Allometric equations for predicting mineralomass in high-forest chestnut stands in Portugal <u>Maria S. Patrício^{1*}, Margarida Tomé²</u>

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Materials and Methods

The present study was carried out in the three high-forest mature chestnut stands located in three mountains of Northern Portugal: Marão (41° 14' 46" N, 7° 55' 04" W), Padrela (41° 30' 41" N, 7° 37' 15" W) and Bornes (41° 29' 42" N, 6° 55' 12" W) which have been monitored over time. Sampling followed a west-

methodology of biomass collection was described by Patrício et al. (2005). These samples of tree-biomass

guarantee of the additivity of the mineralomass of the tree-components to obtain the

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total mineralomass of the tree

Table1. General characteristics of the studied chestnut stands (Northern Portugal).

Marão

Padrela

Bornes

to-east transect across to northern Portugal from a more-Atlantic-to-less-maritime influence

components were analyzed to determine their mineral concentrations.

Chestnut stands Altitude (m a.s.l.)

In order to obtain biomass data, 34 trees were felled according to the existent diameter classes. The



The information of the content of mineral elements in the tree-component biomass is essential understand their status and flow in the whole system, as well as to assess the productive capacity of ecosystems and the management implications for forest sustainability. However, the evaluation of nutrients in biomass tree-components is a process time consuming and expensive, often involving tree felling, not always possible or desirable. On the other hand, the concentration of minerals in tree-biomass compo for a given species varies considerably between tree-components, sites and it is not always available in the literature. Given the importance of the relationship of biomass and nutrients (mineralomass) for dynamic and sustainable management chestnut woodlands, aboveground mineralomass was studied in sweet chestnut (Castanea sativa Mill.) high-forest stands located in Northern Portugal.

Objective: To provide allometric equations for chestnut high-forest woodlands for estimating the mineralomass using the dendrometric variables diameter breast height (d) and total height (h) of the tree

Slope (°) Main soil type* 5-10 25-30 15-20 25-30 ric Rego. 12.5 1132 ic Cambisols 11.9 1009 Umbric Regos 11.5-12.0 D Dyst. Mean annual temperature (°C) Mean annual precipitation (mm year⁻¹) 2505 Age (years) 71 64 53 Northern of Portugal Density (tree ha-1) 470 360 1260 Mean DBH (cm) 41.2±9.0 33.6±6.3 26.1±6.1 N 21.7±2. 22.4±2.7 Mean height (m) 28.7±2.7 *According to World Reference Base for Soil (FAO, 1998) Borr Padrela Marão The collected samples of biomass of leaves, flowers and barks were dried in a stove at 70±2°C, while the log samples and branches, were dried at 103±2°C (until constant weight) for determining the water content and estimating the dry matter. After the drying process the biomass samples were finely ground. Sub-samp were taken for chemical analysis. The following elements were determined: N, P, K, Ca, Mg, S, B and C in all tree-components biomass above ground. We consider the following mineralomass of tree-components: bark (M Bark), leaves and flowers (M_Ltot), live branches (M_Bliv), main stem under bark (M_Wood), main stem over bark (M_Stem) and the total aboveground mineralomass (M_Tot). Model selection: 3 Data analysis: Table2. Biometric variables of the 34 sampled trees ✓The normality of the studentized residuals was analysed using normal QQplots. The presence of heterocedasticity associated with the error term of The mineralomass equations were fitted by the ordinary least squares method (OLS) associated with both the PROC REG (linear models) and PROC NLIN (non-Stand. the models was checked by plotting the studentized residuals against the Minin linear models) procedures of SAS/STAT. The modified Gauss-Newton ite Mear Max predicted values DBH (cm method was applied in the non-linear model fitting. 10.25 33.01 The regression assumptions departure was solved with non-linear iteratively A simultaneous fit by SUR method using iterative seemingly unrelated regression (ITSUR) by PROC MODEL procedure of SAS/STAT was used for the final 11.55 21.91 30.40 4.63 re weighted least squares (IRWLS) using the Huber function with the maximum value of r=1 and weighting factors. The procedure was repeated for each h (m) DPU / ompatible selected mod mineral **Results and Discussion** M Red N (6) (4g) M_TM 040 1.451 (1.699) 0.340 (0.427) 1.468 (1.543) 0.379 (0.279) 0.297 (0.206) 2.703 (2.623) Table 3. Mean value and respective ✓ The selected final models were simultaneously fitted by ✓ To model the mineralomass (M) by tree-components, the following candidate allometric equations were tested: standard deviation (in brackets) of 6223 (6194) 6015 (6011) 6074 (6083) 6036 (6038) 6037 (6038) 6038 (6038) 6116 (6100) (0.155) 0.017 (0.015) 0.005 (0.005) (0.005) 0.005 (0.007) 0.000 (0.000) 0.461 (0.366) (2.4%) 0.048 (2.042) 0.201 (2.201) 0.201 (2.201) 0.204 (2.201) 0.129 (2.104) 0.125 (2.021) 0.106 (2.001) 0.106 SUR method with the ITSUR procedure for each mineral. the mineralomass (n=34 trees) for minerals N, P, K, Ca, Mg, S, B Final compatible mineralomass equations and C $M = \beta_0 + \beta_1 d^2 h$ (1) (1.1) (2) (2.2) (3) $M = \beta_0 + \beta_1 d^{-1} M$ $M = \beta_1 d^2 h$ $M = \beta_0 + \beta_1 d + \beta_2 d^2$ $M = \beta_1 d^2$ $M = \beta_1 d^2$ Nitrogen: N_Bark = 0.5877 10-5 d2h; EM d represent the DBH 0.8871 and *h* the total height of the tree N_bark = 0.587/10-324; N_ltot = 0.1700 10-342; N_Bilv = 0.2930 10-3 d2; N_Wood = 0.3660 10-3 d2; N_Total Phosphorus: P_Bark = 0.1400 10-4 d2; P_ltot = 0.1200 10-4 d2; P_Bilv = 0.3400 10-4 d2; 0.7266 0.5437 0.4609 0.7209 (4) (5) (6) $M = \beta_1 d + \beta_2 h$ $M = \beta_1 (d^2 h)^{\beta}$ $M = \beta_1 d^{\beta_2}$ (M_Wood) mineratomass of main sent sectors as of stem bark, (M_Bliv) mineralomass of mass of leaves and flowers, (M_Tot) the total bark, (M_Bark) minetalomas branches, (M_Ltot) mineralor 0.6318 Table 4. Fitting and prediction statistics of the models with the best performance for the Final mineralomass equations fitted by OLS method 0.3639 Wood = 0.3800 10-4d2; 0.2128 0.4951 mineralomass by tree-component and by _Total Nitrogen: Magnesium: P_104al Potassium: K_Bark = 0.2812 10⁻⁵ d²h; K_Ltot = 0.6600 10⁻⁴ d²; K_Bliv = 0.1480 10⁻³ d²; K_Wood = 0.7100 10⁻⁴ d²; K_Total mineral, after weighting. $\begin{array}{l} \text{Mg}_{\text{Bark}} = 0.4750 \ 10^{-4} \ d^2; \\ \text{Mg}_{\text{Ltot}} = 0.2991 \ 10^{-4} \ d^2; \\ \text{Mg}_{\text{Bliv}} = 0.8383 \ 10^{-4} \ d^2; \end{array}$ 0.5853 0.6634 0.5638 Bark = 0.6260 10⁻⁵ d² h; MSE 0.507 10-7 0.718 10-6 0.2357 10-4 0.2357 10-4 0.284 10-4 7 10-3 EM 0.957 0.837 0.767 0.830 0.944 S R²pred 0.862 0.715 0.477 0.417 0.803 0.720 0.632 0.672 P95 0.065 0.264 0.832 0.530 2.853 P5 -0.101 -0.163 -0.260 -0.286 d Comp. M_Bark M_Ltot M_Bliv M_Wood M_Stem maPRES 0.033 0.076 0.181 0.180 0.611 N Ltot = 0.1768 10-3d2; (1.1 (3) (3) (3) (3) 0.003 0.007 0.043 0.054 0.096 N Bliv = 0.2505 10-3 d² N_Bliv = 0.2505 10 ° d , N_Wood = 0.3232 10⁻³ d²; 0.0932 0.7427 0.2357 10⁻⁴ 0.284 10⁻⁴ 0.257 10⁻³ 0.536 10⁻⁶ 0.216 10⁻⁷ 0.372 10⁻⁷ $Mg_Wood = 0.3080 \ 10^{-5}d^2 h$ $Mg_Tronc = 0.2325 \ 10^{-4}d^2 h$; 0.43 1.929 0.016 0.015 -0.829 -0.010 🗸 -0.008 Calcium Calcium: Ca_Bark = 0.4730 10⁻³d²; Ca_Ltot = 0.2600 10⁻⁴ d²; Ca_Bliv = 0.2491 10⁻³ d²; Ca_Wood = 0.8796 10⁻⁵ d²h; Ca_Total Magnesium: The analysis 0.2546 Tot = 0.4138 10⁻⁴ d² Mg Total = 0.0336+0.9950 10-5 d² h 0.4772 0.4221 0.5882 0.7998 brought to you by 🗓 CORE View metadata, citation and similar papers at core.ac.uk 101 64011 1166 S_Bliv = 0.1063 10⁻⁴ d²; (3) M_Bliv 0.786 10⁻⁵ (1.1) M_Wood 0.156 10⁻³ (1.1) M_Stem 0.002 0.274 0.192 1.034 0.398 0.580 0.049 0.631 0.673 5.256 P Bliv = 0.3070 10⁻⁴ d² Magnesium: Mg_Bark = 0.4300 10⁻⁴ d²; Mg_Ltot = 0.3000 10⁻⁴ d²; Mg_Bliv = 0.9700 10⁻⁴ d²; 0.096 0.078 0.393 0.4369 0.7398 component: $P_Wood = 0.3217 \ 10^{-4} d^2;$ $P_Tronc = 0.1713 \ 10^{-3} \ d^2;$ $S_Wood = 0.1550 \ 10^{-5} \ d^2h;$ $S_Tronc = 0.4420 \ 10^{-5} \ d^2h;$ M_Tot M_Bark M_Ltot M_Bliv M_Wood M_Stem 0.036 0.392 10⁻⁴ 0.337 10⁻⁶ 0.359 10⁻⁴ 0.352 10⁻³ 0.088 0.171 0.224 0.016 0.198 0.148 2.260 0.719 0.242 0.451 0.401 0.538 0.498 -0.274 -0.629 -0.021 -0.492 -0.258 -6.362 0.925 0.852 0.749 0.707 0.773 0.891 0.023 0.009 0.002 0.027 0.023 0.119 0.5323 Mg_Wood = 0.3100 10⁻⁵d² h; Mg_Total Sulfur: S_Bark = 0.2441 10⁻⁶ d²h; P Total = 0.1030 10-3d2: S Total = 0.2580 10⁻⁵ d² h; 0.7125 0.7246 Potassium: K Bark = 0.2400 10⁻⁵ d²h; Boron: B_Bark = 0.3386 10⁻³ d²; M_Tot M_Bark M_Ltot M_Bliv M_Wood M Stem 0.414 10⁻⁵ 0.752 10⁻⁶ 0.229 10⁻⁶ 0.283 10⁻⁵ 0.229 10⁻⁴ 0.001 0.870 0.357 0.719 0.465 0.681 0.637 0.882 0.779 0.822 0.759 0.874 0.893 0.286 0.024 0.014 0.059 0.037 0.243 0.687 -0.565 -0.048 -0.022 -0.083 -0.071 -0.540 0.5537 K_Ltot = $0.6220 \ 10^{-4} \ d^2$; K_Bliv = $0.1370 \ 10^{-3} \ d^2$; B Ltot = 0.9340 10-4 d2 S Ltot = 0.7388 10-5 d2 0.7147 0.232 B_Bliv = 0.6070 10⁻³ d²; B Wood = 0.7160 10⁻³ d²; S Bliv = 0.1100 10⁻⁴ d² 0.6622 S_Wood = 0.1872 10⁻⁵ d²h; S_Total 0.3827 K Wood = 0.2430 10⁻⁵ d²h M_Tot M_Bark M_Ltot M_Bliv M_Wood 0.818 0.835 0.852 0.797 0.616 0.775 0.125 0.003 0.003 0.007 0.036 0.642 0.326 0.510 0.010 0.692 0.009 0.619 0.036 0.314 0.183 0.461 0.239 -0.203 -0.009 -0.009 -0.010 0.054 0.479 10 0.321 10 0.155 10 0.023 0.128 10 0.143 10 0.5925 K_Tronc = 0.3036 10⁻⁴ d²h; B Tronc = 0.00438 d² Boron: B_Bark = 0.3330 10⁻³ d²; B_Ltot = 0.9200 10⁻⁴ d²; B_Bliv = 0.655 10⁻³ d²; B_Wood = 0.7940 10⁻³ d²; 0.8000 0.5354 0.6128 B_Total = 0.9437 10-4 d² h; 0.351 10 0.260 10 K Total = 0.4060 10⁻³ d²: Calcium: Carbon: 0.956 10⁻³ 0.397 10⁻⁷ 0.119 10⁻⁴ 0.491 10⁻⁵ 0.125 10⁻³ 0.150 10⁻³ 0.169 10⁻³ C_Bark = $0.0076 (d^2 h)^{0.7880}$; C_Ltot = $0.0045 d^2$; C_Bliv = $0.0490 d^2$; M_Tot M_Barl 0.82 0.008 0.034 0.631 0.159 -0.060 Ca_Bark = 0.4152 10-3d2; 0.6011 0.780 0.507 0.562 0.576 0.055 0.397 0.407 0.236 Ca_Ltot = 0.2824 10⁻⁴ d²; Ca_Bliv = 0.2671 10⁻³ d²; M_Ltot M_Bliv M_Wood 0.684 0.786 0.806 -0.090 -0.513 -1.191 B Total 0.7830 Carbon: C_Bark = 0.010008 (d2h)0.7 0.9491 4.063 2.335 8.348 5.862 188.41 64.273 -3.473 -2.487 -7.686 -3.541 -52.166 -40.100 C_Wood = 0.0138 (d² h)^{0.9360} Ca Wood = 0.8670 10-5 d²h; M_Tot M_Bari 0.237 10 0.915 -0.00 0.831 0.819 C_Ltot = 0.004172 d²; C_Bliv = 0.041554 d²; C_Wood = 0.010784 (d²h)⁰ Ca Tronc = 0.2041 10-3 d² h; Tronc = 0.0342 (d² h)^{0.9299} 0.712 0.5602 0.933 0.5124 0.9314 0.9103 1.976 35.974 26.027 M_Ltot M_Bliv M_Wood 0.004
0.887
0.012 C_Total = 0.0630 d ^{2.3754} Ca_Total = 0.1062+0.3777 10-4 d2h; C_Total) 0.982 -3.611 0.984 -0.942), Mineralomass of the rei g efficiency, (m_PRESS) m s of the PRESS residuals, (F the PRESS residuals M_Tot 0.860 mass of B in (g), Mi 34.370 0.972 66.810 rais in (kg), (M 107.66 ✓ We present the modeling efficiency (EM) of the equations, a measure similar to the e remaining minera S) mean of PRESS ils, (R²pred) R² of p adjusted R^2 in linear models. The *EM* obtained by *SUR* method is generally lower than that obtained by *OLS*, but with a smaller standard error of the coefficients and with the

Conclusions

✓At the end of this study we available equations of mineralomass by tree-components and mineral for the sweet chestnut high-forest management. The information obtained with these mineralomass equations applicable to data of individual trees, can be applied to the forest inventories as well as to a great variety of ecological problems, like wildfire studies, the carbon sequestration and to evaluate the harvesting impact on site nutrient export and site sustainability. References: FAO. (1998), Wold reference base for sol resources. Wold Besources Reports, Rome, 84. Particio, M.S., Mortenio, M.L. and Come, M. (2005), Biomass Equations for Castanee safwa High Forest in the Northwest of Portugal. Acta Hot. 693:727-732.