Factsheet # 5

# Allometric Equations for Estimating Above-Ground Biomass Carbon Sequestration in Trees in Agroforestry Systems: A Guide for Ontario Landowners

By

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## Agroforestry and Carbon Sequestration

Agroforestry, as an integrated land-use system, offers a multifunctional approach to land management. This integrated cropping system not only addresses environmental challenges but also enhances sustainability and economic viability for growers / landowners. The United Nations Framework Convention on Climate Change (UNFCCC) emphasizes the importance of such strategies to meet climate goals. In Canada, agroforestry presents an opportunity to sequester carbon while supporting green technologies. Given the forest fires in Canada, trees in agricultural lands (Agroforestry) can contribute significantly to Canada's climate mitigation efforts. Therefore, understanding the contribution of trees in agroforestry systems to offset Green House Gases (GHG) emissions requires accurate quantification of Aboveground Biomass Carbon (AGBC) at the individual tree species level.

## The Need for Allometric Equations in Agroforestry

Quantifying carbon sequestration in agroforestry systems requires accurate estimation methods. Allometric equations developed for trees in the forest are not suitable for trees in agroforestry systems as the tree density (trees per hectare of land) in agroforestry systems is much lower compared to trees in the forest. Further, trees in agroforestry systems utilize nutrients leached down from adjacent annual crops hence, their growth rate is higher compared to trees in the forest. Given the above two reasons, allometric equations for trees grown in agroforestry systems should be developed. Allometric equations are mathematical models that estimate biomass based on tree measurements like Diameter at Breast Height (DBH) and Height (H). These equations will enable landowners to predict carbon sequestration without harvesting trees, aiding in sustainable management practices. These equations, as predictive models, can be used due to their efficiency and accuracy, allowing growers to assess carbon stocks (for carbon credits) and contribute to climate change mitigation efforts. There are currently no predictive models available to estimate the aboveground biomass for tree species under tree-based intercropping systems on marginal lands in southern Ontario, Canada.

## Study Overview

A study to develop predictive models was conducted at the University of Guelph Agroforestry Research Station (GARS) for estimating AGBC in five tree species within a tree-based intercropping system. Representative trees harvested were Red Oak (*Quercus rubra*), Black Walnut (*Juglans nigra*), Black Locust (*Robinia pseudoacacia*), White Ash (*Fraxinus americana*) and Norway Spruce (*Picea abies*). Through biomass sampling and carbon quantification, regression equations were developed using three commonly used allometric models.

*Site Descriptions*

GARS, located in Guelph, Ontario, featured a 30-hectare tree-based intercropping system established in 1987. The area experiences an average annual precipitation of 904 mm, with 338 mm occurring during the growing season. The soil is Gray Brown Luvisols. The tree density was 111 trees $ha^{-1}$ with a within row spacing of 6 m and between row spacing of 15 m. The tree row width was 2 m, on which no crops were grown. Tree alleys were intercropped with either corn (*Zea mays*), or soybean (*Glycine max*) each year.


**Figure 1**. University of Guelph Agroforestry Research Station (tree-based intercropping system), Guelph, Ontario, Canada.

*Aboveground Biomass Sampling and Carbon Quantification*

The tree harvest was conducted during the winter of 2020, and involved selecting a total of sixty six (66) representative trees across the five species. Trunk, branches, and leaves were separated and weighed in the field, with moisture content and carbon concentration determined through established protocols. Actual AGBC was calculated based on biomass dry weight and carbon concentration, providing the needed data for regression modeling.


**Figure 2.** Tree harvesting, biomass and carbon sampling and measurements; University of Guelph Agroforestry Research Station and lab, Guelph, Ontario, Canada.

*Developing Regression Equations*

To develop allometric equations, three commonly used non-linear regression models were evaluated for estimating the AGBC of trees. Models were fitted to the data of H, DBH, and AGBC using SAS 9.4, and parameterization in each model was done separately for each species using the Iterative Optimization Method. The best-fitted equation for each tree species was selected using standard criteria: the scatter plot of observed and predicted AGBC values (OP) plotted against the 1:1 line using the test portion of the tree data. Mean absolute percentage error (MAPE), over/under estimation (MOUE), and fit statistics of nonlinear regression analysis, including Akaike information criteria (AIC), AIC (Akaike's Corrected Information Criterion), and BIC (Bayesian Information Criterion) were performed for further validation of the selected model.

**Best Allometric Equations for Carbon Prediction**

The study identified the best predictive equations for each species, balancing accuracy, and simplicity. The power function using D as the only predictor in the equation was the preferred model for Black Walnut, Black Locust, White Ash, and Norway Spruce. For Red Oak, however, adding tree height or height classes as an additional predictor into biomass equations can significantly improve the model fitting and performance.

The selected models are listed in Table 1. The listed equations in this table for the respective tree species are the best fitted allometric equations that can be used for open-grown and low tress density land-use systems by landowners.

**Table 1.** Best fitted selected allometric equation for predicting aboveground biomass C in five tree species under an intercropping agroforestry system in southern Ontario, Canada

| Tree Species | Best allometric equation |
|---|---|
| Red Oak | $0.00776(D^2H)^{1.0856}$ |
| Black Walnut | $0.0126D^{2.8417}$ |
| Norway Spruce | $0.03674D^{2.5355}$ |
| Black Locust | $0.0132D^{2.6762}$ |
| White Ash | $0.0231D^{2.6126}$ |

**Conclusion**

In conclusion, the development of species-specific allometric equations provides Ontario landowners with valuable tools to estimate carbon sequestration in agroforestry systems. These equations, validated through rigorous statistical analysis, offer a practical means to assess carbon stocks without the need for tree harvesting. By integrating such predictive models into management practices, growers can contribute to climate change mitigation efforts (carbon credit), while fostering sustainable land use practices.