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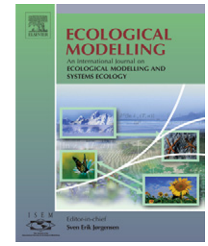

Developing above-ground woody biomass equations for open-grown, multiple-stemmed tree species: Shelterbelt-grown Russian-olive

Xinhua Zhou[a,*], *James R. Brandle*[a,1], *Michele M. Schoeneberger*[b,2], *Tala Awada*[a,3]

[a] *School of Natural Resources, University of Nebraska, Lincoln, NE 68583-0968, USA*
[b] *US Forest Service, Southern Research Station, National Agroforestry Center, Lincoln, NE 68583-0822, USA*

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ABSTRACT

Multiple-stemmed tree species are often used in agricultural settings, playing a significant role in natural resource conservation and carbon sequestration. Biomass estimation, whether for modeling growth under different climate scenarios, accounting for carbon sequestered, or inclusion in natural resource inventories, requires equations that can accurately describe biomass in these species. Russian-olive (*Elaeagnus angustifolia*) is a common tree species used in Great Plains shelterbelts and has a growth form typical to open-grown, multiple-stemmed tree species. Using shelterbelt-grown Russian-olive, we present a procedure of choosing predictors, formulating models, and determining equations by optimizing the accuracy in above-ground woody biomass estimates associated with labor costs for open-grown, multiple-stemmed tree species. Trunk (a primary stem) diameter at breast height and/or tree height were satisfactory for trunk biomass prediction but insufficient for determining branch (secondary stems and limbs) biomass, a major component of biomass in these trees. Incorporating the diameters of the three largest stems into the branch biomass equations improved the prediction satisfactorily. Two sets of equations, each of which includes two equations for trunk and branches, respectively, are presented. One set has the cost-saving-preferred (CSP) equations having lower precision but only requiring easily measured DBH variables of trunk and stems. The other set has the precision-preferred (PP) equations that have better precision but at the added cost required for taking an additional measurement of height and the inconvenient measurements of stem diameters at branch bark ridge. Both sets of equations were used to estimate the biomass of the same representative shelterbelts. The results indicated that the PP equations consistently gave better precision for trunk, branches, and whole tree than the CSP equations, but reduced the relative error in whole-tree biomass estimates by only 0.8–1.2%. Ultimately, the decision to use the CSP or the PP equations will depend on the desired precision level and/or available budget. The procedure we have presented, along with the chosen predictors and formulated models, provides a reference for estimating above-ground woody biomass of other open-grown, multiple-stemmed tree species in agricultural settings.

* *Corresponding author*. Tel.: +1 402 472 9889; fax: +1 402 472 2946.
E-mail addresses: xzhou2@unl.edu (X.H. Zhou), jbrandle1@unl.edu (J.R. Brandle), mschoeneberger@fs.fed.us (M.M. Schoeneberger), tawada2@unl.edu (T. Awada).
[1] Tel.: +1 402 472 6626.
[2] Tel.: +1 402 437 5178x21.
[3] Tel.: +1 402 472 8483.

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1. Introduction

Multiple-stemmed tree species are an important component in conservation plantings, such as field windbreaks and living snowfences, and are used throughout the Great Plains (Cunningham, 1988) and other regions (Nicholas, 1988). A good example of these multiple-stemmed tree species is Russian-olive (*Elaeagnus angustifolia* L., Fig. 1A). It has an irregular globe shape (Fig. 1A) and multiple stems (Fig. 1B). Its stems, branching out of a primary stem (trunk) near, at, and even below the groundline (Fig. 1C), distinguish Russian-olive from most single-stemmed trees. And its obvious trunk and the greater variability in stem diameters distinguish it from shrubs. Planted extensively during the 1930s (Bagley and Sutton, 2002), Russian-olive continues to be an important component of shelterbelts, especially in the drier areas of the Great Plains (Stannard et al., 2002). Biomass estimation of these multiple-stemmed trees, whether for modeling growth under different climate scenarios [e.g., SEEDSCAPE (Guo, 2000; Easterling et al., 2001)], accounting for carbon sequestered (Montagnini and Nair, 2004), or inclusion in natural resource inventories (Chojnacky and Rogers, 1999), requires equations that can accurately describe biomass in these species, as well as measurement protocol that can be easily and economically executed.

The methodologies of developing biomass equations for single-stemmed trees are well documented (Ter-Mikaelian and KorzukhinECOMOD4577BIB271997) and are generally based on trunk diameter and/or height measurements. Due to their branchiness, multiple-stemmed species at a given diameter and/or height have considerable variability in their biomass. Various methods have been used to develop the equations for these species; the most common being the use of allometric relationships between biomass and diameter at different heights. In equations for several species of small multiple-stemmed trees (diameter <7 cm), Telfer (1969) and Brown (1976) used diameter at groundline, Grigal and Ohmann (1977) and Brand and Smith (1985) used diameter at a height of 15 cm, and Roussopoulos and Loomis (1979) used diameter at a height of 1.37 m (breast height). For small multiple-stemmed trees (trunk diameter <3.5 cm), understory trees, and shrubs, other predictors such as crown diameter (Ohmann et al., 1976); crown percent cover (Ohmann et al., 1981); stem number, crown volume, and shrub height (Peek, 1970) were used in biomass equations.

Unfortunately, none of these equations are suitable for multiple-stemmed trees species, especially those growing under the more open-grown conditions common in agricultural settings, such as shelterbelts, riparian forests, small forest tracts, and sparse woodlands. With the greater light exposure and less competition for water and nutrients in these settings, trees tend to allocate a larger portion of growth into canopy biomass than would generally occur in a forest understory (Wittwer et al., 1999). For Russian-olive occurring in agricultural settings, trunk diameter of up to 33 cm (our field data) and height of up to 9 m (Dirr, 1983; Bagley and Sutton, 2002) are well beyond the limits of existing equations for small trees [diameter <12.7 cm (Smith, 1985) or diameter <5 cm (Alemdag, 1984)]. Multiple-stemmed trees have greater variability in stem diameters than typical shrub species (Hightshoe, 1988) and biomass equations for several shrub species are not applicable, either.

To estimate biomass in these open-grown, multiple-stemmed tree species within agricultural settings, more suitable relationships of biomass to measured characteristics need to be developed. Using Russian-olive trees growing in shelterbelts as a case study, we hypothesize that potential predictors for biomass of open-grown Russian-olive trees are diameter of the trunk at the groundline (trunk basal diameter), diameter of the trunk at breast height (trunk DBH), diameter of each stem at the branch bark ridge (stem basal

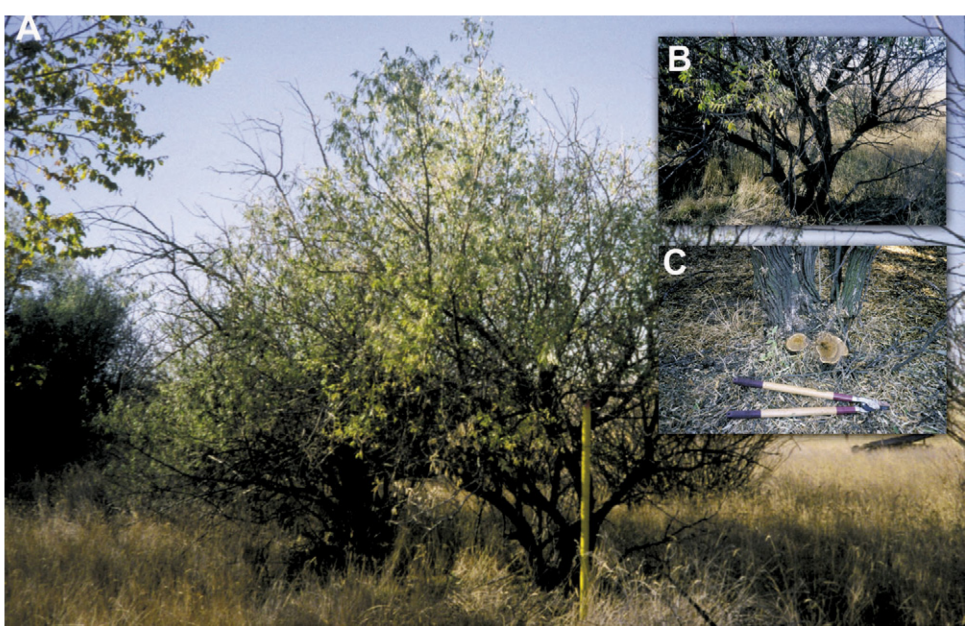

Fig. 1 – A Russian-olive tree under open-grown conditions in Montana, USA (A: crown shape; B: multiple stems; C: stems out of the groundline).