Scaling cross-sectional growth and height growth in Mediterranean pines

Andrés BRAVO-OVIEDO[1], Harry T. VALENTINE[2]

[1]**Sustainable Forest Management Research Institute** Centre of Forest Research, CIFOR-INIA, Cª A Coruña km 7,5 28040 MADRID (SPAIN) bravo@inia.es

[2]**USDA Forest Service, Northern Research Station**, 271 Mast Road, Durham, NH 03824-6400 (USA)

INTRODUCTION

Pipe model theory (Shinozaki *et al*. 1964) has been used successfully to model forest growth from the seminal works of Valentine (1985) and Mäkelä (1986). Recent research has found that cross-sectional area growth scales with height growth almost isometrically (*i.e.* proportional growth) (Valentine *et al*. 2011). Our study applies this finding to four pine species growing in pure to mesic Mediterranean stands and make inference in terms of species, climate and site index comparisons.

MATERIAL & METHODS

Data: Individual diameter and height measures (18.832 pairs) of trees across a climate gradient, from semi arid (SUBSAH) to Borealoid (ORSUB) conditions in Spain, covering the distribution of four *Pinus* species (Table 1).

Analysis approach: Firstly, we fitted model [1] to our data by species. Secondly, we compared the scaling parameter via model comparison using a F-likelihood ratio test.

Table 1. Climate classification

Acronomym	Allue (1991)	Drought length (months)	Rainfall (mm)	tf	Species
ORSUB	VIII(VI)	0-1.25	>950	<=4	Ps
NEMGE	VI(IV)	0-1.25	>950	> 4º	Ps, Pn
NEMEST	VI(VII)	0-1.25	<=950		Ps
NEMDG	VI(IV)	1.25-3		<7.5	Ps, Pn, Pt, Ph
MEDGE	IV	>3	>400	< 9.5º	Pt, Ph
SUBSAH	IV(III)	>3	<=450	>=9.5º	Ph

Ps: *Pinus sylvestris* L; Pn: *Pinus nigra* Arn.; Pt: *Pinus pinaster* Ait.; Ph: *Pinus halepensis* Mill.

$$[1]\quad G_{t+k} = (1+\alpha)^k \cdot G_t \cdot \left(\frac{H_{t+k} - 1.3}{H_t - 1.3}\right)$$

where G is tree basal area, k is the measurement growth interval (years), and H is tree height

RESULTS AND DISCUSSION

#1. Model [1] fitted adequately to our data (fig. 1). There were statistical differences among the species studied individually, although two groups can be established according to the magnitude of the scaling parameter: pure Mediterranean climate species (*Pinus sylvestris-Pinus nigra*) and mesic Mediterranean species (*Pinus pinaster-P. halepensis*) (fig. 2)

#2. Scaling parameter follows a similar value pattern across site index within groups defined in result #1 (fig 3)

Differences in parameter estimation are neglected in *Pinus sylvestris-Pinus nigra* group across site index categories. However, a significance difference is found in the Pure-Mediterranean species group for higher SI values

Values of the scaling parameter are on average higher in *Pinus pinaster-Pinus halepensis* group, indicating a faster cross-sectional growth than height growth, under pure Mediterranean conditions. Conversely, height growth is faster in *P. sylvestris-P. nigra* group. This finding could indicate different competition strategy (asymmetric in *Ps-Pn versus* symmetric in *Ph-Pt*)

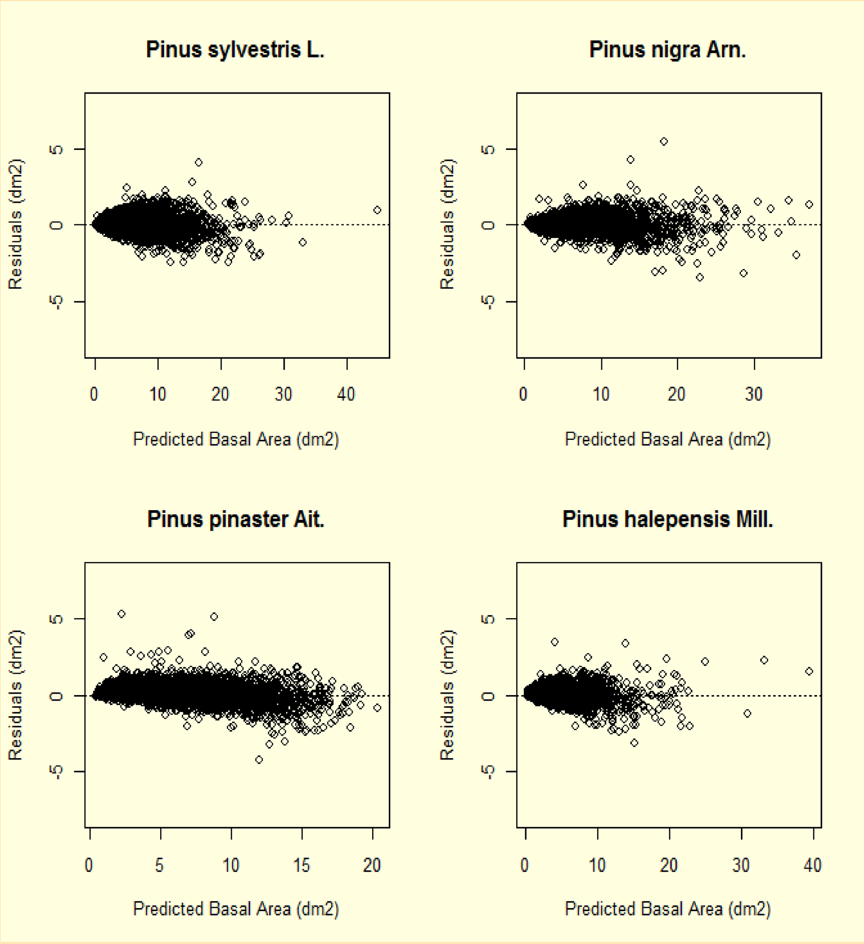

Fig. 1. Model fitting by species

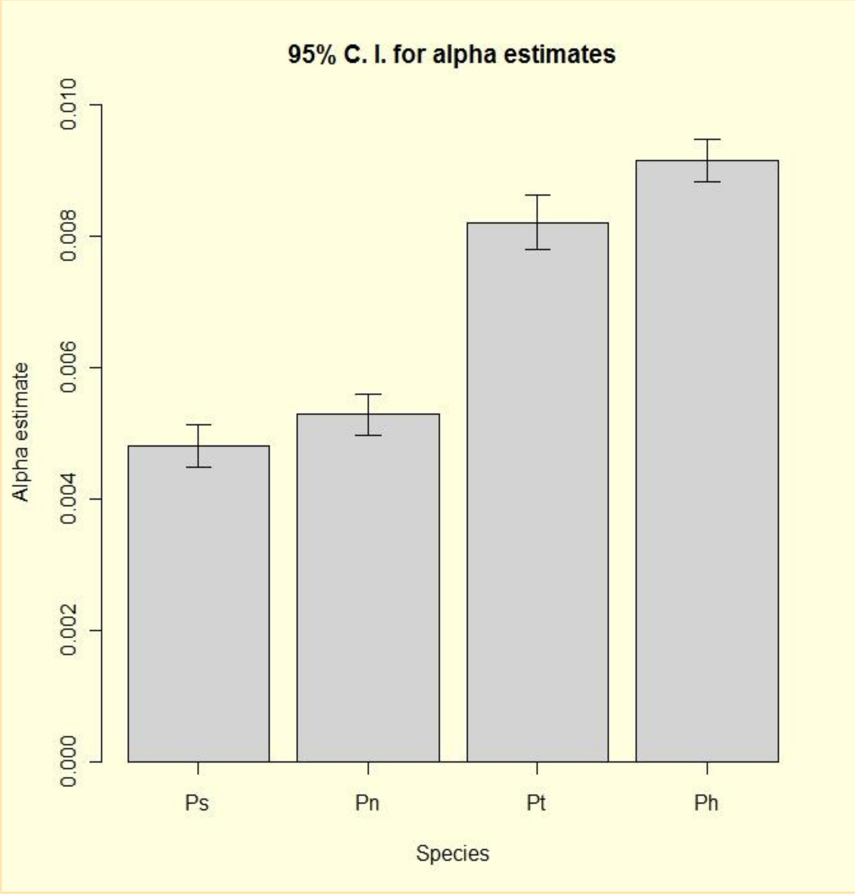

Fig. 2. Mean value and standard error of the scaling parameter of model [1] by species

#3. Differences also appear when species are compared taking into account climate. However, in pure Mediterranean climate (MEDGE) such differences vanish.

Table 2. Likelihood ratio test for comparisons between species and climate in the sacaling parameter

Species	Model	Parameter	Estimate	Std. error	t-value	Pr<|t|	Rse	F	Pr>F
Ps-Pn (NEMGE)	Reduced	α	0.00330	0.00052	6.29	<0.0001	0.32	7.554	0.0063
	Full	α	0.00412	0.00060	6.89	<0.0001	0.31		
		α_1	-0.00332	0.00121	-2.74	0.00647			
Ps-Pn (NEMDG)	Reduced	α	0.00474	0.00014	34.55	<0.0001	0.47	60.201	<0.0001
	Full	α	0.00284	0.00028	10.10	<0.0001	0.47		
		α_1	0.00249	0.00032	47.74	<0.0001			
Ps-Pt (NEMDG)	Reduced	α	0.00633	0.00018	35.04	<0.0001	0.55	169.96	<0.0001
	Full	α	0.00284	0.00032	8.77	<0.0001	0.54		
		α_1	0.00503	0.00039	12.99	<0.0001			
Ph-Ps (NEMDG)	Reduced	α	0.00505	0.00020	24.71	<0.0001	0.42	251.76	<0.0001
	Full	α	0.00944	0.00033	28.30	<0.0001	0.41		
		α_1	-0.00660	0.00041	-15.99	<0.0001			
Pn-Pt (NEMDG)	Reduced	α	0.00638	0.00014	46.77	<0.0001	0.54	85.392	<0.0001
	Full	α	0.00533	0.00018	30.01	<0.0001	0.53		
		α_1	0.00254	0.00027	9.24	<0.0001			
Ph-Pn (NEMDG)	Reduced	α	0.00589	0.00014	42.00	<0.0001	0.45	104.05	<0.0001
	Full	α	0.00944	0.00037	25.49	<0.0001	0.45		
		α_1	-0.00411	0.00040	-10.30	<0.0001			
Ph-Pt (NEMDG)	Reduced	α	0.00816	0.00019	43.67	<0.0001	0.53	10.68	0.0011
	Full	α	0.00944	0.00043	21.80	<0.0001	0.53		
		α_1	-0.00157	0.00048	-3.28	0.00106			
Ph-Pt (MEDGE)	Reduced	α	0.00924	0.00019	48.13	<0.0001	0.46	1.35	**0.2449**
	Full	α	0.00913	0.00021	42.88	<0.0001	0.46		
		α_1	0.00057	0.00049	1.16	0.245			

Ps: *Pinus sylvestris* L; Pn: *Pinus nigra* Arn.; Pt: *Pinus pinaster* Ait.; Ph: *Pinus halepensis* Mill. In parenthesis climate acronomym

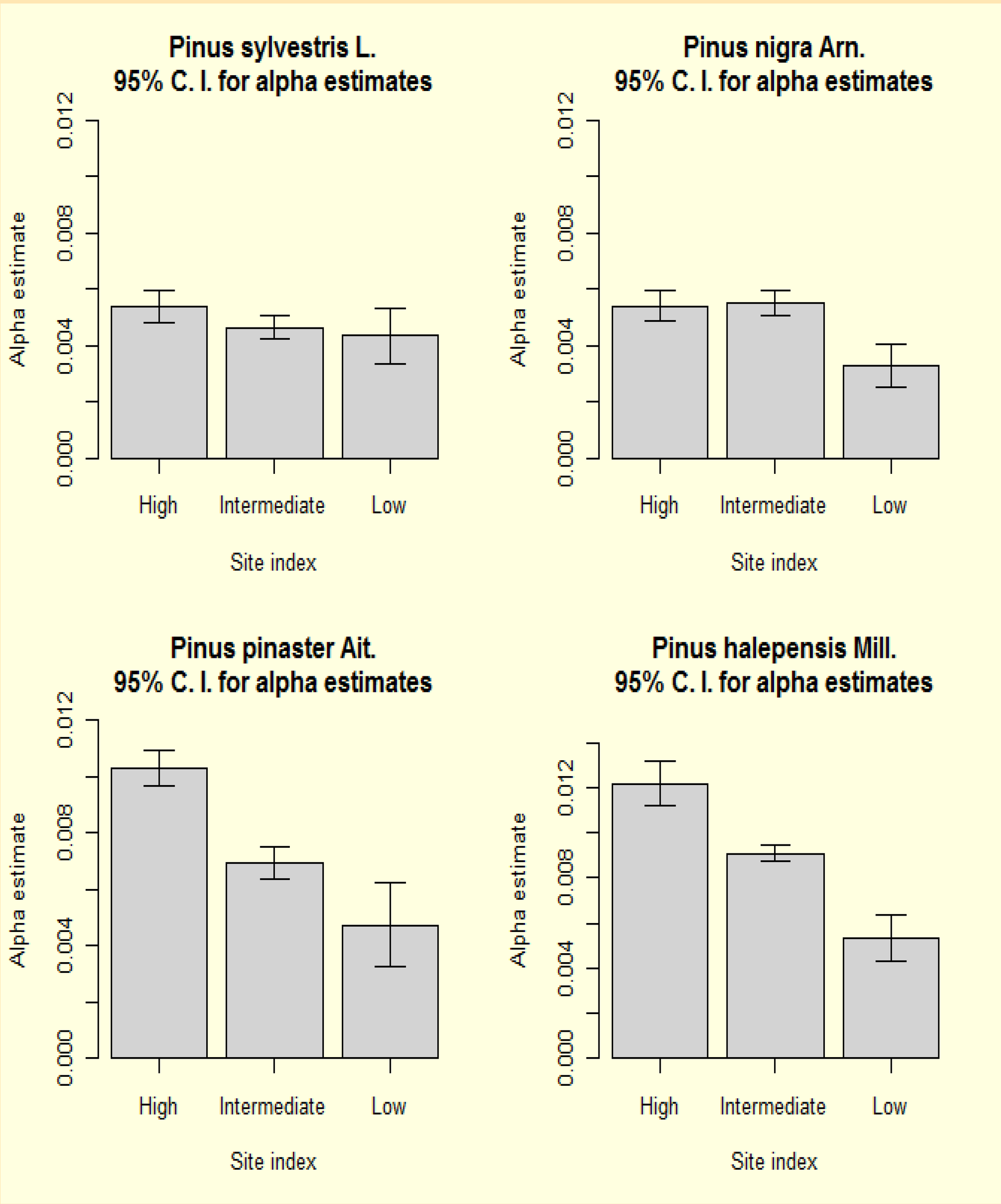

Fig. 3. Mean value and standard error of the scaling parameter of model [1] by species and site index classification

CONCLUSIONS

On the scaling of cross-sectional *vs* height growth...

#1. There exists a climate gradient from sub Saharan climate (south-east of Spain) to Borealoid climate (high mountains) which corresponds to species distribution pattern (Ph-Pt-Pn-Ps) indicating a faster basal area growth than height.

#2. Pure Mediterranean species showed a distinct behaviour according to site index values

#3. .*Pinus halepensis* and *Pinus pinaster* scale similarly in Mediterranean climate

REFERENCES

Makëlä, A. (1986). Implications of the Pipe Model Theory on dry matter partitioning and height growth in trees. *J. Theor. Biol*. 123:103-120

Shinozaki et al. (1964). A quantitative analysis of plant form-the pipe model theory. I. Basic analysis. *Jap. J. Ecol.* 14(3), 97

Valentine, HT. (1985). Tree-growth models: derivations employing the pipe-model theory. *J. Theor. Biol*. 117, 579

Valentine, HT., Mäkelä, A., Green E.J., Amateis, R.L., Mäkinen, H., Ducey, M.J. 2011. Relating stem growth and form to crown length in loblolly pine and Norway spruce. *Manuscript in review.*