Recebido em 6 de Outubro de 1986

# Thinning strategies for maritime pine (*Pinus pinaster* Ait.) in Portugal

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## *SYNOPSIS*

To establish a thinning strategy for maritime pine stands (*Pinus pinaster* Ait) basal area, Wilson relative spacing index (WILSON, 1946), Reineke spacing density index (REINEKE, 1933) and Curtis relative density (CURTIS, 1982) are compared. Reineke's index was chosen to elaborate a field guide for thinnings in maritime pine stands.

## *RÉSUMÉ*

Pour établir une strategie pour l'eclaircie des peuplements de pin maritime (*Pinus pinaster* Ait.) on compare la surface terrière, le facteur d'espacement de WILSON (WILSON, 1946), l'indice de Reineke (REINEKE, 1933) et l'indice de densité de CURTIS (CURTIS, 1982). L'indice de Reineke est choisi pour la construction d'un guide d'eclaircie d'application pratique.

## 1. INTRODUCTION

The absence of a permanent plot network with more than 20 years covering the national territory of Portugal, justifies the use of thinning models for maritime pine (*Pinus pinaster* Ait.) based on empirical indexes with practical application like the Wilson relative spacing index (WILSON 1946), the Reineke spacing density index (REINEKE, 1933) and Curtis relative density (CURTIS, 1982).

In the 1970 years the Wilson relative spacing index was used in Portugal but soon abandoned. This paper proposes the use of spacing density index (REINEKE, 1933) for the establishment of thinning regimes for maritime pine.

## 2. MATERIAL AND METHODS

The measurement of 57 temporary plots, in pure and even-aged stands of maritime pine, naturally regenerated, in Central and North Portugal, where the previous thinning regime was unknown, lead the author to present a variable density yield model (CARVALHO OLIVEIRA, 1985) where the proposed thinnings follow the *C/D* and *D* grades according to HUMMEL *et al.* (1959).

The 57 sample plots where rectangular with variable size, covering the best maritime pine area of Portugal, between 100 and 800 m altitude in granit and schist incipient soils. In the area a real oceanic climatic influence is evident, with more than 1200 mm of annual precipitation, a mean annual temperature between 10°C and 15°C, mild winters and a drought summer pause shorter than three months. The natural forest vegetation is dominated by pedunculate oak (*Quercus robur* L.)

In the last five years some permanent plots for thinning experiments have been established. In the present work we also use data of two sets of twelve plots each, where three different grades of low thinning were applied.

## 3. RESULTS AND DISCUSSION

### 3.1. *WILSON RELATIVE SPACING INDEX ($F_W$)*

The different expressions of relative stand density are useful if not correlated with age *(t)* and site index *(S)*. Then they can be used for a practical definition of thinning regimes and the description of competition levels (CURTIS, 1982), as for stand modeling.

According to the above mentioned yield model for maritime pine, for practical use, the best thinning regime appears to be the $D$ grade ($F_W = 0.23$) when naturally regenerated stands and average site quality stands are considered. However its application as field guide is not satisfactory. The assumption of independence from site quality does not hold for the less productive sites, namely where drought and poor soil conditions dominate as shown in Table 1.

TABLE 1 — *$F_W$ and basal area (G) in sample plots numbers* 83, 103, 35 *and* 30.

| PLOTS | $t$ | $h_{dom}$ (m) | $S$ | $N$ | $d_g$ (cm) | $F_W$ | $G$ ($m^2$/ha) |
|---|---|---|---|---|---|---|---|
| 83 | 34 | 15.8 | $I_{16}$ | 1140 | 20.16 | 0.187 | 36.39 |
| 103 | 25 | 15.5 | $M_{20}$ | 1180 | 14.42 | 0.189 | 19.27 |
| 35 | 13 | 10.0 | $S_{24}$ | 3080 | 11.84 | 0.180 | 33.91 |
| 30 | 14 | 9.8 | $M_{20}$ | 2880 | 8.27 | 0.190 | 15.47 |

**t** – age; **$h_{dom}$** – top height (100 dickest tree per hectare);
**S** – site index in meters with 40 years; **N** – number of trees by hectare;
**dg** – diameter of the mean basal area tree.

In any of the two combinations for equal $F_W$ values we found totally different competition levels. Basal area *(G)* varies twice according the differents site quality and age of the stands.

### *3.2. BASAL AREA*

The different values of maximal basal area ($G_{max}$), optimal basal area ($G_{opt}$) and critical basal area ($G_{crit}$), according ASSMANN (1961), are not known for *P. pinaster* in Portugal. Therefore the thinning guides will not take into account the maximal yield capacity of the different forest sites.

TABLE 2 — *Extreme values for basal area* (G) *in yield table sample plots data and two thinning experiments (plots* V/XII *and* 1/8*)*.

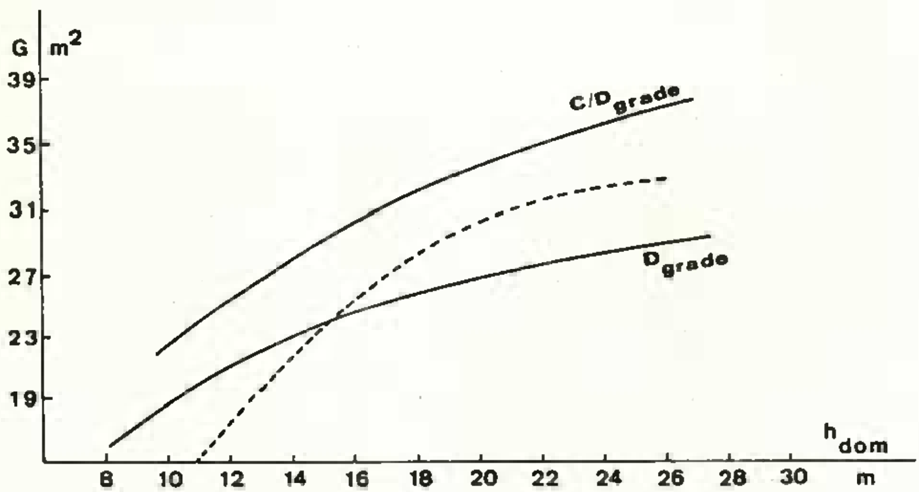
| PLOT | $t$ | $h_{dom}$ (m) | $N$ | $S$ (40 years) | $d_g$ (cm) | $G$ (m²/ha) | $F_W$ | $SDI$ | $RD$ |
|---|---|---|---|---|---|---|---|---|---|
| 33 | 13 | 8.80 | 3700 | $M_{20}$ | 11.16 | 36.20 | 0.19 | 1014 | 18.87 |
| 35 | 13 | 10.00 | 3080 | $S_{22}$ | 11.84 | 33.91 | 0.18 | 928 | 17.40 |
| 21 | 15 | 10.70 | 2560 | $M_{20}$ | 12.57 | 31.77 | 0.18 | 849 | 16.04 |
| 108 | 25 | 16.40 | 1120 | $M_{20}$ | 21.07 | 39.09 | 0.18 | 851 | 17.13 |
| 83 | 34 | 15.80 | 1140 | $I_{16}$ | 20.16 | 36.39 | 0.19 | 807 | 16.17 |
| 101 | 37 | 16.50 | 1030 | $I_{16}$ | 22.48 | 40.88 | 0.19 | 868 | 17.64 |
| 13 | 38 | 21.50 | 620 | $S_{22}$ | 29.65 | 42.81 | 0.19 | 815 | 17.14 |
| 133 | 41 | 19.70 | 740 | $M_{20}$ | 25.99 | 39.26 | 0.19 | 788 | 16.29 |
| 118 | 41 | 19.20 | 850 | $M_{20}$ | 24.12 | 38.84 | 0.18 | 802 | 16.44 |
| 18 | 58 | 27.60 | 360 | $S_{24}$ | 40.23 | 45.76 | 0.19 | 772 | 16.88 |
| 30 | 14 | 9.80 | 2880 | $M_{18}$ | 8.27 | 15.47 | 0.19 | 488 | 12.40 |
| 86 | 15 | 10.50 | 2200 | $M_{18}$ | 10.02 | 17.33 | 0.20 | 507 | 9.30 |
| 96 | 15 | 12.00 | 1600 | $M_{20}$ | 12.43 | 19.41 | 0.21 | 521 | 9.83 |
| 103 | 25 | 15.50 | 1180 | $M_{18}$ | 14.42 | 19.27 | 0.19 | 488 | 9.37 |
| 109 | 26 | 18.30 | 820 | $S_{22}$ | 18.8 | 22.76 | 0.19 | 519 | 10.31 |
| 57 | 48 | 21.20 | 500 | $M_{20}$ | 24.94 | 23.56 | 0.21 | 498 | 9.89 |
| V | 20 | 12.59 | 4300 | $I_{18}$ | 10.35 | 36.20 | 0.121 | 1049 | 19.26 |
| XII | 20 | 10.78 | 3390 | $I_{16}$ | 9.83 | 25.74 | 0.159 | 716 | 13.89 |
| 1 | 22 | 8.90 | 4850 | $I_{14}$ | 10.20 | 39.90 | 0.16 | 1150 | 21.31 |
| 8 | 22 | 8.08 | 4150 | $I_{14}$ | 8.90 | 25.80 | 0.19 | 791 | 14.30 |

Figure 1 shows the change in basal area *(G)* with top height

($h_{dom}$) according *P. pinaster* yield tables (CARVALHO OLIVEIRA, 1985) for grade *C/D* and *D*.

The difference between these yield table curves and the one produced by the Portuguese Forest Service is the national scope of the last one. In fact in the two permanent plot experiments recently installed, naturally regenerated stands with 20 and 22 years of age respectively, basal area varies between 25.74 and 39.90 $m^2/ha$. In absence of more precise information about maximal basal areas ($G_{max}$) for naturally regenerated stands of maritime pine in Central and North Portugal we present in Table 2 the plots with maximal and minimal basal areas between the 56 samples used for the maritime pine yield table (CARVALHO OLIVEIRA, 1985) and the two permanent plot experiment we already refered.

FIGURE 1 — *Relation between G and $h_{dom}$ for P. pinaster yield tables. Dashed line the mean for all Portugal, between 7 and 27 meters according the* FOREST SERVICE (D.G.O.F. 1983).




While in Portugal, for *P. pinaster*, *G* values greater than 45.76 $m^2/ha$ have not been reported, in South Africa, VAN LAAR (1985) refers 87.6 $m^2/ha$ and 82.6 $m^2/ha$ in stands 35 and 39 years old respectively. Unlike Portugal the South Africa plots in Lottering are however locatted in a region without summer drought.

Although we don't know the past of our plots what concerns intermediate cuttings (cleannings and thinnings) also in that case the influence of site index in mean diameter *(dg)* and basal area *(G)* is clear. Regarding these, specially attention must be paid, Table 2, to the following pairs of plots: 86 and 21, 1 and 8, *V* and *XII*.

### *3.3. REINEKE STAND DENSITY INDEX (SDI)*

Presented by REINEKE (1933) his aplicability to european species was tested by DANIEL and STERBA in 1980. For our plots *SDI* was calculated as follows

$$SDI = N(25/dg)^{-1.605}$$

where $N$ – number of trees per hectare; $dg$ – the mean diameter. In fact by the adjustement of REINEKE's equation, Table 3,

$$\ln N = b_0 + b_1 \cdot \ln d$$

to sample plot data used for construction of *P. pinaster* yield table (CARVALHO OLIVEIRA, 1985) we found $b_1$ values about – 1.6.

TABLE 3 — REINEKE*'s equation* (1933) *for sample plot data in P. pinaster yield Table* (CARVALHO OLIVEIRA, 1985).

| | | | $r^2$ |
|---|---|---|---|
| YIELD TABLE | D-GRAD | $\ln N = 11.55 - 1.641 \ln d$ | 0.99 |
| | C/D-GRAD | $\ln N = 11.69 - 1.606 \ln d$ | 0.99 |
| SAMPLE | all | $\ln N = 11.42 - 1.516 \ln d$ | 0.925 |
| PLOT DATA | plots with maximal G | $\ln N = 12.40 - 1.769 \ln d$ | 0.99 |

The maximal *SDI* value for each species gives, like maximal basal area, a good information about yield capacity of a forest stand. STERBA (1981) considers it really and alternative to basal area, avoiding age determination for his applications.

In our yield table data the maximal *SDI* value was 1014, while in our permanent plot experiments it reaches 1150 (Table 2). These values are similar to those presented by STERBA (1981) for forest trees with similar temperament and ecological requeriments like *Eucalyptus* sp with $SDI_{max}$ of 1270, *Pinus taeda* with $SDI_{max}$ of 1150 and *Pinus palustris* with $SDI_{max}$ of 1020. At the moment we are working on a field thinning guide according the methods suggested by DANIEL and STERBA (1981). This index *(SDI)* seems much more appropriated for the expression of stand density than the Wilson factor ($F_W$), Table 2, being also easier the establishment of a field routine, for generalyzed practical application. In the moment it seems already possible, for practical thinning regulation, to recomend *SDI* values between 530 *(D-Grad)* and 680 *(C/D - Grad)*, taking in account *P. pinaster* yield table (CARVALHO OLIVEIRA, 1985). Besides, in Austrian yield tables for scots pine *SDI* varies between 600 and 750.

### *3.4. STAND DENSITY INDEX (RD)*

Presented by CURTIS in 1982 for douglas-fir

$$RD = \frac{G_{obs}}{dg^b}$$

where

$G_{obs}$ – measured basal area
$dg$ – mean diameter
$b$ – coefficient

For the determination of $b$ we need the "normal" stand and following adjustements:

$$N_2 = a_0 \ (dg^c) \ \text{ or } \ G_2 = a_1 \ (dg^2) \qquad b = c + 2$$

For Douglas fir, according CURTIS (1982), $b$ oscilates between 0.3 and 0.5. The author recomends the use of 0.4 when no more information is available (b=1.605+2; b=0.395).

We tried to find the most appropriate $b$ value for maritime pine, according the indication of CURTIS (1982), it means using the concept of open-grown tree. So the adjustement of function to open-grown trees allows the

$$(C_W)^2 = a_2(d_g^{2-b})$$

$C_W$ – crown diameter of open-grown tree

calculation of $b$ to the normal stand in consequence of proportionality of $b$ coefficients in both situations. Using the field data of GOMES (1974) what concerns open-grown trees in the same region

$$\ln \ (C_W)^2 = \ln_2 + (2 - b) \ \ln \ d_g$$

$$\ln \ (C_W)^2 = -2.515921 + 1.734826 \ \ln \ d_g \qquad (r^2 = 0.85)$$

$$2 - b = 1.734826$$
$$- b = 1.734826 - 2 \qquad \therefore \qquad RD' = \frac{G_{obs}}{dg^{0.27}}$$
$$b = 0.27$$

Then it was possible to calculate $RD'$ for our data (Table 2) finding as extreme values 18.87 and 9.30 in yield model plots and 21.31 and 13.82 in the two permanent plots experiments. The extreme values we observed are greater than those proposed, for douglas-fir, by CURTIS (1982) because in our case we have a smaller $b$ coefficient. At the moment $\overline{RD}$ index is not yet being used to control the different thinning regimes at field work. We can only indicate that according *P. pinaster* yield model (CARVALHO OLIVEIRA, 1985) to *C/D Grade* corresponds a $\overline{RD}$ of 13.9 and that to *D Grade*, we found a $\overline{RD}$ of 10.8.

## 4. CONCLUSIONS

Both *RD* and *SDI* indexes seem appropriate for thinning regulation. The Stand Density Index *(SDI)* calculated with Reineke's coefficient – 1.605, gives a first approach of maximal basal area of maritime pine stands in Portugal.

It was possible to find the most appropriate coefficient for *RD* calculation based on open-grown tree crown diameter – diameter relationships. This coefficient would made possible the calculation of *SDI* for all sample plots with a new Reineke's coefficient of – 1.73 in spite of – 1.605. This new approximation turns *SDI* values for d>25 cm smaller and for d<25 cm greater than the first ones. As the relative position of all sample plots what concerns his density, in *SDI* terms, doesn't change we maintain the Reineke's coefficient (-1.605), the best solution also for comparison between different species. *SDI* index was choosed for the construction of practical field guide for thinning in maritime pine stands in Portugal.

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