

SB-ROBUR+H
A Simulator for Four Even-Aged Self-Thinned
Stands of *Quercus robur* and Another Hardwood

Luís Soares Barreto

Professor of Forestry

Instituto Superior de Agronomia. Tapada da Ajuda, 1349-017 LISBOA

Abstract. The author uses his conceptual model of tree competition to propose a simulator for the following even-aged, self-thinned mixed stands: *Quercus robur*+*Acer pseudoplatanus*, *Quercus robur*+*Betula pendula*, *Quercus robur*+*Fagus sylvatica*, *Quercus robur*+*Fraxinus excelsior*. Given the closeness of the competitive ability of these species in each stand, the simulator, written in BASIC, uses Gompertz equations to simulate the dynamics of the number of trees within each stand. In addition to listing the SB-ROBUR+H simulator, a sample of its output is also presented.

Key words: *Acer pseudoplatanus*; *Betula pendula*; *Fagus sylvatica*; *Fraxinus excelsior*; *Quercus robur*; self-thinned even-aged mixed stands; simulation

Sumário. Recorrendo ao seu modelo conceptual para a competição entre árvores, o autor propõe um simulador para os seguintes povoamentos auto-desbastados e regulares: *Quercus robur*+*Acer pseudoplatanus*, *Quercus robur*+*Betula pendula*, *Quercus robur*+*Fagus sylvatica*, *Quercus robur*+*Fraxinus excelsior*. Dada a próxima competitividade das espécies de cada povoamento, o simulador SB-ROBUR+H utiliza equações de Gompertz para simular a dinâmica do número de árvores de cada população. Apresenta-se a listagem do simulador, escrita em BASIC, e uma amostra da sua saída.

Palavras-chave: *Acer pseudoplatanus*; *Betula pendula*; *Fagus sylvatica*; *Fraxinus excelsior*; *Quercus robur*; povoamentos auto-desbastados regulares mistos; simulação

Résumé. L'auteur utilise les résultats de sa recherche théorique sur la compétition entre les arbres, pour établir le simulateur SB-ROBUR+H, pour les peuplements: *Quercus robur*+*Acer pseudoplatanus*, *Quercus robur*+*Betula pendula*, *Quercus robur*+*Fagus sylvatica*, *Quercus robur*+*Fraxinus excelsior*. L'auteur présente le logiciel du simulateur, écrit en BASIC, et un exemple de sa sortie.

Mots clés: *Acer pseudoplatanus*; *Betula pendula*; *Fagus sylvatica*; *Fraxinus excelsior*; *Quercus robur*; peuplements auto-éclaircis mixtes réguliers; simulation

Introduction

In Europe, *Quercus robur* (QR) is a species widely distributed. Thus, a simulator for a few of its mixed stands has a chance to be useful for the forests

of several countries. This situation led me to approach the simulation of self-thinned even-aged mixed stands (SEMS) of QR. In this paper, I deal with SEMS of QR and another hadwood.

To elaborate this paper, I used my

conceptual model for tree competition and my model BACO2, grounded in it (BARRETO, 1998).

This article is a revised version of BARRETO (1999a).

The selected species

The harwoods I chose are the following ones: *Acer pseudoplatanus* (AP), *Betula pendula* (BP), *Fagus sylvatica* (FS), *Fraxinus excelsior* (FE). Thus, simulator SB-ROBUR+H (SQH), here proposed, covers the SEMS QR+AP, QR+BP, QR+FS, QR+FE.

In table 1, I exhibit the ratio of the relative growth rates of the species of each stand. It can be seen that QR is the dominant species in all stands but in SEMS QF+FS.

Also, table 1 evinces that the species of each mixture have close competitiveness.

In their application of Grime's ecological classification of plants to Central Europe tree species, BREZIECKI and KIENAST (1994) classified BP as ruderal, AP, FE as competitors, and QR, FS as competitive stress-tolerants. AP, FS and FE have more affinity to QR than BP.

Table 1 - The ratio of the relative growth rates of the species of each stand

Age	QR/AP	QR/BP	QR/FS	QR/FE
10	1.15	1.89	0.67	1.46
20	1.20	1.78	0.69	1.42
30	1.25	1.67	0.70	1.38
40	1.30	1.58	0.71	1.34
50	1.35	1.49	0.73	1.30
60	1.41	1.40	0.74	1.26
70	1.48	1.32	0.76	1.22
80	1.53	1.24	0.77	1.18
90	1.59	1.17	0.79	1.15

Referring to my tentative typification of the patterns of tree interaction

(BARRETO, 1999b), I verify that the pattern of SEMS QR+AP is type I, and type III occurs in the other stands.

The method

Given the close competitive ability of the species, in each SEMS, I was able to simulate the dynamics of their frequencies using Gompertz equations, as I already did for European and North-American species, in BARRETO (1998, 1999c).

With model BACO2, I simulated 16 SEMS of each mixture, in a complete additive design, with densities, at age 10, of 10000, 20000, 30000, 40000.

To the frequencies of each species at ages 10, 20, 30, ...90, I fitted a Gompertz equation. After, I used the 32 fitted Gompertz equations, of each mixture, to establish SRH. Finally, the values calculated by SRH and model BACO2 were compared.

Simulator SB-ROBUR+H

For the frequencies of each species **p**, let me write the Gompertz equation as:

$$p(t) = pfR^{\exp(-c(t-10))} \quad (1)$$

where **pf** is the final frequency, and **R** is the ratio **p(10)/pf**. **c** is a constant that, as **R**, varies with the initial proportions of the species in the mixture.

From here on, **x** will represent the fraction of trees of QR, at age 10.

To the values of **R** and **c** of each species, I fitted the following equations:

$$R = a \exp(bx) \quad (2)$$

$$c = d + fx + gx^2 + hx^3 \quad (3)$$

It tables 2 and 3, I exhibit the values of the constants in eqs. (2) and (3).

As input for each species, at age 10,

SRH asks the number of trees per hectare, the stem dbh (cm), and the volume of the mean tree (c.m.). SRH uses eqs. (2) and (3) to establish the Gompertz equations for the species frequencies. The simulator projects the frequency, dbh and standing volume (c.m./ha), for each species, at ages 10, 20, 30 ...90.

Table 2 - The values of the constants in eq. (2). All the coefficients of determination are equal to 1.000

Species	a	b
QR	40.11623	1.134165
AP	46.00232	0.872821
QR	21.75703	2.108692
BP	46.00232	1.257487
QR	642.0574	-1.559314
FS	877.5248	-2.222781
QR	29.63997	1.419235
FE	36.35556	1.031554

The performance of simulator SB-ROBUR+H

The comparison of the values, for the frequencies of the species, generated by model BACO2, and SRH can be described

as follows:

1. In SEMS QR+AP, and QR+FE, all errors are less than one per cent of the values given by model BACO2.

2. In SEMS QR+FS, all errors associated to QR are less than one per cent. SRH overestimates the frequencies of FS. The errors increase with the fraction of QR and their maximums occur of age 30 years. All errors are less than one per cent for values of x less or equal to 0.4. For $x=0.8$, at age 30 the error is 5.5%, and it is 1.2% at age 90.

3. In SEMS QR+BP, all errors associated to BP are less than one per cent. SRH overestimates the frequencies of QR. The errors increase with the fraction of QR and their maximums occur at age 30 years. All errors are less than one per cent for values of x less or equal to 0.5. For $x=0.8$, at age 30 the error is 9.5%, and it is 2.6% at age 90.

The larger errors occur in SEMS QR+BP, this is, in the mixture with the species that is more away from QR, in the classification proposed by BREZIECKI and KIENAST (1994).

Table 3 - The values of the constants in eq. (3). All the coefficients of determination are equal to 1.000 but for QR in stand QR+FS that is equal to 0.995

species	d	f	g	h
QR	0.046468	-0.008245	0.004873	-0.002141
AP	0.044941	-0.004351	0.002358	-0.001102
QR	0.030674	0.016841	-0.009146	0.002823
BP	0.034957	0.005531	-0.000957	-0.000246
QR	0.042521	-0.000473	-0.002494	0.001374
FS	0.043040	-0.001327	-0.003039	0.001254
QR	0.036835	0.005378	-0.001078	-0.000129
FE	0.037978	0.002709	0.000079	-0.000421

Final Comments

In a general sense, SRH is a sequel of simulator TWINS, disclosed in BARRETO

(1998). Thus, the conclusive remarks I stated in this article can be reiterated, here.

References

- BARRETO, L.S., 1997. Coexistence and competitive ability of tree species. Elaborations on Grime's theory. *Silva Lusitana* 5(1) : 79-93.
- BARRETO, L.S., 1998. TWINS - A simulator for a few mixed stands with two species of close competitiveness. *Silva Lusitana* 6(1) : 69-99.
- BARRETO, L.S., 1999a. SB-ROBUR+H. A simulator for four even-aged self-thinned stands of *Quercus robur* and another hardwood. Departamento de Engenharia Florestal, Instituto Superior de Agronomia, Lisboa.
- BARRETO, L.S., 1999b. A tentative typification of the patterns interaction with models BACO2 and BACO3. *Silva Lusitana* 7(1) : 117-125.
- BARRETO, L.S., 1999c. US-EVEN. A program to support the forestry of some Even-Aged North-American Stands. *Silva Lusitana* 7(2) : 233-248.
- BREZIECKI, B., KIENAST, F., 1994. Classifying the life-history strategies of trees on the basis of the Grimean model. *Forest Ecology and management* 69 : 167-187.

*Entregue para publicação em Dezembro de 2000
Aceite para publicação em Janeiro de 2002*

Appendix A: Listing of simulator SB-ROBUR+H

```

?" SIMULATOR SB-ROBUR+H"
?
?"A Gompertzian simultor for three self-thinned even-aged mixed stand
?" with Quercus robur and another hardwood"
?" © Luís Soares Barreto, 1999"
?"The stands considered are the following ones:"
?"1=Quercus robur+Fraxinus excelsior"
?"2=Quercus Robur+Betula pendula"
?"3=Quercus robur+Acer pseudoplatanus"
?"4=Quercus robur+Fagus sylvatica"
input "Enter your choice of stand (1, 2, 3 or 4)";ch
on ch goto rodex, robet, robac, rosy1
'-----
'-----

rodex:
?*** Enter density and mean tree volume of each species, at age 10 ***
?:input "Density of Quercus robur (trees/ha)";q
?:input "Density of Fraxinus excelsior (trees/ha)";p
?:input "Mean tree volume of Quercus robur (c.m.)";v1
?:input "Mean tree volume of Fraxinus excelsior (c.m.)";v2
?:input "Mean dbh of Quercus robur (cm)";d1
?:input "Mean dbh of Fraxinus excelsior (cm)";d2
x=q/p+q:vf1=v1/.00071:vf2=v2/.00475
d1f=d1/.0891:d2f=d2/.16811
cf=.036835+.005378*x-.001078*x^2-.000129*x^3
rf=29.63997*exp(1.419235*x)
cp=.037978+.002709*x+.000079*x^2-.000421*x^3
rp=36.35556*exp(1.031554*x)
ff=q/rf:fp=p/rp
lprint " SIMULATOR SB-ROBUR+H"
for t=10 to 90 step 10
q=ff*rf^exp(-cf*(t-10)):p=fp*rp^exp(-cp*(t-10))
vf=vf1*.00071^exp(-.041*(t-10))*q
vp=vf2*.00475^exp(-.038*(t-10))*p
d1=d1f*.0891^exp(-.041*(t-10)):d2=d2f*.16911^exp(-.38*(t-10))
lprint:lprint tab(10) "Age "; t
lprint tab(10)"Quercus robur: ";cint(q); "trees/ha ";cint(vf);
lprint "c.m./ha ";cint(d1); " cm"
lprint tab(10)"Fraxinus excelsior: ";cint(p); " trees/fa ";cint(vp);
lprint " c.m./ha ";cint(d2); " cm"
next t
goto 50
'-----
'-----


robet:
?*** Enter density and mean tree volume of each species, at age 10 ***
?:input "Density of Quercus robur (trees/ha)";q
?:input "Density of Betula pendula (trees/ha)";p
?:input "Mean tree volume of Quercus robur (c.m.)";v1
?:input "Mean tree volume of Betula pendula (c.m.)";v2
?:input "Mean dbh of Quercus robur (cm)";d1
?:input "Mean dbh of Betula pendula (cm)";d2
x=q/(p+q):vf1=v1/.00071:vf2=v2/.01114

```

```

d1f=d1/.0891:d2f=d2/.2233
cf=.030674+.016841*x-.009146*x^2+.00823*x^3
rf=13.71117*exp(2.108692*x)
cp=.034957+.005531*x-.000957*x^2-.000246*x^3
rp= 21.757037*exp(1.257487*x)
ff=q/rf:fp=p/rp
lprint "          SIMULATOR SB-ROBUR+H"
for t=10 to 90 step 10
q=ff*rf^exp(-cf*(t-10)):p=fp*rp^exp(-cp*(t-10))
vf=vf1*.00071^exp(-.041*(t-10))*q
vp=vf2*.01114^exp(-.035*(t-10))*p
d1=d1*.0891^exp(-.041*(t-10)):d2=d2f*.223^exp(-.035*(t-10))
lprint:lprint tab(10) "Age "; t
lprint tab(10)"Quercus robur: ";cint(q); "trees/ha ";cint(vf);
lprint "c.m./ha ";cint(d1);" cm"
lprint tab(10)"Betula pendula: ";cint(p);" trees/ha ";cint(vp);
lprint "c.m./ha ";cint(d2);" cm"
next t
goto 50
'-----
'-----

robac:
?*** Enter density and mean tree volume of each species, at age 10 ***
?:input "Density of Quercus robur (trees/ha)":q
?:input "Density of Acer pseudoplatanus (trees/ha)":p
?:input "Mean tree volume of Quercus robur (c.m.)":v1
?:input "Mean tree volume of Acer pseudoplatanus (c.m.)":v2
?:input "Mean dbh of Quercus robur (cm)":d1
?:input "Mean dbh of Acer pseudoplatanus (cm)":d2
x=q/(p+q):vf1=v1/.00071:vf2=v2/.0032
d1f=d1/.0891:d2f=d2/.14826
ca=.046468-.008245*x+.004873*x^2-.002141*x^3
ra=40.11623*exp(1.134165*x)
cf=.044941-.004351*x+.002358*x^2-.001102*x^3
rf= 46.00232*exp(.872821*x)
fa=q/ra:ff=p/rf
lprint "          SIMULATOR SB-ROBUR+H"
for t=10 to 90 step 10
q=fa*ra^exp(-ca*(t-10)):p=ff*rf^exp(-cf*(t-10))
va=vf1*.00071^exp(-.041*(t-10))*q
vf=vf2*.0032^exp(-.045*(t-10))*p
d1=d1*.0891^exp(-.041*(t-10)):d2=d2f*.14826^exp(-.045*(t-10))
lprint:lprint tab(10) "Age "; t
lprint tab(10)"Quercus robur: ";cint(q); "trees/ha ";cint(va);
lprint "c.m./ha ";cint(d1);" cm"
lprint tab(10)"Acer pseudoplatanus: ";cint(p);" trees/ha ";cint(vf);
lprint "c.m./ha ";cint(d2);" cm"
next t
goto 50
'-----
'-----


rosly:
?*** Enter density and mean tree volume of each species, at age 10 ***
?:input "Density of Quercus robur (trees/ha)":q
?:input "Density of Fagus sylvatica (trees/ha)":p
?:input "Mean tree volume of Quercus robur (c.m.)":v1

```

```

?:input "Mean tree volume of Fagus sylvatica (c.m.)";v2
?:input "Mean dbh of Quercus robur (cm)";d1
?:input "Mean dbh of Fagus sylvatica (cm)";d2
x=q/(p+q):vf1=v1/.00071:vf2=v2/.00003
d1f=d1/.0891:d2f=d2/.0325
ca=.042521-.000473*x+.002494*x^2+.001374*x^3
ra=642.0474*exp(-1.559314*x)
cf=.043041-.001327*x-.003039*x^2-.001253*x^3
rf= 877.5248*exp(-2.222781*x)
fa=q/rr:ff=p/rf
lprint "
          SIMULATOR SB-ROBUR+H"
for t=10 to 90 step 10
q=fa*ra^exp(-ca*(t-10)):p=ff*rf^exp(-cf*(t-10))
va=vf1*.00071^exp(-.041*(t-10))*q
vf=vf2*.00003^exp(-.043*(t-10))*p
d1=d1f*.0891^exp(-.041*(t-10)):d2=d2f*.0325^exp(-.043*(t-10))
lprint:lprint tab(10) "Age "; t
lprint tab(10)"Quercus robur: ";cint(q); "trees/ha ";cint(va);
lprint "c.m./ha ";cint(d1); " cm"
lprint tab(10)"Fagus sylvatica: ";cint(p);" trees/ha ";cint(vf);
lprint " c.m./ha ";cint(d2);" cm"
next t
goto 50
'-----
'-----
50 end

```

Appendix B: Sample of the output of simulator SB-ROBUR+H

SIMULATOR SB-ROBUR+H

Age 10

Quercus robur: 4000 trees/ha 4 c.m./ha 3 cm
 Fraxinus Excelsior: 2777 trees/ha 72 c.m./ha 10 cm

Age 20

Quercus robur: 1004 trees/ha 12 c.m./ha 7 cm
 Fraxinus Excelsior: 704 trees/ha 99 c.m./ha 18 cm

Age 30

Quercus robur: 396 trees/ha 23 c.m./ha 12 cm
 Fraxinus Excelsior: 280 trees/ha 125 c.m./ha 26 cm

Age 40

Quercus robur: 212 trees/ha 36 c.m./ha 17 cm
 Fraxinus Excelsior: 150 trees/ha 148 c.m./ha 34 cm