2012

GYMMA Model

BRIEF DESCRIPTION & EQUATIONS

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Background Introduction

Eucalyptus globulus Labill. planted forest is of crucial importance for the Portuguese economy being the main source for high quality raw material for the pulp and paper industries. Portugal has a long experience in developing empirical growth models for eucalyptus even-aged stands for which the planting date is known. Age is one of the most important variables in growth and yield modelling of even-aged stands. However, plantation date is often unknown for Portuguese eucalyptus stands and stand age is especially hard to assess for fast growing species with no well defined tree rings like is the case of Eucalyptus. In order to solve the problem of unknown stand age, GYMMA model Growth and Yield Model Missing Age, was developed and is at present being applied to project uneven-aged stands (Barreiro et al. 2004). Additionally, a set of biomass functions per component was included to complement the model (Oliviera xxxx).

Model Description

Tree or stand growth modelling is usually achieved with so-called theoretical growth curves, such as the Lundqvist growth function; one of the most commonly used in growth and yield modelling. A methodology to formulate growth functions as age independent difference equations was applied to the Lundqvist function in order to model dominant height and basal area, the driving variables. By formulating growth functions as age independent difference equations the problem of modelling growth of trees or stands when age is not available is solved (Tomé et al. 2006, Barreiro and Tomé 2010).

Dominant height and basal area models were fitted with the procedure PROC MODEL of the SAS statistical software (SAS Institute Inc. 1993), whereas for the mortality and volume models linear regression was used through the procedure PROC REG of the same software.

The growth and prediction functions that make up the GYMMA model are presented in **Tables 1** to **6**.

Table 1. GYMMA model projection function for dominant height.

Dominant height

(1) $$hdom_2 = A\ e^{\frac{-k}{\left(\left(\frac{-k}{\ln(hdom_1/A)}\right)^{\frac{1}{n}}+1\right)^n}}$$

$$k = k_0 + k_1\ G + k_2\ hdom$$

model	a	K₀	K₁	K₂	n
(1)	84.2463	3.0839	-0.1142	0.1202	0.4057

Where G is the stand's basal area; hdom is the stand's dominant height and If k≤2.5 then k=2.5 else if k≥5.5 then k=5.5.

Table 2. GYMMA model projection function for stand basal area.

Basal Area

$$(1)\quad G_2 = A\ e^{\frac{-k}{\left(\left(\frac{-k}{\ln(G_1/A)}\right)^{\frac{1}{n}}+1\right)^{n}}}$$

$$k = k_0 + k_1\ hdom + k_2\ \frac{N_{(d>5)}}{1000}$$

$$A = a_0\ hdom$$

model	a_0	K_0	K_1	K_2	n
(1)	63.9939	9.8573	0.4420	-2.2890	0.4141

Where G is the stand's basal area; hdom is the stand's dominant height; $N_{(d>5)}$ is the number of trees with DBH greater than 5 cm and If k≤9.0 then k=9.0 else if k≥20 then K=20.

Table 3. GYMMA model Mortality functions.

Alternative Projection/Prediction Functions for Mortality

$$(1)\quad N_2 = N_1\ e^{a_0}$$

$$(2)\quad N_{(d>5)} = a_0 + a_1\ N + a_2\ G$$

$$(3)\quad N_{(d>5)} = \frac{N}{\left(1+e^{-\left(a_0 + a_1\ hdom\right)}\right)^{a_2}}$$

model	a_0	a_1	a_2
(1)	-0.00988	-	-
(2)	-10.5204	0.8549	6.0069
(3)	-1.5163	0.1075	0.1667

Where N is the number of trees; $N_{(d>5)}$ is the number of trees with diameter at breast height greater than 5 cm, hdom is the stand's dominant height and G is the stand's basal area. Note that models 2 and 3 are alternative models.

Table 4. GYMMA model prediction functions for stand total volume.

Total Volume

$$V_i = A\ hdom^b\ G^c \qquad A = a_0 + a_1\ rot$$

model	a_0	a_1	b	c
V	0.5207	-	0.9933	0.9285
Vu	0.3625	-	0.9885	0.9879
V_st	0.4602	0.0012	0.9796	0.9750
Vu_st	0.3202	0.0023	0.9756	1.0343

Where Vi represents the following stand volumes: V is the stand over bark volume with stump, Vu is the stand under bark volume with stump, V_st is the stand over bark volume without stump and Vu_st is the stand under bark volume without stump; G is the stand basal area; hdom is the dominant height and rot is the stand rotation (0 for planted and 1 for coppice stands).

Table 5. GYMMA model prediction functions for merchantable stand volume.

Merchantable Volume

$$(1)\quad Vmdi = V\_st\ e^{a\left(\frac{di}{dg}\right)^b} \qquad (2)\quad Vmudi = Vu\_st\ e^{a\left(\frac{di}{dg}\right)^b}$$

model	a	b
(1)	-1.0033	3.8608
(2)	-1.0173	3.8929

Where Vmdi is the merchantable volume over bark without stump up to a top diameter di; Vmudi is the merchantable volume under bark without stump up to a top diameter di; V_st is the stand over bark volume without stump; Vu_st is the stand under bark volume without stump and dg is the quadratic mean diameter at breast height.

Table 6. GYMMA model biomass prediction functions.

Biomass

$$W_i = a\ hdom^{b}\ G^{c}$$

$$W_a = W_w + W_b + W_l + W_{br}$$

$$W_r = a_0\ W_a$$

$$a = a_0 + a_1\ rot$$

$$b = b_0 + b_1\ \frac{N}{1000}$$

$$c = c_0 + c_1\ rot + c_2\ \frac{N}{1000}$$

model	a0	a1	b0	b1	c0	c1	c2
W_w	0.1108	-0.0002	1.1569	-0.0085	1.0195	-	-
W_b	0.0262	-	0.8500	-0.0564	1.1964	-0.0080	-
W_{br}	0.3015	-	0.1263	-	0.9963	-0.0030	-0.0126
W_l	1.4570	-	-0.4065	-	0.9870	-	-0.0080
W_r	0.2487	-	-	-	-	-	-

Where Ww is the biomass of wood; Wb, is the biomass of bark; Wbr is the biomass of branches; Wl is the biomass of leaves; Wr is the biomass biomass of roots; Wa is the total aboveground biomass; rot is the stand rotation (0 for planted and 1 for coppice stands) and N is the stand density.

Final Remarks

The performance of GYMMA model was compared with Globulus 2.1 model for the driving variables (dominant height and basal area) and the derived variables (total volume and merchantable volume). Graphical analyses were used to accomplish validation through the relationship of observed stand variables over predicted stand variables for each of the models mentioned and the model performed reasonably well.

However, GYMMA will neither allow to determine the exploitable age nor to estimate a site index value for a given stand, because this is an age dependent variable, which is an important drawback for the model.

Literature Cited

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