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SILVICULTURAL RESEARCH NETWORK OF CIRAD-Forêt FOR NATURAL RAIN FORESTS

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SILVICULTURAL RESEARCH IN NATURAL FORESTS

The first research undertaken by different organizations in the extremely heterogeneous natural forest was scattered. The means were never sufficient for the established goals, and research and application were often mistaken one for another.

Many experimental plots (almost always too small) were created separately in most tropical forest regions, lacking common guidelines and a similar model, and they were not given the practical possibility to interpret and compare the collected data. In addition, this multitude of plans of action, which were often clever, suffered from the changes in financing and forest doctrine, depending on the successive people in charge.

Thus, at the time when the management of the tropical forest became relevant again (in the mid seventies), there existed a spate of information on natural forest management stating a lot of partial data, often not interpreted, and usable concrete data as well as policies of action were, in reality, extremely rare.

Taking into account the achievements and failures of past research experience, experimental projects to be enacted by the CIRAD-Forêt was established as early as 1976, with respect to the simple principles stated below.

PRINCIPLES AND GOALS

The future of the tropical forest constitutes one of the main worlwide concerns and one of the vital problems for its future can be stated as follows :
What are the possibilities of reconstituting the potential of standing trees and maintaining the biological diversity of tree stands after the first logging passages ? And what simple, cheap measures should be enforced in order to move toward an evolution favorable to valuable species, and thus insure a real sustainability ?

To answer this twofold question, as early as 1976, the CIRAD-Forêt contributed to the establishment of a network of trials corresponding to the following simple principles :

only take into account large (several hectares) plots with as many comparable ones as possible in other places ;
measure simple parameters (circumference, tree location) ;
use statistical means to interpret data.

At the same time, the main targeted objectives focused on

- the study of the dynamics of stands and the growth of trees, per species, in relation to simple silvicultural activities (such as logging, clearing by devitalization) focusing mainly on primary stands made up of trees more than 10 centimeters in diameter ;
- the study of the evolution of regeneration. But since the latter is, as experience shows, difficult to control, no particular treatment was attempted to endeavor to stimulate it, considering that this regeneration is necessarily influenced in a favorable or unfavorable way by silvicultural treatments at the higher level. This stratum, whose dynamics is recorded rather than influenced, is studied thanks to clearly-targeted protocols ;
- the study of treatment impact on the yield, as well as that of the gains obtained in comparison with non-intervention ;
- and lastly, the transfer to the development of technical concepts resulting from experimentaion, in order to test them on a large scale basis within demonstrative forest management projects.

Over the last fifteen years, the CIRAD-Forêt produced substancial endeavours to acquire and synthesize knowledge in the field of the study of the dynamics of the natural forest, with or without man's intervention. This study has been developed considerably, thanks to the help of a network of large-scale experimental projects located not only in Africa (in the Ivory Coast, the Central African Republic and Gabon), but also in American (in Brazilian Amazonia, and French Guiana) and recently in Asia (in Indonesia).

The main trials (as far as we know) located on three continents are presented in the tables on the next pages.

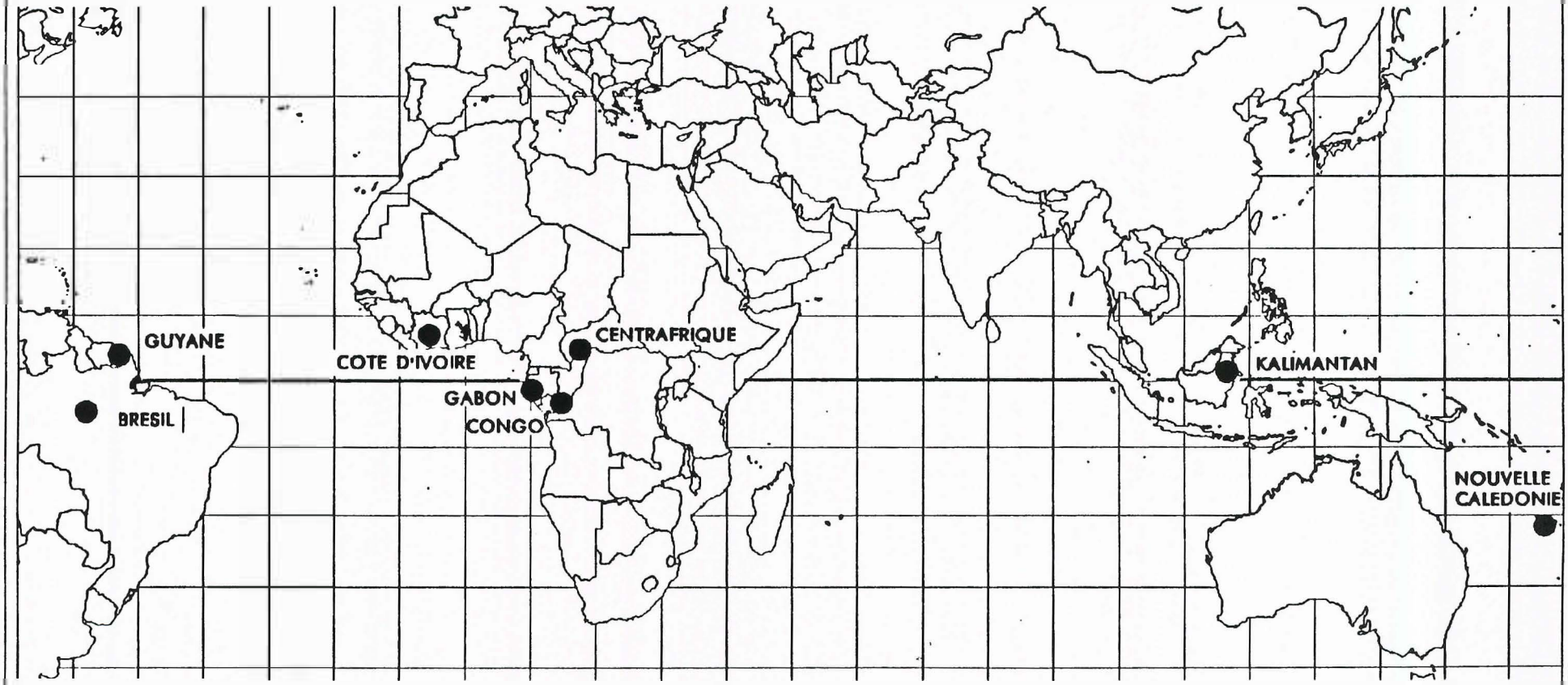
FOREST DYNAMICS PLOTS

Year of plots's set up	Countries	Research's partners	Sites	Main research topics	Number of plots	Total trial area
			AFRICA			
1981	Centrafrique	Office National des Forêts de Bangui CIRAD-Forêt	M'BAIKI	effects of various treatments on stand dynamics	1O	90 ha
1987	Congo	SNR/Office Congolais des Forêts CIRAD-Forêt	N'GOUHA II	effects of various silvicultural treatments on Okoumea stand dynamics (natural stands)	8	8 ha
1976 1976 1976 1986	Côte d'Ivoire	SODEFOR CIRAD-Forêt	MOPRI IROBO LA TENE YAPO	effects of various silvicultural treatments on stand dynamics	25 25 25 16	400 ha 400 ha 400 ha 144 ha
1987	Gabon	Direction des Eaux & Forêts de Libreville CIRAD-Forêt	OYANE	effects of various silvicultural treatments on Okoumea stand dynamics (natural stands)	34	30 ha
1985	Ghana	Ghanean Forestry Departement ODA	a network of plots in the country	growth and yield monitoring plots	600	?
			ASIA			
1988	India	India Institute of Science (Bangalore) STRI/CTFS	MUDUMALAI	effect of fire and elephant browsing on forest regeneration	1	50 ha
1989	Indonesia	AFRD (Ministry of Forestry) PT INHUTANI I CIRAD-Forêt	BERAU	effects of various silvicultural treatments on stand dynamics	18	288 ha
1992	Indonesia	DGFU (Ministry of Forestry) ODA	SAMPIT	-	?	?
1974	Malaysia	AIFM Ag.Canad.Coop.	Gunung Tebu Forest	Effects of silvicultural treatment on stand dynamics	?	150 ha
1986	Malaysia	FRIM, the Arnold Arboretum of Harvard University, STRI/CTFS	PASOH F.R.	demographic study of several commercially important species ; analysis of the human use and economic valuation of forest resources (about 800 species under study)	1	50 ha

Year of plots's set up	Countries	Research's partners	Sites	Main research topics	Number of plots	Total trial area
1991	Malaysia	Sarawak Forest Depart., Arnold Arboretum of Harvard Un., Plant Ecology Lab. of Osaka City Un.	LAMBIR NAT.PARK	wildlife survival in an isolated forest with limited food resources ; silvicultural research aimed at restoration of logged areas ; anthropological research on the relation between local shiftingagriculturalists and the Park	1	50 ha
1992	Sri Lanka	Sri Lanka Forest Dept., Rockefeller Foundation, Un. of Peradeniya	SINHARAJA	silvicultural management for diverse forest products including hardwood ; forest restoration, and the biological stability of forest of low biological diversity	20	5 ha
1991	Thaïland	Royal Thai Forest Department, Kasetsart and Mahidol Universities, Arnold Arboretum of Harvard University	HUAI KHA KHAENG	study of the dynamic relationship between evergreen and deciduous forests in view of the conservation of both types of forest and of their wildlife	1	50 ha
			LATIN AMERICA			
1970	Brazil	FCAP	CURUA UNA	forest dynamics after logging and climber cutting	2	200 ha
1979	Brazil	EMBRAPA/FAO	TAPAJOS	forest dynamics after logging poison-girlding and climber cutting	1	64 ha
1982				effect of four logging intensities	4	144 ha
1980	Brazil	EMBRAPA	JARI Morro do Filipe	effects of various logging intensities and silvicultural treatments	?	500 ha
1980	Brazil	INPA (instituto Nacional Pesquisas Amazonia) CIRAD-Forêt	MANAUS (ZF2)	effects of various silvicultural treatments on stand dynamics (species composition and volumes of timber))	8	72 ha
1985	Costa Rica	CATIE	GUAPILES SARAPIQUI	stand dynamics (primary and secondary forest)	10	20 ha
-	Costa Rica	La Selva Nat.Park.Un. of N.Dakota	LA SELVA		1	12,4 ha

Year of plots's set up	Countries	Research's partners	Sites	Main research topics	Number of plots	Total trial area
1983	French Guyana	CIRAD-Forêt INRA	PARACOU	effects of various silvicultural treatments on stand dynamics (species composition and volumes of timber)	12	108 ha
1991				" "	3	27 ha
1991				dynamics of untouched forest	1	25 ha
1989	Guyana	Guyana National Resource Agency, University of Guyana, University of Utrech (Tropenbos project)	MABURA HILL district	comparative study of floristic diversity ; general information on lesser know tree species ; population structure, dynamics and reproduction of importants tree species ; growthn and productivity of important tree species	?	?
?	Mexico	Nat. Un. of Mexico	LOS TUXTLAS	forest dynamics ; phenology ; genetics	1	5 ha
1980	Panama	STRI/CTFS	BARRO COLORADO ISLAND	forest dynamics ; phenology ; seedling demography and tree genetics. Other projects on the island, but not confined to the 50 ha plot, including studies of herbivory, leaf biochemistry. Approximately 200 species are under study	1	50 ha
1976	Suriname	University of suriname, University of Wageningen	ZANDERIJ BELT	effects of silvicultural treatments on stands dynamics	8 1	10 ha 16 ha
?	USA (Puerto Rico)	Un. of Puerto Rico	LUQUILLO		1	16 ha

SILVICULTURAL RESEARCH NETWORK FOR NATURAL RAIN FORESTS



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MAIN RESULTS

These various Permanent Sample Plots (PSP), materialized by CIRAD-Forêt supply a considerable and steady flow of information which is difficult to present exhaustively in what follows. It thus seems preferable to present exclusively the main concepts that can be drawn regarding growth, productivity, vulnerability, mortality and regeneration.

THE IMPACT OF LOGGING : In the Central African Republic, in a forest whose total volume of standing trees (above 10 cm in diameter) was slightly higher than 300 m^3/ha, 3 to 4 trees whose diameter was more than 80 cm were removed, which represented 50 to 65 m^3/ha of the total volume. By adding the volume which was logged to that corresponding to damage, the potential which disappeared was from 68 to 95 m^3/ha, that is, from 20 to 30 % of the initial volume.

In Guiana and Brazil, for forests from 310 to 370 m^3/ha, the logging of about ten trees with a 50 cm diameter means removing about 50 m^3/ha and an average disappearance of 75 m^3/ha, which represents 20 to 25 % of the initial potential.

In Indonesia, in East Kalimantan studies have disclosed similar outputs regarding the damages generated on the different strata during the felling and the skidding phases. One of the main conclusions is the specificity of each of both phases, felling and skidding, which have to be assessed separately. It was confirmed that the felling creates more injuries meanwhile the skidding plays an important role in the mortality. Globally, with all the variations linked to the logging intensity, 21 % of the stand undergo differents types of injuries with a dominance of crown damages (65 %) whereas around 20 % of the original stand is destroyed especially during the skidding. On average, 41 % of the trees up to 10 cm suffered and 35 % for the saplings from 2 to 10 cm diameter.

Thus, the direct impact of logging is considerable. The "dose" of the intervention must be carefully measured in order not to go above the threshold of the irreversible deterioration of the stand (a priori, 40 % of the potential). This is all the more necessary as the mortality rate induced two to three years after the logging turns out to be abnormally high - from 2 to 4 % per year of the total number of stems.

The reaction of trees to the opening of the canopy resulting from the logging is a positive one for growth in diameter. This result is however mitigated by the fact that it only affects a relatively small percentage of the trees constituting the stand, because of the heterogeneity of this activity in different places.

THE EFFECT OF THINNING : It was accomplished at the expense of so-called "secondary" species, unmarketable as timber. They were cleared by the devitalization of standing trees (with or without arboricides) so as to reduce cost and damage. It affects primarily the trees of the higher stratum, which are a priori the most troublesome for future trees. Since logging removes valuable, tall trees and thinning gets rid of tall trees which have no commercial value, the total activity may be considered to create "younger" stands in order to stimulate their growth. On the other hand, it preserves **biodiversity** since it only concerns large-size categories (for all species).

The opening of stands by thinning (and also by harvesting) leads to a very favorable reaction from trees of most species, and notably for small and middle-size trees. The first results obtained in the Ivory Coast, which were very promising, were confirmed and made more precise over time, not only by the experiments in Africa (in a similar environment), but also by those in America in a very different type of forest. In Guiana, for instance, the reaction of valuable species is unquestionable four years after being treated since the gain in growth is close to 75 % for stems from 10 to 25 cm in diameter and 50 % for trees 25 to 40 cm in diameter. In the same way, for the same period, the yearly growth of trees has on the whole doubled in the Central African Republic.

On the other hand, treatments to taller trees, which are subjected to less competition from their surrounding stand, are almost without effect.

The reaction of trees to treatment is, in fact, very individualized. In control plots (which are untouched), most trees belonging to the same species grow slowly, whereas a few have inexplicable much faster growth. Thus, the opening of the canopy could act on the growth of tree stands by modifying the proportion of slow and fast units, to the benefit of the latter. The same is true for recruitment of stems, a higher number of which reach a 10 cm diameter thanks to the treatments.

In addition, it is noted everywhere that valuable species react the best, and particularly when dealing with higher growth which is much stronger. The fact that young, valuable stems appear more quickly in the higher level is very reassuring with regard to the dynamics of seedlings and saplings resulting from regeneration.

In theory, the effect of thinning (combined or not with that of logging) continues until the initial basal area is reconstituted. Hence, for stands for which the opening of the canopy corresponds to a 25 to 45% suppression of the basal area, the models of evolution over time indicate 30 years - or more - as the average time span to return to a state of equilibrium.

The initial basal area does not change much in control-plots. Its variation is positive or negative depending on the years, and equilibrium (or stability) is maintained by the occasional loss due to natural mortality, which makes up for the overall increase in the stand.

NATURAL MORTALITY : It constitutes the original mechanism of forest reconstitution (self-regeneration from dead wood). It is an extensive phenomenon which, however, is difficult to quantify and study.

It only concerns a few units a year per hectare, that is, 1 to 2 % of the total, but overall loss in volume may be considerable when large stems are concerned.

No connection could be established between the natural mortality rate and how intense the opening of the stand was : trees die whatever their size, whatever their growth, both in treated and untouched plots. It is a discontinuous phenomenon (contrary to the growth in diameter and regenerative growth), and an exceptional occurence, whose assessment requires very long periods of observation, following what must be done in climatology.

During the work done on establishing **a model for the dynamics of the stands** in relation to silviculture to simulate growth and the production of management series, it became evident that the factor with the highest impact on the model was mortality. The slightest variation in the survival rate of a tree stand leads to considerable variation in the number of marketable stems at the end of the cycle.

REGENERATION :

The research work which was started in different experimental projects, is concerned with stems which are 2 to 10 cm in diameter. This research is far from being conclusive, but it may be suggested that treatments tend to favor the regeneration of most species (major and secondary ones), and without bringing about a major floristic modification outside the areas particularly affected by logging. Neither were they able to establish a close link with the presence of species (seed-bearers) at the higher level.

Estimates in this field remain temporary for a long time, since a long period is necessary to encompass the successive effects of a single action.

THE IMPACT OF FIRE

A fire occurred in 1983 in one of the three projects in the Ivory Coast. This accident was used to quantify the scope and the consequences of the damage. On the whole, the areas most damaged by fire were those which had been thinned and exploited and which, due to the abundance of dry standing trees and fallen ones, presented a higher degree of combustibility than that of untouched plots. This discovery, which is not very encouraging for forests which have been modified by man, had the advantage of pinpointing the fact that the protection of the ecosystem is an "everyday matter" and that being a good silviculturist is not sufficient. One must, above all, pay daily attention to the preservation of the investment and capital.

THE RESULTS OF PRODUCTION : Taking into account all the valuable species in the stand (above 10 cm in diameter), yearly yields in volume correspond to treatment (integrating growth, mortality and regenerative growth).

The figures obtained, in Africa for example, are similar and show production has doubled. Four years after treatment, the increase in volume in the Ivory Coast was as follows :

- O.7 to 1.8 m^3/ha/year for untouched stands ;
- about 2.5 m^3/ha/year for exploited stands ;
- and from 2.2 to 3.6 m^3/ha/year for thinned stands.

This corresponds to a yearly productivity rate of valuable species between 0.5 and 2 % of the volume of standing trees (100 to 150 m^3/ha) for untouched plots ; 1.5 % for exploited plots and between 2 and 3.5 % for thinned plots.

Within the same period of time in the Central African Republic, the results were similar in spite of the differences in standing tree potential, species and treatment.

- 1.35 m^3/ha/year, that is, O.9 % for untouched stands ;
- 1.50 m^3/ha/year, that is, 2.1 % for explpoited stands ;
- 2.45 m^3/ha/year, that is, 3.2 % for stands which were first exploited, then thinned.

On the other hand, results are less homogeneous for gains in volume (or in basal area) for trees beyond the cutting limit. In the Ivory Coast, for instance, the gain in production obtained by thinning or logging turns out to be relatively low, that is, between 0.5 and 1.5 m^3/ha/year.

This may be explained thanks to the results which were stated previously
- the growth of dominating trees is almost independent from the type of treatment ;
- the mortality rate is very variable and can in no way be related to silvicultural activities ;
- the gain in volume by passing to the category of exploitable trees is clearly influenced by the treatment and its intensity. Average-size trees benefit the most from the elimination of competitive trees.

In fact, the loss in commercial volume by natural mortality turns out to be in the same range as the increase in volume of exploitable potential. It is the arrival of new trees (reaching 60 cm) accelerated by man's activity which brings about the gain in production quantified here.

Thus, the gains are practically non-existent within untouched forests, and so, thinning and the mobilization of resources within productive forest management plots are extremely important.

CONCLUSION

This paper stating the main results in silvicultural research in natural forests is only a short and partial assessment which makes it possible for the reader to have an overall vision of the knowledege and experimentation necessary for forest management whose importance is out of proportion in relation to the modest means that are usually available to it.

One of the main conditions for experimental and silvicultural success is continuity over time: the sudden discarding of silviculture in natural forests a few decades ago, to the benefit of industrial reforesting (presented in those days as a panacea) must encourage a very conservative approach. Forests have always suffered from fashions.

Research on the dynamics of natural forest stands and their silviculture have effectively supplied pragmatic tools that can now be used by forest managers. However, the level of knowledge is still modest and such concepts as natural mortality and the behavior of numerous species are still only partially known.

Lastly, one has, however, to emphasize that the experimental results obtained on middle-size areas raise the problem of extrapolation to larger ones, hence the necessity to associate a phase of financially well-established research to any forest management operation in full-size forests.

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