ivory Coast shows that specifying 72 main species of attractive commercial value and secondary species of lesser interest, the following distinctions can be made between:

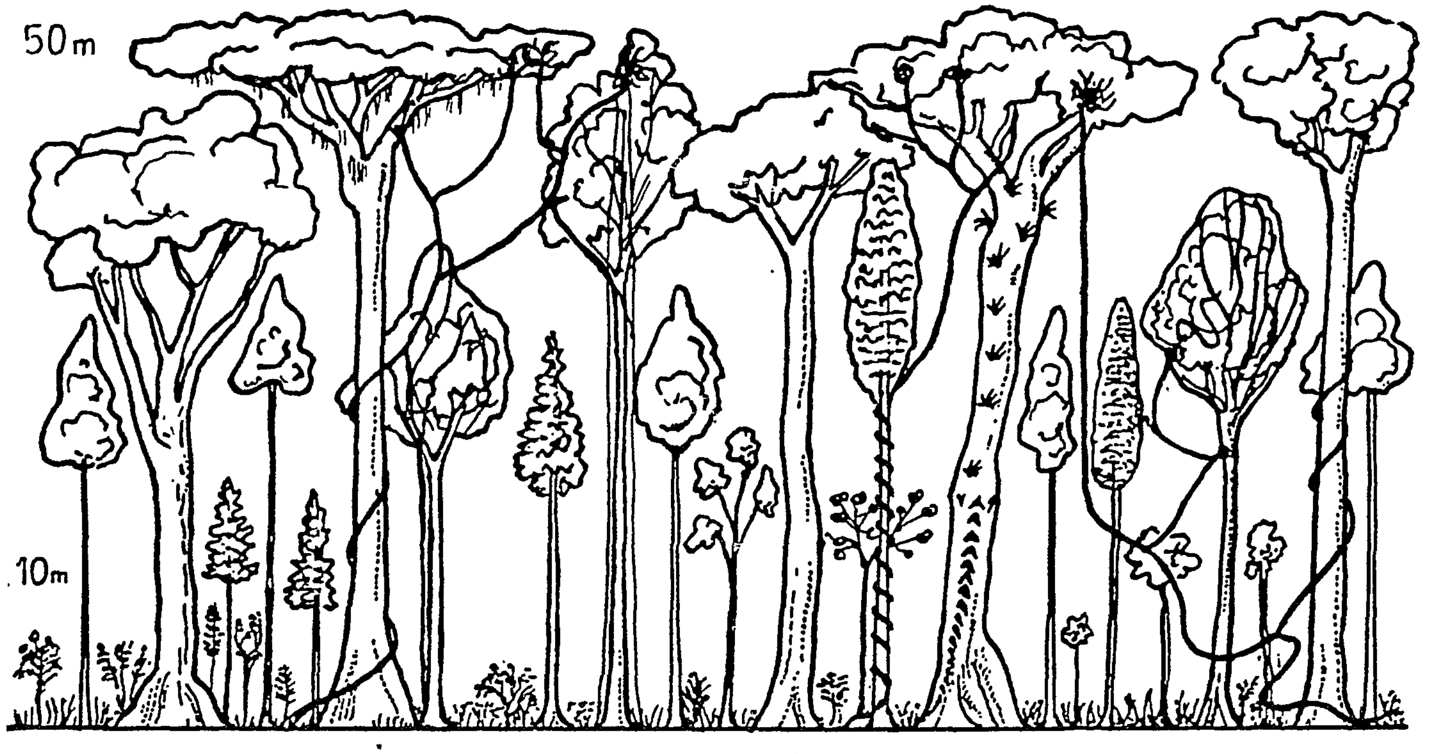

Fig. 1 - Evergreen dense moist forest

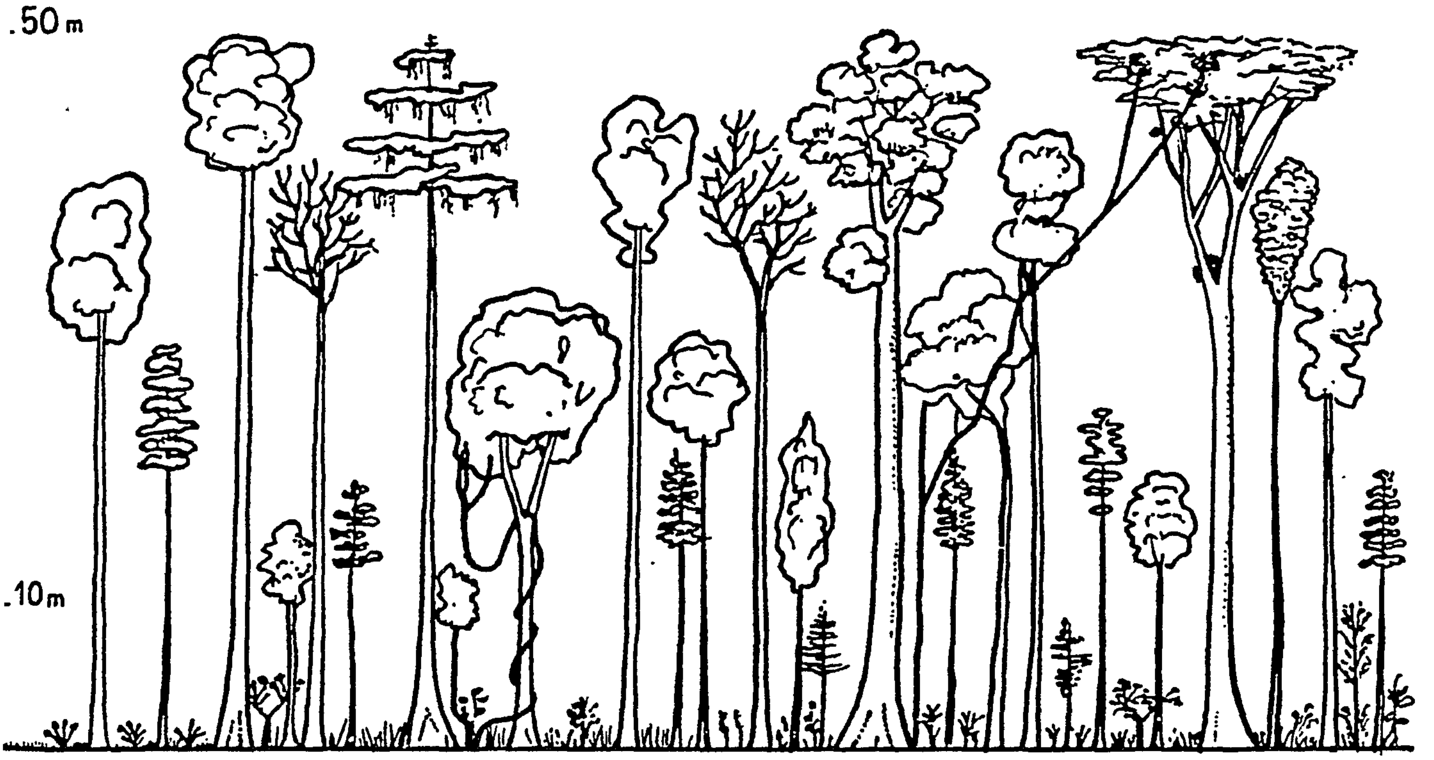

Fig. 2 - Semi-deciduous dense moist forest

Fig. 3 - Dense dry forest

- an evergreen, rain forest
- a semi-deciduous, rain forest
- a transition, dense moist forest, of semi-deciduous type but with species frequencies which constitute some transition between the two preceding ones.

	Semi-deciduous forest		Evergreen forest		Transition forest	
	Number of stems/ha	Basal area m²/ha	Number of stems/ha	Basal area m²/ha	Number of stems/ha	Basal area m²/ha
Main Species(72)	208	20.5	106	8.6	169	13.5
Secondary Species	186	7.4	347	15.9	192	9.1
TOTAL	394	27.9	453	24.5	361	22.6

(Source: CTFT, 1985)

The vegetation formations as described will make up the field wherein the artificial enrichment planting took place.

The first trials, around 1910, on the one hand, and the first large-scale actions on the other hand started above all in evergreen, dense moist forests for the following reasons:

- in West Africa, they are geographically distributed along the coast, which provided for an easier access at the start of operations,

- their floral composition shows a smaller number of main species and thus a quicker depletion after logging.

112 - The concept of enrichment

Contrarily to what the first foresters dealing with the tropical forest at the turn of the century thought, the tropical forest does not hold an important volume of standing crop. With 250 to 300 m^3/ha, it does not at all reach the level of the productive forests in the temperate regions.

If the marketable volume only is to be taken into consideration, the figures are much lower. They range from 5 to 25 m^3/ha on average in relation to the extent of the logging of the forest and of the commercial value of its specific composition.

The commercial value has considerably changed over the years. It used to concern a relatively small number of species at the beginning of the forestry departments' operations and yet these departments have rapidly shown concern about the loss in the value of stands and the necessary remedial procedures.

Thus, the major preoccupation was to define and perfect forest actions aiming at increasing or, at least, maintaining the timber potential of a natural stand. So, the objective was to ensure a sustained yield that could be as homogeneous as possible, within the framework of forest management. Enrichment became a saving grace for the forest for which two major options became apparent, dividing those involved into proponents of natural regeneration on the one hand, and proponents of artificial regeneration on the other hand.

The choice of either system gave rise to many debates and conflicts, notably brought to the fore during the Forestry Conference in Abidjan in 1952, thus prolonging in the tropics the controversy started in Europe in the 30's. We shall only study here the systems requiring relatively large-scale plantations, and we shall only quote the different systems of natural regeneration or the improvement of the dynamics of natural stands:

- As for the systems related to natural regeneration, three major techniques have been used on a large scale in Tropical Africa:

. "Selective Management" in Ghana,
. "Improvement of Natural Stands" in the Ivory Coast,
. "Tropical Shelterwood System" in Nigeria.

For these three techniques, it was very difficult to check the results stemming from the treatment of important areas. As the distribution of precious species (especially on a large scale) was heterogeneous and the forest operations were spread over lengthy periods, radically different treatments had to be applied. Unsatisfactory grading of light exposure led to the proliferation of lianes, the outbreak of worthless heliophilous species, a strong luxuriant regrowth, etc... However, the fact that the work was spread over in space and time led to the dissipation of energies and to the withdrawal in 1966, for lack of homogeneous results in keeping with the means involved.

- The silvicultural techniques for the improvement of the dynamics of stands aim at accelerating the growth of all valuable species of any size among a constituted stand. What is taken into account is the dynamics of the stand as a whole, not really attaching importance to provoking regeneration on the forest floor.

The initial techniques, the "improvement of Okoume stands"* (Aucoumea klaineana) and "uniforming from the top" were followed by experiments still in progress nowadays.

. The first technique was aimed, in the Gabonese forest, at spots or clumps of Okoume resulting from the natural sowing of clearings. The idea was to bring, as quickly as possible, the maximum number of trees to maturity stage (thinnings).

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* See the list of species with corresponding scientific and commercial names in Appendix.

This management-scale silvicultural activity undoubtedly favoured the dynamics of the stands where Okoume was dense or suppressed and thus whose growth was impaired. Unfortunately, the increase in yield was not measured.

. The second system, uniforming from the top, was applied to particular structures of the dense, moist forest and on relatively small areas of what is now Zaire, around the 50's. It aimed at favouring the medium categories of the best represented precious species, while getting rid of any competition from worthless trees, through simultaneous action in all layers. However, this kind of trial was discontinued for historical reasons.

The experiments now in progress have the following prerequisites:

- To take into consideration large unit plots only (several hectares) with as many replicates in space as possible,

- To measure simple parameters above all (e.g. diameter, tree location...),

- To have at one's disposal statistical means to interpret data (computerization...),

- The treatments chosen are limited to the exploitation of marketable stems and the elimination via graded poisoning of species with no technological future.

Plans of action have been established in the Ivory Coast and Central African-Republic (as well as in French Guiana and Brazil, in South America). New plans of action are scheduled for Cameroun (and for Kalimantan in Indonesia, Southeast Asia). The first results show that a simple silvicultural action (through devitalization of tall species with no commercial value, or through exploitation of valuable species) creates an imbalance favourable to the growth of the remaining stand and especially to that of precious timber species, which is indeed the objective aimed at. Canopy-opening treatment especially leads to a better dynamics of small and medium stems on which competitive phenomena are heavily exerted.

Forest planting or "enrichment planting" (the subject of this document) should on the other hand, by planting in a relatively changed forest environment, result in the introduction of valuable species which, in the long run, will constitute most of the yield. Extra yield may possibly be brought by existing valuable species or those that appeared via natural regeneration. The word itself, "enrichment", has sometimes been used in the French forest terminology to refer to actual conversion planting, because of a progressive evolution of techniques towards a more and more elaborate transformation of the original ecosystem into an almost artificial, mainly economically-directed environment.

Some distinctions can be made in relation to the degree of transformation of the original environment characterized by its heterogeneous character and its genetic wealth and whose ultimate end may be a monospecific even-aged stand.

The first trials were very cautious and concerned only a few well-known species (Mahogany: Khaya spp., Sapelli: Entandrophragma cylindricum, Okoume: Aukoumea klaineana, Iroko: Milicia excelsa (synonym: Chlorophora excelsa), Samba: Triplochiton scleroxylon) which were sure to find outlets on export markets; this was done with a view to "incite and help nature, to hasten its work".

The action on the original natural forest later intensified for commercial reasons (wider range of regularly-exported species) and silvicultural reasons (better knowledge of the character and reactions of the species used).

The enrichment planting techniques can be classified according to the extent of operation and change of the initial ecosystem. Limited operation, in narrow "layons" (Francophone Africa-style lines) with wide spacing, causing little disruption on the environment, finally evolved towards preliminary and total destruction of the natural forest, largely mechanized in fact.

The term of origin "enrichment" has now a more destructive and intense meaning attached to it, in so far as it is very difficult, even impossible to transform the forest ecosystem into a more productive system without the help of techniques which lead to a radically new system. It then really becomes conversion planting.

The FAO Committee for the Tropical Forest Action Plan in the report of the 2nd Session in October 1969 recommended the following terminology:

- "Enrichment planting: planting by groups or in lines, with varying intensity, aimed at enhancing the percentage of desired species in natural forests without eliminating the existing useful trees. Natural regeneration is a significant part of the crop at mature stage.

- Conversion planting: planting aiming at a complete replacing of existing natural vegetation by an entirely new artificial forest".

Besides, the former definition matches the meaning that foresters in English-speaking countries have always given to this system, whereas in French-speaking countries, the progressive evolution of techniques was not followed by the parallel evolution of terminology, hence the use of the term "enrichissement" for all the systems, from the least intensive to actual reconversions. However, the English meaning of the term should be adopted.

12 - Description of enrichment planting techniques tried in West and Central Africa (rain forest)

Numerous systems have been tried with varying success and have changed over the years, with sometimes few differentiation criteria, thus creating transitions rather than separations among them.

We shall briefly describe these systems in order of increasing transformation of the initial forest.

121 - Planting in layons ("méthode des layons") (Fig. 4)

It is an extensive system, which gives off a rather loose enrichment planting ending up in the homogeneization of stands, in the long run only, at least two rotations .

It consists in opening, in the forest, parallel equidistant layons and in introducing, at regular intervals, seedlings grown in nurseries, of so-called "noble" species. The seedlings benefit from more light, while remaining in a forest "atmosphere".

On the forest floor, the vegetation is cleared on 2 m wide and the plants are spaced 2 x 2 m, 2.5 x 2.5 m or 5 x 5 m on a single line. But since the plants are in the open, they also require a relatively intense destruction of the side canopy. The distance between the layons has changed over the years and now reaches 20 to 25 m with layons largely cleared from the top (8 to 10 m). At the same time, all the trees with thick and low cover preventing satisfactory light exposure of the layon are ring-barked, i.e. the live tissues of the stem are destroyed with a notch around the trunk, thus putting an end to any sap flow until death occurs. Besides, an early cleaning has to be effected to ensure the seedlings' survival and avoid protrected maintenance.

122 - Planting along improved layons

In the above system, the reduced width of layons provides 7 to 8 % relative light exposure only. But the character of the species was poorly known at the beginning of these actions. Taking into account the necessary needs of the light-demanding species implanted, the following steps had to be taken:

- increasing direct light exposure with a wider layon, without going to extremes so as to establish one planting line only.

- increasing side light exposure by reducing the height of the stand between layons, through (phytohormone) devitalization.

With a 5 m wide layon and a stand height down to 15 m, 25 % direct light exposure and 35-40 % side light exposure are obtained, i.e. a total of 60-65 % relative light exposure.

Practically speaking, the technique is as follows:

- to establish 5 m wide layons spaced 10 x 10, 15 x 15 or 20 x 20 m according to the enrichment rate chosen;

- in the layon, to log manually , at knee length, all trees of less than 15-18 cm in diameter. This permits to keep a forest micro-atmosphere at forest floor level without interrupting the biological dynamics while ensuring some protection against the invasion of undesirable pioneer species, e.g. the umbrella-tree (Musanga cecropioides). Besides, the presence of this regrowth will permit to "corset" young plants and help them to grow straight and lop themselves;

- over the whole extent of the forest, to devitalize all the trees which exceed 15-18 cm in diameter. Those with a smaller diameter

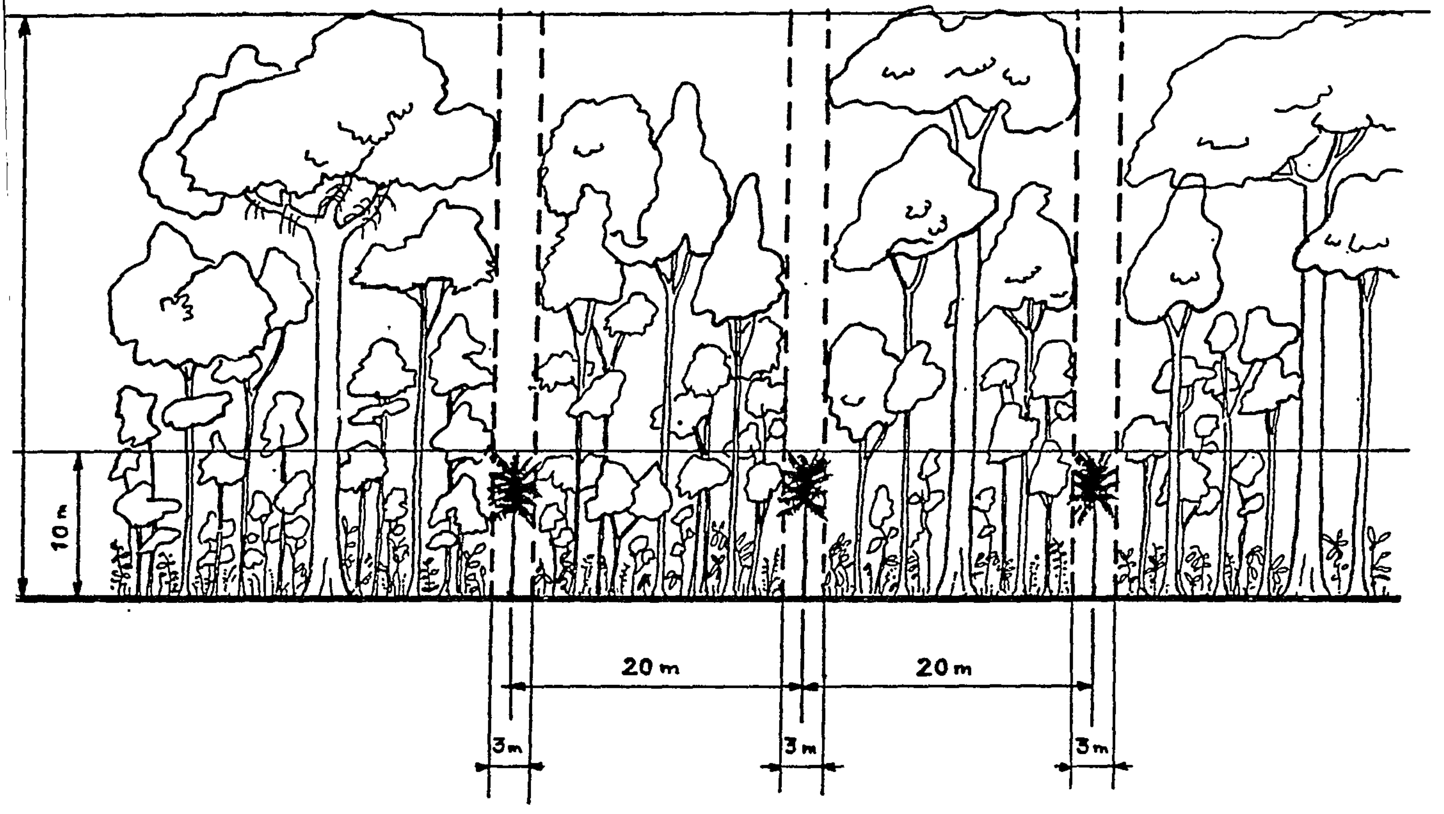

Fig. 4 - Méthode des layons

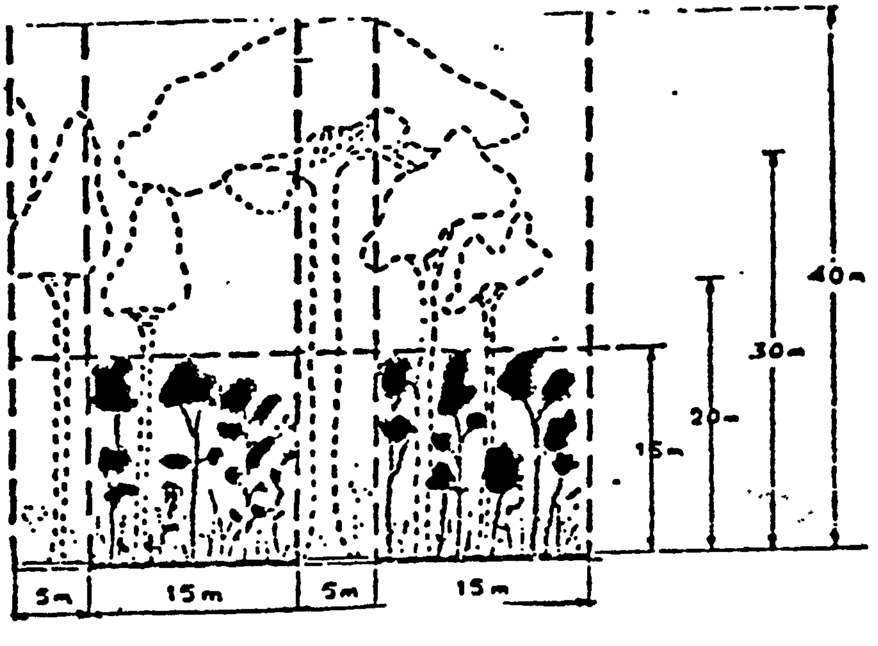

Fig. 5 - Méthode du sous bois

most probably are not over 15 m in height and thus do not prevent side light exposure;

- to plant in the layons a planting line spaced 3 x 3 m;

- to clean seedlings manually (lianes), while keeping the regrowth under their crown.

This system permits to get an average of fifty élite trees per hectare with a satisfactory growth, providing they are given full attention and strict treatment to ensure their protection against natural competition.

123 - Planting on sample spots

This system, used by Belgian foresters in Zaire, stems from Anderson's system used for reforestation in the Scottish moors.

The technique consists in introducing the species for regeneration at a high density. The seedlings are grouped in sample spots of the same area, equally distributed on the land with wide spacing between sample spots. Practically speaking:

- creation of mobile nurseries in the forest to accustom seedlings to grow in the shade,
- defining 4 m square plots with inter-group distances 10 m x 10 m, centre to centre in the four cardinal directions,
- in the plots, cleaning lianes and herbaceous regrowth without interfering with shrubs,
- planting in a dense manner the species concerned, in varying forms: seedlings, stumps,...
- as soon as the seedlings take, progressive elimination of shrubs and, with utmost caution, of the tree canopy.

This system aims at preserving the ecological environment and recreating at once the state of stands for the species introduced, while scattering the sample spots for economical reasons.

The relative light exposure thus obtained for young plants is hardly over 5 to 10 %.

124 - The technique of the undergrowth (Fig. 5)

This technique is based on the manual yet partial destruction of the canopy at planting time.

Unlike what will be described later, the objective here is to maintain, between the planting lines, the understorey called "undergrowth" to establish species which do not bear direct light exposure immediately after being planted, e.g. Sipo (Entandrophragma utile). This technique can also be adopted for heliophilous trees for which intensive light exposure linked to high density may nevertheless lead to the development of specific parasites, e.g. Mahogany (Khaya ivorensis).

The technique consists in devitalizing the trees of the overstorey, in opening planting layons and maintaining between these layons part of the undergrowth which will be cleaned progressively according to the growth of the plants introduced.

125 - Entire and progressive destruction of the forest through devitalization

The aim is to destroy the preexisting forest without any mechanical usage which scrubs the forest floor and leads to the too rapid growth of secondary species, e.g. the umbrella-tree.

A. The technique of the Regrowth (Fig. 6)

This system consists in providing the seedlings to be introduced with the maximum light as soon as they are planted, while also ensuring the protection of the forest floor through the preservation of a regrowth of shade bearers. The regrowth covering the floor maintains its fertility, prevents the development of the umbrella-tree (*Musanga cecropioides*), the fatal enemy of seedlings in the first years and ensures the latter satisfactory straight growth with natural lopping. Thus, one abides by an old cultivation rule that requires that seedlings shall be "their feet in a cool place and their crowns in the sun".

This system includes the following operations:

- knee-high manual felling of trees of less than 15-20 cm in diameter. They are left on the cutting ground without burning. Their small size does not require any further crosscutting;

- immediate devitalization by phytohormones of all or part of the standing trees left according to the degree of light exposure required;

- establishing seedlings with spacings 4 x 4 m to 6 x 6 m in narrow layons manually reopened in the regrowth. The seedlings which provide the maximum initial growth according to species are used: stumps (aged plant whose stem is lopped and roots pruned) or entire plants with tall stems;

- manual maintenance, repeated over a period of 5 to 8 years according to the species growth, should ensure that the regrowth under the crowns of noble species is maintained, while fighting against the umbrella-tree more especially.

B Martineau system

We are no longer dealing with dense plantation under forest. Noble species are being introduced cautiously under a progressively destroyed canopy. That is one of the first systems for planting in the open designed for the dense tropical African forest, aimed at replacing the heterogeneous forest by an even-aged stand of commercial species.

The technique is as follows:

- to destroy manually the undergrowth composed of the stems of up to 10 cm in diameter;

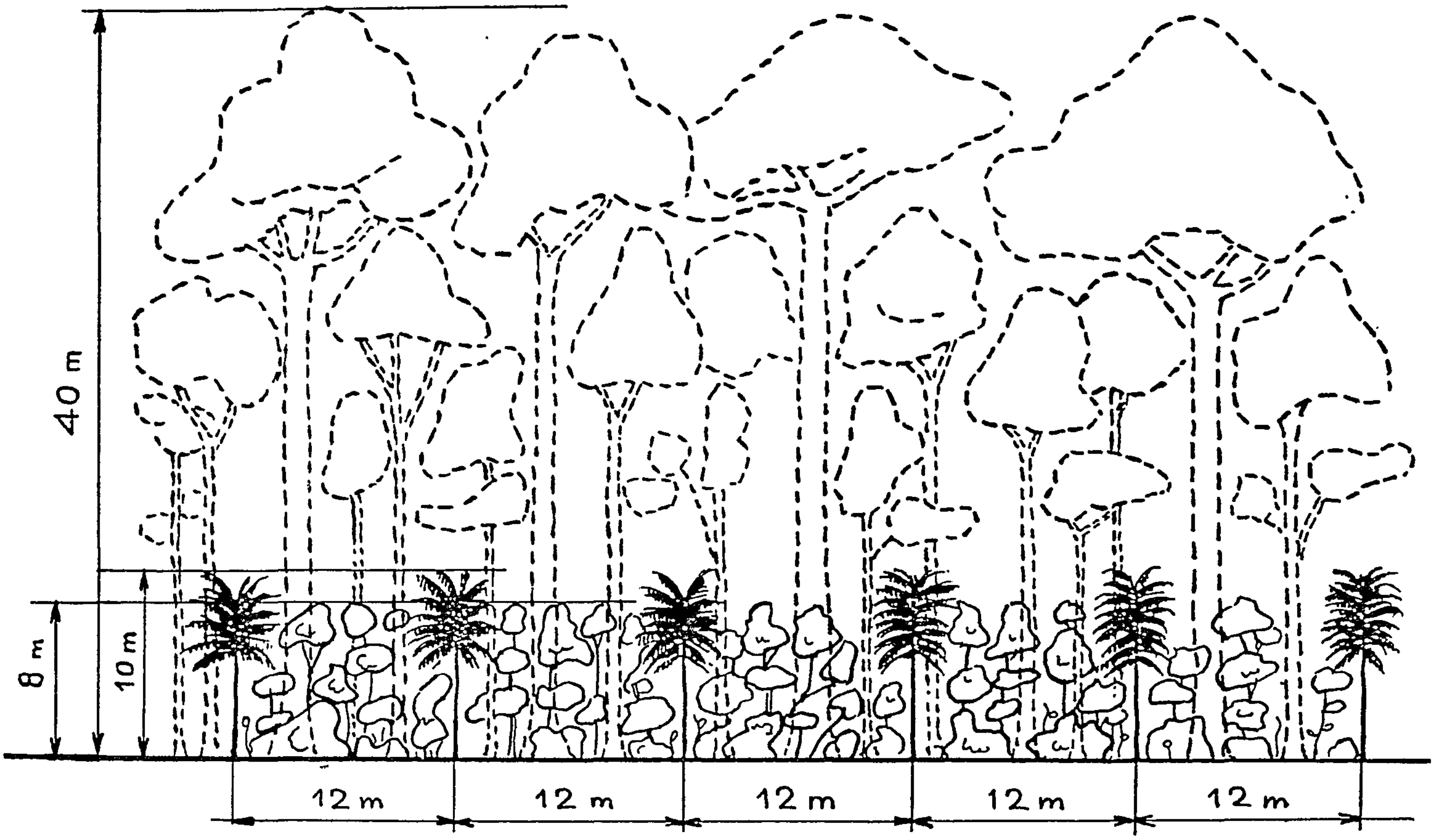

Fig. 6 - Méthode du recrû

- to place 2,500 seedlings/ha and ensure the cleaning of young plants;

- to destroy progressively, by ring-barking, the main canopy, one, two and five years after planting. Then, to ensure the extra light through maintenance visit every five years as of the tenth year.

Unlike the preceding system, the plantation is in the shade of the canopy trees with progressive cleaning after planting.

126 - Complete destruction of the forest before planting

The forest cover must be entirely suppressed in one operation to provide the species to be established with full light exposure from the start.

A The "Taungya" system

Plots from forest estates are temporarily granted to farmers to set up a forest plant - interplanted cultivation association.

The objective aimed at is to make the tree benefit from the advantages of the preparation of the ground undertaken by the farmer: light exposure preparation, working of the soil, fertilization, and of the maintenance of the cultivation by the latter.

A plantation of light-demanding species should avoid the utilization of bare roots. Plantation distances heavily rely on the type of interplanted cultivation chosen.

The plants established by either partner then benefit from good conditions for growth during the two to three year-cultivation period; the forest department is then in charge of the maintenance operations as long as need be.

This agro-forest system which generally favours the forest part is an economical means to reforest land that might have been taken off the forest estate sooner or later.

In exchange for his work, the farmer enjoys social benefits as incentive bonuses, besides the right to cultivate and have the crop at his disposal. His main interest lies in the temporary access to the forest estate, where he can find fertile land. The Taungya system has given good results in the areas where a lack of fertile land has established itself, indicated by shorter fallows.

B - "Limba" system (Fig. 7)

Limba (*Terminalia superba*) is a light-demanding species which grows naturally straight and does not need to be pruned during its growth. Keeping an adjunct regrowth or having too dense plantations are thus unnecessary.

The system consists in the complete clearing of the preexisting forest to permit to establish plants satifactorily before the dry season.

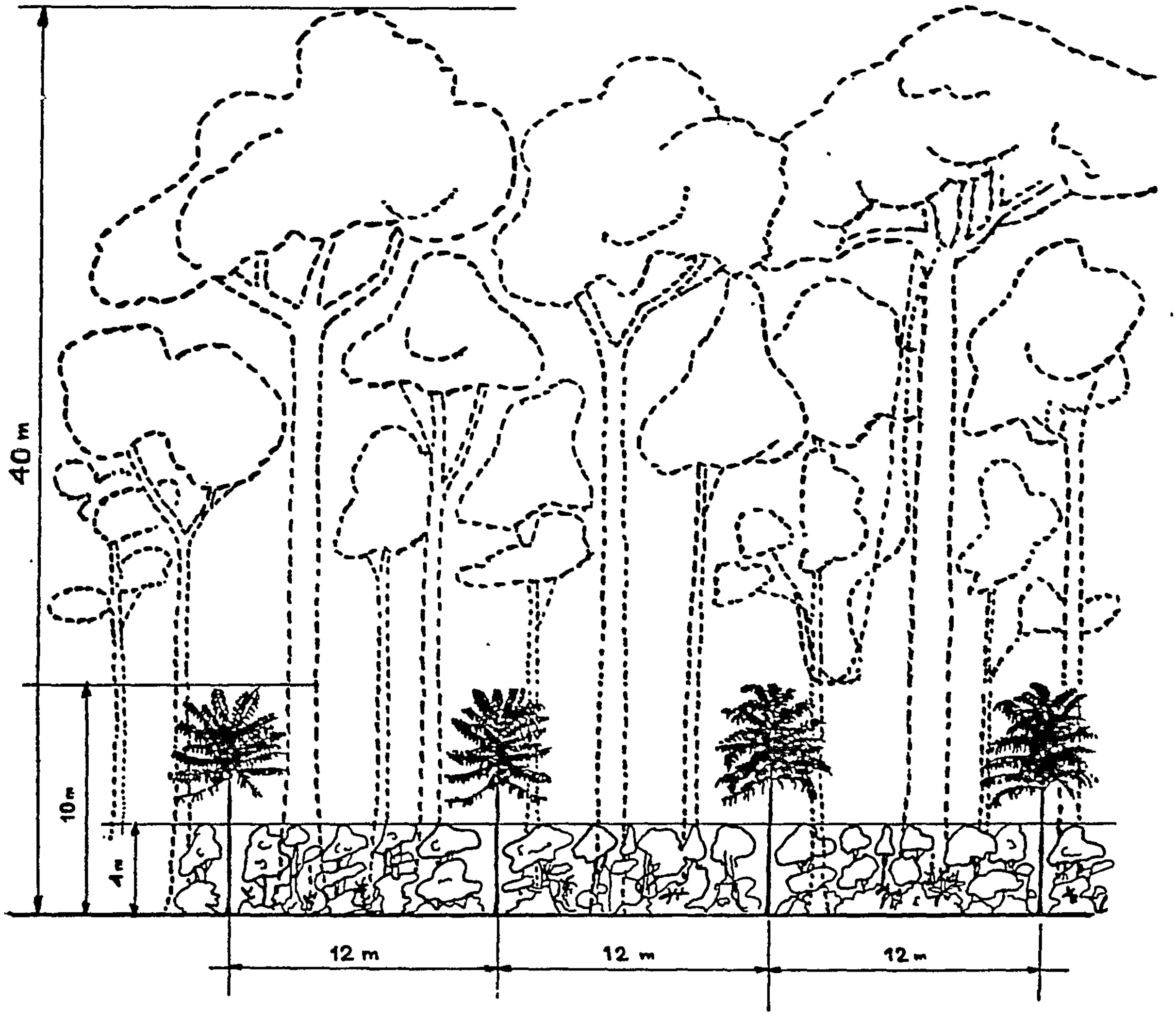

Fig. 7 - Méthode "Limba"

The technique includes:

- manual felling of trees of less than 30 cm in diameter;
- ring-barking or poisoning of all the trees of over 30 cm in diameter;
- burning all slash;
- opening planting lines in the vegetable fragments;
- establishing Limba plants in stumps of 1 m to 1.5 m in height. The planting distances can be permanent, 12 - 14 m, or semipermanent if a future selection is to be carried out;
- maintenance should be strict for the first years to clean the plants of lianes and umbrella-trees. It should be pursued for 6 to 7 years.

C - Techniques based on mechanized deforesting (Fig. 8)

The preceding system was adapted to Okoume plantations (Aucoumea klaineana), the only difference lies in the mechanization of deforestation.

The trees of less than 30 cm in diameter are felled with a bulldozer whose power is adapted to the type of initial vegetation, the larger trees are poisoned. The fragments are windrowed and burnt, the seedlings placed in the ground in between the windrows. The selection of planting distances is wider since the field is entirely free. Maintenance is important, yet less strict because of the initial scrubbing of the forest floor.

This system is now well adapted to many other species, e.g. Terminalia ivorensis and T. superba, Samba (Triplochiton scleroxylon), etc...

13 - A few examples of the application of the systems described

After forest departments had set up in West Africa, resource managers quickly brought to the fore the problems posed by the heterogeneous composition and regeneration of the dense tropical African forest. Thus artificial enrichment operations to homogenize the environment were undertaken in the various countries involved.

131 - The Ivory Coast

A - From 1930-31, dense planting under forest was done in the forest of Yapo, about fifty km North of Abidjan (Martineau system). A 90 ha area was enriched with Niangon (Tarrietia utilis) small wildings, spaced 2 x 2 m, i.e. 2,500 trees per hectare. This species found itself in its natural range. Other species were also introduced in small proportion, e.g. Mahogany (Khaya ivorensis), Dibetou (Lovoa trichilioides), Tiama (Entandrophragma angolense), etc...

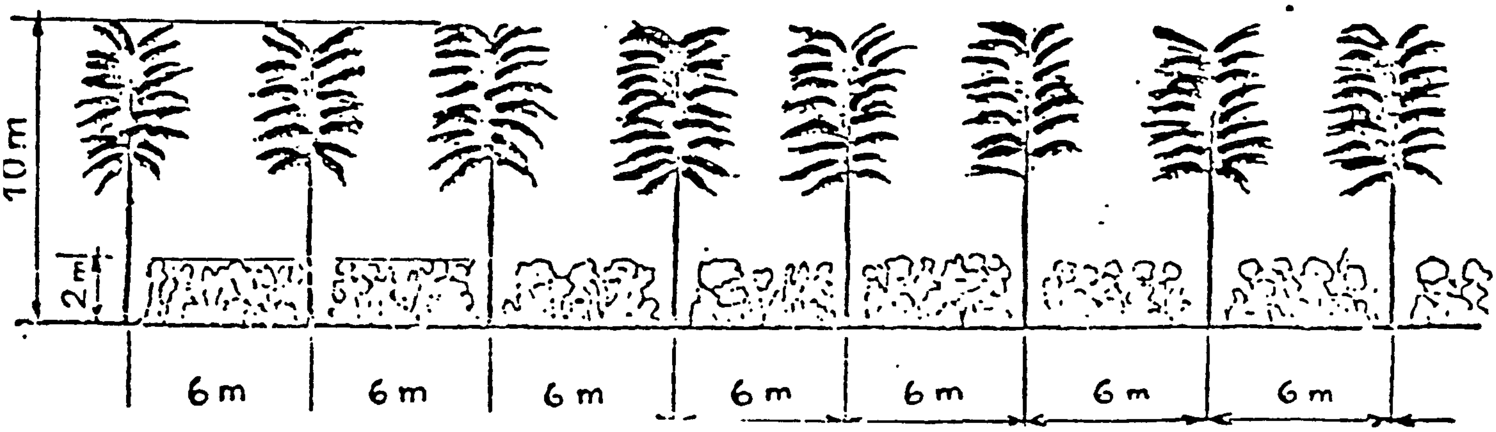

Fig. 8 - Techniques based on mechanized deforesting

An analysis of the plots concerned, carried out in 1985, shows that the results were not outstanding but relatively satisfactory. On two plots covering 23 ha, the residual density of Niangon (Tarrietia utilis) was 90 to 130 trees per ha (over 30 cm in diameter), often frail in appearance. Following findings established during the lives of these stands, it appears that:

- the initial canopy was definitely cleared too late. At the age of 30 years, a few trees of secondary species still dominated the stand;

- the first thinnings took place when the stand was well on in years, 25 - 30 years. Which did not allow a dynamic reaction of the remaining stand and weakened the latter's resistance to bad weather conditions (increased risk of windbreak);

- maintenance was regularly performed for the first 8 years and then irregularly later.

At the age of 30 years, the following results were recorded on Niangon (Tarrietia utilis) in Yapo:

- 55 to 98 stems/ha of over 30 cm in diameter,
- mean basal area: 20 m^2/ha,
- mean diameters:
  . 15 to 20 cm for all
  . 26 to 31 cm for the 150 largest stems
  . 32 to 38 cm for the 50 largest stems
- mean annual increment on the diameter:
  . 0.6 cm for all
  . 1.0 cm for the 150 largest stems
  . 1.13 cm for the 50 largest stems
- the mean volume ranged from 130 to 200 m^3/ha with an increment of 4.3 to 6.7 m^3/ha/year.

At the age of 48 years, if the increment of the 150 largest trees/ha only is taken into account, the result for dense plantations (Martineau system) 0.92 cm/year is better than that for the low density plantations (layon planting): 0.80 cm/year.

As for Mahoganies (Khaya ivorensis) mixedly planted, they behaved better than Niangon (Tarrietia utilis) : their diameter increased by 1.5 cm/year.

B - A few years later, for the sake of economy, among other reasons, planting in layons 10 m apart, at 5 m or 2.5 m spacing along the planting lines (i.e. 200 or 400 seedlings/ha) was started.

850 ha were thus planted with Niangon (Tarrietia utilis), Mahogany (Khaya ivorensis), Tiama (Entandrophragma angolense), Dibetou (Lovoa trichilioides), Makore (Tieghemella heckelii) and Azobe (Lophira alata).

At the age of 23 years for Niangon (Tarrietia utilis), the residual density was 94 plants/ha with an annual increment of 1 cm/year in diameter and 1 m/year in total height. At the age of 40, the residual density was only 26 plants/ha.

C - until 1948, the plantations benefited from lines 25 m apart with plants at 2 m or 2.5 m along the lines, i.e. 160 to 200 plants/ha. The species planted were still: Niangon (Tarrietia utilis), Mahogany (Khaya ivorensis), Dibetou (Lovoa trichilioides), to which were added Framire (Terminalia ivorensis), Bosse (Guarea spp.), Sipo (Entandrophragama utile). About 11,000 ha were thus established.

At the age of 21 years, a residual density of 45 plants/ha - all species together - was found. The mean annual increment in diameter was 1 cm for the largest trees and in total height of 0.7 m.

In 1985, densities ranged from 6 to 28 trees/ha.

D - The following years were often devoted to the follow-up of existing plantations, with a special interest in the maintenance as for the plants and especially, ensuring access to light by a reduction of the canopy closure on the one hand and by thinning on the other.

Combined systems were also used to enrich plots where natural regeneration was deemed insufficient. Mahogany (Khaya ivorensis) plantations, in particular, were established at 10 x 5 m with a certain amount of leeway, giving the plant the best living space while cleaning the initial forest as little as possible.

E - The "Taungya" system was used at different times. Its expansion was quite limited in the dense forest, in general over areas of 1 ha in groups of 3 or 4.

The species tried were Frake (Terminalia superba), Framire (Terminalia ivorensis) and Samba (Triplochiton scleroxylon); they gave promising results at first, but were unequal at a more advanced age. There were more successes in the savanna, in particular with Teak (Tectona grandis), Gmelina (Gmelina arborea), Cassia (Cassia siamea), etc...

F - Since the 60's, the preference has been given to planting in the open, on fields entirely cleaned by mechanized destruction of the initial forest. This technique was adopted especially for light-demanding species such as: Frake (Terminalia superba), Framire (Terminalia ivorensis), Samba (Triplochiton scleroxylon), Teak (Tectona grandis), Gmelina, etc...

That however did not prevent the continuation of plantations under devitalized forest as in Yapo, Anguededou, L'Abbé. The spacings widely differed: 7 x 3.5 m; 7 x 5 m; 6 x 4 m; 15 x 3 m; 10 x 4 m; 8 x 3.33 m.

The cleaning was regular and supplementary devitalizations, of the umbrella-tree (Musanga cecropioides) in particular, were needed in Yapo among other places. At the age of 10-12 years , Niangon (Tarrietia utilis) measured 12 m with a mean increment in diameter of about 1 cm/year, with a good reaction at late poisoning.

On these recent plots (1965 to 1971), thinnings were made around the age of 6 years, bringing the initial density of 400 plants/ha back to 170-200 stems/ha.

Combinations of species were carried out with, apart from Niangon (Tarrietia utilis), Mahogany (Khaya ivorensis), Okoume (Aucoumea klaineana) and Makore (Tieghemella heckelii). Mahogany (combined at 5 to 25 %) and Okoume (50 %) gave better increments than Niangon, whereas Makore remained inferior.

G - In the 70's and on an experimantal basis, forestry research gave time over the study of the light environment in layons especially because of the difficulties encountered in Sipo's (Entandrophragma utile) silviculture. Precise studies of photology (pyranometers, as well as analysis of hemispheric photographies) tried to characterize and determine the effect of different treatments (layon width, intensity of felling or devitalization in the natural stand in the intralayon) over the light for the seedling introduced in the layon. These studies showed the difficulty to control and especially to homogenize the quantity of light reaching the seedlings, and that for the species requiring some shade, the latter may be given by the monospecific planting of an accessory species, which could be controlled (Leucaena leucocephala, Gmelina arborea, etc...).

132 - Nigeria

Nigeria's foresters showed concern for artificial regeneration of dense forests early. From 1916, loggers had to plant 24 young trees for every pole felled; which was a praiseworthy obligation, but hard to enforce, because of the scattered operations and the staff required. These plants could not be systematically protected against natural vegetation and few signs have remained.

Planting in layons was then used in the 30's, yet with few changes in the operations and especially very little steady maintenance and thinning. Thus meaningful conclusions could not be drawn. Later, in the 50's, the Taungya system started being used on a large scale for short rotation species such as Cassia siama, Eucalyptus spp. as well as for species with a longer longevity, such as Teak (Tectona grandis), Terminalia spp., Bilingua (Nauclea trilesii).

The plantations were either mixed or pure. In the former case, shade tolerant species, e.g. Mahogany* were selectively introduced, a spacing of 4 m was chosen for plants, short stump plants or sometimes striplings (entire plants on which only two end leaves are left).

In pure stands, spacings were changed to 6 x 6 m especially for the planting of Bilingua and Terminalia spp. Maintenance was effected everywhere the 2nd year and until the 6th year cleaning of the plant only was done.

Thinning was scheduled for the 11th year ou earlier if necessary.

Nowadays, the plantations needed to reconstitute the forests destroyed are done in full sun, on entirely cleared spaces and mechanically prepared ground.

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* Mahogany (Khaya ivorensis, Khaya anthotheca and K. grandifolia) can be in full sun and its growth is then much faster. However, because of attacks from bud borers (Hypsipyla robusta Moore) much more frequent in full light, Mahogany is often considered and planted as a "shade tolerant species" (see section 124).

133 - Cameroun

Artificial enrichment started very early; especially in Mbalmayo forests and Makak-Nyong reserves. It was pursued in other regions.

A - In Mbalmayo forest, planting in layons was used from 1932 onwards for species such as Ayous (or Samba: Triplochiton scleroxylon), Mahogany (Khaya ivorensis), Sapelli (Entandrophragma cylindricum), Bibolo (or Dibetou: Lovoa trichilioides), etc...

At the age of 18 years, only 48.5 % of the stems established remained, but with a substantial addition from natural regeneration which brought the percentage of interesting trees to 75 % compared to the number of plants artificially established. Besides, this addition led the forestry departments to change their enrichment systems, in favour of natural regeneration. The latter was followed on one hectare plots together with a controlled rearing. These plots, grouped in blocks of 100 to 300 ha, were demarcated by layons where Mahogany (Khaya ivorensis), Sapelli (Entandrophragma cylindricum) and Bibolo (Lovoa trichilioides) were planted. A hundred hectares include 20 km of lines, i.e. 4,000 plants spaced 5 x 5 m. Counting about fourty natural seedlings per ha, an average of 80 trees for marketable timber per hectare is obtained.

In the most ill-favored plots, one can consider planting 2 or 3 additional lines.

B - In Makak - Nyong reserve, 2,500 ha were planted between 1932 and 1949. 181,650 seedlings were established, in particular: Sapelli (Entandrophragma cylindricum), Mahogany (Khaya ivorensis), Bibolo (Lovoa trichilioides), Iroko (Milicia excelsa), Bosse (Guarea sp.), Ayous (Triplochiton scleroxylon), Kosipo (Entandrophragma candollei), etc...

Planting in layons was not favourable to strictly heliophilous species there either. In decreasing order, the best successes favoured Mahogany (Khaya spp.), Dibetou (Lovoa trichilioides), Sapelli (Entandrophragma cylindricum). About the age of 15-18 years, Sapelli was successful at 75 % in number of residual stems and Mahogany 50 %. One of the reasons for the failure was the use of too small plants (under 1 m), whereas stems of at least 2 m permit to avoid competing natural regrowth and damage by wild animals.

C - Along the South coast of Cameroun, Okoume was planted to emulate enrichment programmes carried out in the neighbouring country, Gabon.

D - The system of planting in wide layons was also used experimentally around 1975 in the semi-deciduous forest in the East (Belabo) and in the dense forest along the coast. 5 m wide layons 15 to 20 m apart were planted spaced 3 x 3 m along the line. The undergrowth was set back at knee height and all the trees of over 20 cm in diameter were ringed or poisoned.

The species established were Terminalia ivorensis and T. superba, Entandrophragma cylindricum, E. utile, Khaya ivorensis, Triplochiton scleroxylon, Tarrietia utilis, Afzelia africana, Lovoa trichilioides, etc...

134 - Congo

In this country, Limba (Terminalia superba - or Frake: commercial name given to Limba North of the Equator) was very early the subject of particular attention because of its rapid growth and quality timber.

In 1937, densely-planted square plots were established to serve as forest gardens.

Planting in layons was then initiated, with spacings 10 x 5 m. These first trials showed that Limba required no complement to grow straight and lop itself. In the early 50's, the decision was made to plant it at final spacing, i.e. 12 x 12 m or 12 x 14 m.

Limba, a light-demanding species, requires to be planted in total clearing. The latter was obtained in two steps:

- the selected space, already highly exploited, was entirely stripped in a widely-open layon;

- high stump plants were established;

- the following year, the tall trees were ringed;

- then cleaning started in the layons to prevent the canopy closure over the plants and the overgrowing of lianes, five times the first year, three or four the second year. This system was later replaced by trials in full sun with mechanized deforesting and ground preparation.

135 - Ghana

Planting in layons was also used in evergreen dense forests, where heavy forest exploitation left no hope for natural regeneration.

1.8 m wide layons spaced 20 x 20 m were opened, lianes eliminated over 5 m on each side of the layons. The canopy was progressively diminished through poisoning, so as to let enough light go through for plants, yet with not enough light to increase the development of lianes. The plants were spaced 5 x 5 m and 1 m minimum in height to avoid damage by game. Mahoganies (Khaya ivorensis), Sapelli (Entandrophragma cylindricum), Tiama (Entandrophragma angolense), Niangon (Tarrietia utilis), etc... especially were planted. For Mahoganies, among others, the results were better than with dense planting.

Block planting was also tried with Framire (Terminalia ivorensis) and Niangon (Tarrietia utilis) with 5 x 6 m spacing. In the late 60's, large areas were enriched, half of which with the Taungya system and the other half with the technique of the regrowth with species such as Samba (Triplochiton scleroxylon), Framire (Terminalia ivorensis), Teak (Tectona grandis), Cedrela (Cedrela odorata), etc...

136 - Zaire

For this country, a distinction should be made between the systems which were applied within the framework of extensive programmes and trials. Indeed, the activity of Belgian researchers at INEAC was highly developped, especially on Yangambi station, before Zaire's independance. Numerous techniques were experimented, and among them:

A - Enrichment by uniforming from the bottom

This system is a specific application of the agro-forest system and differs from the Taungya system by the spotting and preserving, at the start of cultivation, of the young plants of precious species and at the same time the planting of a hundred or so Terminalia superba per hectare. The stand stemming from this system should be a heterogeneous secondary forest whose overstorey should include, apart from Terminalia superba, the precious species saved at the start of cultivation, the commercially-attractive species stemming from natural regeneration: Chlorophora (Milicia), Ricinodendron, Combretodendron, Entandrophragma and Ceiba.

B - Enrichment in layons has also been experimented with varying intensities. Experience shows that this system is better suited to the enrichment of relatively open formations or even fallows, rather than of constituted forests, little exploited or unexploited. Rapidly-growing light-demanding species, developing a normal shape even in an isolated state (e.g. Terminalia spp.), give good results with this system.

C - Wide strip planting

10 m wide, 25 to 50 m long strips are laid every 50 m (10 ares per hectare) wherein a main species (Entandrophragma, Autranella) and accessory species are planted, at spacings ranging from 4 x 4 m, 2 x 2 m to 1 x 1 m.

D - Direct seeding in narrow strips after clearing the undergrowth

This consists in minutely cleaning strips of 2 m in width and spaced 20 x 20 m, having taken out the natural rootage mess and their seeding, at the rate of 6 seeds per m² every 2 m. Such experiments are variously successful according to species.The growth can be compared to that obtained with planting in layons, but seeding allows for a higher density and the shape is slightly better than with planting, the opportunities of getting quality timber and the scope provided by thinning are much wider.

E - System of sample spots

Originally, the system inspired by Anderson's sample spots consisted in large sample spots of 1 to several ares set under an umbrella-tree grove (former wildland) whose undergrowth had been cleaned and the plants introduced at spacings ranging from 4 x 4 m to 1 x 1 m. The results obtained, especially with 1 x 1 m or even 2 x 2 m plots, led Belgian foresters to design the System of spaced dense sample spots (E.MAUDOUX). This system tried to combine the biological advantages of dense plantations of small spacing with the lower costs of extensive systems of enrichment. It consisted in planting or sowing small groups of seedlings at small spacing, the groups being widely distant over the area to be enriched. The principle was adapted to different environments and gave satisfactory results in open environment (moors, open savannas, deforested fields), but in dense forest encountered the same problems, concerning the canopy opening, the control of the regrowth and the maintenance of the plants, as those encountered with planting in layons, with an additional drawbrack: since the sample spots were scattered, they were not within easy reach.

F - Enrichment on complete clearing of woodland

This system is reserved to areas entirely exploited for firewood or industrial wood. It consisted in enriching the forest fallow with valuable species by planting heliophilous species, Terminalia superba, Milicia (Chlorophora), excelsa, ... at regular spacing, 10 x 10 m or 15 x 10 m. It was hoped that the regrowth would lead the valuable plants introduced. There too, the difficulties to check the regrowth and to maintain the plants introduced arose.

Out of all these experimented systems, only the first two, "uniforming from the bottom" or "Limba system" and "enrichment in layons" were applied on a certain extent, especially in Mayumbe, and were then abandoned for historical reasons. No recent data concerning their results could be obtained.

137 - Other countries: Guinea, Sierra Leone, Liberia...

The other countries from the region (West Africa) applied, at a relatively small scale, the techniques experimented or determined elsewhere.

In Guinea, enrichment in layons was realized in several reserved forests; however, there are no data on either the extent of these plantations or their results.

In Sierra Leone, the different techniques for the improvement of natural stands were used. On the one hand, the techniques favouring natural regeneration, such as the Tropical Shelterwood System (T.S.S.), also used in Nigeria and Ghana, were applied at the rate of several hundred hectares per year and the areas thus treated reached almost 4,000 hectares in the late 50's. On the other hand, the systems involving planting strictly speaking covered about 5,000 ha in 1960, but the statistics do not distinguish intensive plantations, the Taungya system, planting under canopy and planting in layons; all the techniques are mentioned, yet not differentiated. The results of these operations are not known. However, the over extensive systems, and planting in layons among others, were abandoned in the early 60's because of the heavy agricultural pressure on the land.

Finally, in Liberia, except for a few trials, no system to improve or enrich natural forests was implemented. At the end of 1977, the Forestry Development Authority had 5,500 ha of plantations (Pines, Teak, Gmelina...).

14 - The established data

141 - The light factor

In the forest environment we are here interested in, it was soon realized that the factor that impaired the growth of young trees was light. It is true that the forest atmosphere did not bring this fact to the fore and, besides A. AUBREVILLE had noted that "Growth depends to a wide extent on the quantity of light the crown can get. Noone could have thought otherwise, of course, but in the constantly hot environment of the rain forest, it seemed that vegetation could develop even if luminosity was poor".

The lack of knowledge of the character of commercially-attractive species did not permit to show the prevailing role of light. Research work and more advanced silvicultural techniques demonstrated that light-demanding species do not tolerate shade and shade bearers or semi-light-demanding species adapt perfectly to full sun (however, establishment into full sun generally goes with serious disturbances of the micro-climate: hygrometry, temperature, etc... that may disturb certain species).

Accurate measurements showed that the relative light exposure in a 8.5 m wide layon only reached 5 %, rising to 20 % after canopy opening at the top of the layon.

If the overhead canopy between the layons is cut, the side light exposure is increased, thus bringing the preceding total value to 60-65 %. The skill of the forester then consisted in dosing as correctly as possible, in space and time, the light exposure required by the plantations introduced. That is the explanation for the graded transitions rather than the marked differences existing between the systems described in the preceding chapter.

By way of example, the following table supplies explanations; it concerns Niangon plantations in the Ivory Coast, measured at the age of 30 years.

Number of trees measured	Mean Diameter (cm)	
	Martineau planting	layon planting
150 largest trees per ha	31.1	22.7
50 largest trees per ha	38.2	34.8

(Source: R.CATINOT BTF n°102, 1965)

But if light favours the growth of the species introduced, it also possesses a dynamic action over all kinds of invading species whose development is harmful to newcomers. The particularly aggressive pioneer species, e.g. the umbrella-tree, tend to spread over the cleared land. The same holds true for lianes which become stifling aerial competitors and which bend out of shape the plants by means of mechanical action.

The follow-up of the young plant will thus require the right balance between the dosing of light and keeping of natural vegetation at a distance.

142 - The choice of species

The first enrichment planting trials were developed at a time when the number of commercially-attractive species, i.e. with a stable market, was limited. The emphasis had thus to be laid on the latter so as to enrich the forests where they had grown, but which had been impoverished because of intensive exploitation, or to bring more value to stands where they were lacking, e.g. Mahoganies (Khaya spp.), Niangon (Tarrietia utilis), Samba (Triplochiton scleroxylon), Sapelli (Entandrophragma cylindricum).

Then, two factors broadened the choice: first the widening of the commercial range and second, the foresters' new awareness of the need to use light-demanding species for their operations of artificial plantations. Terminalia spp., Teak, Gmelina, etc... appeared then. However, the emphasis was still laid on valuable species which, even though only a few remain after severe selection - natural selection more than man's - greatly enhance the value of the hectare planted.

With a still relative canopy, the introduction of Mahoganies, Niangon, Dibetou, Tiama, Sapelli, Sipo and Samba was pursued. The progressive cleaning to the point of total clearing enabled to introduce more heliophilous species, e.g. Terminalia spp. and Okoume.

The utilization of the Taungya system also allowed to work with Teak, Gmelina among others in the open and without competition.

143 - Results

From the preceding section, it is easy to infer that the plants that survived in the various trials are those which benefited from a better light exposure and intensive protection against natural vegetation.

Generally speaking, these operations of enrichment planting cannot be said to have met with success. The first planting in layons suffered from too large a canopy and from the dense competition from the undergrowth and the regrowth. But, when the layons were widened, competition, from lianes among others, became sharp. The number of operations for maintenance and for cleaning became high and repetitive. The more light the plants were given, the more attention had to be given to the development of the potential competing vegetation (above all in the system of the regrowth, where the accessory vegetation had to be kept under control).

So, the successes of the various systems were especially dependent on the foresters' perseverance to protect their noble species; however their action was often checked by the lack of staff and funds. That shows the limits of this technique: it is a technique of extensive treatment of the forest, so it should be applicable to large areas with a very low financial, material and human investment per unit area. And yet, paradoxically, it has become almost as costly in terms of means and staff as an intensive plantation whose high productivity is concentrated on a small area. Besides, during the Second World War, many operations and investments in the forest sector were stopped and the forestry departments disorganized. Thus, nature gave free rein to spontaneous competition which rarely favoured the species introduced, except for the most pioneer ones, e.g. Okoume and Terminalia spp. Wherever the composition of the original vegetation did not include too many invaders, such as the umbrella-tree, and where the canopy had been greatly reduced, the stands introduced could be followed and gave plots where the quantity and the quality of the standing crop had been greatly improved.

Thus, one might think that the Taungya system is the most effective, as it requires an almost entire clearing, and permanent maintenance everywhere to ensure the survival of the associate cultivation. But this system, which has always remained a constraint for the African farmer, has not developed as was expected, and it is far from the developments in Asia. In Africa, it spread more over the regions of open woodland and savannas, for varying reasons, e.g. ease of access, of clearing and especially lack of available land. It has produced beautiful stands of Teak, Gmelina among others in the Ivory Coast, Nigeria, etc...

But, this system is systematically connected to the farmers' lack of land, and in many regions, farmers have in fact free access for their shifting cultivation, even in the Forest Estate, as the Forestry Department is unable to protect its grounds and impose a contract for Taungya cultivation. Besides, since the natural environment is more competitive, the farmer tends his own cultivation more than the trees introduced because of need and the exchange of mutual benefits is very poor. After the agricultural period, the Forestry Department often lacks the necessary means to fight natural vegetation that exercises its authorithy again very quickly.

After loose plantations in constant fight with natural vegetation, dense plantations were not more successful as long as the necessary forest actions were not provided. These plantations left very little room for upper or lower competition, but on the other hand they presented major drawbacks. For instance, the concentration of non-gregarious trees enabled the development of devastating parasites. This concentration can give a worthwhile increment for a marketable final product only if thinning is done periodically when needed. Which was not always the case, for lack of means once more.

It is easy to understand why enrichment planting techniques developped to conversion planting, permanently carried out on entirely cleared land with ground preparation that totally transformed the original space, with mechanical devices allowing much greater yield and work qualities. Under these conditions, the ecosystem is substituted, entailing new silvicultural rules to be enforced, yet the same exacting demands, to reach the expected result.

But the main result of these trials is the pointing out of the factors limiting these techniques:

- importance of technical, human and financial means, incompatible with the extensive treatment of large areas,

- duration of follow-up and work requiring close watch and repeated cleaning over a long period,

- economic and demographic evolution of tropical African countries preventing the immobilization of large areas for low productivity.

It should be stressed, in this connection, that a major part of previous trials were abandoned before maturity stage, because of agricultural clearings.

15 - General conclusions on the enrichment planting techniques used

Enrichment planting techniques were successful only where close and prolonged care was given by foresters. That proves that these techniques cannot be used intensively with satisfactory results. Finally, the cost of such techniques is in complete disagreement with the very low increase in economic productivity actually reached.

Considering the current evolution of the countries concerned, the importance of the different techniques of forest production should be stated.

The preservation of the genetic and ecological heritage on sufficient areas should be kept in mind and will be achieved through the creation of national parks and biosphere reserves, but this concern, as well as the roles of the forest, a climatic buffer and a hydrologic regulator, are not taken into consideration here.

One of the main characteristics of human activity in tropical African countries is <u>mobility</u>: mobility of agriculture which exploits, until complete exhaustion, the land recovered from the forest by clearing, and then moves; mobility of rearing; and last, mobility of forest outfits which exploit an area in the forest and then move to new sites when the previous ones are commercially exhausted. This mobility entails an actual <u>tapping of the resource</u>, without caring about its renewal. This type of activity may occur only when offer is greater than needs, it becomes harmful when needs increase and the resource is limited. The various mobile activities then compete on the same territory. For instance, when agriculture burns an important volume of standing crop to meet its needs in new land, it does not only destroy a certain quantity of marketable forest products, it also destroys the forest production potential of the area. In case of uncontrolled shifting agriculture - as in Tropical Africa - the forest and forest activities may simply completely disappear, quickly or not depending on demographic pressure.

To keep the resource, to save the natural environment, while allowing a balanced development of the country, the different human activities have to be regulated within the framework of a <u>National Management Plan</u>. This plan, based on the most accurate data concerning the different regions, should distribute the economic activities geographically in relation to the various potentials acknowledged. Thus the National Management Plan means <u>determining the human activities</u>. It allows <u>to save the natural environment and manage the resource</u>.

The determination of the forestry activities requires <u>the creation of a permanent forest estate</u>. In this estate, the different functions of the forest will, in the same way, be distributed geographically in relation to the potentials acknowledged, within the framework of a Forest Action Plan. As the exploitation no longer bears on new areas, foresters will have to deal with the renewal of the resource. Planting (any planting) and the silvicultural treatment of the natural forest after exploitation are the techniques developed by foresters to ensure the regeneration and sustained yield of a permanent forest estate.

The demographic and economic evolution of some countries in Tropical Africa no longer allows the immobilization of large forest areas. Residual forests, even with improved yield, will not give the quantity of raw material required for the economic development of these countries. Thus, high-yield intensive afforestation is a requirement.

To describe the importance of the different techniques, three types of situation should be distinguished:

A - The natural forest has (almost) completely disappeared

Such is the case in Guinea, Burundi...

The forest production can only come from high-yield intensive plantations (whether state- or privately-owned). The last chunks or stands of natural forest (if any) should be left out of this production; they will make up entire reserves playing the ecological role of a climatic, hydrologic regulator and of genetic heritage.

B - The natural forest occupies only limited areas and is under heavy pressure from shifting agriculture (e.g. the Ivory Coast).

It is urgent to implement a national management action and within this framework determine a permanent forest estate. Most of the production will come from intensive planting established on land abandoned by agriculture and included in the permanent forest estate. The Forest Action Plan for natural formations will have to establish a real programme for the management of the stands concerned, after cartography and identification of potentials. The plan will schedule all the operations, in all qualitative and quantitative aspects, from regeneration to exploitation, including the silvicultural actions required for a better sustained production of the raw material chosen. The global production will be a mix of the known and expected yield from artificial stands and the more fluctuating yield from natural forests.

C - The natural forest still covers important areas and above all it is not subject to any demographic pressure. Such is the case in countries as Zaire, Congo, Gabon, Cameroun.

In these countries where some stands are not even exploited yet, all the resource comes and will still come from the natural forest for a long time. The productive and especially accessible stands will have to be assessed so as to determine their potentials and to draw action plans which will allow to maintain a production supported by a better silvicultural management of the stands. The areas not included in the production programmes, because of low potentials or specific conditions putting the ecological balance at risk, will be graded as protected units where their survival will be guaranteed.

Thus, the current trend is to separate the modes of timber production clearly, favouring intensive artificial actions as soon as the natural potential has reached too low a level (in area or content). In the other case, the dynamics of the stands has to be improved through actions whose return certainly comes later, but which allow to maintain a varied and sustained production at a lower cost. Such is the framework within which a possible resumption of forest enrichment planting work may occur. However, the results from the first trials seem to reject this technique in favour of the treatment of natural stands (management, exploitation, protection with or without improvement silvicultural work).

2 - ENRICHMENT PLANTING IN DENSE, DRY FOREST

21 - The environment and the objectives

The vegetation formation concerned has already been described in section 11, according to the definition chosen at the meeting in Yangambi in 1956. It heavily depends, as does the rain forest, on the Sahelo-Sudanese type climate with a very long dry season.

It usually is a two-storied semi-deciduous dense forest; the high forest made up of trees of about 20 m in height and the undergrowth of a dense coppice with shrubs, lianes and herbaceous plants.

Unfortunately, these forests are often degraded, especially by shifting fires, and they turn into more open formations of the tree savanna type.

So, the aim is to increase the wood potential by means of the rehabilitation of these stands so as to improve their productivity and economic value, while exploiting them more regularly.

The purposes of these spaces will be determined and the resources will be managed rationally within the framework of an overall action plan here too.

22 - The example of Casamance (Senegal)

Enrichment trials have been undertaken by the Department for Research on Forest Production at the Senegalese Institute of Agricutural Research, so as to determine silvicultural techniques liable to be integrated in a management system.

221 - The technique

Different techniques of improvement of natural stands have been used in evergreen dense forests. They are either techniques aiming at favouring natural regeneration, or artificial plantations in layons within the forest, without destroying the latter. These techniques have been met, in the African rain forest, with either a very high maintenance cost when the canopy was not closed because of highly-competing undergrowth, or with low productivity of the plants established when the canopy, as it had been kept, retained most of the light.

In the dry forest of Casamance, the canopy is much lighter and the undergrowth less luxuriant. The restricting factor is no longer light and the undergrowth can be controlled more easily, because of the very long dry season. Consequently, one attempted to determine a low-cost technique that could be used on large areas easily. The idea came from the layon planting technique advocated by Professor A. AUBREVILLE for the evergreen dense forest in the Ivory Coast, yet with the following difference: the cleaning concerns the undergrowth only and thus the technique is close to Martineau's (complete cleaning of the undergrowth without canopy opening).

East-West layons are opened up with a bulldozer, or possibly manually, to recover maximum light; their spacing is related to the forest canopy and the undergrowth density. The aim is to keep the forest canopy as much as possible (forest atmosphere). So, the bulldozer takes away the herbaceous and arborescent understorey only and winds in between the tall trees. The machine also has to scarify the soil 60 cm deep with its three-toothed ripper. The plants are then arranged in quincunx along the scarifarying lines, with spacing at 3 x 3 m along the line, the ripper teeth being 90 cm apart. The high density of young plants along the line will later allow them to resist either destruction due to the future exploitation of the space between layons or to natural accidents. The layon's width should be that of the front blade of the bulldozer. The machines which met the test successfully for this kind of work are 200 to 300 HP bulldozers fitted with a three-toothed ripper and a 4 m front blade.

222 - The first results

The trials were carried out in the classified forest of Bayottes in Casamance (Latitude 12°28'N - Longitude 16°16'W - Altitude 20 m).

Rainfall :	1936 - 1966 :	1,547 mm
	1977 :	700 mm
	1978 :	1,391 mm
	1979 :	1,194 mm
	1980 :	693 mm

The enrichment planting of 1977 (Table 1) shows that the layon planting technique was satisfactory, as it allowed the local species to grow again. The percentages are good, except for a forest fire in April 1978 which made the cutting back of a major part of the plants necessary. In fact, maintenance had been done and resulted in the satisfactory behaviour of the plants, since, wherever the fire crossed the layon, death occurred, and where the plants had simply dried out because of radiated heat, there was an overall take from the stub.

TABLE 1

Various species planted in layons in June 1977

H = height of plants in cm
% = percentage of success

Species	12.1977		12.1978		12.1979		12.1980	
	H	%	H	%	H	%	H	%
Albizzia ferruginea	51	100	61	87	70	93	63	83
Bixa orellana	55	99	73	60	97	61	121	52
Erythrophlaeum guineense	20	96	51	78	97	76	132	76
Antiaris africana	25	92	32	62	43	73	38	75
Afzelia africana	60	100	79	69	78	76	80	70
Daniellia oliveri	7	85	9	43	13	60	9	66
Spathodea campanulata	63	100	124	96	205	97	272	96
Prosópis africana	36	88	53	78	75	79	85	86
Terminalia ivorensis (introduced)	42	91	134	64	190	64	255	64
Cedrela odorata (introduced)	32	95	51	22	76	17	99	11
Alstonia congensis (local)	43	100	56	75	113	75	107	69
Ailanthus malabaricum (introduced)	41	100	71	64	123	64	142	61

In 1978, a systematic comparison between two types of exposure, in the open and in layons, was made, including both pot and bare-rooted planting. The table of results (Table 2) shows that Daniellia oliveri, Afzelia africana, Erythrophlaeum guineense and Antiaris africana give better results in layons than in the open. Terminalia ivorensis, Spathodea campanulata and Albizzia ferruginea have an interesting behaviour in layons. On the other hand, Afzelia africana and Erythrophlaeum guineense can easily be bare-root planted, a low-cost technique which has given good results with these species.

Table 2

Exposure in layons vs in the open
Results of measurements in December 1979

Species	A1		A2		B1		B2	
	H	%	H	%	H	%	H	%
Khaya senegalensis	121	100	71	72	85	90	-	-
	Borer		Borer		Browsed			
Daniellia oliveri	25	2	0	0	12	60	-	-
Terminalia ivorensis	170	89	82	58	146	89	-	-
Cedrela odorata	80	6	0	0	63	95	0	0
Spathodea campanulata	207	95	101	100	-	-	-	-
	Browsed		Browsed					
Ceiba pentandra	45	77	65	57	-	-	-	-
	Browsed		Browsed					
Detarium senegalense	29	20	47	36	37	34	50	28
					Rodents		Rodents	
Parkia biglobosa	-	-	-	-	-	-	0	0
							Rodents	
Albizia ferruginea	69	95	-	-	47	100	37	45
	Browsed				Browsed		Browsed	
Afzelia africana	49	48	70	25	40	60	48	45
Alstonia congensis	107	100	72	44	87	99	63	48
Erythrophlaeum guineense	72	85	-	-	78	95	67	60
Prosopis africana	63	85	-	-	53	84	43	14
Antiaris africana	41	67	0	0	48	90	10	4

Legend : A = ripped field
B = ripped layon
H = Height in cm

1 = pot
2 = bare root
% = percentage of survival

Besides, one can notice that the caïlcedrat or Senegal Mahogany (Khaya senegalensis) which is heavily damaged by the shootborer (Hypsipyla robusta Moore) in the open, is almost unharmed in layons. It is however browsed by the game or cattle moving around the forest, as are Spathodea campanulata, Ceiba pentandra and Albizzia ferruginea. These species are also browsed in open terrain, but it is easier to protect them with fences around plantations, which cannot be done with layons. Another damage observed is the collar-ringing of Detarium senegalense by unspecified rodents.

So, this second trial confirms the interest of this technique whose rather moderate cost should allow to enrich large areas and increase the value of natural forests in Lower Casamance. However, the species should be selected, as it is impossible to protect them from game. Other introduction techniques (high barbatelles and rosettes) have been tested, notably to prevent this damage from game.

New measurements in December 1985 give the results shown in Table 3.

TABLE 3

Results in December 1985

Species	Planting Year	H (m)	G (cm)	% alive
Albizzia ferruginea	1977	1.3	-	9
Afzelia africana	1977	1.5	-	25
Ailanthus malabaricum (introduced)	1977	4.4	17.6	56
Alstonia congensis	1977	1.9	-	32
Cedrela odorata (introduced)	1977	4.2	-	10
Erythrophlaeum guineense	1977	3.5	12.0	71
Prosopis africana	1977	1.4	-	69
Spathodea campanulata	1977	5.6	23.9	94
Alstonia congensis	1976	1.8	-	12
Cedrela odorata (introduced)	1978	6.0	21.8	9
Detarium senegalense	1978	1.0	-	9
Erythrophlaeum guineense	1978	4.4	18.0	60
Khaya senegalensis (Thies, Senegal)	1978	3.2	13.9	90
Khaya senegalensis (Djibelor,Senegal)	1978	3.5	15.3	82
Prosopis africana	1978	1.7	-	28
Spathodea campanulata	1978	5.4	22.4	90
Terminalia ivorensis (introduced)	1978	5.6	20.8	55

In 1979, in order to lower the cost of layon planting even more, direct seeding was tried for some local species and compared with pot planting. With the technique used, i.e. planting 3 lines arranged in quincunx spaced 1 x 1 m with planting points 3 m along the line, a percentage of 50 % of occupied planting points could be deemed very satisfactory. So, direct seeding was very interesting for Afzelia africana, Erythrophlaeum and Khaya senegalensis.

In 1980, cleaning in layons was initiated. There were several possible techniques: manual cleaning (efficient, but expensive), mechanized cleaning with disk sprinkler surrounding the planting line in the centre of the layon (interesting), chemical cleaning which raised the question of the choice of products, but whose implementation was easy; cleaning had to be effected during the first two or three years, depending on the species planted.

In 1983, it was decided to plant high stems only (1.8 to 2 m) so that plants would not be browsed by game.

In 1985, 1986 and 1987, three planting trials with very high stems were established in already open strips where all the plants introduced had disappeared the previous years. The seedlings grown in nursery for 3 years were spaced 2 x 2 m or 1.5 x 1.5 m. The new growth of transplants is generally difficult, especially during dry season. Good results were obtained with Afzelia africana, Albizzia ferruginea, Antiaris africana, Chlorophora regia, Erythrophlaeum africanum, Khaya senegalensis.

223 - Extended technique

The trials showed the possible enriching, with valuable species, of highly degraded Guinean dry forest thanks to a moderate investment. This enrichment technique was used within the framework of the management of Tobor forest, Senegal (PNUD-FAO Project).

Integration of the technique into management:

As the treatment mode is characterized by the search for an elementary structure determined from a given stand, the enrichment techniques described here lie within the framework of a management technique, so as to bring the stand an overall structure of one or two-storied coppice with standards.

So, in a chronological order, the various programmable operations will be as follows:

- cleaning existing valuable species and, possibly, logging species at maturity stage, while ensuring their natural regeneration;
- enriching in East-West layons (density, creation of wealth)
- cleaning and thinning species introduced and, possibly, logging species at maturity stage in the space between the line;

- possibly, new thinning on layons;

- second enriching in layons either North-South, or in the same direction as previously and cut in the space between layons;

- cleaning, etc...

The first results showed that the new growth was mixed, and so was the increment of the species introduced in relation to the sun spots in the layon. This finding led to advocate the technique of sample spots, taking advantage of the sun spots as an enrichment technique within the framework of management, however that was not tested experimentally.

23 - Another trial in Senegal

The Project of Management and Reforestation of Forests in Mid-East Senegal, created in 1982 with joint funding by the World Bank, the French Fund for Aid and Cooperation, the Central Office for French Economic Cooperation, FAO, and Senegal, first aimed at planting, among others, 2,000 ha of Eucalyptus camaldulensis. The poor quality of the soil discovered and the bad weather conditions brought a change in the project which then turned to the reintroduction of local species with strip plantings. The rainfall deficit over the 1969-1983 period was about 150 mm/year compared to the means of the previous decades, in Kaffrine region. The drop in rainfall aggravated the low potential of soils for the reforestation in exotic species.

Revegetalizing the natural forest, sometimes degraded to the state of very clear savanna woodland, was tried with direct seeding and planting techniques.

In 1985, 65 ha were planted in direct seeding. The soil was ripped 60 cm deep with the three-toothed ripper, at the beginning of the dry season. The soil was worked between and around large trees. Natural regeneration, based on Combretum spp. was undisturbed. Anogeissus leiocarpus was sown in situ, the other species in patches (about fifteen species were sown).

The plots which had been cleaned were rather successful. Germination occurred satisfactorily wherever the herbaceous regrowth was little (either because it had been checked by means of cleaning, or because it was naturally less vigorous than on the adjacent plots). However, the results were highly mixed. Wherever the herbaceous regrowth was more vigorous, there were no self-comers. Unfortunately, the data concerning the quantity of seeds per hectare are not complete. The good results are not confirmed on some plots which also benefited from cleaning. It will be interesting to follow up the evolution of this enrichment planting. This follow-up, as well as maintenance, will however be difficult, as it is very difficult to find the ripping lines (as the bulldozer avoided the existing vegetation, it did not advance in a straight line).

For enrichment planting, the ground preparation was the same with holing at planting time. The wood vegetation was left undisturbed. Plants were spaced 6 x 8 m. Four months after planting, the survival percentages for the species tried range from 40 % for Detarium microcarpum to 100 % for

Tamarindus indica.

Table 4 shows survival rates in November 1987, two and a half years after planting.

TABLE 4

Species	May 1987		November 1987	
	Survival rate (m)	Mean Height alive (m)	Survival rate (m)	Mean Height alive (m)
Pterocarpus lucens	*	*	40	0.83
Detarium microcarpum	6	0.48	6	0.55
Tamarindus indica	86	0.75	90	0.95
Cordyla pinnata	10	0.15	10	0.45
Albizzia chevalieri	64	0.73	54	1.05
Prosopis africana	48	0.94	48	1.14

* Some species with no leaves at all and reduced to twigs cannot be counted at the end of the dry season, as they are difficult to identify.

24 - Comments

Contrarily to the dense moist tropical forest, the limiting factor here is no longer light. Indeed, there is no need to look for light as the environment where the operations occur is already very open. On the other hand, the weather changes, especially irregular rainfall, are the deciding factor in the success of the various introductions.

Enrichment by direct seeding seems inappropriate to the region's conditions, especially on account of the vigorous herbaceous vegetation.

High stem planting (1.8 to 2 m) gives better results if plants escape the drought. The forest floor should not be scrubbed with a bulldozer. Besides, marking plants should be made easier with the use of straight strips and stakes.

But, on the whole, the success of these operations depends on two preponderant factors which must be mastered:

- the cleaning of the planted areas for a certain number of years according to the plantation, then thinning in the dense lines,

- the protection against devastating bush fires and the damage caused by roaming cattle.

In spite of the extensive character of the technique, the latter is nevertheless costly because of repeated subsequent operations.

One might think that extensive artificial enrichment techniques are only for highly degraded areas. But the species that do well are in fact, just like the native species, for firewood, so that the value of the investments can hardly be enhanced. It is all the more true as the natural regeneration of the existing species is more dynamic and almost sufficient when adequate protection of plots is given.

In dry areas, a well-programmed closure against browsing, followed by the use of plots in cycles, is quite effective to regenerate the forest potential.

In parts of Senegal with a favourable climate, such as Casamance, timber enrichment can still be obtained.

All these trials are interesting because they are recent and certainly open new horizons if they are associated with further research work. However, it seems obvious that all the operations will have to be part of a coherent programme stemming from an overall management plan which will determine the judicious use of plots or stands, thus allowing a rational management of resources with the appropriate means.

3 - ECONOMIC ASPECT OF ENRICHMENT PLANTING IN WEST AFRICA

In tropical forests, numerous techniques have been used to try to restore the degraded production potential and thus maintain the indisputable economic value of the stands concerned.

The techniques have been numerous, varied and have changed over the years, especially for dense moist tropical forests. In 1965, a comparative study examined the techniques tried until then. The following table shows the list of operations in time with their economic effect evaluated in work units (man-day), machine-hour, litres of diesel oil for devitalization for an easy comparison. Manpower allocated to management tasks is not included, as it generally varies according to site conditions. Nevertheless, an average of 10-15 man-day units seems reasonable.

A few comments on Table 5 (on page 34) should be made:

- A natural silvicultural technique (N.S) is also compared to artificial silvicultural techniques (A.S). The technique is the Tropical Shelterwood System (T.S.S), which represents the operations of natural regeneration in this environment (see section 1).

- Thinnings are not mentioned, as in those days few stands had already been thinned. Later, some stands were thinned, e.g. Tarrietia utilis in the Ivory Coast, but the costs for these operations varied too much depending on the survival of the stands, the maintenance effected and the reaction of the existing forest, for a mean value to be given.

The comparative study of the techniques should be carried out according to the following aspects:

- cost of the work: this criterion clearly gives the advantage to natural silvicultural, Taungya and improved layon techniques , then to standard layon technique and then come Limba, Okoume and the regrowth (Limba technique does not require thinning and thus costs about the same as the others);

- duration of work: here, the techniques are ranked exactly in opposite order (except for Taungya which remains the leader);

- number of plants produced: whereas T.S.S. and the layon technique aim at introducing 100 to 150 trees per ha only in order to get 25 to 40 actual trees, the other techniques plan to get 60 to 100 actual trees per ha.

But, these figures should be given in terms of volume of wood yield per ha at the end of the rotation. If the log volume of a commercial tree is estimated at 3 to 6 m^3 according to species, the final volume to be expected for T.S.S. and layons should be around 75 to 200 m^3/ha, whereas with the other techniques, it would range from 200 to 400 m^3/ha.

- growth rate: there are no precise data concerning this subject, but Taungya, Limba, Okoume and regrowth techniques seem to have given much better results than T.S.S. and layons.

Table 6 (on page 35) shows the comparative results.

TABLE 5

Comparative costs of enrichment planting techniques
in rain forest

Nature of the work	Work units per ha (time in man-day units)						
	Standard T.S.S.	Taungya	Limba	Okoume	Standard Layons	Improved Layons	Regrowth
Plot; prospection	2	2	2	2	2	2	2
1st year N.S.:cutting lianes,poisoning A.S.:nursery,destruction of forest, planting,cleaning	10	32 to 36	69	29 & 4-5 h B.Dozer	25 to 35	28 to 39 & 130 l d. oil	56 to 62 & 130 l d. oil
2nd year: N.S.:poisoning lianes A.S.:cleaning	6 & 30 l d. oil	-	8	12	2	3 to 4	3
3rd year N.S.:cleaning or logging A.S.:cleaning	4	-	10	12	5	3 to 4	7
4th year N.S.:cleaning A.S.:cleaning	3	3	9	8	3	3 to 4	7
5th year N.S.:cleaning A.S.:cleaning	3	3	7	-	5	3 to 4	6
6th year N.S.:cleaning, logging A.S.:cleaning	6	-	9	-	3	3 to 4	6
7th year N.S.:cleaning A.S.:cleaning	3	-	-	-	5	3 to 4	-
8th year N.S.:cleaning A.S.:cleaning	3	-	-	-	3	-	-
9th year idem	3	-	-	-	5	-	-
10th year idem	3	-	-	-	3	-	-
Total (man-day units)	46 & 30 l d. oil	40 to 44	114	63 4-5h B.D	61 to 71	48 to 59 130 l d. oil	87 to 93 130 l d. oil

TABLE 6

Comparison of enrichment techniques in rain forest

Techniques	Cost of work	duration	Number of plants at planting	Number of plants final	Vol/m3/ha	Growth rate	Rotation
T.S.S.	46 MD+ 30 l d.o	10	100	25-50	75-200	poor	75-100
Taungya	40-44MD	5	400	60-100	200-400	excellent	40-60
Limba	114 MD	6	60-65	60-65	200-400	excellent	40
Okoume	63 MD+	4	500	60-65	200-400	excellent	60
Standard layons	61-71MD	10	130-200	25-50	75-200	poor	75-100
Improved layons	48-59MD+ 130l d.o	7	130-200	25-50	75-200	good (?)	60-75
Regrowth	87-93MD+ 130l d.o	6	400	60-100	200-400	excellent	40-60

Finally, one criterion for comparison should be the investment ratio of average productivity at the trees' maturity. When these first comparative studies were carried out, there were no sufficient data on the growth of the natural or artificial stands, to assess the respective advantages of the different techniques.

For dense dry forests, the available data are more recent; they concern the work carried out in 1987 for strip enrichment in Senegal (300 ha with 178 plants/ha). Unfortunately, the costs for the different operations could not be given separately. The total expenses per treated hectare are as follows:

Personnel		: 22 man-day units
Equipment	- bulldozer (250-300 HP)	: 0.7 h
	- bulldozer (150-200 HP)	: 0.4 h
	- wheel-type tractor (60-90 HP)	: 1.5 h

Enrichment work, strictly speaking, based on the artificial introduction of productive elements has often involved extensive techniques. The latter required repeated care in order to give the young plants the best opportunities for survival. Thus, there was a great need for manpower over a long period, with the disadvantage of a limited silvicultural skill, which, in case of delicate dosing, impaired the operations' profitability.

The evolution towards more intensive conversion techniques did not lower the costs per hectare. However, it allowed the concentration of work in time and space, especially improving the management of investments. The economics of foresting are well-known and its profitability can be assessed relatively easily, especially in case of short or medium-rotation species.

The figures in the above tables show that the techniques using natural regeneration are less costly, in the first stage at any rate. So, they might be preferred by those involved in the forest development. However, their actual cost would have been much higher if the maintenance and cleaning work required for their success had been done.

Limited enrichment planting trials in natural forest were followed up for a rather long period in the forest of Yapo, in the Ivory Coast. They lead to the conclusion that there is an increase in productivity of about 50 %.

Thanks to another number of operations, an economic study of the management of natural forests, using techniques of improvement of their productivity, was carried out by the FAO in 1976. It is precise and explicit enough in itself. However, some figures should be quoted, also taken from FAO surveys: in natural forest it is estimated that the investment for the production after 30 years of an extra m^3 is US $5.6, whereas foresting requires US $7.4 to produce one m^3 within the same time limit. More recent estimates say the latter figure is now US $12.

The interest of the management of natural forests may be belittled because of the drawbacks, i.e. the need for large areas, large capital, slow and uncertain responses to silvicultural techniques, etc...

The economic debate is currently open, especially in favour of the increase in production of homogeneous wood as raw material, through total conversion of the natural forest with intensive reforesting, or in favour of the restoration of the production potential of the natural forest through silvicultural action. So, enrichment planting is entirely rejected, in particular for the rain forest, notably because of its high cost of implementation and follow-up and the low production of raw material.

One should bear in mind that within the framework of an overall economy, choices have to be made within a general plan which will take into consideration all the socio-economic data, including those which cannot be directly quantified to calculate profitability or those whose effects can be assessed in the long term only.

4 - ENRICHMENT LINE PLANTING IN THE NEOTROPICS

1. Introduction

1. With the exception of those in Puerto Rico and Suriname the line plantings in the neotropics have usually failed to comply with the five necessary conditions and eight technical specifications defined by Dawkins (1966), (Annex 2). Consequently, most of the neotropical line plantings have been expensive failures.

2. In this report, *Cedrela* means *C. odorata* and *Swietenia* means *S. macrophylla*, unless the text mentions by name some other species in either genus.

3. Descriptions extracted from the literature are given in alphabetic order of country within the neotropics.

4. This report is based on a draft prepared in 1981 for the USDA Institute of Tropical Forestry, while the author was a Technical Cooperation Officer of the U.K. Overseas Development Administration and based at the Centro Agronomico Tropical de Investigación y Enseñanza (CATIE) in Turrialba, Costa Rica. That draft was used and acknowledged by Weaver (1987).

2. Geographical distribution and description of techniques

2.1. BRAZIL

Federal Territory of Amapá

5. Paul Ledoux started the Estaçao Experimental at Mazagao in 1955. *Cedrela* was planted in the open and in francophone Africa-style "layons" cut in secondary forest. Ledoux and Lobato (1972) reported that the *Hypsipyla* sho[illegible] was never observed on the plants in the layons. Following this success, [illegible] introduced *Swietenia* also in layons in 1967-1968 at IRDA, Campo Verde (Porto Platon), Amapá. Results have not been reported. Ledoux left Mazagao in 1969 and commented in 1976 (pers. comm.) that he had no growth data from these trials.

6. John Pitt (1961) began enrichment line planting trials at four locations in Amazonia: Commissao Brasileira-Americana (CBA), Santarém, trials begun in 1956-58, now abandoned; Centro de Treinamento em Maderas, Santarém, trials begun 1956-57, now abandoned; Porto Platon, Amapá, begun 1956-60, now abandoned; most of the work was concentrated at the principal site of the FAO project at Curuá-Una.

7. Forest at Porto Platon was enriched at 10 x 10 m in 1957 and 1958, with some replacement of failed plants in 1959. However the initial shade was too great and most plants had died by May 1960. Eleven species were tried (Pitt 1961, page 68). Quantitative data are reported in Appendix VIII, pages 49-60 of the annex to Pitt's report.

State of Pará (Santarém)

8. At CBA Santarém, four canopy-opening treatments in old secondary forest were enriched by planting at 10 x 10 m in 1957-58. Results were given by Pitt to November 1960 for six species (page 60 of his main report, 1961). At CTM Santarém, a small area of poor, repeatedly cleared secondary scrub was enriched at 2.5 x 5 m. Gmelina arborea did well, Albizia lebbeck less so, and nine species failed or performed very badly (pages 62-64).

State of Pará (Curuá-Una)

9. At Curuá-Una itself Pitt tried group planting on areas where he had previously burned lop and top (page 40). Eight species were tested with intra-group spacing of 4-5 m; initial height increment was 1.5-2 m. Line planting was used on 90 ha of compartment 4. Eighteen species were tested on 45 km of cut lines, 2-3 m wide and 20 m apart. Intra-line spacing was 5 m unless desirable existing natural regeneration was within 1-2 m of the intended planting spot. Compartment D was also used for enrichment trials on the planalto clay soil and compartment N on the flanco sands (pages 49-50).

10. Jean Dubois was at Curuá-Una from 1962 to 1967, revisited in 1968 and 1969 and reported on progress up to March 1969 in his 1971 report. All the 1958-60 line plantings failed on the planalto clay. Dubois gave three reasons: the initial reduction in basal area by logging was insufficient, the follow-up arboricide treatments did not open the canopy sufficiently to stimulate the height growth of the planted seedlings, and the nursery stock was too small at planting time.

11. Improved line planting technique was described by Dubois (pages 36-37) with Anderson groups (pages 37-38) and direct sowing (page 39). The Anderson groups were formed by 13 plants geometrically arranged with 0.5-1 m between plants and 25-50 m between groups. Dubois reported a trial of mechanized line clearing (pages 34-35). A D-6 tractor opened lines and scarified the soil with ripping teeth in two passes. Bagassa guianensis was planted in lines and Anderson groups. After four years, average total height in this plot (CE/RA/7b, on the planalto) was similar between ripped and unripped soil.

12. Araujo (1974) reported that line planting in that year covered 150 ha at Curuá-Una and that the controlling agency SUDAM proposed a further 75 ha for Bertholletia excelsa, Aniba duckei and A. roseadora.

13. Lowe (1980) reported, curiously, that enrichment planting had begun "recently", with successful growth of Carapa guianensis in shade but failure of Cedrela in both shade and sun.

State of Pará (Bragança)

14. Albrechtsen (1974) and PRODEPEF (1976) reported on the species trials in the Bragança region of eastern Amazonia. This work was directed by Dubois at three sites. Low scrub resulting from repeated clearings and burnings from the early years of this century was enriched by Anderson groups and one-tree-plots. The group had 13 trees arranged as in the earlier work at Curuá-Una and spaced 1 x 1 m with inter-group distances 10 x 10 m, centre to centre. The trials mostly had seven randomised groups per species. In addition, one-tree-plots were spaced 3 m along lines cut 1 m wide and 8 m apart, with 12

replicates (OTPs) per species. Pre- and post-planting thinnings were prescribed in the scrub to maintain a light overhead shade by medium-sized trees with medium-sized crowns.

15. The 1976 PRODEPEF report gave mean heights and survivals per species per plot type for two of the three sites for the last pre-publication assessment; the ages at that assessment varied from 6 to 27 months. The third site, Taira de Baragança, had OTPs spaced 5 x 5 m and Anderson groups with 2 m between plants within a group. Thirty (30) lines each of 20 plants and 5-10 lines of Anderson groups had been established by late 1974, under a light even canopy 6-7 m high of secondary scrub. The PRODEPEF report does not mention these plots, perhaps because they were burned in 1976. These trials in Bragança were established by two PRODEPEF projects: "8-048-1 Estudos de técnicas de plantio para espécies nativas de valor comercial da Regiao Amazônica" and "8-050-2 Seleçao de espécies nativas promissoras para atividades de reflorestamento em funçao de suas características silviculturais."

State of Pará (Belterra and FLONA Tapajos)

16. Dubois (1971, page 40) recommended trials of Catinot's "méthode des recrû" with spacings 4 x 4 to 6 x 6 m. Two trials were established at Belterra in 1976 and reported to mid-1980 by Gazel Yared and Carpanezzi (1981). The matrix was a 22-25 m tall secondary forest which resulted from the abandonment of a Hevea brasiliensis plantation 25 years previously. The basal area of forest on the heavy clay was 25 m2/ha. Each experiment of one hectare comprised five replicates of five species in an RCB design, with plots of 25 plants spaced at 4 x 4 m. Two months prior to planting the undesirable trees of <20 cm dbh were felled by axe or machete and their crowns chopped to pieces. Undesirable trees of 20-<30 cm dbh were ring-barked and those >=30 cm dbh were poisoned with Tordon 155 in old engine oil at 20 months after the experimental seedlings were planted. A second poisoning, of about 130 trees per hectare, was required after a further 11 months because the first was insufficiently effective. The matrix between the planting lines was lightly thinned after 41 months from the time of planting the seedlings and again 8 months later. The plots were assessed after 4 years. Survival, mean dbh and mean height were reported for each of the ten species planted. The probable reduction in growth, caused by the delayed poisoning and insufficient cleaning of the plots during the first two years, was acknowledged.

17. The same types of trial as in Bragança (see paragraphs 14 and 15), using mainly the same but also some more local species, were established in 1975-76 in the FLONA Tapajos, km 53 rodovia Santarém-Cuiabá. The 1976 PRODEPEF report classed the initial tree performance into five groups but gave no supporting quantitative data (pages 42 and 43) and did not distinguish between the trials in full sun and those in shade.

18. A separate project of PRODEPEF, "3-007-1 Conversao de capoerias em povoamentos de rendimento" was not clearly distinguished from either of the two projects noted above. It was established in secondary forest about 14 years old which resulted from farms which produced food for the forest workers. Four enrichment techniques were used: méthode des recrûs, the Congo 'mafuku' variation of méthode des recrûs, Anderson groups and line planting. Spacing within the méthode des recrûs was 4 x 4 m or wider. The mafuku mounds were 60-80 cm in diameter and arranged in quincunx spaced 3 x 3 m. However, trees were planted only on the mounds at 5 x 5 m and the remainder used for growing sweet potato, maize, rice and bananas. It would seem that no data have been reported

from the trials so far but the 1976 PRODEPEF report mentioned good initial growth of Cordia goeldiana, Didymopanax morototoni and Enterolobium maximum. The last named also gave 51 per cent germination on direct seeding. Eleven species were tested in méthode des recrûs (including the mafuku variation), 13 species in Anderson groups spaced 6 x 6 to 10 x 10 m and 5 species in line plantings.

19. Lowe (1980) observed that Carapa guianensis line-planted at km 53, FLONA Tapajos, had reached heights of 8 m in five years. However, planting had ceased because of lack of funds. At Belterra, Lowe noted good growth in the enrichment trials of the following species: Bagassa, Carapa, Cordia, Didymopanax, Jacaranda copaia and Swietenia. In the Anderson groups, Hymenaea (probably H. courbaril, planted in 1976) had reached 2-4 m and was notably straighter than when observed at age 2, while Vochysia maxima planted in 1977 had achieved heights of 3-4 m.

State of Amazonas

20. The 1964 enrichment plantings in INPA's Reserva Ducke near Manaus were summarised at age 8 years by Volpato, Schmidt and Araujo (1973). Twelve species were planted in monospecific square plots of 25 trees spaced 5 x 5 m. The unexploited forest had been treated in 1962 by ring-barking the leaning and over-mature trees and those of no known economic value. Non-commercial trees of less than 20 cm dbh were felled. Unlike the plantings at Curuá-Una and FLONA Tapajos which have received very little maintenance, the Reserva Ducke lines have been cleaned sometimes annually. However, the labourers who did this work were generally not supervised. They did not pay any attention to the degree of canopy closure and intensity of shading above the enrichment lines. Consequently, although the Carapa guianensis, Cedrelinga catenaeformis and Goupia glabra have shown good increment it is unlikely that they will have grown at rates approaching their potential maximum. Data for ages 3-8 years were mean heights of survivors per plot; for ages 7 and 8 some mean diameters were included also.

21. Between 1962 and 1969 about 26 hectares of species trials were established in Reserva Ducke. Most of the plots were one-quarter to one hectare in size and were planted in the shade of the canopy trees of the natural forest. The understorey was felled or ring-barked before planting. These plots were not intended as enrichment plantings and the inter-tree spacing was close.

22. Also in Reserva Ducke, Araujo established a paired plot between 1962 and 1966. Half of the plot had the natural forest felled and cleared. In the other half only the climbers and palms were cut. Lines were cut through each half at 5 m intervals. 21 species were planted, one per line, at 2.5 m spacing along the lines, so that 15 plants per species were in dense shade and 15 plants were in the open. Alencar and Araujo (1980) presented graphs of mean total height and survival against years from 1970 to 1978 and histograms of mean diameter in 1978 for each species in each half of the plot. The lines were cleaned twice yearly. The years show the expected striking difference between growth in full light and growth in "tunnels" in forest whose basal area was scarcely reduced from the natural state.

23. INPA is the controling agency for the Estaçao Experimental de Silvicultura Tropical, km 45 (formerly km 60) on the Manaus-Caracaraí road BR-174. Dr R Catinot visited INPA from CTFT in 1971 and 1973. He made

recommendations for re-starting silvicultural research. On his advice, layons were installed in 1972. The unexploited forest was thinned out by ring-barking in two stages. East-west lanes 3-4 m wide were cut through the understorey, about 20 m apart. Seedlings were planted at 4 m intervals along the lanes. 13 ha of Swietenia, 3 ha of Carapa and 1 ha of Cedrelinga were planted, either all in 1973 or most in 1973 and some in 1974. However, the common amazonian problem of rapid turnover in staff led to the neglect of the vital early maintenance. Both survival and growth were poor by 1975. There do not seem to be any published assessments of these layons. Lowe (1980) reported that the Carapa and Cedrelinga had grown well, and that competing natural regrowth had been poisoned.

22. COLOMBIA

24. Berrio et al. (1974) summarised the work of INDERENA in Carare-Opon. Line planting and group enrichment were tested. Unfortunately the results distinguished between plantings in the open and in shade only for Cariniana pyriformis and Virola flexuosa. Graphs showed annual height growth to ages 5 and 4 years respectively.

25. Berrio et al. (1974) also noted briefly the initiation of strip enrichment trials (2 m wide) by INDERENA at the Estación Experimental de Las Teresitas in the Choco. No quantitative results were available.

26. Suriname-style line planting (3 trees in a group, 5 m between groups in a line, 10 m between lines) was tested by Empresa Maderas y Chapas de Nariño at Tumaco (Berrio et al. 1974) under the direction of R B Peck from 1970. Eleven native species were tried. The line planting was abandoned, perhaps because it was realised that the poor growth and survival could have been due to the failure to follow the Dawkins "rules".

23. COSTA RICA

27. At Florencia Norte on the CATIE estate, P Rosero planted five species at 5 m intervals along strips cut 5 m apart. One hectare was planted in two year old regrowth from felled late secondary forest and one hectare in three year old regrowth. By the end of 1978 the only well established species was Cordia alliodora (Combe and Gewald 1979).

24. ECUADOR

28. IFLAIC (1969) reported line planting in Ecuador. The forest was logged for commercial trees and the undesirable residuals were ring-barked and poisoned twice at six months' intervals. Initial spacing was 1.5 x 7 m, later widened to 4 x 8 m. Ten species were used and mean heights at age 1 year were summarised. 60 ha were planted in the first year.

25. MEXICO

29. Budowski (1956) referred to strip plantings in Yucatan by sawmill companies and in Honduras by the United Fruit Company, but gave no details. He noted also the direct seeding of Cedrela on abandoned logging roads. About

20,000 ha were thought by local foresters to have been enriched after logging by planting with Cedrela and Swietenia. Avila Hernández (1962) mentioned the use of 6-8 months old seedlings of Swietenia and 16-20 months old seedlings of Cedrela, planted at 2-3 x 5-10 m in east-west strips which needed to be cleaned for the first 2-5 years. Cedrela required freedom from shrub competition and the retention of light high shade. Brief statistics of growth were given for these strip plantings. The experimental station of INIF (now INIFAP) at San Felipe Bacelar in Quintana Roo has continued with trials. Chavelas Polito (1976) reported the establishment of the following trials:

1972 8 ha Cedrela, Cordia dodecandra, Swietenia, and Tabebuia rosea in lines under high shade canopy;

1973 6 ha with 10 species, including Gmelina arborea, Platymiscium yucatanum, Simaruba glauca, Spondias mombin, Tectona grandis.

30. In the next paper in the same issue of Ciencia Forestal, Cedeño Sánchez (1976) reported the establishment of a trial of five methods of line planting under high shade at the experimental station at El Tormento in Campeche. No published information has been traced on results from these trials in Yucatan.

26. PERU

31. Ricse Tembladera and Masson (1978) reported on two enrichment trials in the Bosque Nacional "Alexander von Humboldt", near Pucallpa in Peru. The "prueba de enriquecimiento" included 15 species and was established in 1974. Seedlings were planted at 5 m intervals in lines cut 3 m wide and spaced 10 or 20 m apart and 600 m long. In the "ensayo" established in 1975, 16 species were planted at 5 m intervals in lines cut 3 and 5 m wide spaced 20 m apart, and also in 5-tree 5 x 5 m quincunx or "bosquetes" at intervals along access lines cut 1 m wide. It is not clear how many trees constituted a plot in the "prueba", which covered 52 hectares, but in the "ensayo" there were 5 plants per plot and three replicates of the treatment (spacing) x species combination. The results were reported in a rather confusing manner but essentially mean height and survival at age 2 years were given for each species, spacing and replicate in the "ensayo".

32. Díaz Reátegui (1974) briefly recorded strip plantings in the Bosque Nacional de Iparia, Iquitos. 2 ha of Tectona grandis were a failure in the wet climate. Cedrela was also a failure, ascribed to insufficient light and spacing. Cedrelinga, Chorisia insignis and C. integrifolia were very promising. Cedrelinga had increments (? annual) of 2 m in height and 2 cm in dbh.

33. Santander (1974) reported trials at the Escuela de Peritos Forestales de la Universidad Nacional de la Amazonía Peruana, 22 km from Iquitos at Puerto Almendras. 1.5 ha of Cedrelinga were planted in March 1967 at 5 x 10 m in secondary forest. Pre-treatment of the forest was inadequate but trees with access to light had reached 15 m in height and 12 cm in dbh* (? by 1974 or earlier ?). Another trial had 0.25 ha of Pinus caribaea planted in November 1972 in 1-1.5 m lines cut in secondary forest. Spacing was 5 x 5 m. 8 lines of 15 plants were established. Growth was reckoned to be good but no data were given.

27. PUERTO RICO

34. Weaver (1987) reported on the management-scale plantings of *Swietenia mahogani* x *macrophylla* and the experimental-scale enrichment with *Anthocephalus chinensis*. Both species were planted in the subtropical wet forest life zone of the Luquillo Mountains.

35. Planting began in 1963 in the Rio Chiquito area which was then covered with brush and secondary forest of little commercial value. Line planting techniques varied. 1275 ha were enriched in 1963 with the mahogany hybrid at 3 x 3 m by direct seeding under a canopy which was gradually poisoned. Competition from the matrix vegetation was controlled chemically in the first two years and repeated thinnings were used to liberate the better trees. A 30 per cent thinning was made at age 12 years and an assessment on 0.4 ha at age 20 years.

36. Enrichment plantings were extended to adjacent compartments in 1967, 1974, 1979 and 1980 (at least). They covered at least 620 ha by 1987. In these later compartments, seedlings <1 m tall were planted with bare roots in lines cleared 2 m wide. Spacing was 2 m within lines and 11 m between lines. Weeding was given two or three times a year for up to five years and the overstorey was gradually poisoned with arboricide. An assessment in 1983 showed significant differences in diameter and height growth by topography, and in diameter growth by class of crown exposure to light. Higher basal area in the matrix vegetation was associated with slower growth of the planted trees. There were marked differences in the presence of damage by the shootborer *Hypsipyla grandella* between the plantations established in the years 1974, 1979 1980. However, the differences were not associated with crown class of the planted trees or basal area of the matrix vegetation.

37. The Jiménez area was used for the trial enrichments with *Anthocephalus* in the early 1970s. Bareroot seedlings were used and the same spacings as for the mahogany hybrid planted at Rio Chiquito. The *Anthocephalus* was cleaned by machete twice in the first year and once in each of the second and third years after planting. Assessment at 10 years old was reported by Lugo and Figueroa 1985).

28. SURINAME

38. During 1954-67, *Virola surinamensis* was line planted in logged forest on low-lying terrain. Maintenance costs were high because logging was very selective and the basal area of the original forest was little reduced. With the passage of time, more species and smaller trees were exploited, the residual forest was more open and the accounting system was changed. In order to improve the light conditions for planted trees, the residual canopy was poisoned a year before enrichment during 1969-72. During the last years of the enrichment programme, 1973-77, the lower terrain was planted to *Virola* and *Cedrela angustifolia* and the higher land to *Cordia alliodora*, some 2-3 years after the poisoning of the residual overstorey. The enrichment lines were cleaned intensively. Yields were predicted to be 130-150 trees per hectare with mean dbh of 45 cm at 25-40 years old. Nearly 1700 hectares were planted between 1968 and 1975 (Vega Condori 1976).

39. In addition to these management-scale operations, trials of different

spacings and species were in progress in the early 1970s but do not appear to have been reported in the literature.

2.9. TRINIDAD

40. Lamb (1969) recalled his experience in Trinidad in planting Simaruba amara and Terminalia ivorensis on levelled charcoal pit sites in the 1954 coupe of natural regeneration in the Arena Forest Reserve. This work was not pursued because of the rapid contraction of the charcoal industry from 1955 onwards.

2.10. VENEZUELA

41. Finol U. (1964) referred to a preliminary enrichment planting trial in the Bosque Universitario El Caimital in Barinas. The understorey was cleared and stumps were used for five species in May 1963. No spacings or results are given, except that after 4 months there was still 100 per cent survival. The species were Bombacopsis quinatum, Cordia apurensis, Hura crepitans, Sterculia sp. and Swietenia.

42. IFLAIC (1969) summarised Venezuelan experience for the FAO Committee on Forest Development in the Tropics. 300 hectares of evergreen forest had been enriched by plantings of 5 trees in a group, 12.5 x 20 m between the centres of groups. Cordia alliodora, Samanea saman and Tabebuia pentaphylla were used with one Meliaceae (Cedrela or Swietenia) per group. At 5 years old, trees had reached 4-5 m tall.

43. Vincent and Bustamente (1973) established "limba" type enrichment trials in May 1973 in Proyecto Caparo in three forest types. 12 ha were planted with Bombacopsis and Cordia apurensis. After 6 months, growth and survival were rated as good. Vincent (1974) gave a more detailed background and a longer list of species. He referred also to species elimination trials and pilot scale plantations. Both included plantings under shade (no spacings were given) and "limba" planting at 2 x 6.5 m. No growth data were presented although the trials had begun in 1970. Vincent gave tables of areas by forest type, areas planted by years, and species by type of trial.

44. DRNR/MAC (1974) summarised work on silviculture at the Estaciones experimentales of the Ministerio de Agricultura y Cría. At Turén (Portuguesa) in dry tropical forest the canopy was poisoned progressively to admit light slowly to enrichment groups-in-lines. Five trees formed a group, one of them a Meliaceae, and there were 40 groups per hectare. The lines were cleaned 2-3 times a year. Spacing was not mentioned. Species were Anacardium excelsum, Bombacopsis, Cordia alliodora, Pithecellobium saman and Tabebuia rosea with Swietenia as the Meliaceae.

45. Post-logging enrichment by twoprivate companies in the reserva Forestal de Ticoporo was reported by DRNR/MAC (1974). Empresas Contaca and Emallaca used méthode des recrûs. Strips were cut 5 m wide and orientated east-west. Spacing of plants was 2.5 x 25 m. Species were Bombacopsis, Cedrela, Cordia alliodora, Swietenia and Tabebuia rosea.

46. The Reserva Forestal de Guarapiche (Sucre/Monagas) was under more intensive management (DRNR/MAC 1974). After logging by private companies of the pre-inventoried annual coupe of 460 ha, the forest was refined. Badly

formed and non-commercial species over 15 cm were ringed and poisoned. One year later the enrichment lines were opened at 15 m intervals. Sytriplings were planted at 2.5 m along the lines. Species were Cedrela, Swietenia and Tabebuia rosea. The programme was begun in 1970 and 1600 ha had been treated by 1974.

SUBTROPICS

47. Perhaps there should be a brief mention of three subtropical studies. In Argentina, Cozzo (1964 and 1969) described a small-scale trial of Cordia trichotoma in the Arboretum Garhuape at Misiones. Subtropical forest degraded by frequent logging was opened by strips 5 and 7 m wide separated by untouched bands 2 and 3 m wide (thus making 4 combinations). The strips were cleared of undergrowth and small trees but large ones were left to give shade and protection against frosts in the short winter. Two lines of Cordia were planted in the 5 m strips and three lines in the 7 m strips. Inter-plant spacing was 2.5 m. Average heights were given for ages 1, 2 and 7 years and average dbh at 7 years. Growth was closely associated with available light and space. This method of planting was almost completely successful in preventing the frost damage which affected open plantations.

48. In the state of Minas Gerais in Brazil, Vale et al. (1973) reported height growth and mortality of a five year old experiment in secondary forest. All undergrowth had been cleared, together with climbers and bamboos. A selective thinning then reduced the canopy to give about 40 per cent shade. Three replicates of 6 species were planted at 3 x 3 m with 24 trees per plot. The lack of cleaning in the first year was thought to have had an adverse effect on survival and growth. Caesalpinia peltophoroides was best at five years with 76 per cent survival and an average height of 126 cm.

49. Enrichment line plantings were among the various trials being established in selectively logged forest belonging to the Companhia Vale Rio Doce S/A near Linares in the state of Espírito Santo in Brazil in 1975. No details seem to have been published.

3. Commentary

3. The table of species tested for enrichment planting in the neotropics is given at the end of the main report. It shows the great emphasis given to the Meliaceae, especially the three species Carapa guianensis, Cedrela odorata and Swietenia macrophylla. This concentration is not peculiar to enrichment planting; it is repeated in trials for conventional plantations in the neotropics. Further, the emphasis on the Meliaceae has persisted in spite of repeated failures, mostly due in part to the continued attacks of the pyralid shootborer Hypsipyla grandella.

4. In spite of the efforts of the Interamerican Working Group on Hypsipyla, the results of the major research undertaken at Turrialba, Costa Rica, in the late 1960s and early 1970s have remained little known or little used in the neotropics. The Turrialba work was notable in that most of the individual research studies were published formally in journals and a considerable number of Latin American students worked on different aspects of the research for their M.Sc. dissertations. A high proportion of the research was dedicated to the entomological side and the chemical control of the shootborer. The silvicultural side suffered from the customary Latin American weakness in the definition of objectives and experimental design. There was only a single study on Meliaceae planted in the shade of other trees (see paragraph 11 below). Unfortunately, the synthesis report (Grijpma 1974), which summarised the conclusions of the many individual studies and drew out the practical managerial implications of the research results, was not widely distributed. Some of the results are mentioned below.

31. Conditions under which enrichment planting has been, from a silvicultural point of view, successful

5. Dawkins (1966) drew upon more than twenty years of experience in tropical forestry to compile a list of five necessary conditions and eight technical guides for enrichment line plantings. This consultant (Palmer) concluded, in a 1981 report for the USDA Institute of Tropical Forestry, that there were no recorded cases of failure in the neotropics where these conditions had been fulfilled and the technical guides followed. Dawkins' work was made available in Spanish in 1967 through the FAO Committee on Forest Development in the Tropics (Lamb 1967). However, two of the three neotropical countries which have practised enrichment planting on a management scale (Puerto Rico and Suriname, México being the exception) have English-speaking staff who are known to consult the published literature as a routine aspect of research.

6. In Puerto Rico the matrix vegetation was secondary forest which had grown up in abandoned arable (subsistence) farms or grazing land. The canopy shade was lightened by gradual poisoning, competition was also controlled by arboricide and the better trees were released by repeated thinnings of their competitors. This intensive liberation of closely spaced (3 x 3 m) mahogany hybrid seems to have compensated for the possibly slow initial growth of the direct-seeded plants in the Rio Chiquito area. The bare-rooted stock planted from 1967 at 2 x 11 m also seems to have thrived. The lack of yield plots to give repeated measurements precludes a comparison between the rates of growth between the plant types or spacings. Weaver (1987) and Weaver & Bauer (1986) have used graphs to display what comparisons may be made validly.

7. In Suriname also there was repeated careful liberation of the planted trees. In this country the matrix was lightly-logged tropical moist forest, whose canopy was broken up by arboricide treatment of the undesirable trees. The lines were intensively cleaned so that the crowns of the planted trees received overhead light and were free of climber infestation. This period was not prolonged because the enrichment species were fast growing.

8. In terms of number of trials, the Brazilian experience is by far the most extensive. The reporting has, however, been lacking in cross-references to the accounts of the establishment of the trials. For example, PRODEPEF (1976) describes trials and progress up to that year in Belterra while Yared & Carpanezzi (1981) describe two trials started in 1976. The unpublished tour report by Lowe (1980) does not indicate in which trials he observed the good growth of several species. This consultant (Palmer) has not been able to trace a published series of measurements from these or indeed any neotropical enrichment trials.

9. In many of the neotropical countries where enrichment has been tried there has been a tendency to forget that enrichment is just that. It is intended to supplement existing but inadequate natural regeneration in order to form a managerially worthwhile tree crop. Enrichment, in the paleotropics, was never intended to provide the stocking which would be necessary in an intensively managed monocultural plantation. In only two cases has there been a conscious effort to evaluate the matrix vegetation as well as the planted trees. In Puerto Rico, Weaver & Bauer (1986) used a prism to assess the basal area surrounding each planted tree. As one would expect, the diameter and height growth of the planted trees was inversely related to the surrounding basal area. However the species composition and structure of the matrix was not studied.

10. The other study which evaluated the matrix vegetation was not strictly enrichment planting. The plantations of Swietenia macrophylla in the Columbia River Forest Reserve of Belize between 1955 and 1964 were direct-sown with the taungya farmers' maize. Spacing was generally 9 x 9 m with 6-8 seeds per hole. After the farmers abandoned their milpas there was at least one Forest Department cleaning in most plantations. The 1955 block was also treated to liberate the crowns of the planted trees. The remaining 200 ha of the original 700 ha were inventoried by Wilson (1981); the samples covered the remaining four blocks (1948, 1956, 1957 and 1958). All trees, planted plus natural regeneration, were calipered for dbh. In nearly all 10-cm dbh classes in the four blocks, the Swietenia and the technically acceptable though commercially less desirable timber species provided 50 per cent of the commercial volume. In many size classes the unacceptable species comprised less than a quarter of the volume. The contribution of Swietenia varied from 8 to 26 per cent by volume, from 52 to 188 trees per hectare.

11. There are frequent qualitative comments on the influence of shade on the frequency and intensity of Hypsipyla attacks on Meliaceae. Ledoux & Lobato (1972) and Yared & Carpanezzi (1981) reckoned that shootborer damage was absent or negligible in line or layon enrichment. The Turrialba work showed that Hypsipyla was ubiquitous and capable of reaching the tops of the trees. The single comparative study had plots on different sites, planted in different years and lacked replicates or any formal design. Grijpma (1974), in his summary of all the work in Turrialba up to 1973, concluded that "damage is complete and widespread regardless of whether mahogany trees are located in the open or heavy shade". The various plots of Meliaceae in Turrialba were closely observed by this consultant (Palmer) from 1979 to 1985 and the same conclusion was maintained. It was also reached by Roberts (1968) for the paleotropical Meliaceae in Nigeria. However, there are marked differences between species in their resistance to shootborer attack. Cedrela angustifolia performed best in Turrialba (and also in the Solomon Islands), Carapa guianensis was next best in Costa Rica and Brazil, Swietenia spp. have generally done poorly and Cedrela spp. are notably sensitive to site quality. For lack of well-designed comparative trials it is not clear how much these observed differences are due to innate biochemical resistance and how much to the different abilities to produce soon after planting a large photosynthetic area, and to maintain it. The dramatic success of Swietenia macrophylla in southern Belize after direct-seeding in taungya plantations suggests the importance of good species-site matching and good early maintenance to encourage the establishment of a large leafy crown.

12. The preponderance of effort on the Meliaceae in the neotropics has tended to overshadow the existence of several promising species which are not liable to the same devastating insect attacks. Weaver (1987) suggests that twenty promising species would be a conservative estimate. As regards technique, the guidelines of Dawkins (1966) have yet to be improved upon.

32. Conditions under which enrichment planting has been unsuccessful

13. The majority of neotropical trials have been unsuccessful because the Dawkins conditions and technical guide have not been observed. Concerning the conditions, the main faults have been a failure to open the canopy and to keep it open, and to keep the crowns of the planted trees free of distorting climbers (lianes). It has been common in Brazilian Amazonia to plant enrichment trees in "tunnels" cut in the unexploited forest, so that the planted trees have no direct light and have to compete with an already saturated basal area (e.g., Alencar & Araujo 1980). Sometimes the bases of the trees have been kept well clean but the workers have not been instructed to maintain good light access to the crowns (e.g., Volpato, Schmidt & Araujo 1973). This consultant (Palmer) has frequently seen the V-shaped cross sections of the enrichment lines having their open tops spanned by climbers.

14. Insufficient or infrequent tending is a major cause of failure in the neotropics. Only occasionally is this openly acknowledged (Yared & Carpanezzi 1981). Hence the rare data on costs are not usually of any value as indicators of real costs in a properly conducted enrichment scheme.

15. Other frequent faults include the use of under-sized seedlings, or plants with unbalanced root/shoot ratios. The lack of care to develop good root systems in neotropical nurseries is notorious. Failure to replant dead seedlings in the first growing season, or replanting with poor quality stock, are common faults which apply equally to conventional plantations.

16. The table at the end of the main report shows that a remarkably large number of species have been included in one or more trials of enrichment plantings. The rational for the choice is infrequently explained in the papers cited in the bibliography. In some cases there has been an attempt to select species which, from observation, grew fast in disturbed forest and had good stem form (Ricse Tembladera & Masson 1978). Many trials appear to have included those species for which seed or nursery plants happened to be available. Explicit reference to the Dawkins principles is very rare in the neotropics.

4. Costs of enrichment planting under various conditions and with various techniques

17. As noted above in paragraph 14, cost data are few and mostly meaningless. The most comprehensive data are given by Vega (1976) for line planting in Suriname. They have the advantage that they concern management scale operations, not small research plots, and that they are given in man-days per hectare rather than cash terms. Furthermore, the costs are given as annual figures for up to eight years so that the reader can see what variation is likely to occur. The average annual cost in man-days per hectare were:

reconnaissance and selection of areas for enrichment	1.7
subdivision of the selected area into management blocks	2.4
opening and marking of boundary lines	-
selection and marking of desirable trees in the matrix	0.6
refining of the matrix with arboricides in frill girdles	0.9
opening of the enrichment lines at 10 m intervals	2.3
re-poisoning	-
opening of spaces for triangular groups at 5 m intervals	-
hole digging	1.9
planting	1.9
re-planting	1.9
site survey	0.3
miscellaneous tasks at establishment	1.0
total	15.8

18. Maintenance costs are more variable, depend on the success of the establishment operation, and change with needs over time. Vega (1976) gave the following averages for the same eight-year period at Mapane in Suriname, also in man-days per hectare.

weeding of the triangular group plantings	1.8
widening of the planting lines	1.4
lateral liberation of the planted trees	1.4
liberation of the crowns of the planted trees for direct access to overhead light	2.1
poisoning of the laterally competing matrix	1.2
cleaning of the access roads and tracks	-
pruning, especially of Meliaceae attacked by *Hypsipyla*	1.4
marking for and executing a selective thinning	1.2
miscellaneous maintenance tasks	1.0

19. The paper by Vega gives a considered discussion of many aspects of the line enrichment plantings and the associated costs.

41. Economic benefits, in the form of timber production, from enrichment plantings

20. In the neotropics there are few published estimates of the anticipated yields from enrichment plantings. No scheme has yet reached maturity. Most thinnings (perhaps all so far) have been non-commercial, carried out to liberate the expanding crowns of the better trees from their poorer neighbours in the planting lines or groups.

21. Estimates made by or for the national forest service in Suriname from 1968 to 1974 centred round a target of 130 to 150 stems per hectare of trees with 45 cm minimum commercial diameter at 25 to 40 years old, depending on the species and site quality. This stocking might give 124 m3/ha to a top diameter of 30 cm on 18-25 m2/ha (Vega 1976). However, de Graaf (1986) has questioned the reliability of the official estimates, since they assume a continuation of the rapid early growth seen in well-maintained enrichment strips and lines. Unfortunately there are no recently published data on growth from Suriname. The cited values are not out of line with those estimated for paleotropical enrichment plantings.

22. Besides the anticipated extra volume from the natural regeneration and planted trees compared with unenriched forest, there are expectations of improved stem form compared with that in conventional plantations. The lateral shade afforded by the matrix vegetation should help to stimulate a concentration of growth in the apical buds and restrict a diversification of photosynthates into lateral branches. This expectation is borne out by qualitative observations. The greatly increased net yield from straight and cylindrical sawlogs compared with crooked or eccentric logs of the same volume should be subject to quantitative evaluation, since it is likely to be of greater importance that gross volume.

42. Non-timber benefits from enrichment planting

23. Weaver (1987) pointed out that "many of the enrichment planting techniques simulate conditions of natural gaps by clearing lines and poisoning the overstory trees, or establishing the seedlings of valuable commercial species within existing openings in the forest. Moreover, the species of interest to foresters are the fast-growing secondary species that are among those that require gaps to mature. In summary, then, enrichment planting is closer to nature's way of regeneration and releasing trees than either the establishment of large plantations or natural regeneration below shade". This working with Nature, as advocated by Pitt (1961), should help to reduce managerial costs by diminishing the number of manually intensive interventions needed to maintain survival and growth of the desirable species.

24. The maintenance of soil cover and matrix vegetation throughout the rotation, and the elimination of fire from the silvicultural sequence, are factors conducive to soil and water conservation, the maintenance of the plant and animal gene pools and reduced disturbance of wildlife.

25. Although some enrichment schemes in West Africa employed machinery, those in the neotropics have been almost entirely manual operations. The opportunities for continual employment in rural areas may be attractive to governments which seek to stabilise the rural populations and enhance income. The flexibility of enrichment silviculture, after the establishment phase, compared with the relatively fixed schedules of conventional plantations on a large scale, may appeal to public and private investors. This is especially true where the ability of field managers to take timely decisions and to implement them effectively is in need of upgrading.

5. [New research efforts]

26. This report shows clearly that in the [illegible] that in the neotropics the need is for the effective implementation of existing knowledge rather than for more research. This is not to say that adaptive research (in the CGIAR sense) is not required; it is certainly needed in any spatially extensive land use, agriculture or forestry. A more quantitative and scientific approach to field operations and to research would help to reduce the enormous wastage of effort which has characterised so many forest operations in the region. However this is true of many fields besides forestry and is a problem rooted in the socio-cultural and educational systems which are still prevalent. Training can help to o[illegible]me the deficiencies but these must be backed by convincing demonstrations. The best demonstrations are often found in well-conducted research trials.

5 - GENERAL CONCLUSION

It should be stressed that there are very few comprehensive documents on the results of enrichment planting in Tropical Forests. This essential fact conveys the general failure of these techniques as well as the researchers' disappointment and loss of interest.

As was mentioned above, these failures can be accounted for by their need for financial, material and human investments which make them inapplicable to extensive areas and disproportionate to the low increase in productivity of the forests treated.

Finally, the disappearance in some countries of large areas of treated forest, in favour of agricultural clearing, limits the opportunities for the use of extensive techniques of forest production. Highly productive plantations may be, in this case, more easily justified in socio-economic and space utilization terms in relation to the agricultural need for land.

Nevertheless, for ecological reasons and to preserve the genetic heritage, significant forest areas will have to be kept, part of which may be the object of extensive treatment within the framework of a plan. In the current state of knowledge, the various enrichment planting techniques cannot be adopted, at least for the dense moist forest, as they compete with simpler silvicultural techniques, such as thinning of natural stands, in favour of noble species and at the expense of commercially secondary species.

ANNEX 1

Key to the relation between scientific names and commercial or common names of timber species from rain forest cited in the report

1st part : Identification from scientific names (Tropical Africa)

SCIENTIFIC NAMES		COMMERCIAL OR COMMON NAMES (Pilot commercial name underlined)
Identification	Synonym	
Afzelia africana		Doussié, Lingué, Azodau, Anyan
Aucoumea klaineana		Okoumé
Autranella congolensis	Mimusops congolensis	Mukukungu, Elang
Cassia siamea		Djohar, Cassia, Boix perdrix
Cedrela odorata		Cedro, Cedrela, Cedar
Ceiba pentandra		Fromager, Enia, Okha, Doum
Chlorophora regia, C.excelsa	Milicia regia, M. excelsa	Iroko, Odum, Abang
Combretodendron africanum	Petersia africana	Essia, Abalé, Stinkwood, Abing
Dumoria heckelii	Tieghemella heckelii	Makoré, Douka, Baku
Entandrophragma angolense		Tiama, Edinam, Gedu-Nohor, Edoussié
Entandrophragma candollei		Kosipo, Omu, Atomassié
Entandrophragma cylindricum		Sapelli, Aboudikro
Entandrophragma utile		Sipo, Utile, Assié
Gmelina arborea		Gumari, Gmelina, Yemane
Guarea spp.		Bossé, Mutigbanaye, Obobo, Ebangbewa
Heritiera utilis	Tarrietia utilis	Niangon, Ogoué
Khaya anthotheca		Acajou, Acajou blanc
Khaya grandifolia		Acajou, Acajou à grandes feuilles
Khaya ivorensis		Acajou, Acajou bassam, Lagos mahogany, Ngollon
Khaya senegalensis		Bissilom, Cailcedrat, Mogno, Acajou du Sénégal
Leucaena leucocephala		Ipil Ipil, Leucaena
Lophira alata	L. procera	Azobé, Ekki, Bongossi, Akoga
Lovoa trichilioïdes		Dibetou, Bibolo, Temamire, Apopo, Eyan
Milicia excelsa, M. regia	Chlorophora excelsa, C. regia	Iroko, Odum, Abang
Mimusops congolensis	Autranella congolensis	Mukulungu, Elang
Musanga cecropioides		Parasolier, Aseng, Senga
Nauclea trilesii	Nauclea diderrichii	Bilinga, Badi, Kussia, Opepe, Akondoc
Petersia africana	Combretodendron africanum	Essia, Abalé, Stinkwood, Abing
Ricinodendron heudelotii	Ricirodendron africanum	Essessang, Eho, Corkwood
Tarrietia utilis	Heritiera utilis	Niangon, Ogoué
Tectona grandis		Teck
Terminalia ivorensis		Framiré, Emri, Idigbo, Lidia
Terminalia superba		Limba, Fraké, Ofram, Afara, Akom
Tieghemella heckelii	Dumoria heckelii	Makoré, Douka, Baku
Triplichiton scleroxylon		Obeche, Samba, Wawa, Ayous

ANNEX 1

Key to the relation between scientific names and commercial or common names of timber species from rain forest cited in the report

2nd part : identification from pilot names (Tropical Africa)

COMMERCIAL OR COMMON NAMES		SCIENTIFIC NAMES
Pilot name	Synonym	
Acajou	Acajou bassam, Ngollon, Acajou blanc, Acajou à grandes feuilles	Khaya ivorensis, Khaya anthotheca, Khaya grandifolia
Azobé	Ekki, Bongossi, Akoga	Lophira alata, L. procera
Bilinga	Badi, Kussia, Opepe, Akondoc	Nauclea trilesii, Nauclea diderrichii
Bissilom	Cailcedrat, Mogno, Acajou du Sénégal	Khaya senegalensis
Bosse	Mutigbanaye, Obobo, Ebangbewa	Guaera spp.
Cedro	Cedrela, Cedar	Cedrela odorata
Dibetou	Bibolo, Temamire, Apopo, Eyan	Lovoa trichilioides
Djohar	Cassia, Boix perdrix	Cassia siamea
Doussié	Lingué, Azodau, Anyan	Afzelia africana
Essia	Abalé, Stinkwood, Abing	Combretodendron africanum, Petersia africana
Essessang	Eho, Corkwood	Ricinodendron heudelotii, R. africanum
Framiré	Emri, Idigbo, Lidia	Terminalia ivorensis
Fromager	Enia, Okha, Doum	Ceiba pentandra
Gumari	Gmelina, Yemane	Gmelina arborea
Iroko	Odum, Abang	Chlorophora excelsa, C. regia, Milicia excelsa, M. regia
Kosipo	Omu, Atomassié	Entandrophragma candollei
Limba	Fraké, Ofram, Afara, Akom	Terminalia superba
Makoré	Douka, Baku	Tieghemella heckelii, Dumoria heckelii
Mukulungu	Elang	Autranella congolensis, Mimusops congolensis
Niangon	Ogoué	Tarrietia utilis, Heritiera utilis
Obeche	Samba, Wawa, Ayous	Triplochiton scleroxylon
Okoumé		Aucoumea klaineana
Parasolier	Aseng, Senga	Musanga cecropioides
Sapelli	Aboudikro	Entandrophragma cylindricum
Sipo	Utile, Assié	Entandrophragma utile
Teck		Tectona grandis
Tiama	Edinam, Gedu-Nohor, Edoussié	Entandrophragma angolense

ANNEX 1

Key to the relation between scientific names and commercial or common names of timber species from rain forest cited in the report

1st part : Identification from scientific names (Neotropics)

SCIENTIFIC NAMES		COMMERCIAL OR COMMON NAMES (Pilot commercial name underlined)
Identification	Synonym	
Albizzia lebbeck		Kokko, Weru, Pluk
Anacardium excelsum		Caracoli, Caju açu, Cashew
Aniba duckei		
Aniba roseadora		
Anthocephalus chinensis	A. cadamba	Kadam, Jabon
Bagassa guineensis		Bagasse, tattauba
Bertholletia excelsa		Castanheiro, Castanha, Jubia, Brasil nut
Bombacopsis guinatum	Pachira fendleri	Saqui-paqui, Mahot coton, Ceiba tolva
Caelsalpinia peltophoroides		
Carapa guianensis		Andiroba, Carapa, Nandiroba, Crabwood
Cariniana pyriformis		Abarco, bacu
Cedrela angustifolia		Cedro, Cedar, Red cedar
Cedrela odorata		
Cedrelinga catenaeformis		Tornillo, Cedro-rana
Chorisia insignis		
Chorisia integrifolia		
Cordia alliodora		Laurel
Cordia apurensis		
Cordia goeldiana		Freijo
Didymopanax morototoni		Morototo
Enterolobium maximum		
Gmelina arborea		Yemane, Gumari
Goupia glabra		Goupi, Cupiaba
Hevea brasiliensis		Hevea
Hura crepitans		Assacu, Javillo, Saandbox, Possumwood
Hymenaea courbaril		Courbaril, Algarobo, Guapinol, Jatoba
Hypsipyla grandella		
Jacaranda copaia		Parapara
Pinus caribaea		Pitch pine, Ocote pine, Yellow pine
Pithecellobium saman		
Platymiscium yucatum		Trebol, Macawood
Samanea saman		
Simarouba amara		Marupa, Aceituno, Bitterwood
Simarouba glauca		
Spondias mombin		
Sterculia spp.		Kobé, Castano, Chicha
Swietenia macrophylla		Mahogany, Caoba, Acajou
Tabebuia pentaphylla	T. pallida	Apamate, Amapa, Roble
Tabebuia rosea		
Tectona grandis		Teak
Terminalia ivorensis		Framiré, Black afara, Emri, Idigbo, Lidia
Virola flexuosus		Virola, Ucuhuba branca, Camaticaro, Chalviande
Virola surinamensis		
Vochysia maxima		Quaruba, Quarabu

ANNEX 1

Key to the relation between scientific names and commercial or common names of timber species from rain forest cited in the report

2nd part : Identification form pilot names (Neotropics)

COMMERCIAL OR COMMON NAMES		SCIENTIFIC NAMES
Pilot name	Synonym	
Abarco	Bacu	Cariniana pyriformis
Andiroba	Carapa, Nandiroba, Crabwood	Carapa guianensis
Apamate	Amapa, Roble	Tabebuia pentaphylla (=T. pallida), T. rosea
Assaçu	Javillo, Sandbox, Possumwood	Hura crepitans
Bagasse	Tatajuba	Bagassa guineensis
Caracoli	Cajuaçu, Cashew	Anacardium excelsum
Castanheiro	Castanha, Jubia, Brasil nut	Bertholletia excelsa
Cedro	Cedar, Red cedar	Cedrela odorata, C. angustifolia
Courbaril	Algarobo, Guapinol, Jatoba	Hymenaea courbaril
Framiré	Emri, Idigbo, Lidia, Black afara	Terminalia ivorensis
Freijo		Cordia goeldiana
Goupi	Cupiaba	Goupia glabra
Hevea		Hevea brasilensis
Kadam	Jabon	Anthocephalus chinensis (=A. cadamba)
Kobe	Castano, Chicha	Sterculia spp.
Kokko	Weru, Pluk	Albizzia lebbeck
Laurel		Cordia alliodora
Mahogany	Caoba, Acajou	Swietenia macrophylla
Marupa	Aceituno, Bitterwood	Simarouba amara, S. glauca
Morototo		Didymopanax morototoni
Parapara		Jacaranda copaia
Pitch pine		Pinus caribaea
Quaruba	Quarabu	Vochysia maxima
Saqui-saqui	Mahot coton, Ceiba tolva	Bombacopsis guinatum (= Pachira fendleri)
Teak	Teck	Tectona grandis
Trebol	Macawood	Platymiscium yucatum
Tornillo	Cedro-rana	Cedrelinga catenaeformis
Virola	Chalviande, Ucuhuba branca, Camaticaro	Virola flexuosus, V. surinamensis
Yemane	Gumari	Gmelina arborea

ANNEX 2

Necessary conditions for line planting
(H.D. DAWKINS)

1. There must be little or no demand for thinnings in the area concerned. If thinnings are required the method is insuitable ; if large timber and veneer logs are in demand the system is suitable .

2. The species planted must be fast-growing (five feet (1.5 m) of height per year as a minimum), naturally straight and self-pruning, i.e. generally of the colonising or gap-filling light-demanding type.

3. There must be no upper canopy ; only clear-felled, clear-poisoned or low secondary forest is suitable.

4. The regrowth between the planted lines must be non-inflammable.

5. Browsing animals must be absent, scarce or of negligible effect on planted trees.

Provided all five conditions are met, the following technical specifications are required.

1. Planting lines should be spaced equal to or slightly more - up to 20 % more is reasonable - than the expected crown diameter of healthy final crop trees of the species concerned. The reason for this is to prevent any possibility of serious between-line crown competition before maturity, to save on establishment costs and to give more scope for possibly superior species which may arise naturally between the lines.

2. Plants should be spaced along the lines at approximately one-fifth of the spacing between them, to allow a selection of about one-in-four for the final crop. If poisoned overwood is likely to be abundant, as in very lightly felled natural forest being planted, then up to 30 % losses must be expected and spacing in the lines should be nearer 1/6th to 1/7th of spacing between lines. Only be this means can good form of the final crop be assured.

3. Planting lines must be well-cleared, about 6 feet (1.8 m) wide at first and made easy to move along, at least along one side of the planted trees, by removal of most if not all woody snags. Once planted the lines must be kept clean and no overhanging or threatening growth tolerated. Since this clearing work is confined to a very small fraction of the area, labour costs are low and several cleanings (sometimes up to six or seven are necessary) can be afforded in the first twelve months.

4. Plants must get away to a quick start. For most species this means using potted stock ; stumps or striplings are not likely to be suitable. Cedrela has shown itself capable of starting from direct seed, but this içs quite exceptional.

5. Planting must follow immediately on clearing the planting lines ; clearing in the early dry season and planting three to five months later in the parly rains is thoroughly bad technique and will result in at least two more clearings than otherwise. Poisoning of the upper canopy also should be timed to let in the light at time of planting, not before. It is recognized, however, that this is not a precise possibility.

6. Trees arising between the lines; unless superior in value to the planted species, must be cut or poisoned immediately they "threaten" the plants, i.e. before they overshadow them. The greatest threat is form Musanga, trema and Macaranga. Similarly, climbers over-arching form the bush regrowth beside the lines, must be vigorously out back before they over-shadow the plants, provide ladders for climbers or obstruct quick access along the lines.

7. Thinning along the lines is a matter of selecting the stems of superior form and height. (Unless the disparity in size is very great, form and height should both be regarded as more important than mere girth). The first thinning will generally be at three to four years, by which time the trees should be well above the shrub and climber regrowth. It will probably require about 50 % culling of crop.

8. In the special case of West Africa, species subject to epidemic insect attacks, such as Chlorophora or Khaya, would not be "sensibly chosen".

Legend to table of species represented in trials of enrichment planting in the Neotropics

The table shows tree species included in enrichment trials or management practice in the neotropics. It has been compiled from the literature cited in this report

Botanical names are as given in the sources, unless it is clear that there has been a typographical error. Several reports do not distinguish clearly between species planted in the shade for enrichment of existing vegetation and species planted nearby in the open; in case of doubt, species have been omitted from this table. Rows are species in alphabetic order of botanical names. In a very few cases, a named species is not associated with a particular site. This indicates that it has been mentioned in passing in one of the reports not listed in this table.

The 28 columns are sites or trial types, in alphabetic order of country. An asterisk indicates a trial of enrichment by direct sowing. In order to show all the sites on one page, the table is inevitably cramped. The headings are repeated at the bottom of each page, as an aid to reading the table.

BRAZIL

1. Santarém, CBA - letters C, F, J or M indicate the silvicultural treatment plot which was enriched. (source: Pitt 1961)

2. Santarém, CTM - the former SPVEA sawmill site. '+' for inclusion of a species. (source: Pitt 1961)

3. Porto Platon - '+' for inclusion of a species. (source: Pitt 1961)

4. Curuá-Una, patches - '+' for inclusion of a species. (source: Pitt 1961)

5. Curuá-Una, lines - compartments D, N and 4 were wholly or partly enriched. (source: Pitt 1961)

6. Curuá-Una, A - trials of Anderson groups. '+' for inclusion of a species. (source: Dubois 1971)

7. Curuá-Una, other lines - '+' for inclusion of a species. (source: Dubois 1971)

8. Igarapé-Açú, Bragança, A - trials of Anderson groups. '+' for inclusion of a species. (source: PRODEPEF 1976)

9. Igarapé-Açú, Bragança, OTP - one-tree-plots. '+' for inclusion of a species. (source: PRODEPEF 1976)

10. Trinidade, Bragança, A - trials of Anderson groups. '+' for inclusion of a species. (source: PRODEPEF 1976)

11. Trinidade, Bragança, OTP - one-tree-plots. '+' for inclusion of a species. (source: PRODEPEF 1976)

12. FLONA Tapajos, Km 53 - PRODEPEF scoring of initial performance in trials. 1 = best growth rates and good general appearance, 2 = good growth and appearance, 3 = reasonable growth, 4 = slow initial growth, 5 = species of doubtful value because of attacks by insect pests. (source: PRODEPEF 1976)

13. Old rubber nursery and secondary forest ('capoera') at Belterra, Tapajos - letter indicates the type of trial: A = Anderson groups, L = line planting, R = méthode des recrûs. (source: PRODEPEF 1976)

14. Secondary forest ('capoera') at Belterra, Tapajos - R = méthode des recrûs. (source: Yared & Carpanezzi 1981)

15. Old rubber nursery and secondary forest ('capoera') at Belterra, Tapajos - '+' for mention by RGLowe of notably good growth observed during a visit in 1980. (source: Lowe 1980)

16. Reserva Ducke, INPA, Manaus - trial of 12 species planted in 1964, '+' for inclusion of a species. (source: Volpato, Schmidt & Araujo 1973)

17. Reserva Ducke, INPA, Manaus - comparative trial in full shade and fully open conditions of species planted 1962-66, '+' for inclusion of a species. (source: Alencar & Araujo 1980)

18. Estação Experimental de Silvicultura Tropical do INPA, Manaus-Caracaraí BR-174, Km 45 - '+' for inclusion of a species. (source: Lowe 1980)

OTHER NEOTROPICAL TRIALS OF ENRICHMENT

19. Colombia - C = Carare-Opon (INDERENA), N = Nariño (Empresa Maderas y Chapas de Nariño). (source: Berrio et al. 1974)

20. Costa Rica - Florencia Norte on the CATIE estate in Turrialba, '+' for inclusion of a species. (source: Combe & Gewald 1979)

21. Ecuador - '+' for inclusion of a species. (source: IFLAIC 1969)

22. México - Campo Experimental Forestal at San Felipe de Bacalar in Quintana Roo, '+' for inclusion of a species. (source: Chavelas Polito 1976)

23. Perú - I = Bosque Nacional de Iparia or Escuela de Peritos Forestales, Iquitos; P = Bosque Nacional Alexander von Humboldt, Pucallpa. (sources: Díaz Reátegui 1974, Ricse Tembladera & Masson 1978, Santander 1974)

24. Puerto Rico - '+' for inclusion of a species. (source: Weaver 1987)

25. Suriname - Mapane, '+' for inclusion of a species. (source: Vega 1976)

26. Venezuela - Bosque Universitario El Caimital in Barinas, '+' for inclusion of a species. (source: IFLAIC 1969)

27. Venezuela - Reserva Forestal de Caparo, C = trials and pilot plantations under canopy shade ('cubierta'), L = méthode du limba. (source: Vincent 1974)

28. Venezuela - other enrichment trials: G = Reserva Forestal de Gurapiche, P = Reserva Forestal de Turén (Portuguesa), T = Reserva Forestal de Ticoporo. (source: DRNR/MAC1974)

Species represented in trials of enrichment planting in the neotropics

reference no. in bibliography:	22	22	22	22	22	14	14	23	23	23	23	23	23	33	19	31	2	19	5	9	16	8	24	32	28	15	29	13
locality	Santa.				Curuá		Curuá		Igarap		Trinid		Belterra			RDucke											Venezuela	
site or trial type	CBA		PLT		lin		lin		OTP		OTP		Bel		Bel		RD		COL		ECU		PER		SUR		Cap	
site or trial type		CTM		pat		A		A		A		Tap		Bel		RD		K68		COS		MEX		RIC		EIC		DRNR
botanical name																												
Albizia lebbeck	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	P
Amburana cearensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Anacardium excelsum	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Andira parviflora																												
Aniba canelilla																												
Aniba duckei	-	-	-	-	-	-	-	-	-	-	-	-	ALR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aniba fragrans	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	--	-	-	-	-	-	-	-	-	-	-	-
Anthocephalus chinensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
Apeiba membranacea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-
Aspidosperma desmanthum	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aspidosperma macrocarpum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Aspidosperma spp.	-	-	-	-	-	+	-	-	-	-	-	-	A	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aspidosperma vargesii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Astronium fraxinifolium	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
Astronium lecointei	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aucoumea klaineana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Bagassa guianensis	-	-	-	+	4	+	+	+	-	-	-	1	ALR	R	+	-	-	-	-	-	-	-	-	-	+	-	-	-
("berajuba")	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bertholletia excelsa	-	-	-	-	4*	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Bombacopsis quinatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	CL	PT
Bombax spp.	-	-	-	-	-	-		-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P
Brosimum spp.	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Brosimum utile	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Buchenavia grandis	-	-	-	-	-	+	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Byrsonima spp.	-	-	-	-	-	-	-	+	-	+	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calophyllum angulare	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Calophyllum brasiliense	-	-	+	-	4*	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Calophyllum longifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Carapa guianensis	CFJM	+	+	-	4*	-	+	+	-	+	-	5	R	R	+	+	+	+	N	-	+	-	-	-	-	-	-	-
Cariniana pyriformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	+	-	-	-
Caryocar villosum	C	-	-	-	D	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cedrela angustifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	CL	-
Cedrela fissilis	-	-	-	-	-	-	+	-	+	-	+	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cedrela odorata	CFJM	-	+	-	4N	-	+	-	+	-	+	5	-	-	-	+	-	-	N	-	-	+	PI	-	+	-	C	TG
Cedrelinga catenaeformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	I	-	-	-	-	-
Centrolobium paraensis	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorophora excelsa	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chorisia insignis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	PI	-	-	-	-	-
Chorisia integrifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	PI	-	-	-	-	-
Chrysophyllum spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Clarisia racemosa	-	-	-	-	4D	-	+	-	-	-	-	-	A	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Clarisia spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-

reference no. in bibliography: 22 22 22 22 22 14 14 23 23 23 23 23 23 33 19 31 2 19 5 9 16 8 24 32 28 15 29 13
locality Santa. Curuá Curuá IgarapTrinid Belterra RDucke Venezuela
site or trial type CBA PLT lin lin OTP OTP Bel Bel RD COL ECU PER SUR Cap
site or trial type CTM pat A A A Tap Bel RD K68 COS MEX RIC EIC DRNR

Species represented in trials of enrichment planting in the neotropics

reference no. in bibliography:	22	22	22	22	22	14	14	23	23	23	23	23	23	33	19	31	2	19	5	9	16	8	24	32	28	15	29	13
locality	Santa.			Curuá		Curuá		IgarapTrinid					Belterra			RDucke											Venezuela	
site or trial type	CBA		PLT		lin		lin		OTP		OTP		Bel		Bel		RD		COL		ECU		PER		SUR		Cap	
site or trial type		CTM		pat		A		A		A		Tap		Bel		RD		KAO		COS		MEX		RIC		EIC		DRNR
botanical name																												
Clitoria racemosa	-	-	-	-	-	-	-	+	-	+	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copaifera reticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Copaifera spp.	-	-	-	-	4N	-	-	-	-	-	-	-	-	-	-	+	+	.	.	-	-	-	-	-	-	-	-	-
Cordia alliodora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	+	+	-	P	-	+	-	CL	PT
Cordia apurensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	CL	-
Cordia dodecandra	.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Cordia goeldiana	-	-	-	-	-	-	-	+	-	-	-	-	ARL	R	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Couepia bracteosa	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Couma macrocarpa	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Couratari sp.	-	-	-	-	-	-	-	-	+	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Crudia bracteata	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
("cumarurana")	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Dalbergia spruceana	-	-	-	-	-	-	-	+	-	+	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Dinizzia excelsa	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dipteryx odorata	-	-	+	-	DN	+	+	+	-	-	-	3	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Emmotum fagifolium	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Entandrophragma sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Enterolobium cyclocarpum	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enterolobium maximum	-	-	-	-	-	-	-	-	+	-	-	-	RL*	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Enterolobium schomburgkii	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erisma uncinatum	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus alba	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus camaldulensis	-	+	-	.	.	.	.																	.		..	-	-
Eucalyptus grandis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Eucalyptus saligna	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
Eucalyptus tereticornis	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Genipa americana	-	-	-	-	-	-	-	+	+	+	+	2	AR	R		.	..	..	-	-	-	-	-	-	-	-	-	-
Glycydendron amazonicum	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gmelina arborea	-	+	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-
Goupia glabra	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Guazuma spp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Hieronyma chocoensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
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Humiria floribunda	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hura crepitans	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Hymenaea courbaril	-	-	-	-	-	-	+	+	-	+	-	2	AR	R	+	-	-	-	-	-	-	-	-	-	-	-	-	-
Hymenolobium excelsum	-	-	-	-	4N	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hymenolobium petraeum	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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site or trial type		CTM		pat		A		A		A		Tap		Bel		RD		K68		COS		MEX		RIC		EIC		DRNR
botanical name																												
Jacaranda copaia	-	-	-	+	-	-	-	+	+	+	-	-	-	-	+	-	-	-	N	-	-	-	-	-	+	-	-	-
Jacaranda paraensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Khaya senegalensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Licania incana	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manilkara huberi	-	-	-	-	-	-	-	-	+	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mezilaurus itauba	-	-	-	-	D	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Nauclea diderrichii	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ochroma lagopus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-
Ocotea cooperi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Ocotea guianensis	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ocotea rubra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Olmediophaena maxima	-	-	-	-	-	-	-	+	-	+	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ormosia coccinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Ormosia spp.	-	-	-	-	-	-	-	+	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parkia gigantocarpa	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parkia pendula	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parkia sp.	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pinus caribaea	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	I	-	+	-	-	-
Piptadenia suaveolens	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pithecellobium niopodes	-	-	-	-	-	-	-	+	-	+	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pithecellobium racemosum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-
Pithecellobium saman	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	P
Platonia insignis	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Platymiscium pinnatum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Platymiscium trinitatis	-	-	-	-	-	-	-	+	-	+	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Platymiscium yucatanum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Poupartia amazonica	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pouteria spp.	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pradosia pracalta	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pterocarpus spp.	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Qualea cf. acuminata	-	-	-	-	4D	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Qualea rosea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Sapindus saponaria	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Schizolobium amazonicum	-	+	-	-	-	-	-	+	-	-	-	1	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Scleronema micranthum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Simaruba amara	-	+	-	+	N	-	+	-	-	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-

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Simaruba glauca	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
Sloanea sp.	-	-	-	-	-	-	-	-	-	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Spondias mombin	-	-	-	-	-	-	-	+	-	-	-	3	-	-	-	-	-	-	N	-	-	+	-	-	-	-	-	-
Sterculia pruriens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Sterculia spp.	-	-	-	-	-	-	-	+	+	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Stryphnodendron pulcherrimum	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Swietenia macrophylla	C	-	+	-	4D	-	+	+	+	-	+	5	AR	R	+	-	+	-	-	+	+	+	P	+	-	+	CL	PTG
Swietenia mahagoni	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
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Tabebuia capitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	P	-	-	-	-	-
Tabebuia rosea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	CL	PTG
Tabebuia serratifolia	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tabebuia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
Tachigalia alba	-	-	-	-	-	-	-	-	+	-	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tapiria guianensis	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Taralea oppositifolia	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tecoma aff. conspicua	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Tectona grandis	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	I	-	-	-	-	-
Terminalia amazonia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	+	-	-	-
Terminalia ivorensis	FJN	+	+	+	-	-	+	+	+	+	+	1	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Terminalia macrophylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Terminalia oblonga	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Terminalia sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-
Terminalia superba	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Terminalia tanibouca	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toona ciliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Trema micrantha	-	-	-	-	-	-	-	+	+	-	-	-	A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triplaris surinamensis	-	-	-	-	-	-	-	+	+	+	+	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Virola dioxonii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-
Virola flexuosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-
Virola reidii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-
Virola sebifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
Virola sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	C	-
Virola surinamensis	-	-	+	-	4D*	-	-	+	+	+	+.	4	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
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Vouacapoua americana	-	-	+	-	4D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zanthoxylon tachuelo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	N	-	-	-	-	-	-	-	-	-
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site or trial type		CTM		pat		A		A		A		Tap		Bel		RD		K60		COS		MEX		RIC		EIC		DRNR

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