Mixed Multi-Scalar Methods to Assess Wood Biomass Availability on Family Forests in Virginia's Southside

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ABSTRACT: *Interest in wood-based bio-energy production systems is increasing. Multi-scalar, mixed-method approaches focusing on both biophysical and social aspects of procurable feedstock are needed. Family forests will likely play an important role in supplying forest-based biomass. However, access depends in large part on the management trends among family forest owners. This paper outlines proposed research to estimate feedstock availability in Virginia's Southside using United States Forest Service Forest Inventory Analysis data, cluster modeling, silviculture guidelines, property-level samples, and landowner management intentions. Aims are to contrast property-level volumes as mediated by owner intentions with values derived using a landscape level analysis.*

KEYWORDS: Bio-energy, Forest Inventory Analysis, Theory of Planned Behavior, wood biomass, ethanol, family forests, disproportionality, silviculture.

Introduction

Rising energy costs, climate change, geopolitical instability, and widespread uncertainty about the future of fossil fuel are profoundly influencing energy strategies in the United States (US) (Duffield and Collins 2006). Expanding production of domestic renewable energy is gaining traction as a potential approach (Dincer 2000). As a result, interest in using wood to generate large-scale bio-energy has resurfaced. Forest-based biomass from private, family forests constitutes an increasingly popular component of wood-based energy solutions in the US (Munsell and Germain 2007).

Forest-based bio-energy is advantageous for several reasons. Using food crops, such as corn, to produce bio-energy is highly controversial (Pimentel 2003). Wood has a higher energy return than other popularized feedstock and conversion technologies are improving (Amidon 2006; Keolian and Volk 2005; Shapouri et al. 2002). Biomass markets are needed to facilitate management on much of the nation's family forests (Munsell et al. 2008). All told, procurement of wood biomass from family forests seems quite appealing. Yet accessing large feedstock volume on family forests may not be entirely straightforward.

Family forest owners are diverse (Butler and Leatherberry 2004). Objectives vary and are increasingly amenity- rather than commodity-based (Kendra and

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In: McWilliams, Will; Moisen, Gretchen; Czaplewski, Ray, comps. 2009. 2008 Forest Inventory and Analysis (FIA) Symposium; October 21-23, 2008: Park City, UT. Proc. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1 CD.

Hull 2005). Moreover, exurbanization is shaping a new period defined by smaller parcels and more owners (Sampson and DeCoster 1997; Butler and Leatherberry 2004). If forest-based bio-energy production systems are to succeed in regions dominated by family ownership, multi-scalar, mixed-method approaches focusing on both biophysical and social aspects of procurable feedstock are needed. The basic premise is that, regardless of scale, available volume does not supersede owner intentions to supply it and vice versa.

To estimate feedstock availability in Virginia's Southside, we plan to use multi-scalar, mixed-method evaluations within the context of an impending bio-energy plant in Mecklenburg County. Our research will estimate supply within a 30-mile road distance woodshed around a proposed ethanol plant. We will use US Forest Service Forest Inventory Analysis (FIA) data, cluster modeling, and silvicultural guidelines to estimate above-ground sustainable yield. We will also survey landowners about their intentions to commercially harvest and inventory their forests to assess above-ground wood biomass potential. We will then contrast this potential with owner intentions to estimate a margin of error for potential accessibility. Our ultimate goal is to contrast the insight gained from landowner surveys and property assessments with FIA estimates of wood biomass availability.

Rationale

Erroneous estimates of wood biomass availability can be detrimental. Financial investors, potential processors, energy consumers, forest owners, and resource managers stand to lose. For example, in 2007 the Nevada Department of Corrections invested 8.3 million dollars in forest-based bio-energy. Adjacent federal forests were assessed and deemed to house sufficient volume. One prison and two local communities expected to receive resulting energy. In the end, however, the actual supply fell dramatically short.

> *Officials from the Nevada Department of Corrections had predicted that the plant would replace energy from electricity and natural gas at Northern Nevada Correctional Center and the neighboring Stewart Conservation Camp. The plant, however, has not run more than three days straight since it opened six months ago. "Wood continues to be an issue for us," said Lori Bagwell, department director of support services. "We do not have an adequate and appropriate supply." -Nevada Appeal, March 2, 2008.*

Much was blamed on public input policies for federal forest management. Adequate stock did not beget adequate supply due to social processes unaccounted for when deriving initial estimates. And though the Nevada example pertains to public forests, its general lesson resonates in terms of family forests. Volume means little if owner inclinations preclude procurement. This is particularly relevant in the eastern US, where most forests are family owned and management objectives and behavior vary widely (Butler and Leatherberry 2004). Thus, forest-based bio-energy systems in the eastern US should be careful to calibrate volume-based feedstock estimates using management trends among family forest owners.

Context

In Virginia, close to 65% of the forests are family owned (Virginia Department of Forestry 2008). A sizeable percentage of these forests are located in its southern region, or "Southside". Southside Virginia is loosely defined as the area of the state that lies east of the Blue Ridge Mountains and south of the James River. Tobacco production has historically been the dominant economic enterprise. However, tobacco quotas and production have steeply declined over the past decade, leaving local economies in question and forcing landowners to look for profitable alternatives.

In 1999, the Virginia General Assembly created the Virginia Tobacco Indemnification and Community Revitalization Commission (VTICRC) to help address the challenges Southside and Southwest communities face when transitioning out of tobacco production. The VTICRC's regional classifications are displayed in Figure 1. Among many diverse awards, VTICRC, along with Virginia Block Grant, recently allocated $650,000 to install a 12-inch water main to the site of a future 100 million gallon per year Bluestone Bio Energy LLC ethanol plant in Southside's Mecklenburg County.

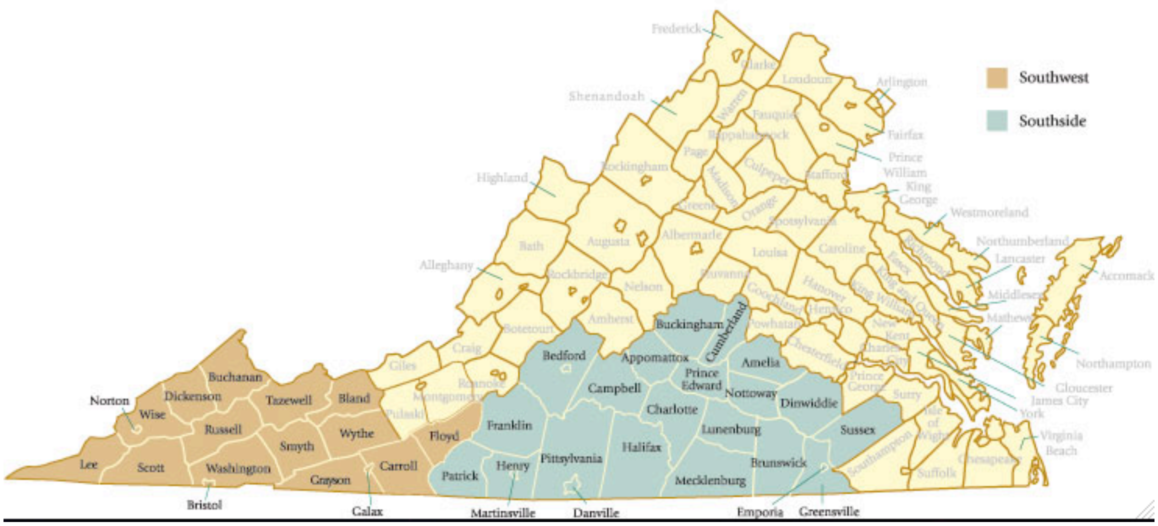

FIGURE 1: VTICRC's classification of Virginia's Southside and Southwest regions. Available at: http://www.tic.virginia.gov/tobmapupdated.shtml

Bluestone Bio Energy LLC was born from Osage Bio Energy, which primarily manages barley to ethanol production. Located in Glen Allen, Virginia, Osage Bio Energy is an auxiliary of Osage Incorporated, which is the largest motor-grade ethanol distributor in the eastern US. Bluestone primarily plans to procure and process hull-less barley biomass, though substantial interest in wood biomass also exists.

Given Bluestone's attention to wood, forest-based biomass seems like a potentially promising management option in Virginia's Southside. Many former tobacco farmers and other landowners in the area possess ample woodlands and could supply considerable volumes of feedstock. What is more, wood biomass is presently on hand in great quantities, whereas other feedstock, such as the hull-less barley, may take some time before sufficient biomass volumes are obtainable.

Before forest-based bio-energy systems can take root in the Southside, immediate and long-term availability must be understood. To do this, we propose using biophysical and social metrics at different scales to capture both the human and biological constraints on supply. We believe the combination will help construct realistic procurement strategies that are sustainable in light of the region's potential to provide wood biomass. Using this underlying principle within the Southside case described above, our primary research question is to determine the extent to which landscape-level estimates of procurable, above-ground wood biomass correspond to property-level estimates derived using biophysical and social measurements.

Objectives

We will pursue 5 objectives to answer the primary research question. They are: 1) use selected FIA attribute data, cluster modeling, and silvicultural guidelines to estimate immediately available wood biomass across the Bluestone case study woodshed; 2) survey 40 randomly selected family forest owners with 20 acres or more in the case study woodshed about their intention to commercially harvest wood within the next 5 years using sociopsychological scales; 3) measure corresponding FIA attributes within the 40 forests held by case study owners and use aggregated data to estimate immediately available wood biomass across property-level cases; 4) Combine owner intention measurements and property-level wood biomass estimates to explore disproportionate relationships between biophysical and social measurements and adjust aggregated estimates to reflect differences; and 5) compare the adjusted property-level estimate with the original FIA-based, landscape-level estimate to determine potential error range.

Theory

FIA

FIA is managed by the United States Department of Agriculture (USDA) Forest Service. It uses a three-phased sampling protocol to measure and monitor the nation's forests in a standardized manner. In phase one, a uniform pattern of plots is overlaid across the US. Remote sensing data is then used to stratify plots into groups based on similar condition or cover. On-the-ground measurements of attributes are taken at each plot during phase two. Phase three estimates are then calculated using phase two data and the total area represented by each plot (Forest Inventory and Analysis Program 2008). Using FIA data, it is now possible to make large, landscape estimates from national to county levels.

Silviculture

Silviculture is a system wherein healthy communities of trees and other vegetation are established and maintained for the benefit of people (SAF 2001). It consists of three interdependent component treatments – regeneration, tending, and harvesting. The appropriate and timely use of these treatments should ultimately improve tree and vegetation stability and quality, optimize benefits to a landowner, shorten investment periods, contain costs, and sustain ecological health and productivity (Nyland 2002). Forestry practices based on silviculture can balance a wide variety of commodity and non-commodity values over time. Sawtimber, pulp fiber, small-scale fuelwood, soil stability, ecological habitat, and aesthetics are achievable ends. We will use silviculture's sustainable tenets to guide our landscape- and property-level evaluations.

Theory of Planned Behavior

Several studies characterize management intentions among family forest owners as a way to estimate timber availability (Birch 1994; Karppinen 2005; Kuuluvainen et al. 1996; Young and Reichenbach 1987). We will build upon these sociopsychological investigations by modeling the intentions of case study family forest owners to commercially harvest wood in the next 5 years. Model results will highlight significant social and psychological drivers of harvesting aims on case study forests and, in doing so, help calibrate wood biomass estimates as well as allude to potential political and marketing strategies that may effectively encourage increases in commercial harvests to sustainably supply forest-based bio-energy. We will use Azjen's (2005) Theory of Planned Behavior to structure our model (Figure 2).

The Theory of Planned Behavior states that an individual's attitudes, normative beliefs, and control perceptions about a behavior predict their reported intention to perform it. Intention can then be used as a proxy for predicting actual behavior. In other words, a family forest owner's future harvesting behavior can be predicted by measuring their intention to harvest and their behavioral beliefs and attitude towards doing so (i.e., cost benefit analysis), normative beliefs and how they feel important peers will perceive the behavior, and whether and to what extent they perceive external controls (what barriers they feel may prevent them from performing the behavior). Lastly, the relationship between behavioral intention and actual behavior is influenced by exogenous behavioral controls. Controls, such as a law or the availability of a needed service, can alter an individual's ability to act on their behavioral intention.

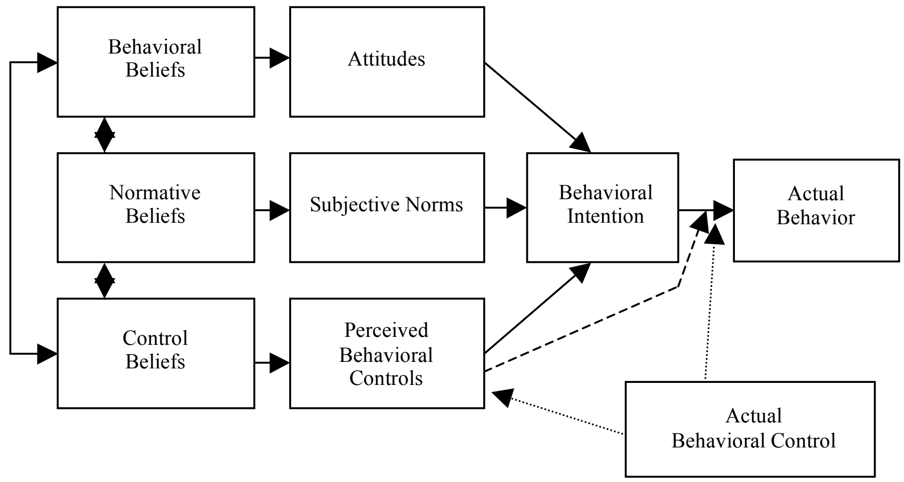

FIGURE 2: The Theory of Planned Behavior (Ajzen 2005).

Disproportionality

Disproportionality in social science is typically associated with between-group variability. For instance, environmental justice researchers often compare racial groups to identify if one group is disproportionately located in areas with environmental problems. Nowak et al. (2006) argues that it is helpful within natural resources sustainability to examine disproportionality within groups because it is possible to more closely examine how group members influence outcomes. That is, a few outliers within a group may help explain a great deal about aggregated group characteristics.

We plan to use within-group variability to explain disproportionality between the social and biophysical aspects of case study wood biomass supply at the property-level. Said differently, we plan to test the extent to which an owner's intention to commercially harvest wood proportionally relates to forest size and procurable wood biomass. Figure 3 displays a hypothesized relationship between mixed, multi-scalar variables. In this hypothesis, a landowner's intention to harvest is proportionally related to parcel size and volume per acre.

The hypothesis stems from trends indicating that owners of larger parcels are more likely to engage in management (Butler and Leatherberry 2004). Yet family forest parcel size continues to decrease and management objectives are changing (Sampson and DeCoster 2000; Kendra and Hull 2005). For example, many case study forests may be ready for harvesting according to silviculture, yet only a small amount of these owners intend to harvest. What is more, those intending to harvest may have disproportionate acreages, which would further affect aggregated wood biomass availability. Such a result would suggest levels of future supply may differ from estimates gleaned using only generalized biophysical capacity or gauging family forest accessibility by solely relying on models of owner harvesting intentions.

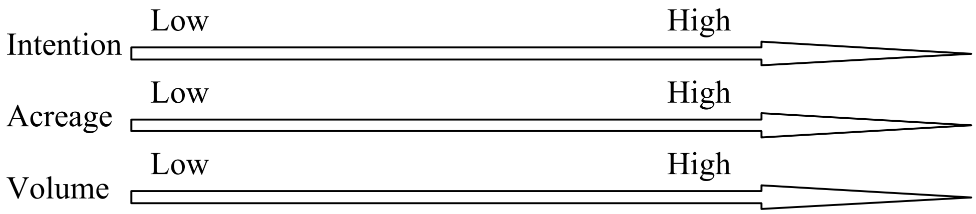

FIGURE 3: Hypothesized relationship between variables effecting wood biomass availability.

Methods

A Geographic Information System (GIS) was used to create the case study's 30-mile road distance woodshed polygon. Bluestone's future location constitutes the polygon's center point. The 30-mile distance was chosen based on Bluestone's procurement interests. A woodshed area polygon was created in ArcMap® using network analyst and ESRI Street Map USA (Figure 4). The polygon totals 1,022,397 acres and includes portions of Mecklenburg, Lunenburg, Charlotte, Halifax, and Prince Edward Counties in Virginia and Warren, Granville, and Vance in North Carolina.

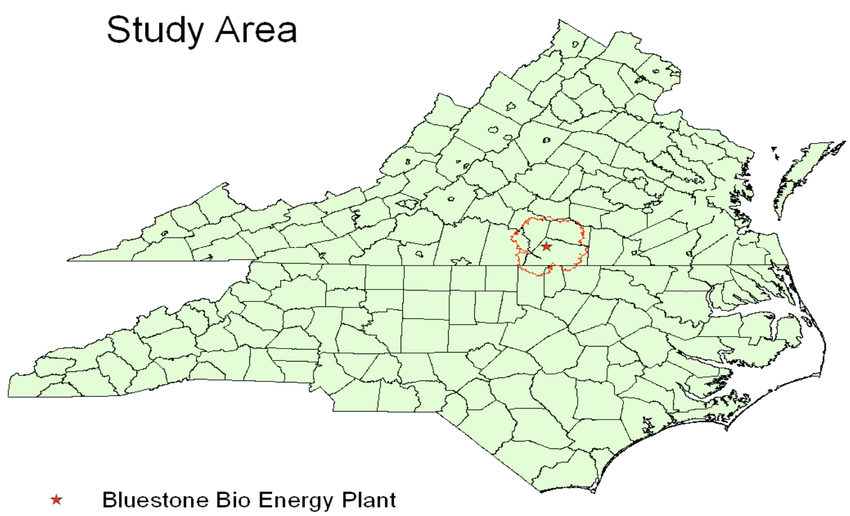

FIGURE 4: Case study polygon, overlaid on a map of Virginia and North Carolina. Plant location is symbolized by a star and is located in Mecklenburg County, Virginia.

To select FIA plots, point locations surveyed between 2000 and 2007 were projected and then chosen using an error threshold of no more than one mile beyond the woodshed polygon boundary. The error was allowed because all FIA plot coordinates have been altered (or *fuzzed*) up to 0.5 miles. For this reason, an uncertainty analysis using 0.5 mile buffers around all plots was conducted to determine upper and lower estimate bounds. For the base estimate, all plot centers located within the polygon were used. Plots centers located in the polygon with 0.5 mile buffers intersecting the polygon boundary were removed for the lower bound estimate. Plots located outside the polygon, but with buffers intersecting were added and used in the upper bound estimate. The number of plots selected in the uncertainty analysis are annotated in Table 1.

TABLE 1: Number of FIA plots included in the uncertainty analysis.

Selection	# of plots selected
Base Estimate	242
Lower Bound	221
Upper Bound	267

Estimates of wood biomass per acre will be reported for each of the three FIA plot groups listed in Table 1. Each FIA plot is adjusted based on the forested acres it represents. In terms of wood biomass estimations, pre-calculated, easily obtainable biomass values also exist for each FIA tree. At the landscape level, key case study FIA attributes will be used in the cluster analysis to assemble plots into like groups for silvicultural evaluation. Attributes include forest type, site index, growing stock or stocking, and average diameter at breast height (DBH). We will use these data and silviculture stocking guides following Roach and Gingrich (1968) to estimate immediately sustainable wood biomass yield for even-aged conditions. In uneven-aged circumstances, we will estimate wood biomass yield using the Arbogast (1957) curve to distribute sustainable removals across tree diameters.

To identify property-level cases, we will draw a random sample of approximately 1000 case study family forests from the supply woodshed. Real property data from each county and a spatial query using GIS will be used to identify the names and mailing addresses of owners with qualified forested properties. A letter will be sent to each sampled owner to inquire about willingness to participate.

Sampled owners will be able to reply to the letter using a self-addressed stamped postcard. On the card, respondents will indicate their willingness to participate and confirm acreage, forest type, and property location. We will send a reminder letter two weeks following the first mailing and assess non-response bias after six weeks. Property selection will be purposive and based on available information about regional forest characteristics and sampled properties. We will strive to include cover types and property sizes at rates that reflect Southside trends.

For each forest, we will measure corresponding FIA attributes at the property level following Munsell and Germain's (2007) field survey method. The field survey consists of a randomly placed grid system oriented to cover the forested area. Measurements will be taken in 1/10th acre fixed-area circular plots randomly selected within the grid. Sampling will cease if the margin of basal area error per plot is $\leq$20% around the mean basal area at the 95th percentile. If not, plots will be added until reaching this threshold. We will use data and silvicultural guidelines to estimate wood biomass yield from sampled family forests.

We will survey owners in person or over the phone with a Likert-type instrument designed using the Theory of Planned Behavior. The instrument will use summated rating scales to measure and operationalize constructs within a theoretical model that will explain an owner's intention to commercially harvest timber in the next 5 years. Summated rating scales allow for a more accurate differentiation among respondents (Spector 1992). We will assume that intention to harvest commercially acts as a proxy for potential to supply wood biomass. Behavioral, normative, control, and intention variables will be measured using bi-polar, multiple response statements on a scale from 1 to 5.

We will use verbal protocol focus groups to test statement validity. The protocol allows researchers to test if questions or statements invoke desired thought processes among respondents using an interpretative-qualitative method (Sudman et al. 1996). We will also use expert review. Cronbach's Alpha will be used to test summated scale reliability. Reliability (which is also referred to as the internal consistency of the instrument) measures the survey instrument's ability to convey the same meaning to the entire sample population.

We will also measure owner characteristics, such as demographics, land acquisition, length of ownership, management plan use, and previous management activities to name a few. We will use these variables when modeling latent aspects of the Theory of Planned Behavior to account for external factors. To measure internal validity, each survey will end with questions involving hypothetical management tradeoffs. We will present owners with a range of tradeoffs to gauge which objectives more strongly affect harvest intentions. Our aim is to test whether the theoretical measurements remain constant when faced with realistic management decisions.

A K-means cluster analysis will be used to group case study FIA plots into types based on selected attributes. K-means cluster analysis clusters samples into a pre-specified number of groups using Euclidean distances between sample and cluster means and multiple iterations to achieve sufficient group convergence. Stepwise multiple regression will be used to model owner intentions. One component model will be tested to identify statistical significance and assess overall change in R^2. Final outputs will include beta coefficients, t-values, F values, R^2, and model significance. Forest size, sustainable wood biomass estimates, and owner intentions will be cross-tabulated to characterize disproportionality.

Implications

Case study results will test the extent to which attitudes, beliefs, objectives, and general landowner characteristics predict an owner's willingness to commercially harvest. Insights will help explain drivers of disproportionate relationships between social and biophysical aspects of potential wood biomass supply. Benefits include gaining a better sense of potential supply relative to a future ethanol plant and demonstrating a multi-scalar, mixed-method approach for assessing wood biomass availability more generally.

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