**SUPPLEMTARY MATERIAL**

## Riofrío, J. *et al.* (2019) Species mixing effects on height-diameter and basal area increment models for Scots pine and Maritime pine. *Forests.*

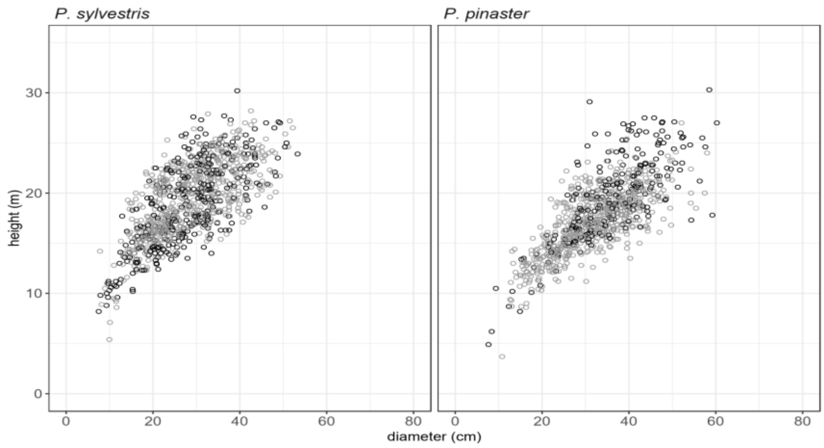


**Figure S1.** Tree height plotted against diameter of Scots pine (*Pinus sylvestris)* and Maritime pine (*Pinus pinaster)* in mixed (black open symbols) and pure stands (gray open symbols) for the triplets network dataset (Training dataset).

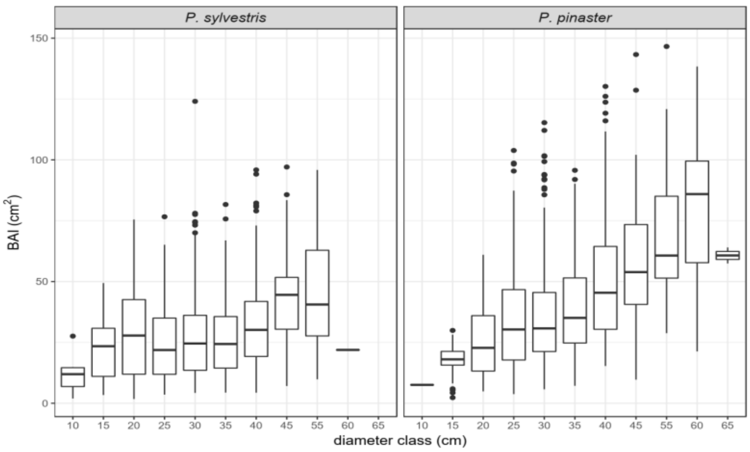


**Figure S2.** Basal area increment data used for models fitting in 5 cm diameter classes for Scots pine (*Pinus sylvestris)* and Maritime pine (*Pinus pinaster)* in mixed and pure stands.

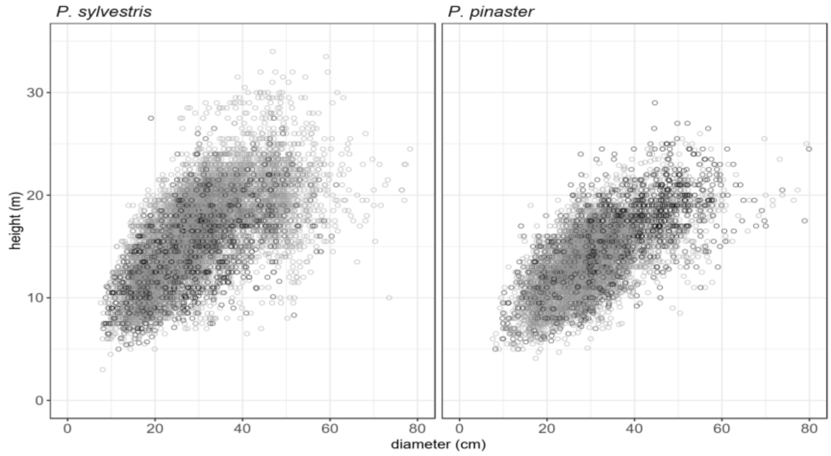


**Figure S3.** Tree height plotted against diameter of *Pinus sylvestris* and *Pinus pinaster* in mixed (black open symbols) and pure stands (gray open symbols) from National Forest Inventory data (Validation dataset).

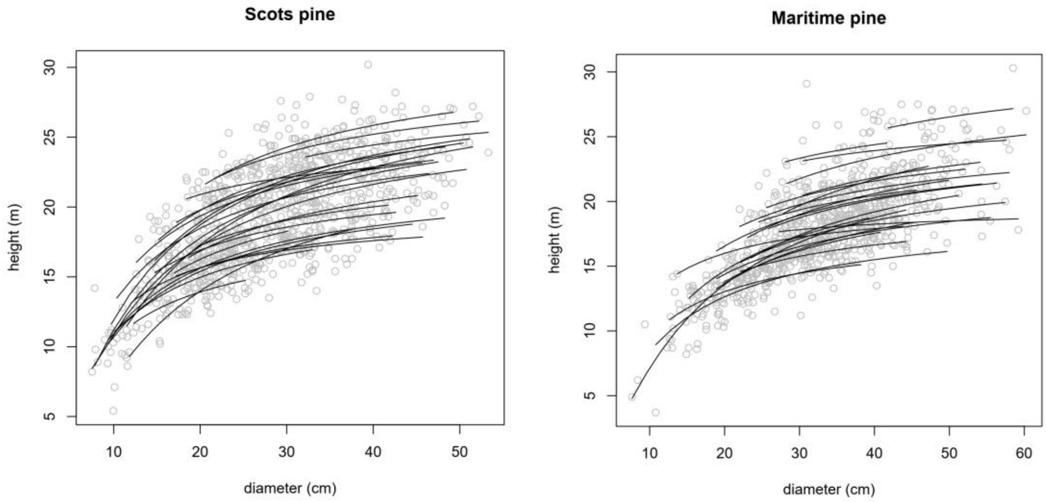


**Figure S4**. Plot-specific *h-d* curves using fitted models overlaid on the measured tree heights (gray dots) for Scots pine and Maritime pine.

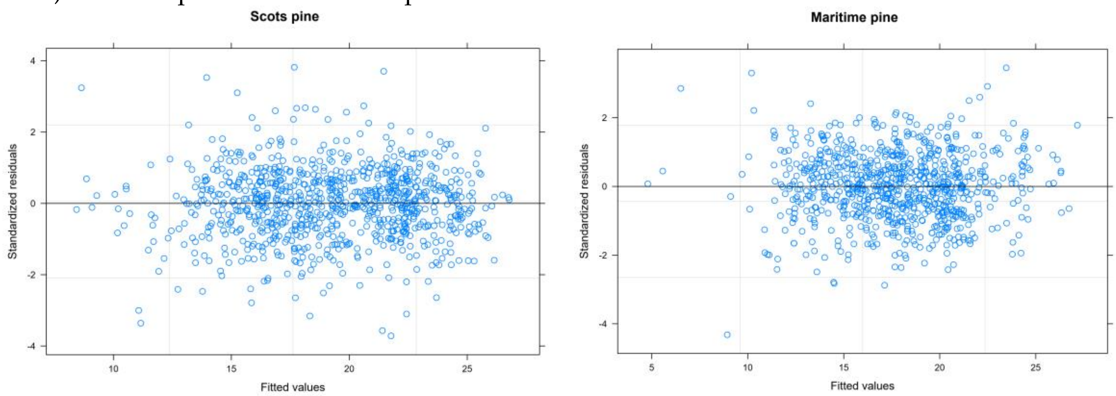


**Figure. S5.** Standardized residuals of generalized non-linear mixed-effects *h-d* models for Scots pine and Maritime pine.

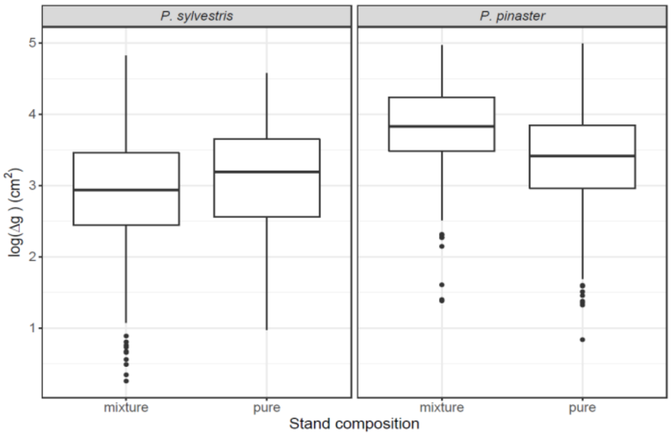


**Figure S6.** Mean 5-year basal area increment of *Pinus sylvestris* and *Pinus pinaster* in mixed and pure stands.

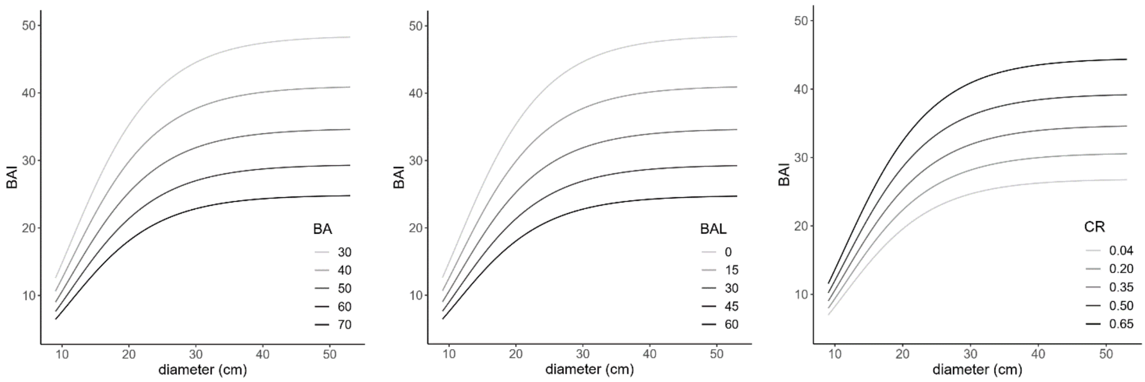


**Figure S7**. Effects of stand basal area (BA), basal area of larger trees (BAL) and crown ratio on the final basal area increment model for Scots pine (Table 4). Curves were produced using the parameter estimates in Table 2 and varying one explanatory variable at a time. Mean values of the data were used for predictors and the range of the variable of interest in the figure.

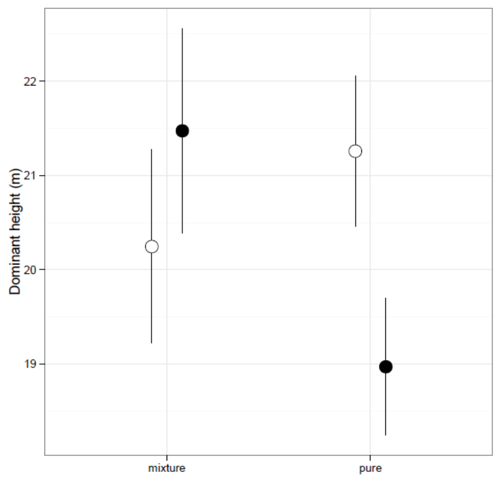


**Figure S8**. Differences of dominant height of each species between mixed and pure stands. Mean and standard error for Scots pine (white circles) and Maritime pine (black circles).

## Appendix S1.

*Screening for generalized h-d models*

In this study we used nonlinear functions widely used for modelling *h-d* relationships. We evaluated functions tested previously to fit the *h-d* relationships for both species in mono-specific stands (M1-M5 in Table S1) and asymptotic general functions used for other species (M6-M9 in Table S1). The basic function forms were expanded for including covariates that described stand characteristics, which would have significant influences on the *h-d* relationships and improve tree height estimates. This was accomplished by expressing the asymptotic parameter in each equation ($\alpha_0$ parameter) as a function of the selected covariates.

**Table S1.** Generalized height-diameter equations evaluated.

| Function number | Function form | Parameter expansion | Source base function |
|---|---|---|---|
| M1 | $h = 13 + \alpha_0\, e^{\left(\frac{-\alpha_1}{\sqrt{d}}\right)}$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Schöder & Álvarez (2001) |
| M2 | $h = \alpha_0\, e^{\left(\frac{\alpha_1}{d}\right)}$ | $\alpha_0 = \beta_0\, Ho^{\beta_1} \cdot V_2^{\beta_2} \cdot \ldots \cdot V_i^{\beta_i}$ | del Río (1999) |
| M3 | $h = \alpha_0\, e^{\left[\alpha_1\left(\frac{1}{d} - \frac{1}{Do}\right)\right]}$ | $\alpha_0 = \beta_0\, Ho^{\beta_1} \cdot V_2^{\beta_2} \cdot \ldots \cdot V_i^{\beta_i}$ | del Río (1999) |
| M4 | $h = Ho\, e^{\left[\alpha_0 \cdot \left(\frac{1}{d} - \frac{1}{Do}\right)\right]}$ | $\alpha_0 = \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Michailoff (1943) |
| M5 | $h = Ho\, e^{\left[\alpha_0 \cdot \left(\frac{1}{d} - \frac{1}{Do}\right)\right]}$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Michailoff (1943) |
| M6 | $h = 1.3 + \alpha_0 \left[1 - e^{(\alpha_1 \cdot d)}\right]^{\alpha_2}$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Richards (1959) |
| M7 | $h = 1.3 + \alpha_0 \left[1 - e^{(\alpha_1 \cdot d^{\alpha_2})}\right]$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Yang (1978) |
| M8 | $h = 1.3 + \alpha_0\, e^{(\alpha_1 \cdot d^{-\alpha_2})}$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Korf (Zeide 1989) |
| M9 | $h = 1.3 + e^{\left(\alpha_0 + \frac{\alpha_1}{d + \alpha_2}\right)}$ | $\alpha_0 = \beta_0 + \beta_1 Ho + \beta_2 V_2 + \ldots + \beta_i V_i$ | Ratkowsky (1990) |

$h$: tree height (m); *d*: diameter at breast height (cm); $\alpha_0, \alpha_1, \alpha_2$ are species dependent parameters. $\beta_0$ and $\beta_{1\ldots\ldots i}$ are species model parameters for each explanatory variables tested in the model selection procedure. Note that Table S1 contains only the basic fixed effects models of the *h-d* analyzed in this study.

### References


Michailoff, J.L. 1943. Zahlenmäßiges verfahren für die ausführung der bestandeshöhenkurven. Forstw. Cbl. U. Tharandter Forstl. Jahrb. 6: 273-279

Ratkowsky, D.A., 1990. In: Handbook of Nonlinear Regression. Marcel and Dekker, Inc., New York.

Richards, F.J., 1959. A flexible growth function for empirical use. J. Exp. Biol. 10, 290–300.

Río, M. del. 1999. Régimen de claras y modelo de producción para *Pinus sylvestris* L. en los Sistemas Central e Ibérico. Tesis Doctorales INIA nº2. Serie Forestal. 257 pp

Schröder, J.; Álvarez-González, J.G. 2001. Comparing the performance of generalized diameter-height equations for maritime pine in Northwestern Spain. Forstw. Cbl. 120: 18-23

Yang, R.C., Kozak, A., Smith, J.H.G., 1978. The potential of Weibull-type functions as flexible growth curves. Can. J. For. Res. 8, 424–431.

Zeide B (1989) Accuracy of equations describing diameter growth. Can J For Res 19:1283–1286

**Table S2**. Ranking and summary statistics for generalized height–diameter models fitted without considering the species-mixing effects, according to functions of Table S1

| Maritime pine | | | **Scots pine** | | |
|---|---|---|---|---|---|
| **Model** | **AIC** | **RMSE** | **Model** | **AIC** | **RMSE** |
| M3 | 2880.4 | 1.362 | M3 | 3388.2 | 1.568 |
| M2 | 2890.3 | 1.380 | M2 | 3390.1 | 1.569 |
| M4 | 2895.3 | 1.377 | M7 | 3390.4 | 1.571 |
| M9 | 2896.5 | 1.379 | M9 | 3392.7 | 1.584 |
| M5 | 2897.8 | 1.376 | M6 | 3393.2 | 1.571 |
| M7 | 2907.1 | 1.376 | M4 | 3396.9 | 1.573 |
| M8 | 2914.5 | 1.379 | M5 | 3397.5 | 1.573 |
| M6 | 2914.8 | 1.381 | M8 | 3400.7 | 1.576 |
| M1 | 2925.2 | 1.392 | M1 | 3401.2 | 1.576 |

## Appendix S2.

*Models selection*

To evaluate the performance among different set of *h-d* functions and individual tree growth models, we used the multi-model inference approach based on information-theory (Anderson, 2007), which allows evaluation of multiple non-nested models relative to each other and quantification of the relative support for multiple models simultaneously. Fitted models were ranked by lowest AICc (Second-order Akaike Information Criterion) and greater Akaike weights ($w_i$) values. The following Akaike weight of each model is a measure of the probability that model $i$ is the best model, e.g., the most parsimonious, for the observed data and given the set of candidate models:

$$w_i = \frac{exp\left\{-\frac{1}{2}\Delta_i(AICc)\right\}}{\sum_{k=1}^{K} exp\left\{-\frac{1}{2}\Delta_k(AICc)\right\}} \quad (1)$$

where $\Delta$ is the difference in AICc between model $i$ and the best candidate model for $i = 1, \dots K$. Therefore, the final output is a set of candidate models rather than a single model.

### References


Anderson, D. R. Model Based Inferences in the Life Sciences: a Primer on Evidence; Springer, 2007; ISBN 9780387740737.