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# Method SB-BARTHIN to Evaluate the Effects of Thinning An Application to *Pinus pinaster* Ait.

**Luís Soares Barreto**
Professor of Forestry
Instituto Superior de Agronomia. Tapada da Ajuda, 1349-051 LISBOA

**Abstract**. The author proposes a new method to project thinned stands, and applies it to stands of *Pinus pinaster* Ait.. First, the author isolates the sole effect of thinning in dbh and height growth. After, the author presents method SB-BARTHIN to project a stand of *Pinus pinaster*, that reflects the effects of thinning on dbh and height growth, and on the subsequent process of self--thinning. Tabulated values to apply the method to stands of the same species are displayed. The use of the method simulating a neutral thinning, a low thinning and a crown thinning is exhibited. The simulations are coherent and conform to the available knowledge, about the effects on thinnings on growth. The main conclusion about the effects of thinning on the growth of stands can be summarized in a single statement: the sole effect of thinning abides the law of diminishing returns. The author also analysis when self-thinning restarts, after thinning. Method SOBA-2 is also introduced.
**Key words:** effects of thinnings; evaluation of thinnings; *Pinus pinaster*; thinnings

**Sumário**. O autor propõe um novo método para projectar povoamentos desbastados e aplica-o a povoamentos de *Pinus pinaster* Ait. Primeiro, o autor isola o exclusivo efeito do desbaste nos crescimentos do dap e altura. Após isto, apresenta o método SB-BARTHIN para projectar um povoamento de *Pinus pinaster* que reflecte os efeitos do desbaste no crescimento do dap e da altura, e no subsequente processo de auto-desbaste. São apresentados valores tabelados para aplicar o método ao pinheiro bravo. Ilustra-se a aplicação do método na simulação do efeito de desbastes neutro, pelo baixo e pelo alto, obtendo-se resultados coerentes e de acordo com a informação disponível. A principal conclusão é a resposta dos povoamentos aos desbastes respeitar a lei dos retornos decrescentes. O autor propõe um procedimento para detectar quando o auto-desbaste se reinicia, e introduz o método SOBA-2.
**Palavras-chave**: avaliação de desbastes; desbastes; efeitos dos desbastes; *Pinus pinaster*

**Résumé**. L'auteur isole le seul effet de l'éclaircie dans la croissance des peuplements et propose une nouvelle méthode SB-BARTHIN pour prévoir les effets des éclaircies. L'application de la méthode sur les peuplements de *Pinus pinaster* est présentée. La principale conclusion sur les effets des éclaircies avancée par l'auteur est que la réponse des peuplements respecte la loi des rendements décroissants. L'auteur propose aussi une méthode pour détecter le moment où l'auto-éclaircissement recommence après une éclaircie. La méthode SOBA-2 est aussi proposée.
**Mots clés**: éclaircies; évaluation des éclaircies; effets des éclaircies; *Pinus pinaster*

## Introduction

Thinning is a very complex issue, thus it is an almost inexhaustible subject for research. Here, I also dare to incur in a simulative inquiry on the topic. I hope it may have some utility to foresters and field researchers.

The main purpose, of this paper, is to establish a general and expedite method (SB-BARTHIN) to predict the effects of thinning on the growth of forest stands. I use the application of the method to stands of maritime pine (MP; *Pinus pinaster* Ait.) to accomplish its presentation, and to obtain some insight on the effects of thinning.

In this paper, my main strategic choice is to tentatively separate the sole effect of thinning from the growth induced by the characteristic relative growth rate of the species, for the ages after thinning.

The work here disclosed is underpinned by my theory for self-thinned even-aged pure stands (SEPS) (BARRETO, 1990, 1995a), my previous paper devoted to self-thinning and thinning (BARRETO, 1994c), my simulators SPESS, SB-SOBA.MP (BARRETO, 1991a, 2000). It takes also advantage of the yield tables published by OLIVEIRA (1985) for MP stands, of JOHNSTON, GRAYSON, BRADLEY (1967), of OLIVER, LARSON (1990), and probably is influenced by several other readings of the literature dealing with MP stands and the effects of thinning on stand growth.

This paper is a revised version of BARRETO (2001).

## Symbology

From here on, the following symbology will be used:

**t** = age, years

**SEPS** = self-thinned even-aged pure stands

**ds(t)** = mean dbh of a SEPS (or of dbh class), at age t (cm)

**dt(t+10)** = mean dbh of a thinned stand (or of dbh class), 10 years after thinned

**hs(t)** = mean height of a SEPS (or of dbh class), at age **t** (m)

**ht(t+10)** = mean height of a thinned stand (or of dbh class), 10 years after thinned

**H(t)** = dominant height at age **t**

**p** = stand density (trees/ha)

**fr** = frequency of a dbh class (trees/ha)

**F** = Wilson's spacing/top height ratio

**ti** = thinning intensity measured as the fraction of trees removed

**w** = prefix to indicate a weighted mean

**Prx(t)** = a factor to project the dbh or height of a SEPS, to age t+10

**Prp(t)** = a factor to project the density of a stand (or the frequency of a dbh class) of a SEPS, to age t+10

**v** = mean tree volume (c.m.)

**V** = standing volume of a dbh class (c.m./ha)

**SV** = Sum of all V, in a stand

**Rd** = a factor that measures the sole effect of thinning, for a decade, on dbh growth

**Rh** = a factor that measures the sole effect of thinning, for a decade, on the growth of height

**SQ** = site quality

## The basic equations

Method SB-BARTHIN has two parts. The first one reproduces the effect of thinning on dbh and height growth, and has two steps. Let me introduce them.

**Step 1**. *Project the thinned stand as a SEPS, from the age of thinning **t**, to age **t+10***. To accomplish this task, in MP stands, the values of **Prx(t)** and **Prp(t)**, from table 1 are used. The equations are straightforward:

$$ds(t+10) = ds(t)\ Prx(t) \quad (1)$$

$$hs(t+10) = hs(t)\ Prx(t) \quad (2)$$

$$p(t+10) = p(t)\ Prp(t) \quad (3)$$

Now, I am in position to apply the sole effect of thinning to **ds(t+10)** and **hs(t+10)**.

**Step 2**. *Introduce the effect of thinning on dbh and height growth*. Use pre-established values of **Rd** and **Rh**, and the two following equations for this purpose:

$$dt(t+10) = ds(t+10)\ Rd \quad (4)$$

$$ht(t+10) = hs(t+10)\ Rh \quad (5)$$

After, use a pre-established equation for **v**, and the values of **dt(t+10)**, **ht(t+10).**

Here, the critical issues are:

a) The calculations of the values of **Rd** and **Rh**.

b) The self-control of the density after the thinning (part II of the method).

In the next section, I will describe how I accomplished the determination of **Rd** and **Rh**. Later, I will approach b), and I will conclude the description of the method. But before I move to the next section let me establish the basic equation I need to control the density.

Let the number of trees be dimensionless. If **L** is the linear dimension, the area occupied by a tree (**apt**) has the dimension:

$$[apt]=L^2 \quad (6)$$

Obviously, dbh has the linear dimension with power one.

If I admit that there is a relationship between dbh **d** and **apt** of the form:

$$apt=K\ d^x \quad (7)$$

where **K** is a dimensionless constant, I have x=2, and I can write:

$$apt=K\ d^2 \quad (8)$$

Now, I consider, in the same stand, two different densities $\mathbf{p_1}$, and $\mathbf{p_2}$, with average dbh, respectively, $\mathbf{d_1}$ and $\mathbf{d_2}$. Eq. (8) let me write the desired equation:

$$apt\ of\ p_2=apt\ of\ p_1\ (d_2/d_1)^2 \quad (9)$$

Given the time-space symmetry between SEPS and self-thinned uneven-aged pure stand, eq. (9) applies also to the area occupied by two different trees in the latter stand.

To verify eq. (9), the reader can use my programs KHABARD (BARRETO, 1993), KHABSOFT (BARRETO, 1994a), PINASTER (BARRETO, 1994b), SALU (BARRETO, 1995b) or US-EVEN (BARRETO, 1999b).

Eq. (8) can also be obtained using a procedure described in BARRETO (1995a; table 3).

**The establishment of Rd and Rh**

The elaborations I here developed for MP stands are conditioned by the information available to me, about this species.

To calculate **Rd** and **Rh**, I used variants of my simulator SB-SOBA.MP. I projected the unthinned stand as a SEPS (simulation 1), for the next decade. After, I projected a stand with **F** of the thinned stand for the next decade, as a SEPS (simulation 2). The uncorrected value of **Rd** or **Rh** is given by :

Rd or Rh = Value given by simulation 2/value given by simulation 1 (10)

It is known that the growth of a tree is affected by its past history, and the tree never attained the size of those that grew at the post-thinning spacing during all their lives. Thus, the value given by eq.

(10) must be corrected by a recovery factor. At the present state of my knowledge, I hypothesize that the dbh and height of the thinned stand recover 70% of the difference of sizes given by simulations 1 and 2.

For MP, the values of **Rd** and **Rh,** calculated as previously described, are exhibited in table 3.

For MP, I considered three sites: in SQ 24, the dominant height is 24 meters at age 40; in SQ 20, the dominant height is 20 meters at age 40; in SQ 16, the dominant height is 16 meters at age 40. In each site I considered three stands with F=0.19, F=0.21, F=0.23.

The thinning intensities used are ti=0.10, ti=0.15; ti=0.50. I simulated one thinning at ages 10, 15, ...40 years. The values of **F**, just after thinning, are exhibited in table 2.

I verified that the values of **Rd** and **Rh** are not affected by the age of thinning. The growth of the thinned stand is affected because it is given by the product of **Prx(t)** and **Rd** or **Rh**, and **Prx(t)** change with age.

### The effects of thinning on stand growth

The values displayed in table 3 translates the sole effect of thinning on stand growth. Let me comment on this table, before I finish the description of method SB-BARTHIN.

1. As expected, **Rd** is always greater then **Rh**, for the same SQ, **F**, and **ti**.

2. The effect of thinning (TET) changes with SQ, **F**, and **ti**.

3. For the same SQ, and **F**, the greater is **ti**, the greater is TET

4. For the same **ti** and **F**, the better is the SQ, the smaller is TET.

5. For the same SQ and **ti**, the greater is **F** (smaller density), the smaller is TET.

6. For the same **ti** and **F**, the poor is the site, the greater is TET.

7. For the same SQ and **F**, after a certain critical value of **ti**, TET remains invariable.

8. For stands with densities smaller then a critical value, TET on height growth is negligible (**Rh** in SQ 24, F=0.23).

My understanding is that the previous comments can be summarized in a single statement: *the sole effect of thinning abides the law of diminishing returns.* This fiddling is ecological sound and confers credibility to my results.

**Table 1** - The factors to project mean dbh, mean height (**Prx(t)**), and stand density (**Prp(t)**) for a period of 10 years, in SEPS of MP

| **Age** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|
| Prx(t) | 1.425 | 1.317 | 1.239 | 1.182 | 1.139 | 1.106 | 1.082 |
| Prp(t) | 0.493 | 0.577 | 0.652 | 0.716 | 0.771 | 0.817 | 0.853 |

**Table 2** - The values of **F**, just after thinning

| **ti%** | **10** | **15** | **20** | **25** | **30** | **35** | **40** | **45** | **50** |
|---|---|---|---|---|---|---|---|---|---|
| F = 0.19 | 0.200 | 0.206 | 0.212 | 0.219 | 0.227 | 0.236 | 0.245 | 0.256 | 0.269 |
| F = 0.21 | 0.221 | 0.227 | 0.235 | 0.242 | 0.251 | 0.260 | 0.271 | 0.283 | 0.297 |
| F = 0.23 | 0.242 | 0.249 | 0.257 | 0.265 | 0.275 | 0.285 | 0.296 | 0.310 | 0.325 |

To the values of **Rd**, in table 3, I fitted the following equation:

Rd=1.187426 - 2.319312E - 03 SQ - 0.653092 F + 1.463717 E-03 ti (%) (11)
$R^2$=0.882

**Table 3** - The values of **Rd** and **Rh,** for MP. Seventy per cent of recovery

| SQ 24 | | | | | | |
|---|---|---|---|---|---|---|
| | F=0.19 | | F=0.21 | | F=0.23 | |
| ti% | Rd | Rh | Rd | Rh | Rd | Rh |
| 10 | 1.013 | 1.009 | 1.013 | 1.005 | 1.013 | 1.000 |
| 15 | 1.022 | 1.013 | 1.022 | 1.006 | 1.018 | 1.000 |
| 20 | 1.031 | 1.017 | 1.030 | 1.007 | 1.023 | 1.000 |
| 25 | 1.041 | 1.020 | 1.037 | 1.007 | 1.027 | 1.000 |
| 30 | 1.051 | 1.022 | 1.043 | 1.007 | 1.030 | 1.000 |
| 35 | 1.060 | 1.022 | 1.050 | 1.007 | 1.031 | 1.000 |
| 40 | 1.069 | 1.022 | 1.054 | 1.007 | 1.031 | 1.000 |
| 45 | 1.077 | 1.022 | 1.057 | 1.007 | 1.031 | 1.000 |
| 50 | 1.083 | 1.022 | 1.057 | 1.007 | 1.031 | 1.000 |
| **SQ20** | | | | | | |
| 10 | 1.020 | 1.011 | 1.017 | 1.077 | 1.013 | 1.003 |
| 15 | 1.030 | 1.017 | 1.025 | 1.010 | 1.020 | 1.003 |
| 20 | 1.041 | 1.022 | 1.034 | 1.013 | 1.026 | 1.003 |
| 25 | 1.051 | 1.026 | 1.042 | 1.014 | 1.031 | 1.003 |
| 30 | 1.062 | 1.030 | 1.050 | 1.015 | 1.036 | 1.003 |
| 35 | 1.073 | 1.033 | 1.057 | 1.015 | 1.040 | 1.003 |
| 40 | 1.083 | 1.034 | 1.064 | 1.015 | 1.042 | 1.003 |
| 45 | 1.093 | 1.034 | 1.069 | 1.015 | 1.042 | 1.003 |
| 50 | 1.102 | 1.034 | 1.072 | 1.015 | 1.042 | 1.003 |
| **SQ 16** | | | | | | |
| 10 | 1.022 | 1.016 | 1.018 | 1.009 | 1.017 | 1.007 |
| 15 | 1.034 | 1.022 | 1.028 | 1.013 | 1.025 | 1.008 |
| 20 | 1.045 | 1.029 | 1.038 | 1.017 | 1.033 | 1.010 |
| 25 | 1.057 | 1.034 | 1.048 | 1.020 | 1.040 | 1.010 |
| 30 | 1.070 | 1.036 | 1.057 | 1.022 | 1.048 | 1.010 |
| 35 | 1.083 | 1.044 | 1.067 | 1.022 | 1.054 | 1.010 |
| 40 | 1.096 | 1.048 | 1.076 | 1.022 | 1.060 | 1.010 |
| 45 | 1.108 | 1.050 | 1.085 | 1.022 | 1.063 | 1.010 |
| 50 | 1.120 | 1.050 | 1.092 | 1.022 | 1.064 | 1.010 |

Eq. (11) also shows that the effects of thinning on stand growth conform to the law of diminishing returns: the higher is SQ anf **F** (tree spacing) the smaller is **Rd**; the higher is **ti** the higher is **Rd**.

**An application of the method to a MP stand**

Now, let me consider a SEPS of MP, at age 20, in SQ 24 and being F=0.19. The stand is submitted to a neutral thinning, a low thinning and a crown thinning that removes 30% of the standing trees (ti=0.30). In these simulations, the thinning of dbh class 20 cm is always neutral.

In table 4, I exhibit the structure of this stand and its projection to age 30, as a SEPS. From table 1, the values used, in eqs. (1)-(3), are Prx(20)=1.239 and Prp(20)=0.652.

To transform the values of **ds** and **hs** (table 4.B) to **dt** and **ht** (Part B of tables 5, 6, 7) I used Rd=1.051 and Rh=1.022 (table 3), in eqs. (4)-(5). To calculate **v**, I used an equation proposed by OLIVEIRA (1985).

The general pattern of the figures displayed in tables 4 to 7, are coherent with the available knowledge about TET on stand growth.

To adapt the values in table 3, to a recovery factor different from 0.7 (0.zz), use the following equation to obtain the new **Rd** or **Rh** (**NRx**):

NRx={[(Value in table 3-1)/0.7] 0.zz} + 1 (12)

Now, I must clarify how the values of **fr** were obtained, in tables 5, 6, 7.

Eq. (9) is the basic relationship to be used, to calculate the values of **fr**. Also, I must keep in mind that self-thinning operates as a neutral thinning (BARRETO, 1994c).

Let me finish the description of method SB-BARTHIN applying it to control the stand density after thinning. I will use the stand of table 5 (neutral thinning). The application to the stands submitted to low and crown thinning is identical.

**Table 4** - The projection of a SEPS of MP, from age 20 to 30. SQ 24, F=0.19

| **A** - t=20 | | | | **B** - Projected as self-thinned at age 30 | | | |
|---|---|---|---|---|---|---|---|
| d | Fr | hs | V | ds | fr | hs | V |
| 10 | 9 | 7.6 | 0.315 | 12.39 | 5 | 9.42 | 0.344 |
| 15 | 177 | 11.4 | 18.996 | 18.60 | 115 | 14.12 | 22.153 |
| 20 | 552 | 15.2 | 129.521 | 24.78 | 359 | 18.83 | 164.205 |
| 25 | 218 | 19.0 | 94.176 | 30.97 | 142 | 23.54 | 126.812 |
| 30 | 3 | 22.8 | 2.143 | 37.17 | 2 | 28.24 | 2.509 |
| p=959; wd=20.15; wh=15.31; SV=245.151; | | | | p=623; wds=24.99; whs=19.04; SV=316.023 | | | |

**Table 5** - The stand of table 4 being submitted to a neutral thinning at age 20. ti=0.30

| A - After thinned at age 20 | | | | B - Projected to age 30 | | | |
|---|---|---|---|---|---|---|---|
| d | fr | h | V | dt | fr | ht | V |
| 10 | 6 | 7.6 | 0.210 | 13.02 | 5 | 9.63 | 0.356 |
| 15 | 123 | 11.4 | 13.200 | 19.55 | 101 | 14.43 | 21.614 |
| 20 | 386 | 15.2 | 90.571 | 26.04 | 317 | 19.24 | 148.673 |
| 25 | 152 | 19.0 | 65.664 | 32.55 | 125 | 24.06 | 108.750 |
| 30 | 2 | 22.8 | 1.290 | 39.06 | 2 | 28.86 | 2.890 |
| p=669; wd=20.15; wh=15.31; SV=171.074; | | | | p=550; wdt=26.26; wht=19.40 SV=282.286 | | | |

Per cent of satnding volume removed: 30

**Table 6** - The stand of table 4 being submitted to a low thinning at age 20. ti=0.30

| A - After thinned at age 20 | | | | B - Projected to age 30 | | | |
|---|---|---|---|---|---|---|---|
| d | fr | h | V | dt | fr | ht | V |
| 20 | 450 | 15.2 | 105.587 | 26.04 | 324 | 19.24 | 151.956 |
| 25 | 218 | 19.0 | 94.176 | 32.55 | 157 | 24.06 | 136.590 |
| 30 | 3 | 22.8 | 2.143 | 39.06 | 3 | 28.86 | 4.335 |
| p=671; wd=21.67; wh=16.47; SV=201.907; | | | | p=484; wdt=28.23; wht=20.86 SV=292.881 | | | |

Per cent of standing volume removed: 18

**Table 7** - The stand of table 4 being submitted to a crown thinning at age 20. ti=0.30

| A - After thinned at age 20 | | | | B - Projected to age 30 | | | |
|---|---|---|---|---|---|---|---|
| d | fr | h | V | dt | fr | ht | V |
| 10 | 9 | 7.6 | 0.315 | 13.02 | 9 | 9.63 | 0.642 |
| 15 | 177 | 11.4 | 18.996 | 19.55 | 173 | 14.43 | 37.022 |
| 20 | 485 | 15.2 | 113.800 | 26.04 | 474 | 19.24 | 222.306 |
| p=671; wd=18.51; wh=14.09; SV=133.111; | | | | p=656; wdt=24.15; wht=17.84 SV=259.970 | | | |

Per cent of standing volume removed: 46

**Step 3**. *Establish a reference tree*. In table 4.B, the mean tree of the stand occupies 16.05136 square meters (10000/ /623) and has a weighted mean dbh of 24.99.

**Step 4**. *Calculate the area occupied by the mean tree of each dbh class, at age 30.* Eq. (9) is used. Let me illustrate for class I:

Area occupied by the mean tree= =16.05136 $(13.02/24.99)^2$=4.35714 s.m.

For the other classes I obtain: II: 9.82365; III: 17.42855; IV: 27.23211; V: 39.21424.

**Step 5**. *Calculate the area occupied by each dbh class at age 30, without self- -thinning*. I illustrate for class I:

Area occupied by class I, without subsequent self-thinning=6 x 4.35714= =26.14284 s. m.

For the other classes I obtain: II: 1208.30895; III: 6727.42030; IV: 4139.28072; V: 78.42848.

**Step 6**. *Verify if the total area occupied by the trees exceed one ha.* The sum of the areas previously calculate is 12179.58129 s. m. The excess of area is 2179.58129, thus some self-thinning occurred after the thinning, before age 30. This self- -thinning is allocated to the dbh classes in proportion to the area they occupy (self-thinning is neutral).

**Step 7**. *Find the area occupied by each class as a fraction of the total area occupied.* I illustrate for class I: 26.14284/ /12179.58129=0.00215.

For the other classes I obtain: II: 0.09921; III: 0.55235; IV: 0.33985; V: 0.00644.

**Step 8**. *Allocate the excess of occupied area to the dbh classes.* I illustrate for class I: 0.00215 x 2179.58129=4.68600.

For the other classes I obtain: II: 216.23626; III: 1203.89173; IV: 740.73070; V: 14.03650.

**Step 9**. *Calculate the number of trees self-thinned in each dbh class.* I illustrate for class I: 4.68600/4.35714=1.

For the other classes I obtain: II: 22; III: 69; IV: 27; V:0.

**Step 10**. *Subtract the self-thinned trees from the frequencies of the classes, after thinning.* I illustrate for class I: 6-1=5.

For the other classes I obtain: II: 101; III: 317; IV: 125; V: 2, as exhibited in table 5.B.

After age 30, the thinned stands can be projected as a self-thinned till the next eventual thinning. Simulator KHABSOFT (BARRETO, 1994a) can be used for this purpose.

I projected the mean dbh and height of the dbh classes of the stand submitted to neutral thinning, for ages 30, 40, ...80. I used the values at age 20 (not thinned), and these six values to fit the following equation:

$$\text{dbh or height}=\exp( a+b/t+c \ln t) \qquad (13)$$

The values of the constants of eq. (13), for dbh, and height are exhibited in tables 8 and 9.

**Table 8** - The values of the constants in eq. (13), for the growth of the mean dbh of the classes in the stand of table 5. For all regressions $r^2$=1.000

| Class | a | b | c |
|---|---|---|---|
| I | 3.29579 | -17.80036 | -0.06833 |
| II | 3.80849 | -17.86511 | -0.06963 |
| III | 4.08424 | -17.75770 | -0.06744 |
| IV | 4.31110 | -17.78820 | -0.06819 |
| V | 4.49149 | -17.77458 | -0.06777 |

## The restart of self-thinning and gross yield

I used eq. (13), and the figures in table

8, to estimate the age when self-thinning restarted in the stand of tables 5-7. In the stand submitted to crown thinning (small trees left) self-thinning restarted at about 29 years; in the stand submitted to neutral thinning (average trees left) self-thinning restarted at about 25 years; in the stand submitted to low thinning (large trees left) self-thinning restarted at about 22 years.

**Table 9** - The values of the constants in eq. (13), for the growth of the mean height of the classes in the stand of table 5. For all regressions $r^2$=0.999

| Class | a | b | c |
|---|---|---|---|
| I | 2.85366 | -15.38106 | -0.01988 |
| II | 3.24042 | -15.22350 | -0.01626 |
| III | 3.53181 | -15.25183 | -0.01703 |
| IV | 3.75873 | -15.28655 | -0.01771 |
| V | 3.93641 | -15.24502 | -0.01685 |

The effect of SQ, **F**, and **ti** on the age when self-thinning restarts is affected by the size structure of the stand.

For stands with isomorphic structures, I verified the following:

a) For the same SQ, and **ti**, the higher is **F** the later self-thinning restarts.

b) For the same **F,** and **ti,** the poor is the SQ the earlier self-thinning restarts

I submitted the stand of table 4, to a thinning at age 20, with ti=45%, and I verified the following:

- For the low thinning, self-thinning restarted at age 23.

- For the crown thinning, self-thinning restarted at age 26

- For the neutral thinning, self-thinning restarted at age 26.

For the stands of tables 4-7, I estimated the gross yields till age 80 years (c.m./ha) as follows: SEPS: 749; neutral and low thinnings: 725; crown thinning: 664.

**A Complete view of Method SB-BARTHIN**

For a easier appreciation, let me present a summarized complete description of method SB-BARTHIN.

**Part I**. *The effect of thinning on the growth of dbh and height (eqs. (1)-(5))*.

**Step 1**. Project the thinned stand as a SEPS, from the age of thinning **t**, to age **t+10**.

**Step 2**. Introduce the effect of thinning on dbh and height growth.

**Part II**. *The effect of thinning on the number of trees (eq. (9)).*

**Step 3**. Establish a reference tree.

**Step 4**. Calculate the area occupied by the mean tree of each dbh class, at age **t+10**.

**Step 5**. Calculate the area occupied by each dbh class at age **t+10**, without self-thinning.

**Step 6**. Verify if the total area occupied by the trees exceed one hectare.

**Step 7**. Find the area occupied by each class as a fraction of the total area occupied.

**Step 8**. Allocate the excess of occupied area to the dbh classes.

**Step 9**. Calculate the number of trees self-thinned in each dbh class.

**Step 10**. Subtract the self-thinned trees from the frequencies of the classes, after thinning.

**Method SOBA-2**

In BARRETO (1994b), I introduced simulator PINASTER for SEPS of MP; in

BARRETO (1995c) I proposed method SOBA; later, I disclosed simulator SB--SOBA.MP (BARRETO, 2000) to apply the mentioned method to MP stands. This simulator can generate and project SEPS of MP, requiring only the value of **F** and the dominant height at age 40.

These two simulators can be used together for a more precise application of method SOBA to SEPS of MP, named SOBA-2. Let me describe the procedure.

Suppose you have a measured SEPS, at age 10, with **d1(10)** and **h1(10)** and you want to apply method SOBA to it. You pretend to impose the early thinning to the stand, prescribed by the method, at age 15.

**Step 1.** Use simulator PINASTER to obtain the values of dap and height, at age 25, **d1(25)** and **h1(25)**, of your unthinned stand.

**Step 2.** Generate structures of SEPS of MP, for your site, with simulator SB--SOBA.MP. Choose an alternative you find suitable, and retain the values of **p**, at ages 15 and 25, **p2(15)**, **p2(25)**, and of dap, and height, at age 25, **d2(25)**, **h2(25)**.

**Step 3.** Calculate the values of the thinned stand, at age 25, as follows:

$$dt(25)=d1(25)+0.7(d2(25)-d1(25)) \quad (14)$$

$$ht(25)=h1(25)+0.7(h2(25)-h1(25)) \quad (15)$$

**Step 4.** Use simulator PINASTER to project the stand with **p2(25)**, **dt(25)**, and **ht(25)**.

**Step 5.** If your are not satisfied with the structure of the projected stand, obtained in the previous step, return to step 2. If you are satisfied, apply a neutral thinning to your stand, at age 15, and reduce its density to **p2(15)**.

It is my understanding that method SOBA-2 has the advantages of method SOBA (BARRETO, 1995c) associated to more precision.

**A quick method to survey SEPS**

Eq. (9) can be generalized and applied to survey SEPS in an expedite manner.

Eq. (9) is valid for all variables with linear dimension with power 1 (**x**), this is, is applicable to **d**, **h**, **H**, and **SV**. From this general form of eq. (9), I can obtain:

$$x_2=(p_1/p_2)^{1/2}x_1 \quad (16)$$

Suppose a SEPS of MP, at age 20 measured as:

p(20)=1359 trees/ha; ds(20)=16.31 cm; hs(20)=12.70 m; H(20)=14.04 m; SV(20)= =187 c.m./ha

At age 30, I count 885 trees/ha. Eq. (16) let me write:

ds(30)=20.21 cm; hs(30)=15.73 m; H(30)=17.40 m; SV(30)=232 c.m./ha

The reader can use simulator PINASTER (BARRETO, 1994b) to check these predictions.

Using a parallel deductive procedure, I can also write:

$$v_2=(p_1/p_2)^{1.5}v_1 \quad (17)$$

It is conspicuous that eqs. (16), (17) are related to the 3/2 power law, this is, to the main allometry of SEPS. Again, it is shown that the large scale geometry of SEPS can be described with simple equations.

Indeed, tree spacing (or stand density) is a fundamental characteristic of SEPS. Thus, the proposed quick method cannot surprise.

**Improving the performance of program SB-SOBA.MP**

The performance of program SB--SOBA.MP (BARRETO, 2000) can be improved if the following instructions:

```
'----------------------------------------------------------------
' Establishing dbh and standing volume
'----------------------------------------------------------------
s=h*f:pf=6700.12/s^2
if h=>22 and f=>0.21 then k=5.65
if h=>22 and f<0.21 then k=6.36
if 18<=h and h<22 and f=>0.21 then k=5.43
if 18<=h and h<22 and f<0.21 then k=6.01
if h<18 and f=>0.21 then k=5.08
if h<18 and f<0.21 then k=5.57
df=k*s*1.221883
'----------------------------------------------------------------
```

are replaced by the instructions:

```
'----------------------------------------------------------------
' Establishing dbh and standing volume
'----------------------------------------------------------------
s = h * f: pf = 6700.12 / s ^ 2
IF h >= 22 THEN k = (-1625 * f + 939.75) / 100
IF 18 <= h AND h < 22 THEN k = (-1450 * f +
876.5) / 100
IF h < 18 THEN k = (-1225 * f + 790.75) / 100
df = k * s * 1.221883
'----------------------------------------------------------------
```

**Final comments**

Now, let me introduce a few conclusive remarks.

1. I was able to isolate the sole effect of thinning in the growth of stands, in an expedite manner.

2. Also, I was able to present a expedite method to project the density of thinned stands.

3. In this paper, I present a broad picture of the effects of thinning on stand growth. In a systematic manner, I depicted the influence of SQ, **F**, **ti** and age on the same effects.

4. I admit that the results here introduced, and methods SB-BARTHIN, and SOBA-2 deserve the attention of both foresters and plant ecologists. A forester is a particular strain of plant ecologist.

5. The same methods has potential to be applied to other species, and may have impact on the planning of research, in this area.

6. The method SB-BARTHIN avoids the use of theoretical distributions (e.g., Weibull) that generally introduces distortions in the data.

7. The projections of thinnings simulated by method SB-BARTHIN are coherent and conform to the available knowledge of the forest science.

8. Method SB-BARTHIN confirms a law of wide applicability (diminishing returns).

9. To improve the accuracy and range of application of method SB-BARTHIN to MP stands, more data is needed. Also, an open issue is the breath and eventual variation of the recovery fraction. Does it abide the law of diminishing returns?

10. Table 1 shows how early thinnings take advantage of the initial fast growth of MP.

11. Table 1 suggests that in thinning experiments it is highly recommended that all plots have the same age.

12. We can only take all benefits from restricted field experiments if we have a general theoretical framework where their results can be put in enlightening context, and be submitted to a broad, and, if possible, correct extrapolating interpretation. Otherwise, the results will be of circumscribed utility. In this paper, I also attempted to give a contribution to the delineation of this more encompassing setting for thinnings. I hope I was able to bring a new approach and insight to the inexhaustible issue of forest thinnings.

13. Today, when any reader of a scientific journal has access to software for graphics, I find more rigorous, informative, and flexible to provide the values of the variables. The reader has

the freedom to visualise and make the graphical comparisons he finds more relevant. Also, in a more deep manner, he can evaluate the empirical or simulated data exhibited.

With a simple pocket calculator, any person can apply method SB-BARTHIN.

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