PLANTATIONS OF AFRICAN MAHOGANY IN THE MOIST CLOSED FOREST OF THE CÔTE-D'IVOIRE

Bernard DUPUY, M'BLA KOUA

Four different species of *Khaya genus* occur naturally in the Côte-d'Ivoire. These species have closed distribution areas but different ecological characteristics.

Cailcedrat *(Khaya senegalensis)* is typically found in deciduous dry forests and savannas.

The trade name « African Mahogany » is used for three different species : *Khaya ivorensis* in evergreen forest, *Khaya anthoteca* in semi-deciduous forest and *Khaya grandifoliola* at the border, of semi-deciduous forest and dry forests.

The heart-wood of African Mahogany is reddish-brown, durable, and has a fine, fairly regular grain ; it is easy to work but difficult to impregnate. The wood is used above all for high-quality cabinetwork, ship construction, furniture and interior finishings.

African Mahogany, and mainly *Khaya ivorensis,* is one of the first species of plantation which have been used in the moist closed forest of the Côte-d'Ivoire. The plantations started at the beginning of the century.

Khaya ivorensis attains height of 40-50 m and a DBH of up to 200 cm. The bole is straight, branchless up to as high as 30 m above the ground, and bearing well-developed plank buttresses.

PLANTING TECHNIQUES

Mahogany has been planted with different silvicultural planting methods :

- Underplanting closed (2 m × 2 m) monospecific or mixed plantations with Niangon *(Heritiera utilis)* called the « Martineau method » (1930-1931).
- Enrichment monospecific or mixed plantations of enrichment called « Line method » by AUBREVILLE (1931-1946).
- Monospecific plantation with wide spacings in N'zida forest (1952-1954) or for experimentals plots.
- Monospecific or mixed plantations of conversion at high density.
- Experimental mixed plantations with understory of *Leucaena leucocephala.*

Mixed plantations of African Mahogany are possible with numerous tree species.

With manual planting techniques and wide spacings (7 m × 7 m or more), a number of tree species are suited for association including : Framiré *(Terminalia ivorensis),* Samba *(Triplochiton scleroxylon),* Okoumé *(Aucoumea klaineana),* Fraké *(Terminalia superba)...* The mixed rate recommended is about 50 %.

For closed spacings (3 m × 3 m), Mahogany could be associated in plantations with Niangon *(Heritiera utilis),* Badi *(Nauclea diderrichii)* and other species of medium initial increment like Bété *(Mansonia altissima),* Koto *(Pterygota macrocarpa),* Pouo *(Funtumia elastica)...*

PESTS AND DISEASES

The main problem in Côte-d'Ivoire Mahogany plantations is the attacks of the small moth *Hypsipyla robusta.*

The larvae of these moths bore into the unlignified terminal shoots of young trees and eat their way down through the pith. As a result, the shoots die.

Repeated attacks cause deformations of the main axis of the tree, and important losses of increment mainly during the first years after planting.

GROWTH AND PRODUCTIVITY

African Mahogany is a medium-growing, light-demanding species that self-prunes. The young trees tolerate a certain amount of shade. Due to its high vulnerability to attacks of shoot borers, the form of the young trees is often poor. The trunk form rapidly gets better with time and with selective thinnings.

Less satisfactory increments are obtained with the « Line method ». The mean height of a 25-year-old plantation is about 15 m. The average diameter of 50 cm is reached towards 60 years old. The mean volume increment of planted mahoganies is about 1-2 m^3/ha/year. The volume increment of marketable species of the original forest preserved between the lines of enrichment planting is about 1 and 3 m^3/ha/year.

The « Leucaena method » can be used with a good control of the growth of Leucaena by coppicing when Mahogany height has reached 2-3 m. The aim of the use of Leucaena is to protect Mahogany against damage by *Hypsipyla robusta* during the first years and the subsequent establishment of an understory. The mean height of a 20-year-old plantation is about 15 m. The average diameter of 30 cm is reached towards 25-30 years old.

Pure or mixed plantations after clear-cutting give the best results with high planting densities. The mean height of a 20-year-old plantation is about 20 m. The average diameter of 50 cm is reached towards 35-40 years old. The mean volume increment is about 5-10 m^3/ha/year.

SILVICULTURE

Mahogany plantations are established by bare-root stock, striplings, balled seedlings or container plants.

The planting density varies between 1 111 plants per ha (conversion plantation) and 150 plants per ha (enrichment plantation).

All the thinnings (1 to 4 depending on original density and final marketable diameter) are selective.

A final density of 75-100 stems per ha is aimed for. The rotation is about 40-60 years, with marketable diameter of 50-60 cm.

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TREE POPULATIONS IN NATURAL TROPICAL RAIN FORESTS

A case study : Brazilian Amazonia

Bernard ROLLET

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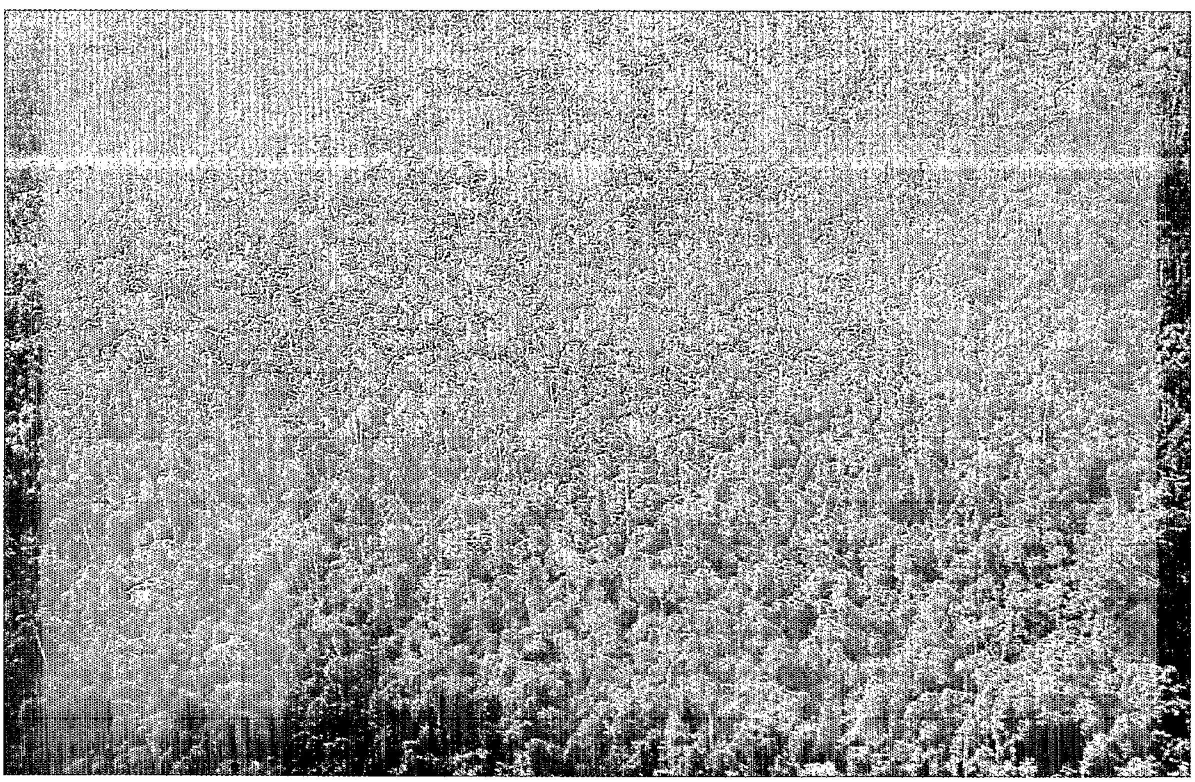


« Selva de bejucos » Venezuela or « Cipoal » or Floresta aberta (Brazil) : a widespread unexplained tropical formation in Brazilian Amazonia and surroundings. Aerial view between Tumeremo and El Dorado (Venezuelan Guiana)

Une formation très répandue mais mal expliquée de l'Amazonie et des régions limitrophes. Vue aérienne entre Tumeremo et El Dorado (Guyane vénézuélienne).

RÉSUMÉ

LES POPULATIONS D'ARBRES EN FORÊT DENSE TROPICALE
Etude de cas : l'Amazonie brésilienne

Les populations d'arbres peuvent être estimées seulement par des inventaires de grande envergure et par des plans adéquats d'échantillonnage exigeant d'importantes ressources financières. De tels inventaires sont bien rares.

Prenons un exemple d'une évaluation de population d'arbres avec 0,001 % de densité pour l'Amazonie brésilienne, grâce à la disponibilité de données obtenues à partir du Projet Radam Brasil. Les populations sont étudiées sur une superficie de 623 000 km^2 pour tous les arbres ayant une circonférence à hauteur de poitrine de 100 cm et plus (558 espèces). Par ailleurs, les populations de cinq espèces d'arbres sélectionnées sont étudiées dans toute la portion centrale de l'Amazonie brésilienne, c'est-à-dire environ 2 300 000 km^2.

Mots-clés : INVENTAIRE FORESTIER ; PEUPLEMENT FORESTIER ; ÉVALUATION ; DISTRIBUTION NATURELLE ; AMAZONIE ; BRÉSIL ; ESPECE LIGNEUSE COMMERCIALISABLE.

ABSTRACT

TREE POPULATIONS IN NATURAL TROPICAL RAIN FORESTS
A case study : Brazilian Amazonia

Is the assessment of the total population of a tree species of interest in tropical forests ? To what extent is it possible ?

The populations of the main species are usually fairly well estimated through so-called commercial forest inventories.

More detailed inventories are necessary to answer questions of different kinds : phytogeographic (definition of tree species, varieties, speciation) ; demographic (structures of all tree species, spatial distributions, stability) ; conservationist (identification of rare species ; basis for a policy of nature protection).

Tree populations can be assessed only through large inventories and adequate sampling designs requiring important financial resources. Such inventories are few.

An example of tree population assessment with 0.001 % intensity is given for Brazilian Amazonia owing to the availability of data from the Projeto Radam Brasil. Populations are studied on about 620 000 km^2 for all trees 100 cm GBH and over (558 species). In addition the populations of five selected tree species are studied in the whole central portion of Brazilian Amazonia, i.e. about 2 300 000 km^2.

Key words : FOREST INVENTORIES ; FOREST STANDS ; EVALUATION ; NATURAL DISTRIBUTION ; AMAZONIA ; BRAZIL ; MARKETABLE SPECIES.

RESUMEN

POBLACIONES DE ARBOLES EN BOSQUE DENSO TROPICAL
Estudio de casos : Amazonia brasileña

Las poblaciones de árboles únicamente se pueden evaluar por medio de inventarios de gran envergadura, así como por planes adecuados de muestreo, que requieren importantes recursos financieros. Son sumamente contados los inventarios de este género.

Pongamos el ejemplo de la evaluación de una población de árboles con 0,001 % de densidad para Amazonia brasileña, debido a la disponibilidad de datos conseguidos por medio del Proyecto Radam Brasil. Las poblaciones se estudian sobre una superficie de 623 000 km^2 para todos los árboles que acusan una circunferencia a la altura del pecho de 100 cm en adelante (558 especies). Asimismo, se estudian las poblaciones de cinco especies de árboles seleccionados en toda el área central de Amazonia brasileña, o sea, aproximadamente unos 2 300 000 km^2.

Términos clave : INVENTARIOS FORESTALES ; RODALES ; EVALUACIÓN ; DISTRIBUCIÓN NATURAL ; AMAZONIA ; BRASIL ; ESPECIES COMERCIALES.

In Northern countries forest inventories can evaluate total tree populations by species with a high global and often high local accuracy. The principal reasons for this are the very low number of tree species and an advanced knowledge on their ecology and forest typology. Thus in Finland only six tree species constitute virtually the whole forest volumes (*Pinus sylvestris* 45 % ; *Picea abies* 37 % ; *Betula pendula* and *B. pubescens* 15 % ; *Alnus incana* and *Populus tremula* 3 %).

In tropical forests the relative importance of the various tree species is completely different because the floristic richness is very high, up to almost 300 tree species above 10 cm DBH* on one hectare (1) to several thousand 10 cm DBH and above on 10 000 km^2. See CAILLEUX (2) for the concept of « richesse aréale ».

If the numbers of trees for each species are shown in decreasing order for any forest area, the decrease is very progressive with (usually) no dominance of any tree species in particular. For small areas (100 ha down to one hectare) 30 to 40 or more among the most abundant tree species are needed to reach 50 % of the total of the forest population of 10 cm DBH and over. In other words, each species (even the most abundant) represents at the most a few per cent of the population. Most tree species are very scattered in the forest, though some may be very dominant, e.g. *Eucalyptus deglupta*, *Shorea albida*, *Mora excelsa*, *Gilbertiodendron dewevrei* to quote only a few. They are exceptions, usually linked with special edaphic conditions.

Consequently the concept of abundance-dominance as defined and widely applied in temperate floras is difficult to apply the humid tropics and is of questionable usefulness in the description of tropical forest vegetation.

Because of the heterogeneity and floristic richness of the tropical forests the evaluation of population is fairly satisfactory for abundant tree species, and just acceptable, mediocre or bad for rare species.

Are these evaluations of some value ? Is there a possible assessment for each species ? Such naive questions as : What is the most abundant tree species of tropical America ? What is the rarest ? cannot be answered straightforwardly. Without the help of regional or national inventories, only fanciful answers and figures can be given, for the simple reason that the best known territories are constantly yielding new rare species and evidence that species supposed to be rare are in fact more abundant than believed.

These various points will be discussed along with a case study pertaining to Brazilian Amazonia.

TREE POPULATIONS IN NATURAL TROPICAL RAIN FORESTS : WHAT FOR ?

In the humid tropics many specialists need evaluations of tree populations for their studies, usually with very specific requirements which can be taken into account in the design of the forest inventories in such a way that versatile samplings will cover particular aspects far beyond the aims and findings of standard commercial forest inventories.

TREE POPULATIONS BY SPECIES AND THE EVALUATION OF FOREST RESOURCES

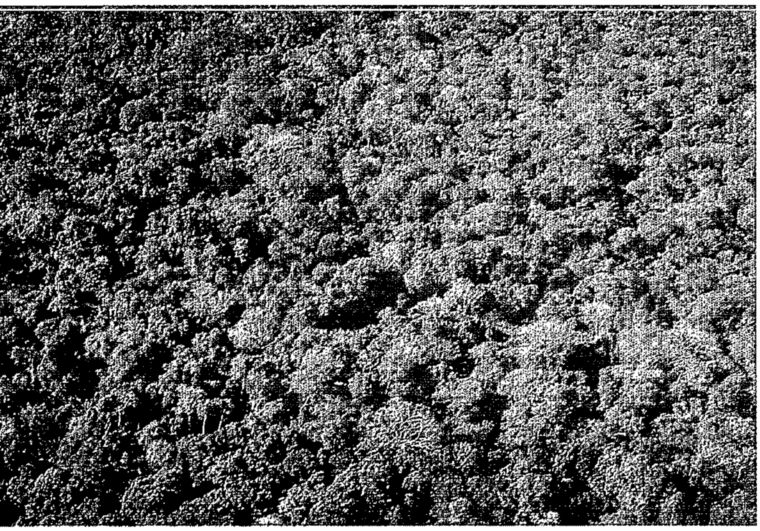
In actual fact, forest inventories are principally used by foresters. Their range of accuracy is very broad, from extensive commercial to intensive detailed surveys, especially regarding the separation of species.

The most simple inventories do not even specify tree species separately. In Malaysia, Indonesia and the Philippines, Dipterocarps are often shown in groups, e.g. white, yellow, red meranti (or lauan). Elsewhere tree species may be grouped according to technological similarities or uses (plywood, sawtimber, colour, wood density, abundance, marketability or known performances, etc.). Alternatively a few common commercial timbers are enumerated separately leaving the bulk of other species pooled as miscellaneous or unknown, which may represent 50 % of the grand total (e.g. F.A.O. National Forest inventory for Vietnam, 1979-1984).

Most commercial forest inventories are of little interest to forest scientists because species are not infrequently pooled under aggregative vernacular names (e.g. Mata mata for all *Eschweilera*, Breu for many *Burseraceae*, Envira for many *Annonaceae*, Abiurana for many *Sapotaceae* in Brazil). However some inventories can yield reliable data usable for constructing geographic areas, or at least for some aspects of the forest organization.

Only inventories taking into consideration all tree species above a given DBH are of special interest to forest ecologists. When detailed inventories are needed foresters usually have recourse to external cooperation : botanists, soil scientists, cartographers, statisticians. Researchers may use the results for further studies or

* DBH means Diameter Breast Height ; GBH means Girth Breast Height.



Aerial view of closed rain forest (Floresta densa) over Amapá (NE Brazil)

Vue aérienne d'une forêt dense tropicale humide (Floresta densa) dans l'Etat d'Amapá (Nord-Est Brésil).

extrapolations, e.g. the functional structure of the forest : biomass, leaf area index, litter, light environment, growth.

A strong constraining factor is the diversity of sampling designs and data formats which make comparisons very difficult or even impossible : original data are usually inaccessible, and when accessible, reprocessing costs are deterrent. The main source of diversity originates from the various lower DBH or GBH limits, metric or non-metric, i.e. in cm, inches or feet. Such lower limits (among others) may be found : 5 cm, 7.5, 10, 12.5, 15, 20, 30, 40 cm or 4", 8" for GBH ; 10 cm, 20 ... 100 cm, 1' (one foot) 2' 3' 4'... for DBH. Odd lower limits (9.6 cm DBH) have been seen in 1992 publications. Moreover various class-ranges (DBH or GBH) are used, e.g. 10 cm, 20 cm DBH classes, 20 cm GBH classes,... even unequal diameter classes : 10 to 30 cm, 30 to 45 cm, etc... Different midpoints are commonly seen, e.g. 10 cm for 5-15 cm class ; or 15 cm for 10-20 cm class. It is high time for a minimal standardization.

Another serious limiting factor in inventory comparisons and result pooling is the level of accuracy in tree identification. Putting side by side the floristic richness of different regions of equal size (or nearly so) above a given DBH will spot identification shortcomings : this is particularly clear in some reports on Brazilian Amazonia, revealing obvious underestimations of floristic richness. In general the larger the inventory, the poorer the quality of tree identification. If one tries to increase the sampling intensity for a given cost and the same forest area, one will lose quality in field identification : quick work means bad work and it may be said that quality does not increase linearly with cost but asymptotically. In spite of all efforts, a certain amount of uncertainty remains in any large detailed forest inventory. Rigorists will think that no tropical inventory will ever be perfect from a taxonomical point of view, and one may recall Huber's belief (1909) that a lifetime would not be enough to evaluate the floristic richness of a square kilometer of the Hylaea (the Amazonian rain forest). A fortiori, several million square kilometers will remain for a long time – if not for ever – inaccessible to human knowledge.

SCIENTIFIC INFORMATION CONTAINED IN FOREST INVENTORIES CONCERNING TREE POPULATIONS

□ Refining tree species definitions and field identifications

The taxonomic examination of large populations of a tree species often reveals existing varieties, gene flux between subpopulations, and species complexes, and prompts the revision of the species concepts : e.g. the geographic varieties of *Hymenaea courbaril* in tropical America ; the readjustment of *Rhizophora mangle* into three species by CHEESEMAN, one being possibly a hybrid between the two others ; the synonymy in the overdescribed genus *Cedrela* ; the speciation of *Symphonia globulifera* after the partition of South America from Africa (same species ? varieties or vicariant species ?) ; the variability (large or small) in species of American Sapotaceae ; frequent hybridization between species of several genera (*Eucalyptus*, *Quercus* and *Lithocarpus*, possibly *Dipterocarpaceae*, *Coccoloba*...).

Advanced knowledge of tree populations will permit a better appreciation of speciation and its monitoring, especially in regions where neighbouring populations are separated by natural barriers, such as mountain ranges, or North-South rivers as in Guyana.

Forest inventories should reflect these taxonomical differences although field identification has strong, sometimes insuperable, limitations, especially when genera are very rich in species. Tree species are often mistakenly pooled during inventories by one team, not by another ; errors of identification may be recognized only at the end of the operations owing for example to a casual fructification, especially when this event is extremely aperiodic or rare.

Large sectors of taxonomy have to be complemented in many floras : many Rubiaceae occurring in the undergrowth remain largely unclassified.

All these improvements have obvious impacts on the understanding of the distribution and migrations of species, and some effects on forest type mapping.

□ Tree populations and structure of tree species Their temperaments or ecological behaviour

Although other tree dimensions (total height, crown diameter...) are sometimes measured, the diameter distribution of tree species is the most commonly available information in tropical forest inventories. It tells something about the temperament of the species, especially its requirements of light at early stages. But it does not summarize entirely the species behaviour, leaving many ambiguities in the correct interpretation of the distribution curves. The shapes of the histograms showing the frequencies (number of trees) in diameter classes are very diverse : steep L, negative exponential, flattened L, flattened bells, erratic distributions, with many intermediary cases. Humps betray accidents in the past generated by windthrows and natural gaps, resulting in mixtures of dimensions and ages which cannot be always clearly separated in the field and properly stratified. These irregularities may also reflect differences in growth speed, or slowdowns or increases in mortality rates. The tails of the distributions (towards large diameters) and also the generally poorly studied early stages of regeneration are worth studying.

The distributions in diameter-classes permit at least a rough classification of tree species according to their early reaction to light : strict heliophytes (pioneers), strong heliophytic opportunists, preferably heliophytic species, semiheliophytes, tolerant species (at least at an early stage), and strictly tolerant species of the undergrowth.

Such classification of tree behaviour is a static interpretation, at a given time of the forest life ; it does not take into account the differential growth and the various mortality rates among species, the sensitivity to disease attack, fire or cyclone hazards, in other words the individual dynamic potentialities for species substitutions, with all their implications in forest typology and sub – or polyclimax. The paucity of reliable growth rings impedes a clear recognition of age classes in a stand : a given diameter class usually displays a considerable range of ages, and a tree 50 cm DBH may have the same age as a nearby tree 100 cm DBH. A gap stimulates growth and generates trees with a high ratio of total height to DBH whereas suppressed trees under the canopy of leaders will stagnate in undisturbed stands with low H/D ratios.

□ Spatial distributions in tree populations, by species

Forest inventories, either in solid blocks or more commonly in systematically or randomly stratified low intensity samples, can visualize through mapping or evaluate through computation the degree of gregariousness in tropical stands. They may elucidate why a given species occurs always in clusters, or seems to be randomly distributed or is quite erratic, taking into consideration the breeding system and the various phases of regeneration from seed to established sapling.

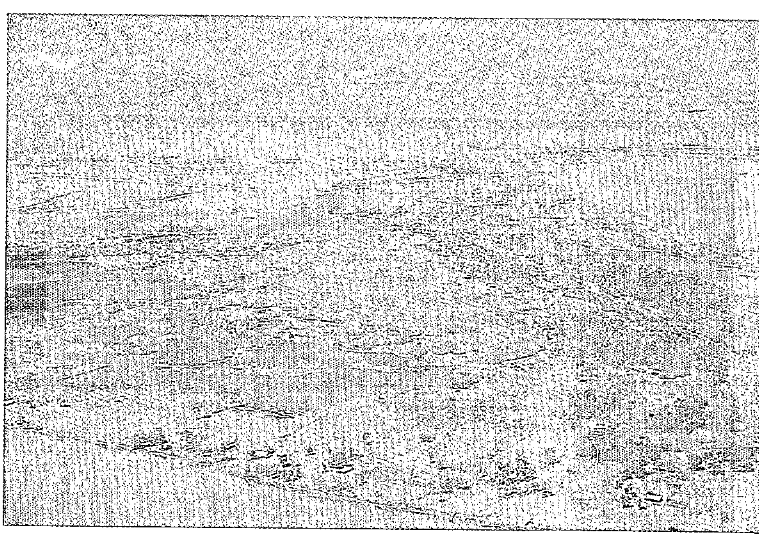
At first sight conclusions are deceptive because they are diverse and very often seem contradictory. In fact, the sampling design carries in itself the answer which could have been different, had the plot size or interval between plots (or the lower DBH) been different.

Gregariousness is almost always a matter of scale : a cluster effect can vanish with a change in the two (or three) mentioned parameters. Hence the idea that levels of « structures » can be detected and depicted into micro – or macro – diversely nested structures for which a biological, environmental or cyclic interpretation is needed. Such structures may be suggested on aerial photos or satellite images, but one should keep a sharp eye on artefacts or unexplained structures, shown e.g. on modified (polarized) radar imagery, or likely to be shown on GIS images because of oversimplified decisions in data processing. A ground check will generally give the answer and should be as intensive as possible.

Small inventories (tiny profiles fancifully distributed in the forest, miniacreages of few hectares) may yield valuable information at some levels but are incapable of yielding information and definite evidence on the macrostructure or the macro-organization of tropical forests, although local detailed reproduction studies might suggest such structures. Again the magnitude of the sample must be adapted to the scale of the work : seedlings are not studied with the same yardstick as giant emergent trees. Only experimental work, experience and common sense can provide guidelines, especially on the time required for the various operations.

□ Rare tree species and nature conservation

The concept of a rare species is rather vague and subjective as long as tree density evaluation is qualitative, i.e. described in such terms as very abundant, abundant, rare, very rare.



Brazilian Amazonia, a country of rivers and forests. Aerial view between Santarém and Alenquer (North of the Amazon River) at the Tapajos-Amazon junction. About 30 km may be flown continuously over water.

L'Amazonie brésilienne : un pays d'eau et de forêts ; vue aérienne entre Santarém et Alenquer au nord. On peut voler au-dessus de l'eau pendant environ 30 km sans interruption.

A tree species which is believed to be rare may happen to be much more abundant when new regions are investigated or more thoroughly surveyed : e. g. cycad species in western Amazonia, huge bamboo stands in Acre (Brazil), *Swietenia macrophylla* in West, Central West and East Amazonia.

Besides a rare species spotted once in a local inventory may not be found again in larger extensive regional inventories, hence the suspicion of a mistake in the former (e.g. *Podocarpus* in the Belem region). However two trees of *Podocarpus sellowii* K.L. (vernacular name : Pinho bravo), one tree in the 30-, the other in the 40 cm diameter class have been found in the alluvial lowlands of the Jurua region, in 220 one hectare plots of closed rain forest and 67 one hectare plots of open rain forest out of a grand total of 181 enumerated hectares including 5 427 trees (over 100 cm GBH over).

Researchers working in small continental or island areas may have quite different criteria from others working in large continental areas concerning the evaluation of scarcity.

Only large detailed inventories can fully bring to light this concept of scarcity.

If tree species are shown individually in decreasing order of their respective number of trees, this order is usually decreasing very progressively. In the tail of the distribution of **any** sample, the number of species with ... 7, 6, 5, 4, 3, 2, 1 individual(s) is steadily increasing, and there are species represented with one individual **only because we deal with a sample,** not with the whole forest. It can be said that this peculiarity is one of the main criteria for checking the quality of the inventory. If the number of tree species does not follow this general trend in the tail of the sequence one may suspect some weaknesses in field identification and taxonomic knowledge.

Concerning rare tree species, one can ask whether they are disappearing or progressing. It seems excessive to think that a rare species is necessarily endangered in all cases ; it may be abundant elsewhere or in a process of immigration at the time of the inventory. *Avicennia schaueriana*, rare in the Lesser Antilles, is abundant in the Atlantic mangroves of Mexico.

Only the conjunction of a certain number of phenomena will be convincing enough for deciding whether a species is really endangered. In the Dominican Republic, *Magnolia pallescens* (V.N. Ebano verde) has been heavily harvested in the past for timber ; few mature individuals remain in the forest ; they are slow growing ; regeneration is usually absent ; seeds appear at very long intervals ; they are heavily damaged by parasites. Ebano verde is certainly an endangered species.

In other cases uncontrolled diseases may virtually wipe out certain species or at least considerably reduce their populations, at least temporarily. The same is true after the eruption of volcanoes, but some species (e.g. *Clusia mangle* on the Soufrière of Guadeloupe) show incredible resistance to adversity and may shoot back from their rootstock, just as the olive tree does after a severe frost in the Mediterranean zone. Conclusions on extinction of species must be very cautious.

An exact knowledge on the populations of the rarest trees is the undeniable basis for a policy of their protection. Silence, i.e. classified information, may be the best protection, a non-democratric but almost inevitable attitude.

Fanatical entomologists will plunder to the last individual such rarities as the magnificent black and green butterfly (the « Brook ») : *Trogonoptera brookianus* which roves in the rain forests of Malaysia. It is known that orchid collectors in their mania of selfishness have destroyed whole sites in Upper Burma and the Himalayas to make sure they would be the unique owners. The lure of profit extends to rare trees such as lignum vitae *(Guaiacum officinale)* or the Fiji sandalwood *(Santalum yasi)* to quote only two characteristic examples which possess a quality highly praised by man, hence a threat to their survival.

Moreover one must point out that societies for nature protection are possibly more easily moved by the extinction of a beautiful insect than by similar dangers to a humble tree species of unknown use in the undergrowth of a remote tropical forest. They are prone to push for gazetting long list of orchids but very few trees indeed. I.U.C.N. * red book lists may need more balance in this respect.

□ Tree populations and evolution

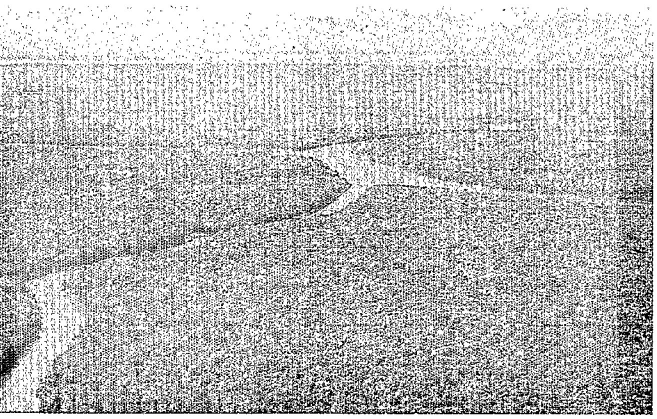
Since a tree species appeared on earth, how much time has elapsed ? How did it evolve ? How many generations have there been ? How many individuals came into being ? A series of questions which have something to do with present tree populations, and which possibly are not clearly formulated.

Evolution is an on-going process with ever-changing species, and from fossil evidence tree species have been submitted to quite different evolutionary speeds : nil or slow (present Cycadaceae, *Ginkgo*), medium (Magnoliaceae), fairly quick (many Myrtaceae etc.).

On the other hand each tree species blooms and fruits at its own tempo : every year, or at every 6 or 7 year-interval, or only once (the so-called monocarpic or hapaxanthic species) such as the bamboos after 10, 20, 30 years and more, some palms *(Corypha, Metroxylon),* some leguminous species e.g. *Tachigalia spp., Spathelia excelsa* (Rutaceae), etc. They may fruit at a very early stage (some years in *Rhizophora*, in several Meliaceae, few Dipterocarps) or only when old.

Hence several significant factors which combine diversely in about 50 000 tropical tree species. Man has evolved for about 3 million years, has reproduced every

* International Union for Conservation of Nature and Natural Resources.



25 years, is now over 5 billion in number, and is thought to have generated about 80 to 90 billion individuals.

The dynamics of tree populations can be studied with mortality and regeneration tables (just as in life insurance). Examples are still very few (e.g. *Euterpe oleracea*, V.N. Palmito). Such studies should be encouraged and will undoubtedly cast some light on the evolutionary processes of tropical trees.

Brazilian Amazonia. Aerial view near Belém at the mouth of the Amazon.

Amazonie brésilienne.
Vue aérienne dans les environs de Belém à l'embouchure de l'Amazone.

EVALUATION OF TREE POPULATIONS MAIN CONSTRAINTS

The value of evaluating tree populations in tropical forests having been discussed and accepted, how is it possible to carry out these evaluations with a reasonable accuracy ?

Tropical forest inventories are dependent on three main groups of techniques : dendrology and botanical taxonomy ; remote sensing in a broad sense ; sampling techniques and mathematical statistics.

First of all it is necessary to identify trees in the field and keep to a minimum the unnamed species. Hence a twofold dependence : the status of tropical floras, most of them being incomplete or under revision ; the status of knowledge of field characters which are usually disregarded, neglected and usually without keys in most floras : although leaves and fruits are fairly well described, venation, identification of seeds, seedlings and barks are insufficiently or not considered.

Secondly it is necessary to interpret the available coverages (photos, radar, satellite) for forest typology and mapping. A hierarchical forest typology has to be developed and ground-checked (landscapes, formations, forest types, understorey communities). Their areas have to be evaluated.

Finally a sampling design must be selected in order to avoid bias ; a compromise must be reached between conflicting aspects : sampling errors on one hand, operational costs and time on the other.

In spite of sequential sampling it is often realized what should have been done only after completion of the field work and data processing.

Before launching large operations, it is advisable to seek for all possible expertise and experience, and use experimental inventories to get information on variabilities and costs. Training of personnel involved in field teams is essential for operational consistency.

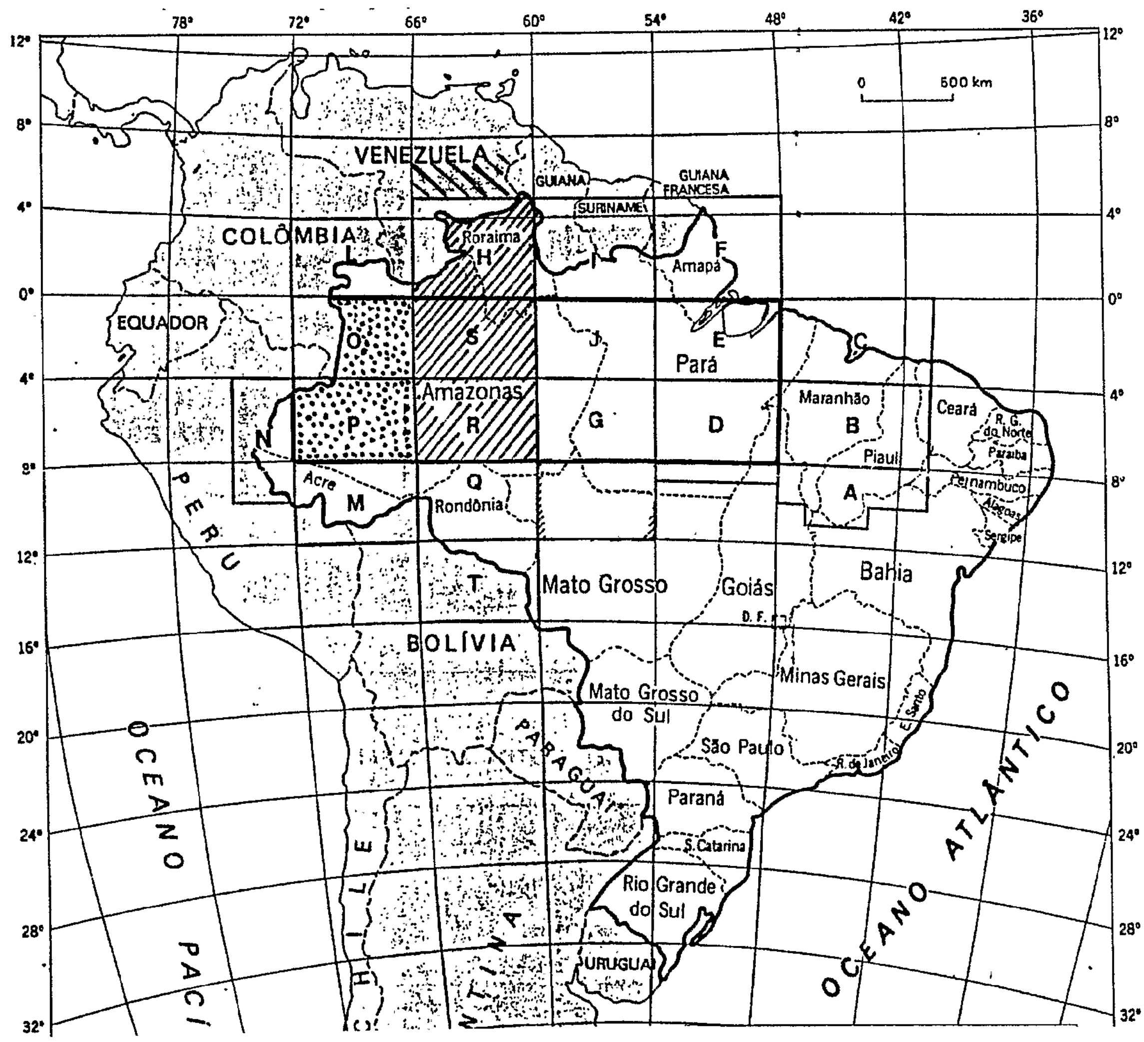
A sampling design will be satisfactory only for some species, usually the most abundant ; much less so for the others, especially the rare species ; many of them will escape the network of the sampling units. Nothing can be done about it : it is a consequence of the heterogeneity of the spatial distributions of tree species, their high number and diversity of their abundance : they may be abundant and frequent (e.g. present in 80 % of the plots) ; irregularly abundant (i.e. gregarious in various degrees) ; rare but frequent (low uniform density) ; rare and erratic (totally unpredictable). Thus there is **not one** possible inventory for a given amount of money and time for completion, but many possible inventories, more accurate in some aspects, less satisfactory in others, all yielding valuable but different information with different levels of credibility. It is up to the designer to justify his choice in quality and accuracy. Very often the sampling design will be a compromise between several arbitrary decisions without sacrificing some elementary rules. Perhaps a long time spent in preparing the operations properly will amply pay for the extra investment, which is sometimes unduly considered as exaggerated.

One should always think about a possible follow-up, i.e. the establisment of permanent plots for growth, species succession, gap monitoring, species collecting, etc.

Many tropical forest inventories are now available : all of them have not the same objectives nor the same scientific value or rigour. Too few are floristically very reliable. Very few are very detailed and reliable, going down to 5 cm DBH, or even 1 cm DBH (as in Pasoh, West Malaysia, on 50 ha).

In large areas enumerated at low sampling intensity, e.g. 0.5 % or less, the main source of expenditure in data collecting is **accessibility,** i.e. time and/or money spent reaching the plots : accessibility accounts for half of total costs in a 0.5 % sampling in Venezuelan Guiana (using rentises).

RADAM BRASIL PROJECT
1968 – 1977
Projet RADAM au Brésil



Imataca, Venezuela. See reference 7.

Area investigated for all tree species ≥ 100 cm GBH.

Area investigated for five important commercial species (only one retained in Table page 54).

J E G D Areas somewhat unreliable for tree species identification.

CASE STUDY : TREE POPULATIONS IN BRAZILIAN AMAZONIA

After 1950 many forest inventories were carried out in Brazilian Amazonia (3) (4) (5) (6). They can be classified – rather arbitrarily – according to several criteria, e.g. sampling intensity, size (local, regional, national), floristic accuracy. Among them, two large reconnaissance inventories with low sampling intensity (0.01 to 0.001 %) are of special interest.

• **The F.A.O. inventories** (3) must be considered as the first large regional inventory in Amazonia (1956-1965), at a time when aerial photos were few and maps were uncertain. Trees over 25 cm DBH were enumerated on 1 381 one hectare plots scattered according to a stratified sample in an East-West belt roughly 150 km wide and 1 500 km long south of the Amazon river between Belém and Manaus on about 19 million hectares. This inventory made possible the very first attempt at an evaluation of tree populations over a large tropical region. One of its main weaknesses is the underestimation of the number of tree species, due to insufficient botanical identifications and excessive pooling of species under the same vernacular name : only 400 tree species were distinguished. Through a tentative extrapolation from findings in nearby Venezuelan Guiana it is considered that at least 700 tree species should have been recorded.

• **The second large forest inventory in Amazonia** was carried out during the vast nation-wide Projeto Radam Brasil (5) between 1968 and 1977 without any extra-Brazilian support. It covers Brazilian Amazonia entirely (see map, p. 50), which has been subdivided into quadrangular regions 6 degrees of longitude East-West and 4 degrees of latitude North-South, i.e. about 300 000 km^2 each. Trees 100 cm GBH and over were enumerated on about 2 000 one hectare plots (with about 0.001 % sampling intensity). A noteworthy effort towards homogeneity of design, field operations, data processing and presentation of the results has been maintained throughout most of the reports. Until now no synthesis of the whole project has been made available.

SOME GLOBAL RESULTS FOR THREE REGIONS OF THE RADAM BRASIL PROJECT

Three regions of Central-Western Amazonia are considered for the evaluation of tree populations for each recorded species : Roraima-Boa Vista, Manaus, and Rio Purus, corresponding respectively to sheets H, S, R (see map) ; 558 tree species 100 cm GBH and over were found on 612 one hectare plots, scattered over about 623 000 km^2.

Each of the 558 tree species has the following number of trees 100 cm GBH and over (rounded off in millions) in decreasing order ; a figure between brackets, e.g. 33(3), means that 3 species have 33 million trees, or more precisely between 33.0 and 33.9.

193/93/77/77/72/72/65/64/53/52/49/49/43/43/41/41/40 /39/38/38/37/37/35/33°(3)/32/29(2)/28(3)/27(5)/26(2)/25 (2)/24(2)/23(7)/22(3)/21(5)/20(4)/19(3)/18(2)/17(4)/16(9)/15(5)/14(3)/13(12)/12(5)/11(8)/10(6)/9(6)/8(9)/7(7)/6(2 1)/5(21)/4(15)/3(28)/2(33)/1(19)/less than one million (229).

Except for the first species, which is twice as abundant as the second, one notices that the decreasing order of population importance is very progressive, whereas the number of tree species with the same population is *grosso modo* always increasing when the population decreases.

An important feature is the high number of species with less than one million trees, that is, for 62.3 millions/ha,less than one tree per 60 ha.

Out of the 558 lines of species arranged in decreasing order of tree populations, only a few will be retained, showing : scientific name, vernacular name, botanical family, tree population in thousands, tree density per hectare, % of total population.

CHARACTERISTICS OF THE THREE STUDIED REGIONS
H, S, R, see map

Region	Boa Vista	Manaus	Purus	Total
Total area km^2	250 740	295 160	293 760	**839 660**
Total forest area km^2	94 763	262 219	266 157	**623 139**
Estimated number of trees 100 cm GBH+ (in thousands)	624 612	1 641 089	1 742 095	**4 007 796**
Number of tree species	396	459	402	**558**
Number of enumerated hectares	84	284	244	**612**

TOTAL NUMBER OF TREES, PERCENTAGE AND NUMBER OF TREES PER HECTARE FOR SOME TREE SPECIES

Scientific name	Vernacular name	Botanical family	Trees > 100 cm GBH (thousands)	%	Trees per ha
Eschweilera odora (Poepp.) Miers	Matamata branca	LECYTHIDACEAE	193 869 *	4.8	3.11
Goupia glabra Aubl.	Cupiúba	CELASTRACEAE	93 168	2.3	1.49
Cariniana micrantha Ducke	Castanha vermelha	LECYTHIDACEAE	77 476	1.9	1.14
Licania membranacea Sagot ex Lanes	Cariperana	CHRYSOBALANACEAE	77 089	1.9	1.13
Pouteria guianensis Eyma	Abiurana branca	SAPOTACEAE	72 829	1.8	1.16
Prieurella prieurii A. DC	Abiurana mocambo	SAPOTACEAE	72 071	1.8	1.14
Bertholletia excelsa H.B.K.	Castanha do Pará	LECYTHIDACEAE	38 689	0.97	0.62
Virola surinamensis (R.D.) Warb.	Ucuúba branca	MYRISTICACEAE	33 221	0.83	0.53
Rollinia exsucca (DC. ex Dunal) A. DC	Ata brava	ANNONACEAE	61	0.00	0.0
Myrciaria floribunda (West ex Willd.) O. Berg	Goiaba da mata	MYRTACEAE	10	0.00	0.0
Fagara capuchoi	Limaozinho	RUTACEAE	10	0.00	0.0

* Weighed result. For accurary see the text below. Note a difference in writing : in English 2 038,25 is written 2,038.25.

All forest types occurring in the three regions are included in this list in order to obtain the absolute dominance of tree species in the whole of a sizeable portion of Brazilian Amazonia.

Considering the results of other inventories in eastern Amazonia giving *Eschweilera odora* as the most abundant species, one can suggest that this species is probably the most abundant in Amazonia (see further details below), all the more because, as a tolerant species, its distribution is balanced and close to a negative exponential, so that the conclusion for trees above 100 cm GBH can be extended to trees below 100 cm GBH. It is far ahead of the next more abundant species : *Goupia glabra.*

Systematic inventories in tropical rain forests of America or of other continents show that the number of tree species totalling up to 50 % of the total number of trees increases when the enumerated area increases.

In the Zaïre lowland rain forest with the same lower girth limit as in Brazilian Amazonia, PIERLOT (8) records 12 tree species totalling up to 50 % of the total population on 40 ha, out of a total of 157 species.

In the rain forests of Venezuelan Guiana (7) with almost the same lower diameter limit (30 cm in Venezuela, 32 cm in Zaïre and Brazil) 16 tree species with 6 805 trees total about 50 % of the total population (13 606 trees) on 155.5 ha of a continuous strip out of a total of 155 species.

In Brazilian Amazonia, 125 ha enumerated in the low plateaux rain forest of the Manaus region, one of the 3 regions considered above, 34 tree species totalize 50 % of the population out of a grand total of 307 tree species.

Hence the number of « dominant » species (totalling 50 % of the whole population) increases constantly with the enumerated area, and reflects the floristic richness of the region, and also the difficulty in characterizing a large area of one forest type by « dominant » species. Exceptions are linked to edaphic conditions.

When we consider increasing areas of a given forest type, more and more species will share the « dominance », a concept which becomes more and more evanescent and useless.

□ Accuracy of tree population estimates in three regions of Brazilian Amazonia

The reader probably noticed some boldness in giving figures to the nearest thousand for tree populations by species occurring in areas ranging from nearly 100 000 km^2 to over 600 000 km^2.

This accuracy is of course illusory. The estimation of the population for each species is calculated from the means of the various strata which are weighed to take into account the different areas of the principal forest types (details are given below). These areas were obtained through a stratification of Radar images, with ground check at the time of field enumerations. Hence several sources of error.

The first source is the sampling error from the stratified sample which is roughly but not strictly proportional to the areas. Each stratum i has its own variability calculated by its variance Vi which is given in the reports. If N_i is the total number of hectares contained in each stratum, n_i the number of the one hectare plots sampled in stratum i, the variance of the general mean $\overline{x}$ for the assemblage of all the strata with a grand total N of hectares, sum of the N_i is :

$$V(\overline{x}) = \frac{1}{N^2} \Sigma N_i^2 \frac{V_i}{n_i}$$

and the sampling error (P = 0.05) on $\overline{x}$ is $\frac{200\sqrt{V(\overline{x})}}{\overline{x}}$ in %.

See (9) p. 55.

A second source of error comes from the estimation of the areas of the strata (earlier usually obtained by point counting with grids of points), the error being calculated on the proportion of the various strata. Nowadays GIS processing would give the results by using the criteria introduced for the definition of the strata. Without adequate ground check biases can be considerable. The error from this source is usually low and has not been given in the reports.

The sampling error (P=0.05) on the whole population for the most abundant species *Eschweilera odora* is 12,8 % for the 3 regions as a whole. It is 15,0 % for the next most abundant tree species *Goupia glabra*. The mean number of trees (100 cm GBH and over) per hectare are respectively 3.11 and 1.49.

The various species behave differently, not only in tree density among the different regions but also in variability between forest types within regions. What has been said about the most abundant species can be repeated for rare species with even more exaggerated features : their patterns seem to be unpredictable ; e.g. *Rollinia exsucca* (V.N. : Ata brava) is present (and very scarce) only in 2 out of a total of 23 strata in the three regions. The calculation of an error is pointless (140 % on the mean P = 0.05). The rarest species is *Fagara capuchoi* with only one tree in the sample. Densities of rare species are therefore poorly known : better knowledge would need more intensive sampling and the extra cost would probably be unacceptable. Credible information on rare tree species is definitely costly.

□ Spatial distribution of tree densities in eight regions of Brazilian Amazonia for a selected species : *Eschweilera odora.*

- **Total area :** 2 293 890 km^2.
- **Forest area :** 1 992 220 km^2 (Montane, Pioneer and Contact Forest/Pioneer excluded).

CHARACTERISTICS OF THE EIGHT STUDIED AMAZONIAN REGIONS

Code in map	O	S	J	E
Region	Iça	Manaus	Santarém	Belém
Total area (km^2)	179 640	295 160	295 160	284 780
Forest area (km^2)	168 000	262 219	223 650	218 840
Code in map	P	R	G	D
Region	Jurua	Purus	Tapajos	Araguaia Tocantins
Total area (km^2)	284 800	293 760	293 750	366 830
Forest area (km^2)	281 014	266 157	249 349	240 140

Three main formations in each region : dense, open, contact forest (ecotone), subdivided into geomorphological strata : low plateaux, tableland, dissected, alluvial...; AR : area of stratum ; ha : number of one ha-plots ; $\overline{x}$ nb. of trees > 100 cm GBH per ha.

COMMENTS ON A SELECTED SPECIES

The following table gives two main characteristics of one species, selected for its abundance.

1. **Tree density** (i.e. number of trees > 30 cm DBH/ha). On the whole the densities of a particular species are highly reliable, either in the various strata within one formation in a particular region, or between formations within a region, or between regions. For details see columns in the table and summarized tables.

2. **Distribution of trees according to diameter classes**

Such distributions are not available for 2 regions (Belém and Araguaia-Tocantins). *Eschweilera odora* in 4 regions shows conspicuously distinct behaviours. See summarized distribution table below.

– *Eschweilera odora* has a negative exponential distribution typical of a tolerant species. The results for 2 regions (Santarém and Tapajos) are discarded because errors in field identification of *Eschweilera* species are suspected.

From the stand table even in the absence of growth measurements, but with simple realistic assumptions of diameter growth, e.g. 5 mm per year, it seems possible to get information about allowable cuts in the natural forest. In the light of available data on growing stocks, it is probable that in some regions several timber species might be dangerously overcut.

Eschweilera odora (Poepp.) Miers
v.n. Matamata branca = Matamata preta
LECYTHIDACEAE

ICA

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	60	61	4.393				10	5	0
Dissected	5	9	2.111				45	54	2.333
Alluvial	21	25	5.240	8	11	4.182			
Tableland				11	8	1.125			
Paleozoic Residual									
High Plateaux									
Terraces									
Total	**86**	**95**	**4.400**	**19**	**19**	**2.895**	**55**	**59**	**2.136**

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	206	122	52	22	8	5	3		418
Open	23	19	6	7					55
Contact	53	41	17	9	4		2		126
Total	**282**	**182**	**75**	**38**	**12**	**5**	**5**		**599**

MANAUS

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	118	125	4.264	9	6	5.833	22	24	2.125
Dissected	15	12	2.913				66	78	3.705
Alluvial	7	23	1.739				15	5	1.800
Tableland	4	4	2.000						
Paleozoic Residual	5	7	3.000						
High Plateaux									
Terraces									
Total	**149**	**171**	**0.632**	**9**	**6**	**5.833**	**103**	**107**	**3.271**

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	54	32	12	5	4	1			108
Open	20	10	2	2	1				35
Contact	157	113	55	23	8	2	2		350
Total	**231**	**145**	**69**	**30**	**13**	**3**	**2**		**493**

SANTAREM

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	107	56	0.911						
Dissected	55	28	0.179						
Alluvial									
Tableland	23	13	0						
Paleozoic Residual	13	15	0.600						
High Plateaux	10	5	0						
Terraces	6	6	0.666						
Total	**214**	**123**	**0.561**						

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	41	19	4	2	2	1			69
Open				**Data not reliable**					
Contact									
Total	**41**	**19**	**4**	**2**	**2**	**1**			**69**

BELEM

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	199	34	0	17	5	0	8	1	0
Total	**199**	**34**	**0**	**17**	**5**	**0**	**8**	**1**	**0**

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense									
Open					**Data not available**				
Contact									
Total									

JURUA

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	108	41	3.366	113	53	3.943			
Dissected									
Alluvial	20	20	5.250	40	67	2.701			
Tableland									
Lower montane									
Paleozoic Residual									
Arrasada Medio Xingu									
Total	**128**	**61**	**3.984**	**153**	**120**	**3.250**			

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	118	60	46	11	5	3			243
Open	179	113	60	21	9	5	2	1	390
Contact									
Total	**297**	**173**	**106**	**32**	**14**	**8**	**2**	**1**	**633**

PURÚS

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	143	103	2.311	36	15	3.438	17	33	1.578
Dissected	12	29	0.862	2	6	1.167			
Alluvial	25	23	2.304	19	8	2.375			
Tableland	11	20	0.950						
Lower montane	1	7	1.143						
Paleozoic Residual									
Arrasada Medio Xingu									
Total	**192**	**182**	**2.236**	**57**	**29**	**2.690**	**17**	**33**	**2.333**

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	239	108	38	14	4	2	1	1	407
Open	39	24	11	3	1				78
Contact	31	23	10	9	3	1			77
Total	**309**	**155**	**59**	**26**	**8**	**3**	**1**	**1**	**562**

TAPAJOS

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	49	39	0.282						
Dissected	27	14	0.071						
Alluvial									
Tableland	69	32	0.312						
Lower montane	9	5	0						
Paleozoic Residual	9	8	0.125						
Arrasada Medio Xingu				87	29	0.033			
Total	**163**	**98**	**0.235**	**87**	**29**	**0.033**			

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense	11	4	5	1	1			1	23
Open	1				**Data not reliable**				1
Contact									
Total	**12**	**4**	**5**	**1**	**1**			**1**	**24**

ARAGUAIA-TOCANTINS

STRATA	Dense AR	Dense ha	Dense x̄	Open AR	Open ha	Open x̄	Contact AR	Contact ha	Contact x̄
Low Plateaux	133	18	0	170	21	0	38	4	0
Total	**133**	**18**	**0**	**170**	**21**	**0**	**38**	**4**	**0**

FORMATION/DBH	30–	40–	50–	60–	70–	80–	90–	100+	TOTAL
Dense									
Open					**Data not available**				
Contact									
Total									

Dense : closed rain forest ; Open : open rain forest = Mata-de-cipó ; Contact = Ecotone = Transition Forest ; 30– = 30,0 to 30,9 cm DBH ; 100+ = 100 cm DBH and over.
AR : total area of stratum in thousands of km^2 ; ha : number of one hectare-plots actually enumerated ; $\overline{x}$: mean/ha of number of trees ≥ 30 cm DBH.

CONCLUSION

Large tropical forest inventories appear to be indispensable for an unbiased evaluation of tree populations. The interest of such evaluations has been discussed.

The differences in tropical forest inventory designs (size, sampling intensity, quality in tree identification...) constitutes a real difficulty when comparisons, data combinations or extrapolations are desirable. Hence a need for a minimal standardization in measurements, sampling decisions, tree identification, data processing and publication formats.

Simple questions about the population of any tropical tree species, such as the most abundant, the rarest or the most endangered species, remain unanswered satisfactorily because they generate more questions involving incompletely known ecological aspects, e.g. on regeneration, growth and mortality.

No region in the tropical world has been surveyed in recent years as thoroughly as Brazilian Amazonia, as far as large regions are concerned.

Radam Brazil inventories represent a definite improvement compared with the pioneering F.A.O. inventories of the fifties.

However a further effort is needed on tree identification with possibly smaller plots in larger numbers, subsampling for small trees, and cross-inventories to evaluate the consistency and quality of the work.

The findings of Projeto Radam Brazil have been published in quite detailed and versatile reports by regions so that abundant material is available for further research and for provisional answers to a forest policy (management, allowable cuts, exports, nature protection). No floristic synthesis has been attempted until now.

It is highy probable that many rare tree species have been missed in the fairly representative but rather loose (0.001 %) network of the one hectare plots.

Many other smaller, more detailed inventories with lower diameter limits permit some extrapolations for the populations of the undergrowth (down to 10 cm DBH), but it is still impossible to say honestly what is the most abundant tree species in Brazilian Amazonia, because of some taxonomic weaknesses in the first Radam Brazil reports. However *Eschweilera coriacea (= E. odora)* is a good candidate.

Possibly a hundred years will be needed to know the Amazonian flora adequately and the tree flora in particular. Nobody would give an estimate for the total number of flowering plants in Amazonia to within 10 000 species (anything between 60 000 and 100 000 has been mentioned).

A large floristic survey of the Amazonian forests remains a prime – if ever feasible – target for future generations. Only a certain « reality » about tree populations by species and floristic compositions, based on very few regional or national forest inventories, is presently accessible. ■

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POPULATIONS D'ARBRES PAR ESPÈCES EN FORÊT TROPICALE HUMIDE NATURELLE
Cas particulier : l'Amazonie brésilienne

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L'évaluation des populations d'arbres tropicaux a-t-elle un intérêt, en outre, est-elle possible ? Quel est l'arbre le plus abondant, le plus rare d'une grande région ? Quelle est la précision de la mesure ?

La réponse à ces questions passe par des inventaires forestiers adaptés à chaque enquête et dont les contraintes principales sont triples : la somme d'argent disponible, le délai d'exécution et les ressources techniques (état d'avancement des flores, capacité d'identification sur le terrain, accès aux moyens de télédétection, maîtrise de la théorie des sondages, moyens de transport...). La qualité des réponses sera fonction de tous ces facteurs et sera le résultat de compromis.

En effet, un même plan d'échantillonnage donnera les informations les plus précises (même localement) sur les espèces dont la distribution spatiale est la moins variable. Les populations des espèces abondantes seront en général connues avec une bonne précision. Cette précision sera médiocre ou franchement mauvaise pour les espèces peu abondantes ou rares.

La rareté et la menace qui pèse sur les espèces sont des concepts difficiles à définir ; ils sont relatifs car mieux appréhendés pour une petite île ou un petit territoire que pour une grande région continentale.

Les inventaires doivent répondre à des questions de plus en plus diverses et de plus en plus « pointues ». Pour les forestiers, l'objectif principal est économique : localisation des effectifs et des volumes par espèces (objectif statique), qui doit être doublé de mesures d'accroissement en vue d'aménagement.

L'écologiste forestier exige des inventaires détaillés pour répondre à des questions plus variées, soit d'ordre phytogéographique : définition des espèces et de leurs aires respectives et, dans des acceptions plus fines, étude des variétés, hybrides, complexes d'espèces, flux de gènes entre populations, spéciation, soit d'ordre démographique : structure des espèces, distribution spatiale et grégarisme, stabilité, immigrations et extinctions ou encore d'ordre conservatoire : identification des espèces rares, nature et causes de cette rareté, bases d'une politique de protection de la nature.

Les populations d'arbres ne peuvent donc être évaluées, pour la totalité des espèces, que par de grands inventaires nécessitant des ressources financières importantes. Même ainsi, un très grand nombre d'espèces passera au travers des mailles du filet de l'échantillon. Un résultat de l'inventaire serait de prévoir, par emboîtements successifs d'échantillons d'intensité croissante, comment et de combien on s'approche de la richesse floristique d'une région.

Les grands inventaires précis sont peu nombreux, on pourrait dire inexistants, car il est une loi non écrite qui veut que la quantité chasse la qualité. En 1993, les inventaires les plus détaillés descendent à un centimètre de diamètre et se limitent à 50 hectares (Pasoh en Malaisie, Barro Colorado à Panama et Mudumalai, Inde), objectifs très en deçà des ambitions que l'on peut avoir pour évaluer les richesses (et les pertes) floristiques des trois grandes régions de forêt dense existant sur la planète, et tenter de donner enfin une réponse circonstanciée à la question, ô combien polémique, de la perte annuelle en espèces du fait de l'homme.

Un exemple d'évaluation de populations d'arbres est donné pour une grande région. Il concerne l'Amazonie brésilienne et n'a été possible que grâce à la disponibilité des résultats du Projet Radam Brasil pour lequel des synthèses – en particulier floristiques – restent à faire. Seuls les arbres de plus de 100 cm de circonférence à 1,30 m ont été inventoriés.

Une région du centre-ouest amazonien, d'une surface d'environ 623 000 km^2, a d'abord été examinée pour les populations de toutes les espèces (558) contenues dans l'échantillon, en particulier pour les deux espèces les plus abondantes : *Eschweilera coriacea* (=E. odora) et *Goupia glabra* avec estimation de leurs erreurs d'échantillonnage respectives.

Une région plus vaste d'environ 2 300 000 km^2, et comprenant toute la partie centrale de l'Amazonie brésilienne, est ensuite examinée pour cinq espèces d'arbres choisies en raison de leur abondance, de leurs différents tempéraments (essences d'ombre, essences longévives de lumière, essences à distribution erratique ...), de leurs exigences topographiques et de leur intérêt économique (arbre fruitier ou donnant du bois). Il s'agit de : *Eschweilera odora*, *Goupia glabra*, *Vouacapoua americana*, *Bertholletia excelsa* et *Carapa guianensis*. Seule la première a été retenue. En ce qui concerne les inventaires détaillés, on ne peut qu'être frappé par la modestie des résultats connus et crédibles.