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# Biomass Equations and Carbon Content of Young Black Locust (*Robinia pseudoacacia* L.) Trees from Plantations and Coppices on Sandy Soils in South-Western Romanian Plain

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**Abstract**

The aim of the paper was to develop biomass equations for young black locust trees from plantations and coppices established in South-West Romania. A destructive method was used to develop allometric biomass equations and to assess the carbon content of the individual tree and its biomass components. 418 black locust young trees (1-4 years old) from 27 plots established in plantations and coppices growing on sandy soils in Dolj and Olt counties were sampled. Simple linear regression models were developed for biomass estimation. The results shown that root collar diameter was the most accurate biomass predictor, whilst intercept and slope values were similar to those identified in other recent studies. The specific carbon content (mean values) was 45% for roots and 48% for leaves, similar to the values provided by Intergovernmental Panel for Climate Change.

***Keywords:*** allometry, individual tree components, root collar diameter

## Introduction

Anthropogenic greenhouse gas (GHG) emissions, and especially $CO_2$ emissions, are recognised as one of the main causes of global warming, this fact being acknowledged in the 4th Assessment Report of the Intergovernmental Panel for Climate Change (2007). The negative impact of planetary climatic changes was also identified in Romania (Pienaru *et al*., 2009), especially in areas with very low percentage of forests, located in the southern part of the country (Lower Danube Plain). Such areas are prone to desertification, due to the prolonged droughts and high temperatures recorded during the summer (above 40°C). In order to mitigate the effects of climate, several local communities and forestry administration initiated an afforestation program for the degraded agricultural lands. The main species established on such lands is black locust (*Robinia pseudoacacia* L.).

On the other hand, Romania, as any other part of Annex I to United Nations Framework Convention on Climate Change (UNFCCC) and as a country which ratified the Kyoto Protocol, accounts for Land Use, Land Use Change and Forestry (LULUCF) activities to demonstrate compliance with its emission reduction target. For this purpose it conducts a National Greenhouse Gas Inventory, as obligations under UNFCCC (and European Union commitments) and implements GHG emissions reductions and carbon sequestration activities. In order to report consistent and accurate national data on carbon stocks and $CO_2$ removal by forest ecosystems, allometric equations are considered the most reliable data source (Blujdea *et al*., 2012; IPCC, 2006), whilst some authors underlines that such equations are of international importance (Basuki *et al*., 2009; Olofsson *et al*., 2011; Parresol, 2009).

The aim of this paper was to provide species - specific biomass equations for young black locust trees (1- 4 years old) from plantations and coppices established on sandy soils. Such equations are very important considering the general lack of allometric data for young/small trees, required for the national reports on GHG removal in the case of degraded agricultural land afforestation, especially in South-Eastern Europe.

## Material and methods

The research has been carried out in the southern part of Dolj and Olt counties (Băileşti and Caracal plains), in areas characterized by mean annual temperatures above 10 °C and a mean annual rainfall of 570 mm. 27 circular sample plots (SP) of 200 $m^2$ were installed in 1- 4 years old pure black locust plantations and coppice stands (of a an area of minimum 0.5 hectares) established on sandy soils. The root collar diameter (DCH, mm), the diameter at breast height (DBH, cm) - where available, and the total tree height (H, cm) were measured for each individual tree of the sample plots. The destructive sampling method (Böhm *et al*., 2012; Picard *et al*., 2012) was applied in order to measure the dry biomass for 418 trees: 225 seedlings and 193 shoots (5-10 individuals for each 2cm diameter class identified in each sample plot). Afterwards, biomass equations were developed at tree level (seedling or stump shoot/root sucker), for biomass components (i.e. root, stem, branches, leaves) and the aggregated ones (total biomass and above ground woody biomass -AGWB). Organic carbon content of biomass was determined for 73 component samples (root, stem, branches and leaves) collected from 21 individual trees (14 seedlings and 7 shoots), using the dry Dumars combustion method (Edu *et al*., 2013).

The allometric model for biomass estimation used in this study was a power one with a single predictor. This approach was justified by the fact that each of the utilised predictors (DCH, DBH and H) explained more than 90% of the variance of biomass.

The assumptions of linear regression (i.e. linearity, independence, homoscedasticity and normality) cannot be tested for power equations. Therefore, the variables were log transformed using the natural logarithm, from a power model ($B = a \times D^b$) to a linear regression model [$\ln(B) = \ln(a) + b \ln D$], where B is the biomass (grams), D is the predictor - DCH (mm), DBH (mm) or H (cm), a and b - regression coefficients.

After testing the linear regression assumptions, the equations were transformed back. This transformation induces a bias which can be reduced by adopting a correction factor (CF) proposed by Sprugel (1983) and based on standard error of the estimate. Thus, the final form of the biomass equation was:

$$B = CF \times e^{(\ln(a) + b \ln (D))}$$

R version 3.0.1 for Windows - open source software (R Core Team, 2013) was used to do the statistical analysis of the datasets.

## Results and discussion

After testing the linear regression assumptions (Fig. 1), the developed allometric models shown that DCH is the best predictor both for the total biomass of the individual tree and for its biomass components. The regression coefficients of the DCH based equations developed for black locust are presented in Tab. 1, both for seedlings (plantation) and shoots (coppice) of ages between 1 and 4 years. Values of intercept [ln(a)] and slope (b) are statistically significant in all cases ($p< 0.001$).

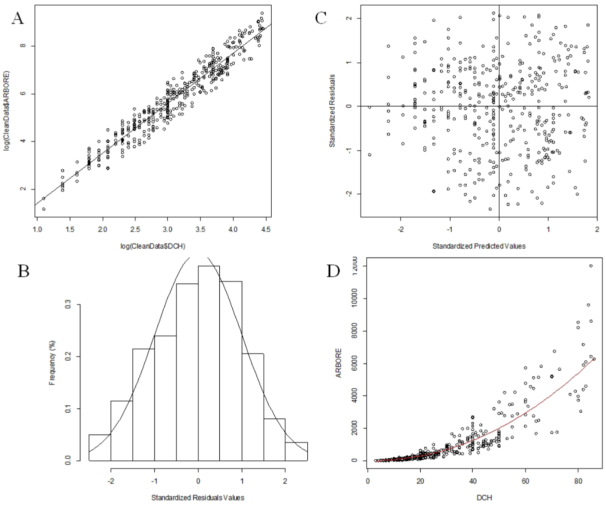


Fig. 1. The statistical testing of the linear regression assumptions: linearity (A) of inputs and residuals normality (B) and heteroscedasticity (C) and the regression curve (D) – DCH as predictor (*R outputs*)

The model based on DCH as a biomass predictor explains between 85-98% of the variability of the dependent variable; nevertheless, the lower $R^2$ values for leaves of shoots (coppice) indicate a precautious approach in using DCH as a biomass predictor for this tree component. As observed from Tab. 1, the model estimates better the biomass for planted seedlings. The low values of the standard error of mean (SEM) and the very significant Fischer test (F) values also indicate the model robustness.

The intercept values are consistent with those published by Blujdea *et al*. (2012), while slope values are close to those developed by Pilli *et al*. (2006) for young trees (2.09). CF values varied significantly, recording higher values for smaller samples or where the model fails to achive high explicative power (e.g. leaves biomass for shoots/ sprouts).

The specific carbon content of tree components in black locust plantations and coppices is presented in Tab. 2. It can be noticed that the specific carbon content (mean values) was 45% for roots and 48% for leaves, similar to the values provided by IPCC (2006) (46-50%).

## Conclusions

The log-transformed power equation proved to be a suitable allometric model to estimate biomass in young black locust plantation and coppices. Among the analysed predictors, the root collar diameter (DCH) represented the most adequate biomass predictor. The measured carbon content of tree components confirmed the validity for young black locust trees of the IPCC recommended generic values.

Tab. 1. The regression coefficients and the results of the model validity testing - DCH as predictor

| Biomass component | *ln(a)* ± SEM | b ± SEM | CF | $R^2$ | F | p |
|---|---|---|---|---|---|---|
| | | Seedlings (plantation) | | | | |
| Roots | -2.45061±0.13921 | 2.30782±0.04473 | 1.134352 | 0.9253 | 2662 | < 0.001 |
| Stem | -2.22443±0.09569 | 2.26553±0.03057 | 1.060552 | 0.9637 | 5493 | < 0.001 |
| Branches | -5.83327±0.25313 | 3.09105± 0.07758 | 1.288592 | 0.8987 | 1587 | < 0.001 |
| Leaves | -1.33825±0.13740 | 1.93595±0.04399 | 1.139922 | 0.9005 | 1936 | < 0.001 |
| Total tree | -0.97829±0.06863 | 2.26105±0.02202 | 1.054000 | 0.9803 | 10540 | < 0.001 |
| AGWB | -2.57776±0.08932 | 2.4642±0.02852 | 1.052861 | 0.9733 | 7661 | < 0.001 |
| | | Stump shoots/root suckers (coppice) | | | | |
| Stem | -1.95865±0.10809 | 2.26294±0.03342 | 1.049837 | 0.9624 | 4586 | < 0.001 |
| Branches | -5.00710±0.28800 | 2.69595±0.08691 | 1.291361 | 0.8514 | 962.2 | < 0.001 |
| Leaves | -0.0569±0.4013 | 1.5162±0.1542 | 1.229705 | 0.5665 | 96.71 | < 0.001 |
| Total tree | -0.47992±0.13385 | 1.94177±0.04117 | 1.081935 | 0.924 | 2224 | < 0.001 |
| AGWB | -1.96634±0.10492 | 2.33189±0.03236 | 1.050143 | 0.9665 | 5194 | < 0.001 |

Tab. 2. The specific carbon content of tree components (plantations and coppices)

| Regeneration type | No. of samples | Age class (years) | DCH category (cm) | Specific C content (%) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Roots | Stem | Branches | Leaves |
| Plantations | 7 | 1-3 | 0.1-2 | 44-47 | 46-49 | 46-49 | 45-51 |
| | 5 | 3-4 | 2.1-4 | 45-47 | 46-49 | 47-48 | 47-50 |
| | 2 | 4 | 4.1-6 | 45-46 | 44-48 | 48 | 47-49 |
| Coppices | 3 | 1-4 | 0.1-2 | NA | 48-49 | 49-50 | 47-49 |
| | 1 | 2 | 2.1-4 | NA | 49 | 49 | NA |
| | 3 | 3-4 | 4.1-6 | NA | 47-49 | 48-49 | NA |

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