A Spatial Model Approach for Assessing Windbreak Growth and Carbon Stocks

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Agroforestry, the deliberate integration of trees into agricultural operations, sequesters carbon (C) while providing valuable services on agricultural lands. However, methods to quantify present and projected C stocks in these open-grown woody systems are limited. As an initial step to address C accounting in agroforestry systems, a spatial Markov random field model for predicting the natural logarithm (log) of the mean aboveground volume of green ash (*Fraxinus pennsylvanica* Marsh.) within a shelterbelt, referred to as the log of aboveground volume, was developed using data from an earlier study and web-available soil and climate information. Windbreak characteristics, site, and climate variables were used to model the large-scale trend of the log of aboveground volume. The residuals from this initial model were correlated among sites up to 24 km from a point of interest. Therefore, a spatial dependence parameter was used to incorporate information from sites within 24 km into the prediction of the log of the aboveground volume. Age is an important windbreak characteristic in the model. Thus, the log of aboveground volume can be predicted for a given windbreak age and for values of other explanatory variables associated with a site of interest. Such predictions can be exponentiated to obtain predictions of aboveground volume for windbreaks without repeated inventory. With the capability of quantifying uncertainty, the model has the potential for large regional planning efforts and C stock assessments for many deciduous tree species used in windbreaks and riparian buffers once it is calibrated.

Agroforestry, the deliberate integration of trees into crop and livestock operations, sequesters substantial amounts of carbon (C) on agricultural lands while providing the production and conservation services for which it was designed (Korn et al., 2003; Nair et al., 2009; Schoeneberger, 2009; Verchot et al., 2007). The Global Research Alliance on Agricultural Greenhouse Gases, established at the 2009 climate change meetings in Copenhagen (http://www.globalresearchalliance.org/home.aspx), explicitly includes agroforestry as a viable C sequestering option for agricultural operations. Of the five main agroforestry practices used in the United States (windbreaks, riparian buffers, alley cropping, silvopasture, and forest farming), windbreaks are especially appealing as a C sequestering option on private lands. Windbreaks, also referred to as shelterbelts, are linear plantings consisting of trees and shrubs. They are used throughout the United States to protect and improve crop yields, reduce wind erosion, manage snow, reduce energy consumption by homesteads and other buildings, and protect livestock. In so doing, they provide additional wildlife habitat in areas dominated by agriculture as well as other benefits afforded by the altered microclimate and landscape structure created by the plantings (Brandle et al., 2009). Although a small portion (about 2 to 5%) of an agricultural field is dedicated to the windbreak, this small amount of land is able to sequester greater amounts of C per unit land area than many of the other agricultural options, thereby contributing significantly to overall greenhouse gas mitigation within a farming operation (Schoeneberger, 2009; USEPA, 2006). Furthermore, the very purpose for windbreak plantings—the use of perennials and the additional services they provide to the landowner—adds a level of permanence not necessarily present in other practices.

Being able to estimate current and future amounts of biomass and C sequestered in agroforestry plantings, such as windbreaks, provides a basis for directing conservation programs and policy development as well as future land management decisions by landowners. Initial estimates made for windbreaks in the north-central United States (USDA NAC, 2001) and for riparian buffers, woody plantings in the unfarmed corners of center pivot fields, and living snow fences in Nebraska (Nebraska Department of Natural Resources, 2001) indicate that agroforestry has tremendous potential as a C sequestering option for these areas. However, more reliable means for generating these estimates are

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Abbreviations: DBH, diameter at breast height; FIA, USDA Forest Inventory and Analysis; PDSI, Palmer Drought Severity Index; STATSGO, State Soil Geographic database.