ESTIMATION OF ABOVE GROUND BIOMASS FOR MULTI-STEMMED SHORT-ROTATION WOODY CROPS

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With the increasing interest in short-rotation woody crop (SRWC) systems, an accurate yet quick, non-destructive means for determining aboveground biomass is necessary from both management and research perspectives. Equations determined using measures of stem volume (D^2H) have been used extensively to estimate plant biomass in single-stem plants (Crow 1978, Ter-Mikaelian and Korzukhin 1997, Tritton and Hombeck 1982). However, little data is available regarding this relationship in multiple-stemmed individuals (i.e. Zhou and others 2007), particularly those grown from cuttings. The objective of this study was to determine how accurately a simple volume equation (D^2H) can predict aboveground biomass (AG_{mass}) for two important short-rotation woody crop species,eastern cottonwood (*Populus deltoides* Bartram ex. Marsh.) and black willow (*Salix nigra* Marsh.). This research evaluated the use of total stem volume (ΣD^2H) to predict AG_{mass} both within and across a species and soil type, compared cottonwood plants regenerated from cutting with plants regenerated from seed, and evaluated the use of a universal curve across our full dataset. We hypothesized that a universal model can be developed that will accurately predict AG_{mass} across species, soil type, and regeneration method.

Over 320 observations were used from multiple datasets to construct volume equations (table 1). Sites utilized in this study covered a wide longitudinal range from northern Wisconsin to northern Louisiana. Contrasting soil types and textures, from very high clay percentages to fine sandy loam, were also represented. All data represents first year growth after regeneration from either seed or cutting. For each primary stem, plant heights were measured from the ground to the base of the terminal bud; basal diameters were measured as close to the node as possible to not account for artificial swell near the base (< 1 cm from the node).

Calculated volumes for each primary stem were summed to calculate a total plant stem volume (ΣD^2H). The relationship of ΣD^2H to AG_{mass} and goodness of fit were determined by linear regressions using the REG procedure in SAS (SAS Institute, Cary, NC). Comparison among treatments (i.e., species, soil texture, regeneration method) were made by analysis of covariance (ANCOVA; same-slopes analysis) using the GLM procedure in SAS 9.3.

The relationship between natural log transformed AGmass (*ln*AGmass) and natural log transformed D^2H (lnD^2H) accounted for a respective 84 and 90 percent of the variation in cottonwood (fig.1A; $r^2 = 0.84$, $p < 0.0001$) and willows (fig.1C; $r^2 = 0.90$ $p < 0.0001$) on loam sites (table 1). Applying this relationship to cottonwood and willow on clay sites described 93 percent (fig.1B; $r^2 = 0.93$, $p < 0.0001$) and 91 percent (fig.1D; $r^2 = 0.91$, $p < 0.0001$) of the variation in lnAGmass, respectively. The slope of cottonwood and willow were not significantly different on either loam ($p = 0.3427$) or clay ($p = 0.2811$) sites while intercept differed significantly for comparisons on loam ($p < 0.0001$) and clay ($p < 0.0001$). When cottonwoods on loam and clay were compared, significant difference emerged in both the slope ($p = 0.0004$) and the intercept ($p < 0.0001$). Significant differences were also found between soil textures for willow in both slope ($p = 0.0004$) and intercept ($p < 0.0001$).

When comparing cottonwoods regenerated from seed ($r^2 = 0.99$, $p < 0.0001$) with all cottonwoods from cuttings ($r^2 = 0.92$, $p < 0.0001$), significant

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Table 1--Parameter estimates for the relationship between the sum of D^2H and above ground mass across soil texture and regeneration treatments using natural log transformed dependent and independent variables

				---------------Parameter estimates---------------	
Regression	n	r^2	p-value	Slope	Intercept
Cottonwood clay	44	0.93	<0.0001	0.84352 ± 0.03482	-0.19723 ± 0.18080
Cottonwood loam	24	0.84	<0.0001	0.61248 ± 0.05639	1.46410 ± 0.38300
Willow clay	48	0.91	<0.0001	0.90110 ± 0.03981	-0.58668 ± 0.19752
Willow loam	24	0.90	<0.0001	0.68503 ± 0.04819	0.89860 ± 0.31981
Cottonwood seed	113	0.99	<0.0001	0.70935 ± 0.00713	-0.02231 ± 0.02027
Cottonwood cuttings	68	0.92	<0.0001	0.80657 ± 0.02860	0.05218 ± 0.16611

differences appeared both in slope ($p < 0.0001$) and in intercept ($p < 0.0001$). Finally, we calculated a single regression across all our data ($r^2 = 0.97$, $p < 0.0001$). In spite of this good fit, a comparison of observed and predicted mass of the median individual from each treatment revealed considerable (as high as 50 percent) error when a universal equation is used.

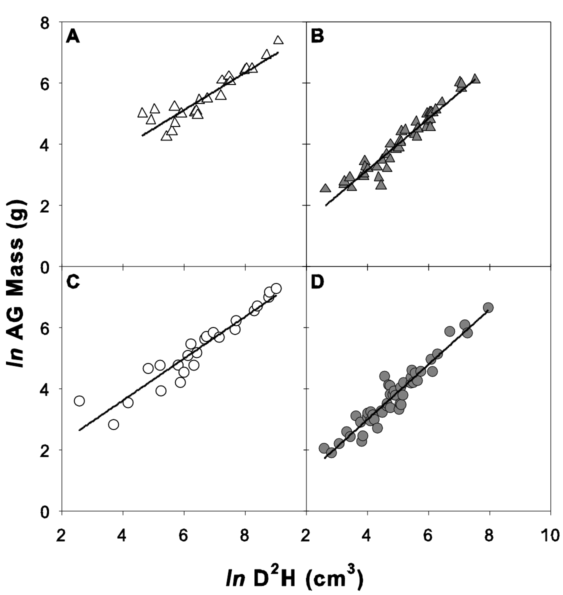

Figure 1--The relationship between natural log transformed above-ground mass and natural log transformed D^2H for cottonwoods grown in loam (A; y = 0.61248x +1.46410, $p <$ 0.0001) and clay soil textures (B; y = 0.84352x -0.19723, $p <$ 0.0001); and for willows grown in loam (C; y = 0.68503x + 0.89860, $p < 0.0001$) and clay soil textures (D; y = 0.90110x - 0.58668, $p < 0.0001$).

In conclusion, we find a very strong relationship between $ln\mathrm{AG}_{mass}$ and D^2H within a species, soil type, or regeneration method. However, the differences between these conditions affect the output of the model greatly, which we feel diminishes the usefulness of the universal model from both a management and research standpoint.

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