THE STRUCTURE OF STANDS OF CORSICAN PINE (PINUS NIGRA ARN. CALABRICA SCHN.) ON COARSE SANDS

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Abstract

This paper is a sequel to a previous article written by the same authors and entitled : " Growth and Development of Stands of Corsican Pine on Coarse Sands ".
It aims to contribute to the development of an appropriate management scheme for these Corsican Pine forests, that are established on the coarse sands of Northern Belgium, by analyzing the stand composition as found at present and by extrapolating existing trends.
The study makes special reference to the internal stand structure, the social stratification within the stand, the quality distribution of the trees and the interrelationship between the latter two factors.
Cost - benefit ratios, however, have not been considered at this stage and variations due to changes in site quality or potential have been found insignificant within the broad soil class of the coarse sands.
Recommendations have been formulated, taking into account customary management interventions and the unavoidable reorientation of the management of these Pine forests towards the production of high quality sawnwood.

INTRODUCTION

Although it has been introduced widely in the Flemish part of Belgium and the total plantation area has increased considerably in recent years, relatively little basic data are available on Corsican Pine (Pinus nigra

Arn. calabrica Schn.) as a plantation species.
The increase in the number of Corsican Pine stands, however, has brought about a wide range of silvicultural management problems. Little doubt exist that the actual situation is far from optimal, as the generally homogeneous, uniform and even-aged stands are susceptible to various extreme external factors, such as frequent windfall and forest fires. The latter periodically destroy large forest areas, while windfall unfortunately is concentrated on the dominant elements of the stands,which have the highest commercial value. In view of the objective of management, - from middle to high quality sa n-wood, a revision of the management technique is required. Therefore, as to allow an in-depth examination of the actual condition of the Corsican Pine population on coarse sands a series of sample mensuration plots were established in " Het Pijnven ", a state forest located in Hechtel/Eksel in Northern Belgium (Coppin P., Lust N., 1980).
The particular aim of this paper is to present in detail an analysis of the data obtained on the composition of the existing Corsican Pine stands. Special reference is made to the internal structure of the stands, their diameter class distribution and the differentiation in social strata within the stands, with the relationship between social position and quality of the individual tree also being examined.
All measurements and observations date from 1976 and were carried out in 46 sample plots, distributed as follows : each of the first four age classes (10 to 19, 20 to 29, 30 to 39 and 40 to 49 years) is represented by 10 plots. No Corsican Pine was planted in the domain between 1913 and 1929, and as the area of older stands is very restricted, only 6 plots were established in the 60 to 65 year old class. All trees within the plots had their diameter at re st height measured, their social position determined and their stem quality assessed.
Results are given, either by sample plot or by age class. Special attention is paid to the untreated and relatively undisturbed 10 to 19 year old class, to the oldest stands in the 60 to 65 year old class and to the so-called " model stand ", said to represent the average population at age 35 in " Het Pijnven " (Coppin P., Lust N., 1980). Note however, that this model stand should not be considered as depicting the optimal situation in the evolution of Corsican Pine populations at that point in time.
To the contrary, its characteristics are the subject of heavy criticism from the management point of view.
No distinction has been made among the local site qualities or potentials, since their influence has been found insignificant within the broad soil class of the coarse sands (Coppin P., Lust N., 1980). Co - benefit ratios were considered outside the scope of this study.

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1. The Diameter Class Distribution within the Corsican Pine Stands.

At a very early stage, there is already a clear tendency towards diameter growth differentiation in the homogeneous, even-aged and uniform stands of Corsican Pine. (Table 1).

Table 1. The number of stems by diameter and age classes

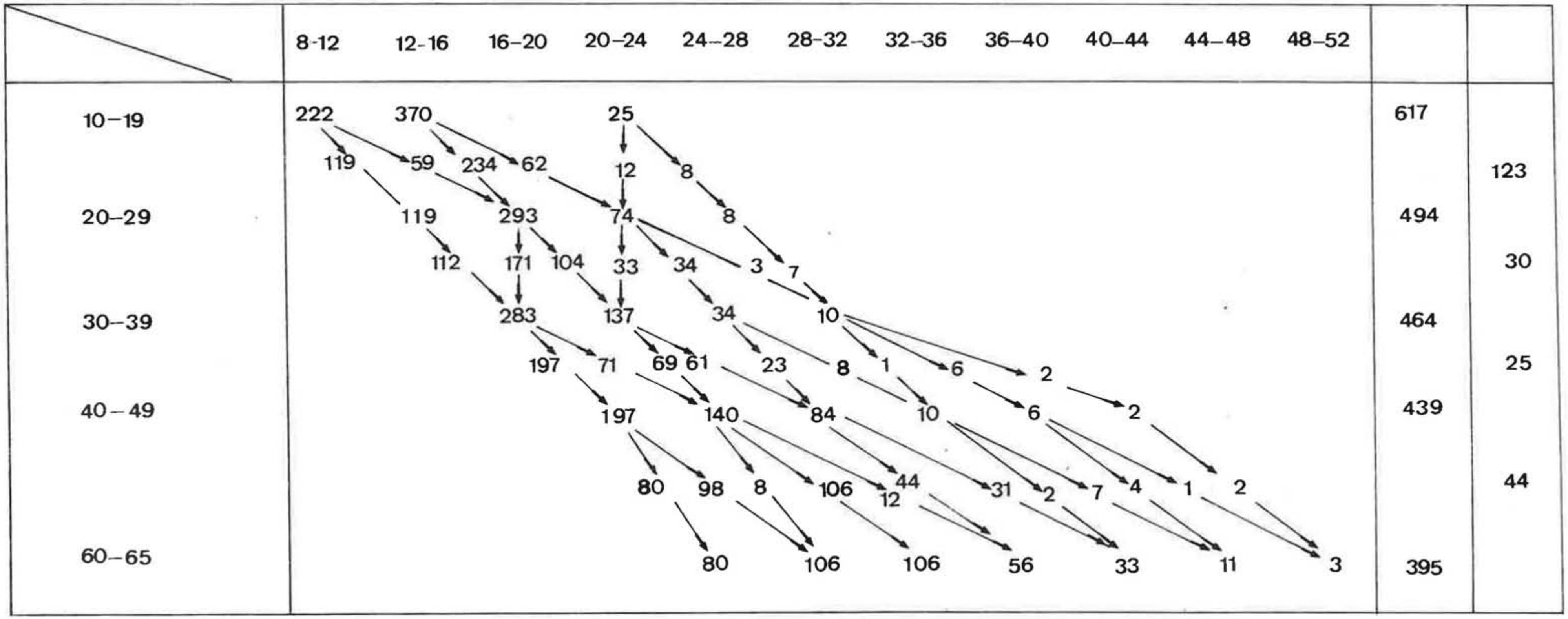
Diameter class (cm)	Age-Class 10-19 years		Age Class 20-29 years		Age Class 30-39 years		Age Class 40-49 years		Age Class 60-65 years	
	N/ha	%	N/ha	%	N/ha	%	N/ha	%	N/ha	%
0-4	1045	17								
4-8	2979	48	747	25	19	1				
8-12	1781	29	1216	41	483	25	57	5		
12-16	370	6	612	21	788	41	187	18		
16-20			293	10	453	23	316	30	15	3
20-24	25	-	74	3	137	7	241	23	27	6
24-28			8		34	2	140	13	89	20
28-32					10	1	84	8	106	24
32-36							10	1	106	24
36-40							6	1	56	13
40-44							2	-	33	7
44-48									11	2
48-52									3	1
Total	6200	100	2950	100	1924	100	1043	100	446	100

The diameter growth differentiation is an expected natural phenomenon in the establishment phase of the Corsican Pine stands. The untreated age class 10-19 already contains 4, exceptionally 5 diameter classes. However, about half of the stems are concentrated in the 4-8 cm diameter class. The type of sylvicultural intervention subsequently practiced unevitably has its impact on the diameter class distribution within the stand.
Two particular trends can be observed in Table 1 :

1. The diameter range of the stand increases gradually with age. The age class 40-49 is characterized by diameter extremes of 10 and 42 cm, which implies 8 to 9 diameter classes of 4 cm each, and by a mean diameter value of 20.7 cm. The oldest stands, actually limited to populations of either 63 or 65 years of age, have diameters varying between 18and 50 cm around a mean value of 32.2 cm.
2. The relative stocking (percentage of total) of the major diameter class within the age class decreases with age. It falls from 48 % of the total number of stems in age class 10-19 and diameter class 4-8, to 24 % in the 60-65 age class and 28-32 diameter class.

The latter trend is logically expected, since the number of diameter classes increases considerably over the same period of stand evolution : for a 50 % fall in relative stocking over a period of 50 years, the number of diameter classes has doubled.
The obviously persistent diameter growth differentiation, however, is a rather surprising phenomenon, especially as low negative selection thinning has been standard practice in " Het Pijnven ". In other words, mainly the shortest trees with smaller diameters have always been removed. Moreover, the differentiation, wich can be observed at all stand development stages, is apparently the combined result of two different but simultaneously occuring factors. First, there is the fact that mostly the lower diameter classes are removed in thinning operations. Second, trees belonging at a certain point in time to a given diameter class, do not remain verly long in that same class. Some experience a reduced growth activity. Others, to the contrary, suddenly demonstrate a surge in growth rate and still others develop at a normal rate. Thus one can say no diameter class is static but is continuously developing. The fact that the age class 10-19 contains 395 trees with diameter exceeding 12 cm, is a rather interesting observation, because this represents approximately the stocking of the 65 year old stand.
The logical question then arises how many of these 395 trees remain as mature stems after 65 years.
Taking into account the gradual reduction of the stocking in even-aged populations, the type of selection thinning as practised in these forests and the fact that at present about two thirds of the upper canopy trees are of good quality, it may be assumed that about 66 % of the mature stems in the 65 year old stand developed from the 12 cm plus diameter classes in the 10 to 19 year old populations. Therefore, a theoretical differentiation model may be developed, incorporating this assumption and leading to a stand density of 395 stems per hectare at age 65. It is illustrated in Table 2.

Table 2. The theoretical differentiation of the diameter distribution emanating from a given situation.



The model implies that of the 130 trees that will form the mature stand after 100 years (Coppin P., Lust N., 1980) almost all originate in the higher diameter classes of the age class 10-19, and consequently from the 32 to 52 cm diameter class at age 65.
The early differentiation in diameter growth in the Corsican Pine stands allows, even necessitates sylvicultural interventions with a positive character, and this as early as the juvenile development phase. From the start, the treatment should be biased towards the favouring of a restricted number of dominant trees, and basal areas of 30, 40 m^2 or even more, as are found at present in " Het Pijnven ", must be avoided.
The concept of the model tree, as defined in Coppin P., Lust N. : " Growth and Development of Stands of Corsican Pine on Coarse Sands ", is irrelevant in this context. The model tree never appears among the stems marked for retention in the future mature stand, especially not in the younger plantations: after 16 years, 2920 trees have greater dimensions. At age 35 this figure is reduced to 800, but all circumstances still point to the elimination of the model tree in subsequent thinning operations. Even after 65 years, 170 of the 400 trees are bigger than the then-model-tree, so that even at this stage the eventuality of its felling remains very likely. The possibility that the model tree will never be part of the mature stand, is prevalent. Thus it has no value as a stand parameter for the management planning.

2. The Social Stratification within the Corsican Pine Stands

Some indications on the differentiation in social strata within the stand, or internal social stratification may be deducted from the study of the diameter growth in Corsican Pine stands. Social stratification, however, results from a multitude of factors, and as such has to be approached with great care, especially when considering the following :

1. The progressive diameter growth differentiation may lead to the assumption that also the social stratification becomes more outspoken with age. This is, however, not the case, as will become evident in the following paragraphs.
2. The height growth of the stands is a rather intricate process (Coppin P., Lust N., 1980). The pattern for the upper canopy or dominant trees, for example, is quite different from that for the middle canopy or co-dominant trees : making abstraction of the age of the trees, a co-dominant element is much taller than a dominant one for a given diameter. This is particularly evident in the younger plantations : an upper canopy tree reaches a height of 2.6 m for a diameter at breast height of 5 cm in a certain stand, while a middle canopy tree will have attained a height of 3.97 m, so to say 53 % more, for the same diameter in an older stand.

Thus as indepth study of the social stratification phenomenon, apart from contributing to a better understanding of the stand structure in general, will give a clearer picture of the competition pattern among the different elements of the stand. Moreover, the social stratification also plays a role as a stand stability parameter, indicating possible windfall hasards and to a certain extent assessing the degree of light tolerance of the species. Finally, it represents a valuable source of information with regard to the required sylvicultural treatment and in the planning of the appropriate management scheme.

Practical experience has proved that it is extremely difficult to define unambiguously the social position of the individual tree within the stand. One method, introduced in Ghent in 1954, is based upon the upperheight of the stand : all trees, taller than two thirds of the latter are said to belong to the dominant storey. In the case of the Corsican Pine stands, this would mean that almost all trees are part of the upper stratum, and this is even more obvious in the older stands. Practically no distinction could thus be made in respect of the social position of the trees. The Ghent method is therefore of no practical use in homogeneous, even-aged populations, since careful field observations have given evidence of significant differences in social position, and this mainly because of the continuous struggle for growing space among the individual crowns.
An ocular assessment of the crown " positions " of the Corsican Pines in " Het Pijnven " has resulted in the following classification:

1. Dominant trees (upper canopy, upper storey), whose crown has ample growing space, is not hemmed in and receives light from all sides. Naturally, these trees have well-developed and deep crowns, of which the major part receives direct sunlight.

2. Co-dominant trees (middle canopy, middle storey), where the crown is laterally enclosed by the surrounding crowns, having, however, unrestricted vertical growing space. The main body of the crown receives little direct synlight.

3. Suppressed trees (lower canopy, lower storey), whose crown is fully shaded by the surrounding trees and thus doesn't receive any direct synlight.

An exact definition of the borderlines separating these classes is nearly impossible. Any assessment of the social position of a tree therefore implies a certain degree of subjectivity. This doesn't mean that the above mentioned appraisal method is less useful and correct than those methods that have their objectivity based upon mathematical relations. To the contrary, in many cases the latter do not take into consideration specific biological phenomena that may only occur on-site.
The social stratification within the various Corsican Pine populations is of course not everywhere identical, whichis clearly illustrated in Table 3.

Table 3. The social stratification in the sample plots

Nr	Age	Upper Canopy		Middle Canopy		Lower canopy	
		N/ha	%	N/ha	%	N/ha	%
1	11	2200	37	3000	50	800	13
2	13	1500	31	2800	58	500	11
3	14	2100	47	2100	47	300	6
4	15	1900	36	3200	60	200	4
5	17	2400	26	4800	52	2000	22
6	18	2500	45	2800	51	200	4
7	18	2100	41	2900	57	100	2
8	18	2400	39	3100	50	700	11
9	19	3000	42	2000	29	2000	29
10	19	1800	21	3600	43	3000	36
11	22	3200	42	3100	41	1300	17
12	23	1300	46	1300	46	200	8
13	26	750	34	1100	50	350	16
14	26	2300	53	2050	47		
15	27	1000	53	900	47		
16	27	750	27	1750	64	250	9
17	29	850	43	1150	57		
18	29	1000	44	1250	56		
19	29	800	41	1150	59		
20	29	850	50	750	44	100	6
21	31	850	33	1700	67		
22	34	650	39	1000	61		
23	34	1200	55	1000	45		
24	34	1750	90	200	10		
25	34	750	47	800	50	50	3
26	34	1250	60	850	40		
27	36	800	37	1350	63		
28	37	850	36	1500	64		
29	39	1150	70	500	30		
30	39	500	48	520	50	20	2
31	40	390	50	390	50		
32	40	500	56	400	44		
33	40	560	46	660	54		
34	43	480	33	940	65	20	2
35	43	620	42	820	55	40	3
36	44	560	65	300	35		
37	44	520	52	480	48		
38	45	560	61	340	37	20	2
39	45	560	52	500	47		
40	47	460	79	120	21		
41	63	290	74	100	26		
42	63	380	61	240	39		
43	63	240	69	110	31		
44	63	300	85	50	15		
45	63	320	84	60	16		
46	65	480	83	100	17		

It is, however, possible to draw some general conclusions by grouping the stands, represented by the different sample plots, in age classes and calculating mean values for the three social strata. This is illustrated in Table 4.

Table 4. The stem distribution by social stratum and age class

Age Class	Average Age	Stem Density					
		dominant		co-dominant		suppressed	
		N/ha	%	N/ha	%	N/ha	%
10/19	16.2	2190	35	3030	49	980	6
20/29	26.7	1280	43	1450	49	220	7
30/39	35.2	975	51	942	49	7	-
40/49	43.1	521	51	495	48	8	1
60/65	63.3	335	76	110	25	-	-

Until canopy closure, the foliar development of all plants is unrestrained. In the terminology of the above introduced classification, all trees belong to the so-called upper canopy. Social differentiation starts with the struggle for light after canopy closure. After only 10 years there is already an outspoken discrimination among the different elements of the stand and quite a number of trees find themselves in a suppressed position.
Table 3 clearly demonstrates that the social differentiation commences at a very early stage, before 10 years of age, and becomes a main feature of the stand structure in a very swift manner. The struggle to occupy the dominant position is so intens, that after 15 years already 65 % of the young trees are relegated to the middle and lower strata and, as such, are almost invariably excluded from the group of the " plus-elements ", from which the mature stand eventually will emerge.
The age class 10-19 bears witness of a few interesting facts. The original planting distance has apparently no influence on the number of dominant trees : smaller planting distances do not result in an increased number of stems in the upper canopy and a wider planting pattern does not bring about any significant reduction in the stocking of the dominant storey. A comparison between plots 1 to 3 and the other sample plots of the age class illustrates this clearly : the former have been established in a 1.25 x 1.25 m planting pattern with selected plant material while the latter have either been sown or more densily planted with unselected plant material. No significant differences can, however, be observed within the age class with regard to the number of trees in the upper stratum. On the other hand it may be remarked that the number of suppressed trees increases with the total number of stems : in plots 5,7 and 9, with a total stocking of respectively 9200, 7000 and 8400 stems per hectare, already 2 to 3000 young trees are relegated to the lower storey. This stratum is thus mainly composed of trees for which no more place is available in the middle and upper canopy.

The independence of the upper canopy stocking from the plantation establishment pattern and the absence of any significant site potential differences within the broad group of the coarse sands (Coppin P., Lust N., 1980), leads to the assumption that the number of stems in the dominant stratum is influenced by the age of the stand only.
Therefore it is not necessary to start from a very high number of plants per hectare. 6400 trees per hectare, or a planting pattern of 1.25 x 1.25 m, are largely sufficient to attain the preset goals. Even more open patterns, such as 1.5 x 1.5 m, with 4444 plants per hectare, could be considered.
One must, however, consider that in formulating this recommendation, no cost-benefit ratio has been taken into account. Wider planting distances might lead to earlier thinning and pruning operations, higher weeding costs and slower canopy closure. This, and the risks the latter factor might entail, should be the object of further study. The upper canopy stocking at age 15 equals the total number of trees at a e 35 and in any case greatly exceeds the number of dominant trees present in the older stands. What really matters from the management point of view is subjecting the upper canopy from an early stage to sylvicultural interventions that favour the plus-trees.
In the absence of human intervention, social differentiation is usually the result of two natural factors. The individual genetic inheritance of the plant and to a certain extent local site conditions lead to differences occurring in growth rates. Then there is the competition for space within the stand, which from a certain moment on accentuates the inherent variance in growth rate of the individual trees. This natural evolution is abruptly altered with the first human intervention. Depending upon the character and the intensity of the interventions, the effects can vary widely.
A first moderate low thinning, which is said to be required under the present circumstances (Coppin P., Lust N., 1980), has little impact on the dominant stratum, since most of the thinnings are suppressed elements. Crown pattern and light distribution within the upper canopy remain practically unchanged. At this stage, the social stratification process is not yet significantly influenced by human intervention.
A second thinning affects mainly the co-dominant trees. Only from the age of 35 years does the number of dominant stems felled become significant. Human intervention will alter and accentuate the natural differentiation process only when the middle storey is the subject of intensive thinning. This becomes even more apparent once the upper canopy is being thinned.
The relationship between stand age and stocking per hectare may be mathematically approximated by an exponential function of the form $y = a.e.^{bx}$. For Corsican Pine populations on coarse sands, the following equations have been obtained and graphically expressed in Figure 1 :

total stocking $y = 14363.4\ e^{-0.0583x}$ with $r = 0.9$

(x = age, ranging from 11 to 65)

upper canopy stocking $y = 3077.3\ e^{-0.0373x}$ with $r = 0.81$

(x = age, ranging from 11 to 65)

middle canopy stocking $y = 9498.3\ e^{-0.0717x}$ with $r = 0.92$

(x = age, ranging from 11 to 45)

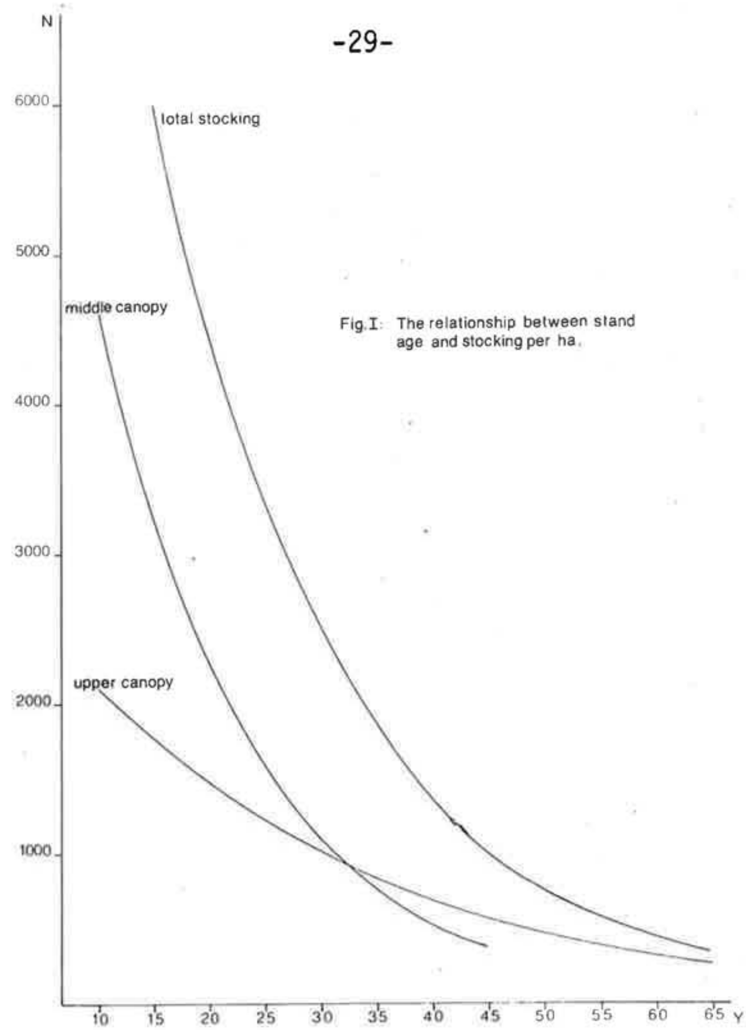


Fig.I: The relationship between stand age and stocking per ha.

It is quite normal and expected that the total number of dominant trees decreases with age in absolute figures, but simultaneously increases relatively within the stand.The relationship between age (x) and percentage of stems in the upper canopy (y) follows a linear equation of the form

$$y = 22.15 + 0.81\,x \qquad \text{with } r = 0.72 \text{ and } F = 47.23$$

The gradually decreasing upper canopy stocking implies a certain pattern of social degradation within the Corsican Pine populations : some dominant elements tend to fall behind in growth rate.
Up to the age of 35, the number of co-dominant trees exceeds that of the dominants. The relative share of the middle storey in the total stocking of the stand remains, however, unaltered at a level of about 50 % in the first fifty years of the stand development. There after, it drops quickly. The nature of the past thinning operations has had a remarkable impact on the 63 and 65 year old Corsican Pine populations, represented in plots 41 to 46 (see Table 3). Although plot 42 has a high stocking figure and plot 43 a low one, both plots have relatively few trees in the upper canopy. On the other hand, plots 44 and 46, with respectively a low and a high stocking figure, have a much higher number of elements in the dominant stratum.

All this eventually leads to the conclusion that intensive thinning is not necessarily equivalent to high thinning, and that thinning operations of low intensity cannot be considered by definition equal to low thinning. The nature of the silvicultural interventions has evidently a considerable impact on the stand structure.
The fact that in the juvenile stand development stage a reasonable number of trees are present in the suppressed stratum, provided that there has been no human intervention, indicates a certain degree of shade tolerancy within the species. Questions then arise : Is it really advantageous to fell the suppressed trees ? Would the stand stability benefit from a denser lower storey ? Would the growth rate, and consequently the value of the dominant trees increase if they were given ample growing space through intensive thinning ?
The stabilizing role of the lower stratum is to a certain extent frequently taken over, and often with better end results, by stems arising from wind dispersed seed of broadleaved species.
Two patterns occur :

1. The seed originates from within the broadleaved fire protection belts, established around the Pine stands using species such as the red oak, birch, Tiwantree, black-cherry and alder. Once the suppressed stems of Corsican Pine have been eliminated from the stand at around the age of 35 to 40 years, and subsequent thinning affects the upper canopy, the broadleaved seedlings encounter the environmental conditions for firm establishment. As the stands are further opened up, the broadleaved plants increase in number and in size. Red oak especially thrives in these conditions.

2. In other cases, Corsican Pine stands have an under storey almost exclusively composed of American bird-cherry, a species characterized by its ability to spread very quickly over considerable areas, making the establishment of other broadleaved species quasi impossible.

Nowadays quite a controversy has arisen regarding the silvicultural value and the role of broadleaved species in homogeneous coniferous populations. They may simply be considered as soil improving agents and be managed as such. This is especially true in the case of black-cherry, as it contributes in a very possitive manner to the humification of the normally acid needle layer in the Pine stands. It represents, however, also a very big desadvantage in that its growth after the felling of the Pine stand becomes so vigorous, that continuous cleaning is required for many years in the newly established plantations, unless chemical products are used.
Although the opinion prevails that the desadvantages of such a broadleaved lower canopy outweigh the advantages, the question still remains if the final result of 60 years of soil improvement doesn't take precedence over the short-term drawbacks. Anyway, the principle of retaining broadleaved natural regeneration and gradually transforming the homogeneous, even-aged and uniform Corsican Pine populations into one or more different types of mixed forests, depending upon the initial stand structure, is slowly gaining popularity.
One may summarize the results of an in-depth examination of the social differentiation phenomenon in Corsican Pine stands as follows :

- Social differentiation commences at a very early stage. Ten years after the stand establishment, strata may already be distinguished.

- Independent from the original plant density, the upper canopy reaches a quasi constant stocking after 15 years, with a range of 1800 to 2500 stems per hectare, all other trees having been relegated to the middle and lower strata.

- As the growth vigour of some dominant trees diminishes, which results in their relegation to a lower storey, the total stocking of the upper canopy decreases gradually with age.

- The first thinning interventions on the lower stratum, which is almost completely eliminated by year 30. At the same time, a certain nummer of co-dominant and exceptionnally dominant stems are removed. After 35 years, the upper stratum is the densest layer and thinning within it then becomes more intensive.

- Once the upper canopy is opened up, broadleaved species infiltrate the Corsican Pine stands.

In view of these facts, and taking into account the local site conditions (for example, close spacing at planting is not essential to secure sufficient survivors to form a plantation, contrary to the condition in the tropics), it appears not necessary to start from a high plant density in the establishment phase. The smaller the planting distance, the more trees will be relegated to the middle and lower strata. Abstract has been made again of the cost-benefit ratios, since no comparative figures were available on this subject at the time of the study.
Up to now only little attention has been paid to the natural phenomenon of broadleaved species penetration in the homogeneous Pine populations. It offers, however, a valuable starting point for transforming the Corsican Pine stands into different types of mixed coniferous-broadleaved forests.
The development of the stands can be manipulated by silvicultural intervention. For example, the character of a thinning operation not only has a decisive impact on the stand structure, but also influences the growth vigour of the trees and the value of the end product. Moreover, it also affects the stand stability and the degree of invasion by broadleaved species.
The most important conclusion to be drawn from the study of the social differentiation phenomenon in Corsican Pine stands concerns the management, and the objectives of the management of the latter. It has been stated that social differentiation occurs already at a very early stage and is quite explicit : the upper canopy may contain up to 1800 to 2500 trees in a first phase, which far exceeds the number that will eventually form the mature stand. Not all of these stems, however, possess the required characteristics : they are either not of sufficient quality or, through heriditary features, show a tendency towards relegation to lower storeys. It is thus evident that silvicultural treatment must be initiated at a very early stage and must favour in the first place the top quality stems with the highest growth vigour, excluding wolf trees that inhibit the normal development of surrounding plus-trees and should thus be removed. This management objective cannot apply to all elements of the upper canopy, since these are much too numerous and do not all meet the required quality standard.

Only in this manner can the formation of stands with a basal area of 30 to 40 m^2 at year 20, or with a stocking level of 1900 trees per hectare at 35 years, be avoided. Such a management planning will also prevent the present instability of the stands between 15 and 35 years, which allows now only for low intensity thinning in the lower strata.
As very little variation in site quality/potential is present and as the spatial distribution of the quality phenotypes is found to be quite regular (Coppin P., Lust N., 1980), the favouring of the better phenotypes immediately concentrates the volume increment on the most valuable trees, leading simultaneously to a bigger diameter and a shorter rotation period. The nature and the timing of such thinning operations will also produce earlier and better establishment conditions for the regeneration of broadleaved species, so that the possibility of eventually transofrming the homogeneous, even-aged and uniform Corsican Pine stands into mixed coniferous-broadleaved or even broadleaved forests, becomes even more viable.

3. The Quality Assessment of the Corsican Pine Stands

A management scheme is meaningful only, when it takes into account actual and potential stand quality data.
Not withstanding specific technological properties of their wood, the quality of individual trees is assessed by means of a visual appraisal of external morphological characteristics. The following are examined in particular :

1. The stem form : curvature, angularity of the stem and butt sweep are considered significant shortcomings.
2. The crown symmetry, where above all things attention is paid to a potential risk of eventual single-sided crown development.
3. The branch habit : both the number of branches per branch whork and the thickness of the branches are accounted for; the branch angle, however, is not considered.
4. The form of the leading shoot is of special importance in young populations : the occurence of forked and/or crooked leaders represents a serious drawback.

It is evident that these factors are not afforded equal values in the overall assessment of the tree quality. A crown deformation, for example, is in most cases of less significance than a stem fault, since a timely and appropriate silvicultural intervention can in many cases counteract such a crown fault. Curvature high up on the stem hasn't the same devalorising impact as has a butt sweep. In the overall assessment, morphological faults are grouped by grade of seriousness and by eventual impact on the tree quality. The following quality classes have been distinguished :

- Good : no apparent shortcomings; excellent stem form.
- Mediocre : at the most one, not too serious defect; useful stem.
- Bad : one or more serious defects and additional less important drawbacks; stem of inferior quality.

Under the locally prevailing conditions, the financial return from the Corsican Pine stands will in the near future undoubtly be based on quality yield and no longer on overall volume production. More attention should therefore be paid in the management planning to quality control, even in species that meantime do not have a high commercial value, as is the case here. The ultimate goal in the management of the Corsican Pine stands should be the production of good quality sawnwood

Existing stand composition and present marketing possibilities offer outlets for different size classes. Sawbogs with a minimum circumference of 70 cm can be produced from age 50 to 55 on, where stocking is 580 to 780 trees per hectare. From age 60 to 65 on, with a stocking of 325 to 435 trees per hectare, logs with a minimum circumference of 90 cm can be extracted. Large sawlogs, with circumference exceeding 120 cm, will be produced at age 80, the stocking then being roughly 200 trees per hectare. More intensive thinning in the upper canopy, which to date has not been practiced, will expedite the attainment of these treshold dimensions for the different sawnwood classes, with bigger dimensions being reached in the mature stands than can be expected under the present management scheme.

The quality assessment of the Corsican Pine population in " Het Pijnven " gave in general good to very good results as demonstrated in Table 5. A sizeable number of good stems is always present. Some stands are even of excellent quality (for example plot 24), others are of relatively low quality (plot 40).

Table 5. The quality distribution in the sample plots

Nr	Age	Good		Mediocre		Bad	
		N/ha	%	N/ha	%	N/ha	%
1	11	3800	63	1200	20	1000	17
2	13	3300	69	1100	23	400	8
3	14	2900	64	1100	24	500	12
4	15	3500	66	1200	23	600	11
5	17	5800	63	2000	22	1400	15
6	18	4000	73	1100	20	400	7
7	18	3700	73	900	18	500	9
8	18	5600	90	500	8	100	2
9	19	4400	63	1600	23	1000	14
10	19	5000	60	1800	21	1600	19
11	22	5400	71	1800	24	400	5
12	23	2350	84	300	11	150	5
13	26	1600	73	550	25	50	2
14	26	3900	90	250	6	200	4
15	27	1400	74	450	23	50	3
16	27	2150	80	350	13	250	7
17	29	1750	87	250	13		
18	29	1700	76	550	24		
19	29	1600	82	350	18		
20	29	1400	82	300	18		
21	31	1950	76	500	20	100	4
22	34	1500	91	150	9		
23	34	1800	82	350	16	50	2
24	34	1900	97	50	3		
25	34	1500	94	100	6		
26	34	1750	83	300	14	50	3
27	36	1800	84	350	16		
28	37	2200	94	150	6		
29	39	1350	82	300	18		
30	39	780	75	180	17	80	8
31	40	680	91	100	9		
32	40	780	87	120	13		
33	40	920	75	280	23	20	2
34	43	1240	86	200	14		
35	43	1400	95	80	5		
36	44	840	98	20	2		
37	44	880	88	120	12		
38	45	820	89	100	11		
39	45	940	89	120	11		
40	47	400	69	140	24	40	7
41	63	330	85	60	15		
42	63	480	77	140	23		
43	63	300	86	50	14		
44	63	280	81	70	19		
45	63	310	82	50	13	20	5
46	65	500	86	80	14		

More insight can be gained by appraising the quality distribution by age class, as is done in Table 6.

Table 6. The quality distribution by age class

Age Class	Average age	Good		Mediocre		Bad	
		N/ha	%	N/ha	%	N/ha	%
10/19	16.2	4200	68	1250	20	750	12
20/29	26.7	2335	79	515	17	110	4
30/39	35.2	1653	86	243	13	28	1
40/49	43.1	890	87	128	12	6	1
60/65	63.3	367	82	75	17	3	1

The growing stock of age class 10-19 is of excellent quality, as the figures above prove : 4200 stems per hectare or 68 % of the total number of trees were assessed as good. In table 5, however, two remarkable phenomena catch the eye :

1. Although plots 1,2 and 3 were established with selected plant material in a 1.25 x 1.25 m pattern, the percentage of good quality stems in relation to the total stocking is rather on the low side. However, a minimum of 2900 good trees, being the equivalent of the total stocking after 25 to 30 years, is still a very high number and largely sufficient in regard to the management objectives. Relative figures may thus be deceiving. Only absolute numbers are meaningful in this context.

2. With 90 %, or 5600 stems per hectare, of its total stocking of good quality, plot 8 excels all others. No valid explenation has been found for this exceptional figure.

As the trees grow, the absolute number of good quality stems decreases while the relative figure, or percentage of the total stocking, increases. This is a completely natural evolution, since good stems are also removed during thinning operations and since for various reasons other good stems are later relegated to lower quality classes. The specific influence of both phenomena and their interrelationship is unknown at this stage and should be the objects of further study.
Table 5 indicates that at 30 years there are already stands, in which more then 90 % of the stock is of good quality. This is even more so in age class 40-49. In the 60 to 65 year old populations, however, the percentage is somewhat lower than expected under this tendency. The explanation for this has to be sought in the origin of the stands.

The records show that the 63 and 65 year old stands belonged originally to mixed populations of Scotch and Corsican Pine. At the outset, the Scotch Pine grew faster than the Corsican Pine. It, however, never attained total dominance. The Corsican Pine caught up at a later stage and suppressed the Scotch Pine. The latter was then gradually eliminated in the succeeding thinning operations. This intimate mixture in the juvenile phase was the cause of heavy interspecific competition. Although the Scotch Pine initially got the upper hand, a fact that certainly didn't improve the growing conditions for the Corsican Pine, it was never able to eliminate the latter from the mixed stand and neither did the vigour of the Corsican Pine suffer at a later stage. Today, only the form of the remaining Corsican Pine stems gives evidence of the earlier heavy competition between this rather tolerent species and the Scoch pine, an extreme light-demanding species.
As was the case with the stocking figures, an exponential function of the form $y = a.e^{bx}$ may represent the quantitative evolution of the good quality stock with age. The stand quality assessment figures, based upon the observations made in the respective sample plots, lead to the following equation. (figure 2).

$$y = 9015.4 \; e^{-0.032\,x} \qquad \text{with } r = 0.93$$

As is reflected by the value of the correlation coefficient of the relevant linear equation, the relationship between the percentage of good quality trees in relation to the total stocking and the age is less evident :

$$y = 60.01 + 0.67\,x \qquad \text{with } r = 0.45 \text{ and } F = 28.42$$

As such, 90 % of the trees would be of good quality at 50 years.

A closer look at age class 20-29 in Table 5 reveals a couple of conflicting figures, at first view unexplainable with the above-cited equations. At the moment of data collection (1976) the total stocking of plot 14 amounted to 4350 stems per hectare with a mean diameter at breast height of 9.7 cm and a basal area of 34.1 m^2. The respective figures for plot 15, however, were 1900 stems per hectare, a mean diameter of 14.4 cm and a basal area of 32.6 m^2, 90 %, a 3900 trees per hectare, of the population in plot 14 were of good quality, while this was only the case for 74 % or 1400 trees per hectare in plot 15.
When taking into consideration the origin of these stands, - plot 14 was directly hand -sown in 1950, while plot 15 was established the more common way with one year old nursery plants in 1949 -, a comparison of the figures might suggest that stand establishment by sowing should be recommended. The absence of similar parallel observations, however, does not permit more definite conclusions. A fact is that both sown and planted stands contain more then enough good quality elements.
It is evident that in the stand quality appraisal, attention is paid in the first place to the number of good trees. When sufficient good material is present, the role of the mediocre and bad stems becomes secondary, and their number of no practical importance with regard to the ultimate management objectives.

Bad trees occur rarely. Even in very closed, unmanaged populations they total less than 20 % of the stock, as is the case in plots 5 and 10 (Table 5). Their number is quickly and drastically reduced by the nature of the first thinning operations, which, as said before, concentrate on the lower strata. After at the most 3 interventions, which are planned in the beginning on a 3-yearly basis, almost all bad elements have been eliminated. Nevertheless, a few bad stems are always present at later development stages.
The group pf mediocre trees, characterized by minor morphological defects, never attain significant proportions and is also eliminated quite rapidly in the succeeding thinning operations. They do not influence the total value of commercial thinning products in a significant way : or they occur in too small numbers, or their shortcomings are of no importance for the wood industry (pulpwood). Moreover, the defects are located mostly in the crowns, so that they have only little impact on the wood quality. Trees with butt sweep, although classified as bad, still occur sporadically in the older populations. As long as they do not impede the development of the plus-trees, they are usually preserved.

4. The Relationship between Social Position and Quality in Corsican Pine Stands

The number of good quality stems in itself cannot be considered a sifficiently indicative parameter for the global stand quality assessment, especially not in homogeneous, even-aged stands. An analysis of the quality distribution within the social strata is essential. Therefore the relevant basic data has been assembled in Tables 7,8,9 and 10.

A close examination of these tables leads to some interesting conclusions. In the age class 10-19, barely 34 % of the good quality stock is found in the upper canopy, while 56 % belong to the middle storey. Moreover 41 % of the bad elements (including wolf trees) are found in the dominant stratum, against 28 % in the suppressed stratum (Table 8). 64 % of the dominant trees, totalling 1410 stems per hectare or 23 % of the total stock, are of good quality : 22 % of the dominant trees are of mediocre quality and the other 14 % are bad. Most plants, however, belong in their juvenile phase, before any silvicultural interventions, to the good co-dominant class, representing 38 % of the total stock (Table 10).
It is obvious that the upper canopy contains relatively few good elements at the juvenile stage, since these belong for the greatest part to the co-dominant stratum. At the same moment, must bad trees are dominant elements and are not found, as one might expect, in the suppressed storey. The first thinning operations should thus remove 36 % of the upper canopy stocking, representing 780 mediocre and bad trees per hectare.
The relative concentration of the good elements in the upper canopy increases with age because of silvicultural treatment. After 39 years, 53 % of the total number of good quality trees can already be found in the upper canopy, a figure that increases to 75 % at 63 years, then representing 275 stems per hectare. This means that 20 % of the original stocking of this stratum (1410 trees per hectare) has remained. In the mean while, decrease in the absolute number of good trees is especially evident in the lower strata : the 430 good stems, present in the suppressed stratum at age 16, have all but desappeared after 60 years and the number of good elements in the co-dominant storey has fallen from 2360 at 16 years to 92 at 63 years, which is only 4 % of the initial figure (Table 8).

Table 7. The social stratification of the good trees in the sample plots

Nr	Age	good trees N/ha	Dominant		Co-dominant		Suppressed	
			N/ha	%	N/ha	%	N/ha	%
1	11	3800	1200	32	2200	58	400	10
2	13	3300	1100	33	1900	58	300	9
3	14	2900	1100	38	1700	59	100	3
4	15	3500	1000	29	2400	68	100	3
5	17	5800	2000	34	3600	62	200	4
6	18	4000	1900	48	1900	48	200	5
7	18	3700	1300	35	2300	62	100	3
8	18	5600	1900	34	3000	54	700	12
9	19	4400	1800	41	1800	41	800	18
10	19	5000	8000	16	2800	56	1400	28
11	22	5400	2500	46	2100	39	800	15
12	23	2350	1200	51	1000	43	150	6
13	26	1600	500	31	900	56	200	13
14	26	3900	1850	47	1750	45	300	8
15	27	1400	650	46	750	54		
16	27	2150	700	33	1400	65	50	2
17	29	1750	750	43	1000	57		
18	29	1700	950	56	750	44		
19	29	1600	650	41	950	59		
20	29	1400	700	50	600	43	100	7
21	31	1950	650	33	1300	67		
22	34	1500	600	40	900	60		
23	34	1800	1050	58	750	42		
24	34	1900	1700	89	200	11		
25	34	1500	750	50	750	50		
26	34	1750	950	54	800	46		
27	36	1800	700	39	1100	61		
28	37	2200	800	36	1400	64		
29	39	1350	1050	78	300	22		
30	39	780	460	59	320	41		
31	40	680	340	50	340	50		
32	40	780	460	59	320	41		
33	40	920	480	52	440	48		
34	43	1240	480	39	740	60	20	1
35	43	1400	620	44	740	53	40	3
36	44	840	540	64	300	36		
37	44	880	460	52	420	48		
38	45	820	500	61	300	37	20	2
39	45	940	540	57	400	43		
40	47	400	340	85	60	15		
41	63	330	260	79	70	21		
42	63	480	260	54	220	46		
43	63	300	200	67	100	33		
44	63	280	250	89	30	11		
45	63	310	260	84	50	16		
46	65	500	420	84	80	16		

Table 8. The social stratification of the quality classes by age class

Age Class	Average Age	Quality	N/ha	Dominant		Co-dominant		Suppressed	
				N/ha	%	N/ha	%	N/ha	%
10/19	16.2	good	4200	1410	34	2360	56	430	10
		mediocre	1250	470	38	480	38	300	24
		bad	750	310	41	230	31	210	28
20/29	26.7	good	2325	1045	45	1120	48	160	7
		mediocre	515	190	37	275	53	50	10
		bad	110	40	36	40	36	30	8
30/39	35.2	good	1653	871	53	782	47		
		mediocre	243	97	40	146	60		
		bad	28	7	25	19	68		7
40/49	43.1	good	890	476	53	406	46	8	1
		mediocre	128	40	31	78	61	10	8
		bad	6	4	67	2	33		
60/65	63.3	good	367	275	75	92	25		
		mediocre	75	57	76	18	24		
		bad	3	3	100				

Table 9. The quality distribution within the upper canopy of the sample plots

Nr	Age	Good			Mediocre			Bad		
		N/ha	% of Ndom	% of Ntot	N/ha	% of Ndom	% of Ntot	N/ha	% of Ndom	% of Ntot
1	12	1200	55	20	600	27	10	400	18	7
2	13	1100	73	23	300	20	6	100	7	2
3	14	1100	53	24	700	33	16	300	14	7
4	15	1000	53	19	600	31	11	300	16	6
5	17	2000	84	22	200	8	2	200	8	2
6	18	1900	76	34	400	16	7	200	8	4
7	18	1300	62	25	500	24	10	300	14	6
8	18	1900	79	31	400	17	6	100	4	2
9	19	1800	60	26	600	20	8	600	20	8
10	19	800	44	9	400	22	5	600	33	7
11	22	2500	78	33	600	19	8	100	3	1
12	23	1200	92	43	50	4	2	50	4	1
13	26	550	73	25	150	20	7	50	7	2
14	26	1850	80	43	300	13	7	150	7	3
15	27	650	65	34	300	30	16	50	5	3
16	27	700	93	25	50	7	2			
17	29	750	88	38	100	12	5			
18	29	950	95	42	50	5	2			
19	29	650	81	33	150	19	8			
20	29	700	82	41	150	18	9			
21	31	650	76	25	150	18	6	50	6	2
22	34	600	92	36	50	8	3			
23	34	1050	88	48	150	12	7			
24	34	1700	97	87	50	3	3			
25	34	750	100	47						
26	34	950	76	45	300	23	15			
27	36	700	88	33	100	12	4			
28	37	800	94	34	50	6	2			
29	39	1050	91	64	100	9	6			
30	39	460	92	44	20	4	2	20	4	2
31	40	350	90	45	40	10	5			
32	40	460	92	51	40	8	5			
33	40	480	86	39	60	11	5	20	3	2
34	43	480	100	33						
35	43	620	100	42						
36	44	540	96	63	20	4	2			
37	44	460	88	46	60	12	6			
38	45	500	89	54	60	11	7			
39	45	540	96	51	20	4	2			
40	47	340	74	59	100	22	17	20	4	3
41	63	260	90	67	30	10	7			
42	63	260	68	42	120	32	19			
43	63	200	83	57	40	17	12			
44	63	250	83	71	50	17	14			
45	63	260	81	68	40	13	11	20	6	5
46	65	420	88	72	60	12	11			

Table 10. The quality distribution within the social strata by age class

Age Class	Average age	Social Stratum	Good			Mediocre			Bad		
			N/ha	% of Nstrat	% of Ntot	N/ha	% of Nstrat	% of Ntot	N/ha	% of Nstrat	% of Ntot
10/19	16.2	Upper Canopy	1410	64	23	470	22	7	310	14	5
		Middle Canopy	2360	77	38	480	16	8	230	7	4
		Lower Canopy	430	46	7	300	32	5	210	22	3
20/29	26.7	Upper Canopy	1045	82	36	190	15	7	40	3	1
		Middle Canopy	1120	78	38	275	19	0	40	3	1
		Lower Canopy	160	67	5	50	21	2	30	12	1
30/39	35.2	Upper Canopy	871	89	45	97	10	5	7	1	0
		Middle Canopy	782	83	41	146	15	8	19	2	1
		Lower Canopy							2	100	0
40/49	43.1	Upper Canopy	476	91	46	40	8	4	4	0	1
		Middle Canopy	406	84	40	78	16	7	2	0	0
		Lower Canopy	8	44	1	10	56	1			
60/65	63.3	Upper Canopy	275	82	62	57	17	13	3	1	1
		Middle Canopy	92	84	20	18	16	4			
		Lower Canopy									

The percentage of good stems in relation to the total dominant stock rises quickly from 64 % in the untreated stands to 82 % after one decade of silvicultural interventions and subsequently stabilizes quite rapidly around 90 % (Table 10).
Table 9 indicates that a maximum of 2000 dominant trees per hectare, or 84 % of the upper canopy stocking, can be considered of good quality in young untreated stands (plot 5), the corresponding minimum figure being 800 stems per hectare or 44 % (plot 10). Already after 35 years, all dominant trees may be of good quality (plot 25), but it is also possible that their number remains restricted at a 76 % level (plot 26). It is also obvious that the stands, that were established in mixture with the Scotch Pine, are of inferior stand quality (plots 41 to 46). While the percentage of good dominant trees is expected to total 95 to 100 % at this age, only 82 % of the dominant stems live up to this expectation.
A mathematical relationship between age and the total number of good dominant or co-dominant stems can be established in the same way as has been done for the different social and quality strata. In this care, the equations are the following (see also Figure 2) :

$y = 2384\ e^{-0.0348x}$ with $r = 0.83$ for good dominant elements

$y = 4251\ e^{-0.0534x}$ with $r = 0.83$ for good co-dominant elements.

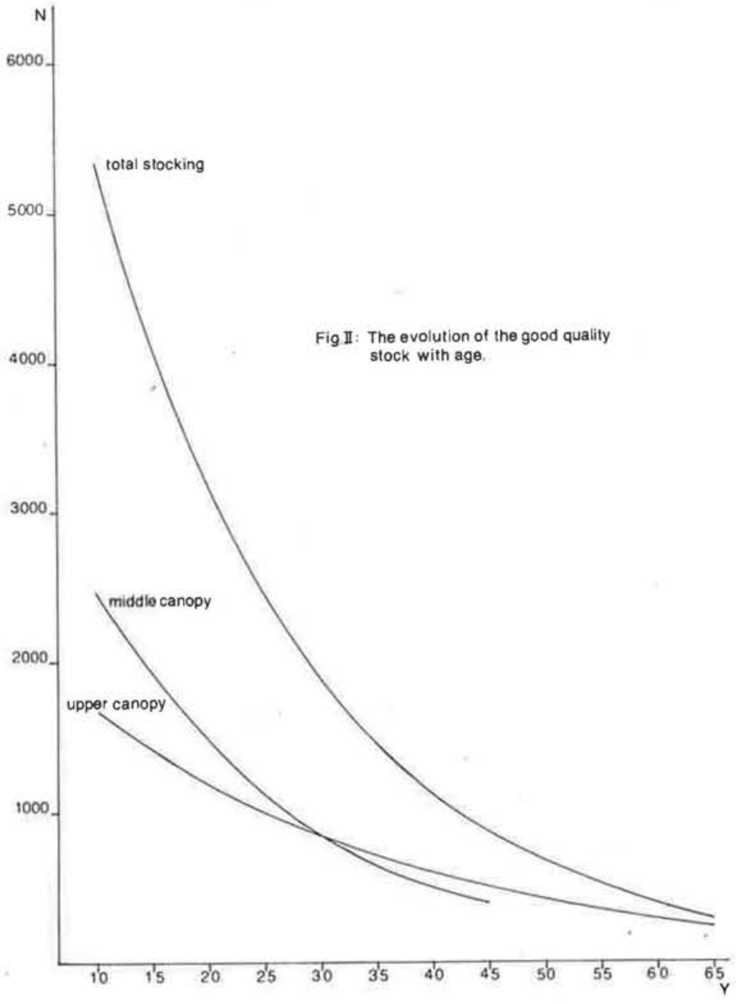


Fig II: The evolution of the good quality stock with age.

In " Het Pijnven " , it is customary to prune 500 stems per hectare at 32 years. The decision which trees to prune isn't a difficult one, since there are still more than 800 good dominant stems at that age. The present management planning also provides for a further pruning of 300 trees at 65 years. There are, however, only 250 good dominant trees left at this age, so 50 good elements of the middle storey will have to be included. Both dominant and co-dominant trees will thus be pruned. About all upper canopy trees will be part of this, since stems of mediocre and bad quality are very rare in this stratum at this age.
The Corsican Pine stands will produce the first sawnwood at an age of 50 to 55 years. After 50 years, 86 % of the stock, or 669 trees per hectare, are of good quality. Thereof, 63 % or 410 belong to the upper canopy. Ten years later, there remain 398 good stems per hectare, representing 92 % of the total stock. The dominant stratum accounts for 74 % of those, being the equivalent of 296 stems per hectare. After 80 years, about 200 trees per hectare will produce sawnwood logs of big dimensions, practically all stems being of good quality and belonging to the upper canopy.
A comparison between pruning habits and possible sawnwood production schemes proves that :

- The first pruning operation is carried out 18 years before any eventual sawnwood exploitation. Fewer stems are pruned than the number of trees that reach the lower limit for sawnwood dimensions at age 50 to 55. A question arises as to the advantage of pruning 800 stems at once, including all good elements of the dominant storey.

- A second pruning operation is planned at age 65, 15 years before the exploitation of any sawnwood logs of bigger dimensions. At this stage, more stems will be pruned than the number of trees that will eventually produce these heavy sawnwood logs at 80 years. A decision to restrict this second pruning operation to 250 trees, encompassing all good elements of the upper canopy, is obvious.

5. Summary and Conclusions

A detailed study of the stand composition of Corsican Pine populations on coarse sands reveals in the first instance the very early start of the social differentiation phenomenon. The latter subsequently proceeds in a decisive manner and remains vigorous even in the older populations. It can be said that the 130 trees per hectare of the envisaged mature 100 year old stand will almost all originate from the highest diameter classes of the 10 to 19 year old populations. The quality of the Corsican Pine stands may generally be assessed as excellent. The 10 to 19 year old stands already contain 4200 good quality stems per hectare, of which 34 % or 1410 trees are found in the upper canopy. The first silvicultural interventions are mainly low thinning operations involving the removal of the suppressed stratum and a major part of the co-dominant elements. Their positive impact on the quality distribution is demonstrated early : while the share of the good quality class within the dominant storey is only 64 % in the untreated 10-19 age class, it increases to 90 % of the dominant stock after the interventions. With the increasing intensity of the thinning and the gradual inclusion of the upper storey, conditions are created which favour the establishment of broadleaved species within the homogeneous Corsican Pine plantations.

To make the production of high quality sawnwood feasible , both thinning and pruning operations are deemed necessary in Corsican Pine stands. To this extent the question arises as to wether a change in the presently applied pruning schedule is required, with pruning at age 32 of 800 trees instead of 500, and 250 trees at age 65 instead of 300. As such, all good elements of the upper stratum will be pruned at both occasions.
The main conclusions of this study, however, concern the necessity of commencing silvicultural treatment at the very early stage of stand development, certainly before 20 years as is now the case, and of redefining the nature of the interventions, which should be aimed at improving the growing environment of the plus-trees in the upper canopy. From the canopy closure on, both the upper canopy and the lower strata should be subjected to thinning operations. The selection system in the dominant stratum have a positive character, which means that selected plus-trees have to be favoured by all means. Thinning of the middle and lower strata must nevertheless also be biased towards the same goal : improving the growing environment of these trees, that have been earmarked to form the tree population, from which the mature stand eventually will emerge.

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