ALLOMETRIC BIOMASS MODELS AND APPLICATIONS FOR BRANCHES OF CHINESE TALLOW IN A MISSISSIPPI BOTTOMLAND FOREST

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Abstract--Chinese tallow [*Triadica sebifera* (L.) Small*,* formerly *Sapium sebiferum* (L.) Roxb.] is a non-native invader moving through the southeastern United States. Tallow can invade a multitude of habitats, from coastal prairies to closed-canopy forests, forming monospecific stands and driving out native flora and fauna (Bruce and others 1997). Tallow has large impacts, both economically and ecologically, and is a growing concern among ecologists, landowners, and the public alike. An understanding of the ecology and biology of tallow, along with its effects on forest alteration, is necessary for any attempt at control to be successful. This paper aims to establish an accurate model for the branch biomass of Chinese tallow to be used in additive modeling and as a tool in future field research under the hypothesis that biomass increases with diameter and length.

INTRODUCTION

Tallow [*Triadica sebifera* (L.) Small*,* formerly *Sapium sebiferum* (L.) Roxb.], native to China and Japan and commonly referred to as the popcorn or chicken tree, is an aggressive invader in the southern United States (Bruce and others 1997). In the introduced range, tallow has the ability to expel native species and forms monospecific stands (Zou and others 2006). The Chinese tallow is versatile in its habitat range, able to tolerate both salt- and fresh-water flooding and shade (Barrilleaux and Grace 2000, Pattison and Mack 2009).

Tallow's rapid growth, high reproductive rates, competitive ability, and large range of tolerances make this species an incredible invader, and consequently, a substantial problem for native species, land owners, and managers. As with any invasive species, a comprehensive understanding of the biology and ecological interactions is a necessary foundation for any successful control or eradication program.

Comprehensive knowledge of the crown biomass is an important component in understanding the biology and ecological functioning of the species, specifically in the assessment of invasive and competitive abilities (Blossey and Nötzold 1995, Perry 1985, Weiner 2004). This study aims to create functional biomass models at the individual branch level to provide an understanding of the total crown biomass for Chinese tallow. Modeling at this small scale allows us to gain an accurate measure of the biomass in different components of the tree to be used in a wide array of comparisons and analyses. Branch models can be used to show the relationship between crown and stem biomass as an indication of competitive ability and become important in carbon storage and cycling dynamics, especially as displacement of native species persists (Blossey and Nötzold 1995, Brown 2002).

In this paper, working biomass models for individual branches of Chinese tallow were created under the hypothesis that biomass increases with length and diameter.

MATERIALS AND METHODS

Location

Tallow was identified and sampled from a site near Poplarville, MS on September 25, 2012. The study site is in Pearl River County, borders the Louisiana state line, and can be classified as a bottomland forest.

Sample Collection and Preparation

Five trees were felled and measured for diameter at breast height (d.b.h.) and total height. Branches were then cut from the bole and saved for measurement. Branches were further cut at any adjoining division that was over 1cm in diameter. Measurements were then taken for branch basal diameter and branch length. Two hundred branches were taken back to the lab for subsample measurements.

Subsample Analysis

The branch subsamples were oven dried at 38.9 °C for 24 hours, until a constant weight was

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reached. Using dry weight as an indicator of biomass, the samples were then weighed and recorded. This information was used in the creation of biomass models and was applied to branches from all five sampled trees.

Statistical Modeling

Biomass, length (L), and basal diameter (D) for each branch were entered into a data set in SAS (SAS Institute 2008) and fitted using regression analysis assuming that biomass was a function of D and/or L. Eight models were tested using varying relationships of L and D and histograms, probability plots of residuals, Akaike's Information Criteria (AIC), R^2, and RMSE values were evaluated for goodness of fit.

RESULTS

From the eight models tested we concluded that biomass is exponentially related to diameter and length. Between the exponential models, only slight differences emerged in goodness of fit between models that included basal diameter only ($R^2 = 0.71$), length only ($R^2 = 0.70$), and models including both diameter and length ($R^2 = 0.71$). Based on our fit statistics, parameter estimations from the best fitting model were used to construct our final branch biomass model:

$$Biomass(g) = 9.2813 + \exp(0.8342 * D) \qquad (1)$$

where *D* is the branch basal diameter in cm and *biomass* is measured as dry weight in g.

When graphed with measured data, this model proves to be an accurate depiction of branch biomass (fig. 1).

This biomass equation was then used to generate biomass estimations for all branches from the five sampled trees. These branch biomass numbers were then grouped by tree and added to obtain a total crown biomass per tree. A preliminary model of crown biomass versus tree d.b.h is shown in figure 2. This relationship appears to be exponential from our data but with the inclusion of a larger data set may in fact be sigmoidal, with a leveling off of crown biomass as tree d.b.h. increases.

DISCUSSION

Biomass models can be accurately constructed through a thorough statistical analysis and prove to be a useful tool in estimating the biomass contained within a tree. This is especially useful when quantifying the impact that an invasive species may have on carbon pools as it invades and displaces native species or when quantifying invasive and competitive abilities (Blossey and Nötzold 1995, Brown 2002, Perry 1985, Weiner 2004). Through our analysis we have found that branch biomass is exponentially related to branch basal diameter and an accurate model to calculate biomass is: Biomass(g)=9.2813+exp(0.8342*Diameter).

We additively calculated the total crown biomass for each tree sampled and compared them to our measured tree d.b.h. In doing so, we provided a first step that will be useful in determining a stem-to-crown ratio for each tree in future research. A tree with a higher crown biomass to stem biomass will demonstrate a higher competitive ability and will be a successful invader (Blossey and Nötzold 1995, Perry 1985, Weiner 2004). It is also important to note that the location in which a tree is found (forest edge versus interior) can have a significant impact on this ratio. In future research, we will show a comparison of tallow crown to stem ratios to those of native species in an attempt to understand and predict tallow's competitive ability in a quantifiable approach.

For field research it will prove useful to have a model in place to easily and accurately evaluate crown biomass from tree d.b.h. In our study, we showed a preliminary relationship between our calculated crown biomass and tree d.b.h. and plan to build upon this model in the future.

Accurate biomass predictions give great insight into a tree's competitive ability and also its role in carbon cycling within a habitat as an indication of stored forest carbon (Brown 2002). As invasive species are becoming an ever-increasing concern, it is critical that these components are understood to comprehend the full impacts of the non-native organisms and as a baseline for any successful control program.

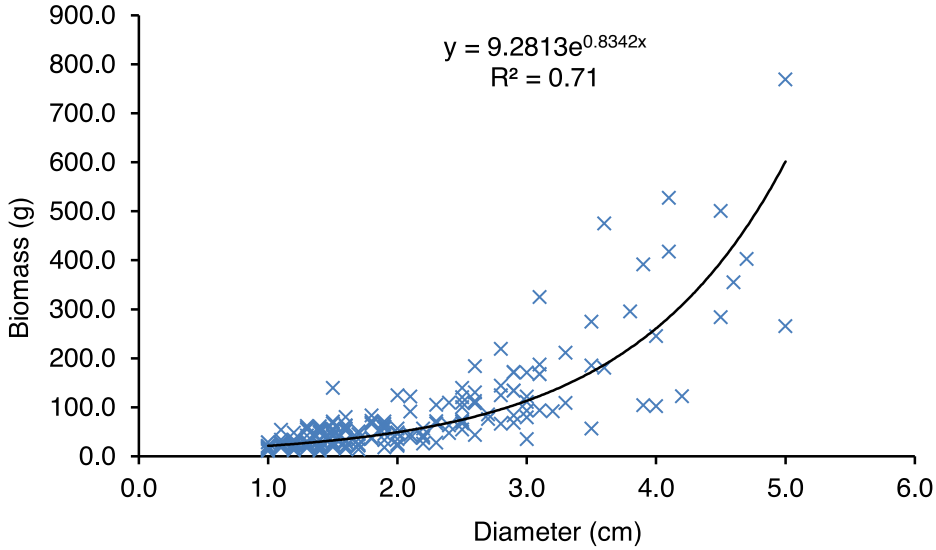

Figure 1--Relationship between Chinese tallow branch basal diameter and branch biomass for 200 samples with model and R^2 value.

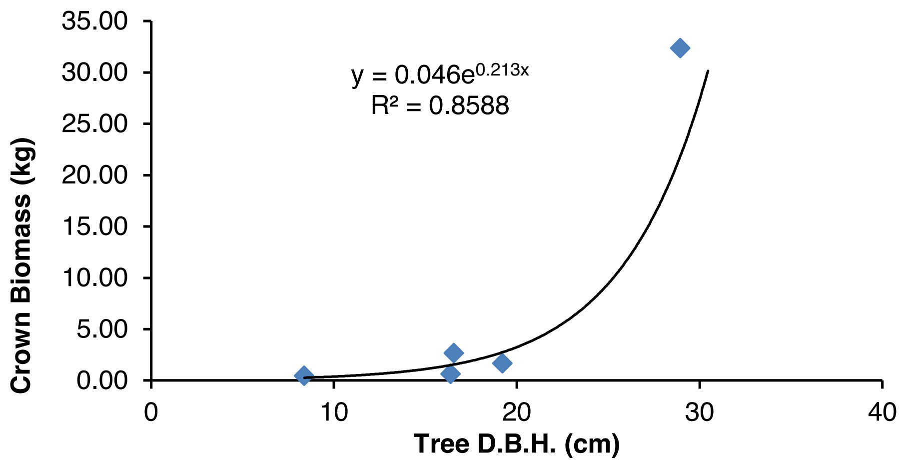

Figure 2--Relationship between Chinese tallow d.b.h. and crown total biomass with model and R^2 value.

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LITERATURE CITED

Barrilleaux, T.C.; Grace, J.B. 2000. Growth and invasive potential of *Sapium sebiferum* (Euphorbiaceae) within the coastal prairie region: the effects of soil and moisture regime. American Journal of Botany. 87: 1099-1106.

Blossey, B.; Nötzold, R. 1995. Evolution of increased competitive ability in invasive nonindigenous plants: a hypothesis. Journal of Ecology. 83: 887-889.

Brown, S. 2002. Measuring carbon in forests: current status and future challenges. Environmental Pollution. 116: 363-372.

Bruce, K.A.; Cameron, G.N.; Harcombe, P.A.; Jubinsky, G. 1997. Introduction, impact on native habitats, and management of a woody invader, the Chinese tallow tree, S*apium sebiferum*. Natural Areas Journal. 17: 255-260.

Pattison, R.R.; Mack, R.N. 2009. Environmental constraints on the invasion of *Triadica sebifera* in the eastern United States: an experimental field assessment. Oecologia. 158: 591-602.

Perry, D.A. 1985. The competition process in forest stands. In: Cannell, M.G.R.; Jackson, J.E., eds. Attributes of trees as crop plants. Abbotts Ripton, UK: Institute of Terrestrial Ecology: 481-502.

Weiner, J. 2004. Allocation, plasticity and allometry in plants. Perspectives in Plant Ecology. 6: 207-215.

Zou, J.; Rogers, W.E.; DeWalt, S.J.; Siemann, E. 2006. The effect of Chinese tallow tree (S*apium sebiferum*) ecotype on soil-plant system carbon and nitrogen processes. Ecosystems Ecology. 150:272-281.