GROWTH OF CHINESE TALLOW IN A BOTTOMLAND FOREST IN SOUTHERN MISSISSIPPI

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Abstract--Chinese tallow tree [*Triadica sebifera* (L.) Small, formerly *Sapium sebiferum* (L.) Roxb.] is a monoecious and deciduous tree, native to central and southern China. As a nonnative invasive tree species, it has aggressively invaded forestlands in southeastern United States, particularly the low- and bottom-land forests along the coastal region of the Gulf of Mexico. This study, on the basis of a destructive sample of 11 tallow trees collected from a bottomland oak-gum-cypress forest in the southern Mississippi, developed a group of individual tree level models to reflect the growth of diameter, total height, and standing volume with age for Chinese tallow. Moreover, we used the destructive sample data to explore allometric relationships between diameter and total height of Chinese tallow. These results are useful to estimate and compare competition potential and establishment rate of tallow trees relative to other native trees threatened by its invasion and rapid establishment. Resource managers could use this information to design efficient treatments to control and mitigate further invasion of tallow.

INTRODUCTION

The Chinese tallow tree [*Triadica sebifera* (L.) Small] has become an invasive species in the United States (Bruce 1993) since its introduction as an ornamental and potential oil species in the 1770s. Bruce and others (1997) reported that coastal ecosystems from Texas to North Carolina were severely invaded by tallow tree. In recent years it has expanded to non-coastal areas and regions further inland (e.g., northward), but has not become abundant in these areas. Studies show that tallow will invade new regions beyond current range (Pattison and Mack 2009, Wang and others 2011). Zou and others (2008) reported that tallow reached maturity after 3 years. Fast growth is an important factor for invasive species rapid colonization and establishment in the affected regions.

Avery and Burkhart (1983) regard growth modeling for a tree as the incremental increase in diameter, height, and volume during a certain period. In growth and yield modeling, diameter at breast height (d.b.h.) is the most used and easily obtained measure of tree size (Avery and Burkhart 1983). In order to estimate the volume of an individual tree or forests, height is another traditionally measured tree attribute (Hann and Larsen 1991). Furthermore, a basal area equation based on d.b.h. was more linear related to volume growth (Hökkä and Groot 1999). Modeling the increment of individual tree diameter or basal area is usually accomplished through a composite or a modifier model (Zhang and others 2004). In a composite model, independent variables usually refer to tree characteristics (such as tree size, crown ratio, vigor) and stand conditions including stand age, site index, and stand density. Response variables are either diameter or basal area increment (Vanclay 1994, Zhang and others 2004). By contrast, a modifier model represents a potential maximum attainable growth for a tree and is able to explain tree growth biologically (Zhang and others 1997). In recent studies (Budhathoki and others 2008, Zhang and others 2004) potential growth is also modeled using more flexible functions (e.x. Chapman-Richards and logistic model) which are physiologically based.

If non-homogeneity of variance exists, best linear unbiased estimate of the parameters is not realized. Therefore, a modified modeling approach using weighted least square regression is used. Meng and Tsai (1986) built a volume growth model for loblolly pine (*Pinus taeda* L.) and compared the weight value of diameter-squared*height (D^2H) and diameter-squared (D^2) in the model. Diéguez and others (2006) developed an individual tree volume model for Scots pine (*Pinus sylvestris* L.) using a modified second-order continuous autoregressive method which was mainly to resolve the high autocorrelation of the data.

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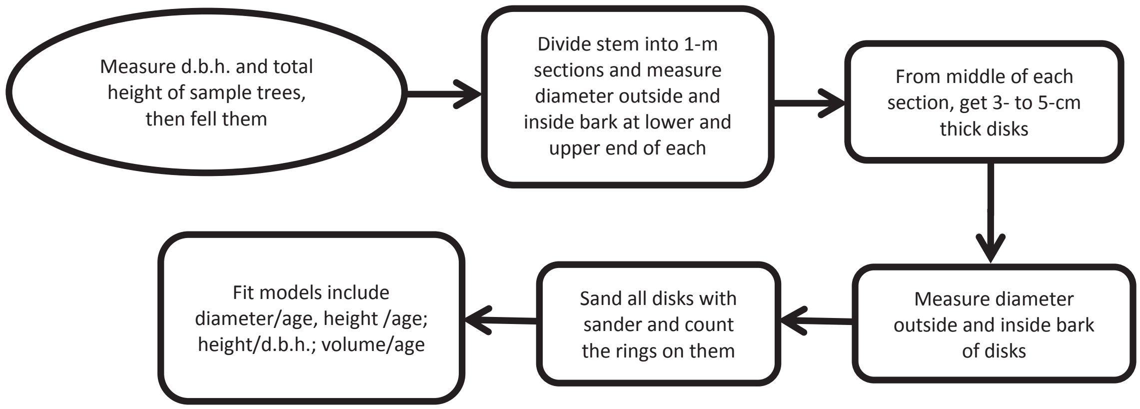

Figure 1--Details of field research and lab work.

Besides the non-constancy of variance during field data collection, spatial correlation still exists leading to the development of distance-dependent models (Aguirre and others 2003, Porté and Bartelink 2002, Zhang and others 2004). However, the difficulty of getting the specific spatial location of each tree makes it impossible under some situations. As a result, a radical intermediary growth model between spatial and non-spatial models appeared. Perot and others (2010) used this method to build a growth model for sessile oak [*Quercus petraea* (Mattuschka) Liebl.] and Scots pine in north-central France, and the results indicated that the radical intermediary growth model had similar behavior with the distance-dependent model.

To obtain the growth rate of tallow in bottomland oak-gum-cypress in southern Mississippi, a group of growth models were constructed to quantify the relationships among diameter, height, volume, and tree age at individual tree level. Models included height, d.b.h., and volume growth with age, as well as allometric models between d.b.h. and height.

DATA COLLECTION

Destructive sampling was used to obtain the tallow tree age and profile data. Before felling sample trees in the field, total height and d.b.h. were measured. Trees were then cut (to a stump height of approximately 10 cm) and the stem was divided into 1-m sections. Disks with 3 to 5 cm thickness were then extracted from the midpoint of each section. Inside bark and outside bark diameters were obtained at the upper end of each section. Diameter at selected height positions (0.8 m and 5.3 m) was also recorded. Disks were transported to the U. S. Forest Service laboratory in Starkville, MS and sanded for an accurate ring count to determine tree age. Details of the field work and lab work were shown in figure 1. To accurately calculate the stem volume, volume of each section in m^3 was firstly computed using equation 1.

$$\mathrm{v} = \frac{\pi}{8}(D^2 + d^2) * \mathrm{l} \qquad (1)$$

where: l was the length of each section (1 m); and *D* and *d* were diameters at the upper and lower end of each section. By adding up the volume of all sections from one tree, the whole stem volume of individual trees was determined (Vol_i) which was used in volume modeling.

METHODS

Models in this study were: d.b.h. increased with age, height grew with age and d.b.h., and volume grew with age. Previous studies showed that there were several models to describe tree height and diameter growth process. Here, we mainly try the Schumacher model, Chapman-Richards model, logistic model, and Mitscherlich model to quantify tallow tree growth (table 1). In all these models, *A*, *r*, and *c* are the parameters to be estimated; *y* is the annual increment of diameter/height/volume and *t* indicates tree age. Based on the collected field data, these four models [equation (1), (2), (3), (4) in table 1] were fitted using SAS statistical software (SAS Version 9.2, SAS Inc., Campus Drive, Cary, NC) and from them we chose the best fitted model.

Table 1--Available growth models to be fitted for Chinese tallow tree

Model name	Model form[a]
Schumacher	$y = a * e^{-\frac{b}{t}}$ (1)
Chapman-Richards	$y = A(1 - e^{-rt})^c$ (2)
Logistic model	$y = \frac{A}{a + me^{-rt}}$ $A, m, r > 0$ (3)
Mitscherlich	$y = A(1 - e^{-rt})$ $A, r > 0$ (4)

[a]In all models, *A, r*, and *c* are the parameters to be estimated. *y* is the annual increment of diameter/height/volume and t indicates tree age.

RESULTS

All fitted models showed that: the DBH-age, volume-age and total height-DBH relationships were quantified by exponential models, while the total height-age relationship was expressed by Logistic regression model (fig. 2). Based on fitted regression models, a 16-year-old tallow tree, on average, can reach up to 25 cm (10 inches) in d.b.h., 18 m (63 feet) in total height, and 0.3 m^3 (10 cubic feet) in stem volume. This d.b.h. and height growth rate is comparable to American sycamore (*Platanus occidentalis* L.), a commonly found bottomland species. Tallow's growth rate is an important parameter to estimate its colonizing and establishing potential in different forest types.

DISCUSSION AND CONCLUSIONS

Tallow has severely invaded coastal forest lands, and its rapid growth makes it an aggressive competitor to many native tree species. To accurately reflect growth rate of tallow in bottomland oak-gum-cypress forests, additional samples are required. Moreover, to evaluate tallow's competitive ability and invasiveness of different forest communities, estimation of tallow's growth under various site and environmental conditions needs further research. Model results show that tallow trees in southern forest stands grow rapidly; meanwhile, these exotic tallow trees are still on the juvenile stage with diameter and height exponentially growing. Hence, it is the time for managers to make some efficient treatments to control further growth and invasion.

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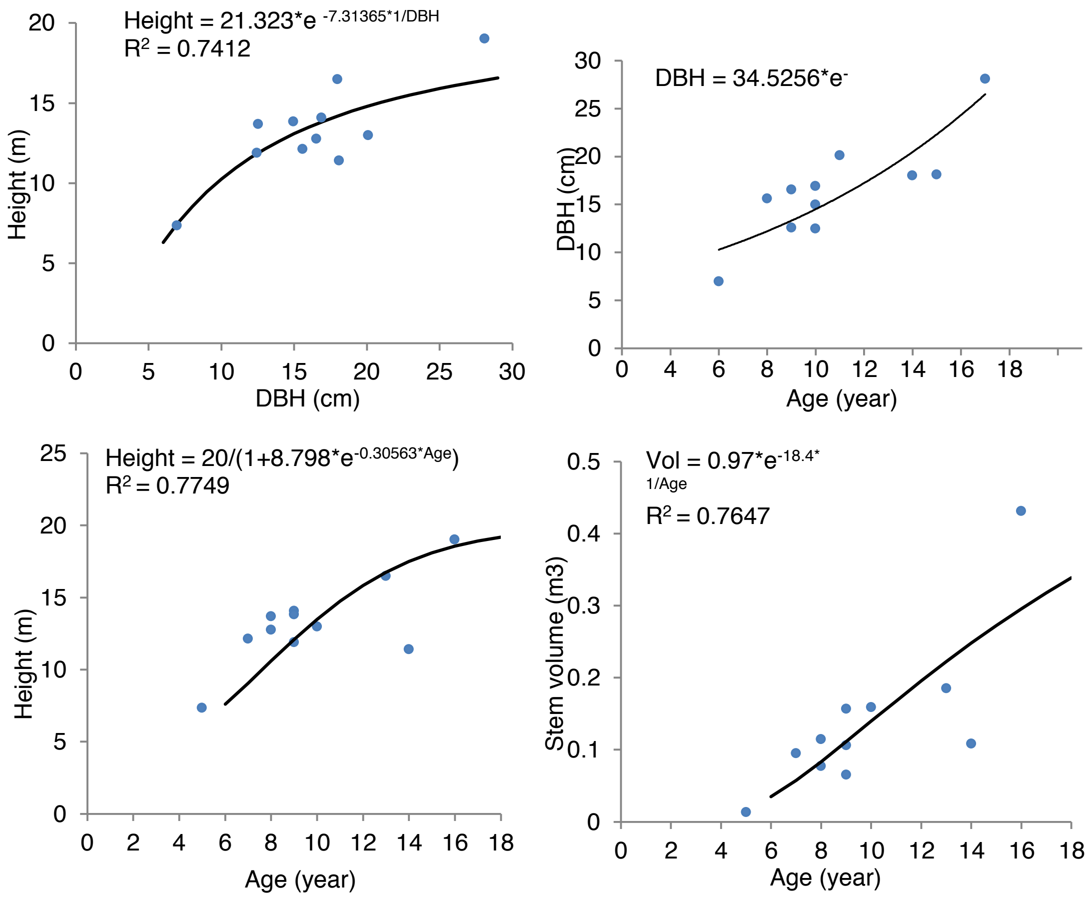

Figure 2--Fitted models of Height-DBH, DBH-Age, Height-Age, and Volume-Age of tallow trees, where DBH is diameter at breast height.

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