A real-time, web-based optimal Biomass Site Assessment Tool (BioSAT)

Module 1. An Economic Assessment of Mill Residues for the Southern U.S.

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ABSTRACT: *Optimal locations for biomass facilities that use mill residues are identified for 13 southern U.S. states. The Biomass Site Assessment Tool (BioSAT) model is used to identify the top 20 locations for 13 southern U.S. states. The trucking cost model of BioSAT is used with Timber Mart South 2009 price data to estimate the total cost, average cost, and marginal costs for biomass facilities that use mill residues for up to 1.5 million dry tons of annual consumption. Demand locations are based on the U.S. Census Bureau zip code tabulation areas (ZCTA). There are 9,353 zip code tabulation areas (ZCTA) in the 13-state study region. Demand point location based on a ZCTA offers an improvement in truck cost estimates when compared to demand point location based on a county centroid. The top 20 ZCTAs in the study region are located in south Mississippi, southeast Georgia, southeast Oklahoma, southwest Alabama, and east Texas. Costs in these areas range from $25 to $38 per dry ton for up to 1.5 million annual dry tons.*

Additional research on BioSAT is forthcoming for 33 eastern U.S. states. These studies will include more types of woody and agricultural biomass (e.g., logging residues, pulpwood, corn stover, etc.). Additional cost models for transportation such as truck combinations with rail and barge will be components of BioSAT.

KEYWORDS: Biomass, economic availability, siting model, BioSAT, mill residues.

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INTRODUCTION

The 20th century was marked by rapid growth and an increase in prosperity throughout the world. Even though there is a current global economic recession with declines in oil and other fossil fuel prices, fossil fuel supply chains remain sensitive to disruption from unanticipated geo-political events. A resurgence of emerging economies in the future will most likely increase the future demand for fossil fuels that exist in complex geopolitical areas. By 2030, some experts predict the world's energy consumption will be 50 percent higher than it is today (International Energy Outlook 2008). As noted in the USDA Forest Service Woody Biomass Utilization Strategy, using woody biomass for renewable energy contributes to the Nation's energy independence (USDA Forest Service 2008). The woody biomass removed during ecological restoration, wildfire risk reduction, and conventional silvicultural activities can become a source of energy that are renewable and contribute to U.S. energy independence (USDA Forest Service 2008).

The forest products industry is an established user of wood wastes and residues for energy generation and is the major supplier of bioenergy in most of the developed world (Sedjo 1997). The proximity of wood wastes to forest products mills makes it a sensible solution for energy production. The emerging bioenergy industry can learn from the forest products industry in the procurement of forest-based biomass. Economic benefits may arise from a synergistic coexistence between the established forest products industry and the emerging bioenergy industry.

The development of any new industry involves the establishment of many relationships (Altman and Johnson 2008). Assessing the economic capability and stability of the bioenergy supply infrastructure is essential for market organization of this emerging industry and is addressed by this study. Perlack et al. (2005) indicate that the nation's forests represent a strategic asset in meeting the national goal of replacing 30 percent of the domestic petroleum consumption by 2030. Even though research has been conducted which estimates the economic availability of biomass (Young and Ostermeier 1989, Young et al. 1991; Lunnan 1997; Walsh 1998, 2000; DiPardo 2000; Ugarte et al. 2000, 2006, 2007; Western Governors Association 2008; Biomass Research and Development Board 2008), additional research on the economics of biomass energy in the context of web-based user tools would benefit bioenergy research and provide practitioners with useful information. An emphasis on the development of web-based information tools for policy makers, planners, and investors is essential for facilitating market organization.

The study presented in this paper develops estimates of the marginal costs curves and supply curves for mill residues, and identifies optimal sites for mill residue using facilities for 13 southern U.S. states.[2] Future studies will be expanded for 20 additional eastern U.S. states.[3] The resolution of the study is the "zip code tabulation area" or ZCTA (U.S. Census Bureau 2000).

The study is on-going and all objectives are not complete. The objectives of the overall study are: 1) develop a Microsoft SQL database of resource data (forest, mill residue, and agricultural feedstocks); 2) develop resource costs for the database; 3) develop a transportation cost model for database; 4) develop a harvesting cost model for database; 5) develop a web-based software of the system (e.g., www.BioSAT.net); and 6) update of key input data, e.g., diesel prices, mill residue prices, FIA data, etc., as necessitated.

METHODS

A model for siting biomass processing facilities ("BioSAT") is developed in the study (Figures 1A, 2A, and 3A in Appendix). The model has three cost components (i.e., resource, harvesting, and transportation) which are discussed in more detail this section. Forest resource data are obtained from the USDA Forest Service current FIA inventory data (U.S. Department of Agriculture, Forest Service 2008). Agricultural resource data development is on-going and will be obtained from state and federal reporting agencies.

Forest Resource Data

County level estimates of all-live total biomass, as well as average annual growth, removals, and mortality are obtained from the Forest Inventory and Analysis Database (FIADB) version 3.0 (U.S. Department of Agriculture, Forest Service, 2008). The latest complete cycle of data for each state is used (Table 1). New FIA data, when available, will be updated in the BioSAT model. Estimates of mill residues, urban waste, logging residuals, thinnings, and other removals are obtained from the Billion Ton 2 (BT2) study (Perlack et al. 2005). All data in green tons are converted to dry tons in the analyses.

County level estimates are allocated to "zip code tabulation areas" (ZCTA's) based on area proportionality, e.g., if a ZCTA accounts for ten percent of a county, ten percent of the county's data are assigned to that ZCTA. If a ZCTA boundary crosses multiple counties, proportions for each county are summed.

ZCTA's are based on the 2000 census definition and are obtained from the U.S. Census Bureau (U.S. Census Bureau 2000). Area proportionality is performed using ArcGIS (http://www.esri.com/software/arcgis/ Accessed January 5, 2009),

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[2] Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.
[3] Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia, and Wisconsin

which produces a file containing ZCTAs, county Federal Information and Processing Standard (FIPS) codes, and the percentage each county has in the ZCTAs. An ORACLE™ database (http://www.oracle.com/database/index.html Accessed January 5, 2009) is created for this file of FIA and BT2 county level data. ZCTA level estimates are derived from the information in this database.

TABLE 1. State and year of USFS FIA inventory data.

State	Year	State	Year
Alabama	2007	Nebraska	2006
Arkansas	2007	New Hampshire	2006
Connecticut	2005	New Jersey	2006
Delaware	2006	New York	2006
Florida	2006	North Carolina	2006
Georgia	2007	North Dakota	2007
Illinois	2006	Ohio	2006
Indiana	2007	Oklahoma	1993
Iowa	2006	Pennsylvania	2006
Kansas	2006	Rhode Island	2006
Kentucky	2006	South Carolina	2006
Louisiana	2005	South Dakota	2007
Maine	2006	Tennessee	2006
Maryland	2006	Texas	2007
Massachusetts	2006	Vermont	2006
Michigan	2007	Virginia	2007
Minnesota	2007	West Virginia	2006
Mississippi	2006	Wisconsin	2007
Missouri	2006		

As ZCTAs do not account for all zip codes, a file containing all possible zip codes as of January 31, 2008 is used from zip-codes.com (http://www.zip-codes.com/ Accessed January 5, 2009*)*. This file contains the zip code, latitude, and longitude of the mail office associated with each zip code. These points are then assigned to the corresponding ZCTA. Users can query using any zip code, although the results are based on ZCTAs. i.e., there are 33,568 zip codes and 24,795 ZCTAs in the 33-state study region.

Confidence bounds of individual county level FIA data can be wide. Therefore, estimates of individual ZCTAs are not used in this study, but ZCTAs are aggregated together into larger groupings or “biosheds” where confidence bounds may be comparable to aggregate county groupings. Confidence bounds of the resource supply in any given bioshed which is a grouping of ZCTAs do not offer any improvement over existing studies which aggregate county-level resource supply data. However, using the ZCTA of a demand point offers improvement of confidence bounds of cost estimates when compared to existing studies which rely on estimates using the county centroid as a demand point. Counties can be large and have geographic barriers that impact transportation time and distance (e.g., bridges over large waterways, mountains, large metropolitan areas, etc.).

Using the ZCTA of a demand point with the transportation network from a grouping of supply ZCTAs will improve the estimate of costs relative to using the centroid of the county as the demand point.

Land use of both counties and ZCTAs are not considered in the current study, i.e., a zip code may be predominately urban, but it will receive the amount of resources assigned to it based solely on area proportion. Future studies and enhancements of the BioSAT model will attempt to recognize county and zip code land type, and hence the allocation of resources to a ZCTA. All areas classified as water and unproductive lands are removed from all datasets before the area proportionality process is performed.

Resource Costs

Resources cost data (e.g., stumpage, mill residue prices, log prices, etc.) for the southeastern U.S. are obtained from Timber Mart South (TMS), see http://www.tmart-south.com/tmart/ (Accessed January 12, 2009). TMS mill residue price data (e.g., hardwood sawdust, pine sawdust, and pine shavings) for a state are allocated equally to all ZCTAs. There are currently no estimates for logging residue stumpage in the model.

Resource cost data in the northern U.S. are obtained from multiple sources (Table 2). A significant constraint for resource cost data in these northern regions is the absence of a regional price reporting system similar to TMS. This research is on-going and results for the northern regions are not reported in this paper.

Transportation Costs

Transportation Network:

Microsoft© MapPoint® 2006 (http://www.microsoft.com/MapPoint/en-us/default.aspx Accessed January 5, 2009) is used in BioSAT to provide the shortest travel time routes and distances between ZCTAs. Road networks in MapPoint® are a combination of the Geographic Data Technology, Inc. (GDT) and Navteq data. GDT data are used for rural areas and small to medium size cities. Navteq data are used for major metropolitan areas.

The GDT data are based on "Tele Atlas Dynamap Streets" which is designed for address level geocoding (http://www.teleatlas.com/index.htm Accessed January 12 2009). When an address level geocode is not available the GDT data set uses cascading accuracy at the ZIP+4, ZIP+2, and ZIP Code centroid to return the highest level of geocode for the address. ZIP code boundary data are based on the Dynamap/5-Digit ZIP code Boundary data from Tele Atlas North America. It is designed to identify the boundaries of United States Postal Service ZIP Codes.

Navteq maps provide a highly accurate representation of the detailed road network including up to 260 attributes like turn restrictions, physical barriers and gates, one-way streets, restricted access, and relative road heights http://www.navteq.com/about/whatis.html Accessed January 12 2009).

TABLE 2. Price reporting sources in the northern 20 U.S. state region.

State/Region	Report	Data	Frequency	weblink
Connecticut	Southern New England Stumpage Price	Stumpage: Sawtimber (multiple species), fuelwood, pulpwood, biomass	Quarterly	http://forest.fnr.umass.edu/snespsr/reports/all%20reports.htm
Illinois	Illinois Timber Prices	Stumpage, FOB: Sawtimber (multiple species), pulpwood	Bi-annual	http://web.extension.uiuc.edu/forestry/il_timber_prices/index.html
Indiana	Indiana Forest Products Price Report	Delivered: Sawtimber (multiple species), pulpwood	Annual	http://www.fnr.purdue.edu/extension/pricereports.shtml
Kentucky	Kentucky Delivered Prices	Delivered: Sawtimber (multiple species), pulpwood	Quarterly	http://www.forestry.ky.gov/programs/utilize/Kentuckys+Growing+Gold+Bulletin.html
Maine	Maine Annual Price Report	Stumpage: Sawtimber (multiple species), fuelwood, pulpwood, biomass	Quarterly	http://www.state.me.us/doc/mfs/pubs/annpubs.htm#stump
Massachusetts	Southern New England Stumpage Price	Stumpage: Sawtimber (multiple species), fuelwood, pulpwood, biomass	Quarterly	http://forest.fnr.umass.edu/snespsr/reports/all%20reports.htm
Michigan	Michigan Stumpage Price Report	Stumpage: Sawtimber (multiple species), fuelwood, pulpwood, biomass	Quarterly	http://www.michigan.gov/dnr/0,1607,7-153-10368_22594-81536--,00.html http://www.michigandnr.com/ftp/forestry/tsreports/StumpagePriceReports/12_Month_Stumpage_Price_Reports/
Minnesota	Minnesota Forest Resources Report	Stumpage: Sawtimber (multiple species), pulpwood	Annual	http://www.dnr.state.mn.us/forestry/um/index.html
Missouri	Missouri Timber Price Trends	Stumpage: Sawtimber (multiple species)	Quarterly	http://mdc4.mdc.mo.gov/applications/MDCLibrary/MDCLibrary2.aspx?NodeID=854
New Hampshire	New Hampshire Average Stumpage	Stumpage: Sawtimber (multiple species), pulpwood	Bi-annual	http://www.nh.gov/revenue/munc_prop/avgstumpval.htm
Ohio	Ohio Timber Prices	Delivered: Sawtimber (multiple species)	Bi-annual	http://www.oardc.ohio-state.edu/ohiowood/
Pennsylvania	Pennsylvania Timber Market Report	Stumpage, Delivered: Sawtimber (multiple species)	Quarterly	http://www.sfr.cas.psu.edu/TMR/TMR.htm
Vermont	Vermont Forest Quarterly	Stumpage: Sawtimber (multiple species), fuelwood, pulpwood, biomass	Quarterly	http://stumpage.uvm.edu/stumpage.php
West Virginia	West Virginia Timber Market Report	Stumpage: Sawtimber (multiple species)	Quarterly	http://ahc.caf.wvu.edu/index.php?option=com_wrapper&Itemid=116

Trucking Costs:

The current transportation cost model estimates trucking costs. The analysis in this paper assumes dry-van storage trailers for trucking given that mill residues are the biomass type being hauled. Other trailer types are planned in the trucking model for different biomass types, e.g., pulpwood, corn stover, switchgrass, etc. The final study will include additional truck/rail, rail, and barge cost models.

The trucking cost model given in equations (1), (2), (3), and (4) is an adaptation of the model by Berwack et al. (2003). Diesel fuel cost efficiencies; tire variable costs; tax and license fees; and management and overhead costs of the Berwack et al. (2003) model are modified for the BioSAT model. Modifications to Berwack et al. (2003) model are made from a review of the model in October 2008 by three trucking companies[4] and one wood-using company that requested anonymity. The trucking cost model is assumed to be for contract carriers of the biomass consuming company. In most cases, contract carriers are the least cost form of truck transportation for a biomass consuming facility (personal communication: see footnote 2).

Trucking costs are a function of: variables costs which are dependent on haul time; variable costs which are dependent on haul distance; fixed costs which are dependent on haul distance; and the quantity demanded at a ZCTA demand point. The following equations are presented for the cost model:

$$\text{Total Truck Cost} = \sum_{r=1}^{z}\left(\left(V_{t,s(i,j)} + V_{d,s(i,j)} + F_{d,s(i,j)}\right) \times B_{(i,j)}\right) \qquad (1)$$

where, $V_{t,s(i,j)}$ = variable cost for t for s of (i,j),
$V_{d,s(i,j)}$ = variable cost for d for s of (i,j),
$F_{d,s(i,j)}$ = fixed cost for d for s of (i,j),
$B_{(i,j)} = Q_i/C_s$ = total hauls for each (i,j) for all routes r, $r = 1….z$,
C_s = legal trailer capacity for s,
Q_i = annual capacity of demand ZCTA, i ($i = 1….m$),
d = round-trip travel distance (i,j),
i = demand ZCTA, $i = 1…..m$,
j = supply ZCTA, $j = 1…..n$,
m = total number of biomass supply ZCTAs,
n = total number of biomass supply ZCTAs,
r = route (i, j), r = 1….z,
s = U.S. state, $q = 1….33$,
t = round-trip travel time (i,j).

[4] Pemberton Truck Lines, Inc. (Knoxville, TN); Skyline Transportation, Inc. (Knoxville, TN); and Mason Dixon, Inc. (Scottsboro, AL).

$$V_{d,s(i,j)} = D_{d,s(i,j)} + M_{d(i,j)} + T_{d(i,j)} \quad (2)$$

where, $D_{d,s(i,j)}$ = diesel fuel cost for *d* for *s* of (*i*, *j*),
$M_{d(i,j)}$ = maintenance and repair cost for *d* for (*i*, *j*),
$T_{d(i,j)}$ = tire cost for *d* for (*i*, *j*).

$$V_{t,s(i,j)} = L_{t,s(i,j)} \quad (3)$$

where, $L_{t(i,j)}$ = labor cost for *t* for *s* of (*i*,*j*),

$$F_{d,s(i,j)} = E_{d(i,j)} + S_{s(i,j)} + N_{s(i,j)} + O_{d(i,j)} + I_{s(i,j)} \quad (4)$$

where, $E_{d(i,j)}$ = equipment cost for *d* for (*i*,*j*),
$S_{s(i,j)}$ = tax for *s* for (*i*,*j*),
$N_{s(i,j)}$ = license fee for *s* for (*i*,*j*),
$O_{d(i,j)}$ = management and overhead cost for *d* for (*i*,*j*),
$I_{s(i,j)}$ = insurance cost for *s* for (*i*,*j*).

The variable cost inputs for the trucking model (e.g., diesel fuel, labor wages, etc.) are updated bi-monthly in the BioSAT model. Minimum transportation travel times and distances between ZCTAs in a bioshed are estimated from Microsoft© MapPoint® 2006 (http://www.microsoft.com/MapPoint/en-us/default.aspx Accessed January 5, 2009).

Trucking costs of the BioSAT model are estimated using equations (1), (2), (3), and (4) between each supply $ZCTA_{(j)}$ and demand $ZCTA_{(i)}$ within a bioshed Q_i. Trucking costs are sorted by least cost between each supply $ZCTA_{(j)}$ and demand $ZCTA_{(i)}$. Trucking variable costs are a function of travel time between ZCTAs and trucking fixed costs are a function of travel distance between ZCTAs. The least cost set of supply ZCTAs to meet a demand quantity are generally dependent on shortest travel time between a supply $ZCTA_{(j)}$ and demand $ZCTA_{(i)}$.

Harvesting Costs

Logging Residues:

The BioSAT model uses the Subregional Timber Supply (SRTS) model to estimate and project logging residues in the southeastern U.S. SRTS uses U.S. Forest Service FIA data to project timber supply trends based on current conditions and the economic responses in timber markets (Abt et al. 2000). Abt et al. (2000) note SRTS is a partial equilibrium market simulation model that can be used to analyze various forest resource and timber supply situations. It uses a

biological inventory projection model and a conventional supply/demand framework to project future timber prices and inventories given exogenous assumptions about land area and demand.
SRTS was developed initially to provide an economic overlay to traditional timber inventory models, e.g., ATLAS (Mill and Kincaid 1992), and to develop a consistent methodology for disaggregating the impacts of national and global models, e.g., TAMM (Adams and Haynes 1996), that treated the South as a homogenous supply region (Abt et al. 2000). Timber market and inventory modules are the two major SRTS model components**.** Market parameters are first used to solve for equilibrium price changes, where the market is defined by all of the included subregions. Price and supply shift information from the individual regions are used to calculate harvest change by subregion.

The internal inventory module in SRTS is based on the GRITS model (Cubbage et al. 1990). GRITS extrapolated forest inventories based on USDA Forest Service FIA estimates of timberland area, timber inventory, timber growth rates, and timber removals. GRITS classifies data into 10-year age class groups by broad species group (softwoods and hardwoods) and forest management type (planted pine, natural pine, oak-pine, upland hardwood, and lowland hardwood). FIA data by species group, forest management type, and 10-year age class are summarized for each relevant region in the analysis. Land area trends by forest management type are exogenous to the model. Within a management type, the model can allocate harvest across age classes based on starting harvest proportions, current inventory proportions, or oldest age class first (Abt et al. 2000).

Logging Residue Costs:

Even though logging residue estimates are not presented in this paper, the Fuel Reduction Cost Simulator (FRCS) as modified for the Billion Ton Study (Perlack et al. 2005) by Dykrsta (2008) will be used in future estimates from BioSAT to estimate the cost of harvesting logging residues (Fight et al. 2006; Stokes 1992). The original FRCS model was designed to simulate fuel-reduction treatments in the Interior West, where wildfire is a significant problem (Dykstra 2008). The FRCS was substantially revised by Dykstra (2008) including the development of new procedures to simulate harvests in the North (North Central and Northeast), the South, and the coastal West as well as the Interior West.

In the modified FRCS model the following harvesting operations are considered to collect biomass (Dykstra 2008):

- Manual felling and whole-tree extraction, either with conventional skidders or with cable systems; the simulator uses cable systems if the average ground slope is 40% or more;
- Mechanized felling and whole-tree skidding where mechanized felling is not used with cable yarding.

For ground-based logging, the FRCS model calculates the production rates and costs for both of the possible alternatives (manual felling and mechanized felling). The model then selects the lower-cost alternative for use in deriving the supply curve for the Billion Ton Study which is the same approach that will be used in the BioSAT model.

The variable cost inputs for the FRCS model (e.g., diesel fuel, labor wages, etc.) are updated bi-monthly in the BioSAT model. Forest resource input data is obtained from the USDA Forest Service current FIA inventory data and logging residue estimates are obtained from the SRTS model (Abt et al. 2000).

RESULTS

Mill Residue Economic Supply

The physical supply of mill residues from U.S. Forest Service data indicates distinct regions in the 13-state study region that have high densities of mill residue for potential biomass using facilities (Figure 1). BioSAT estimates the economic availability of such residues and is discussed in this paper.

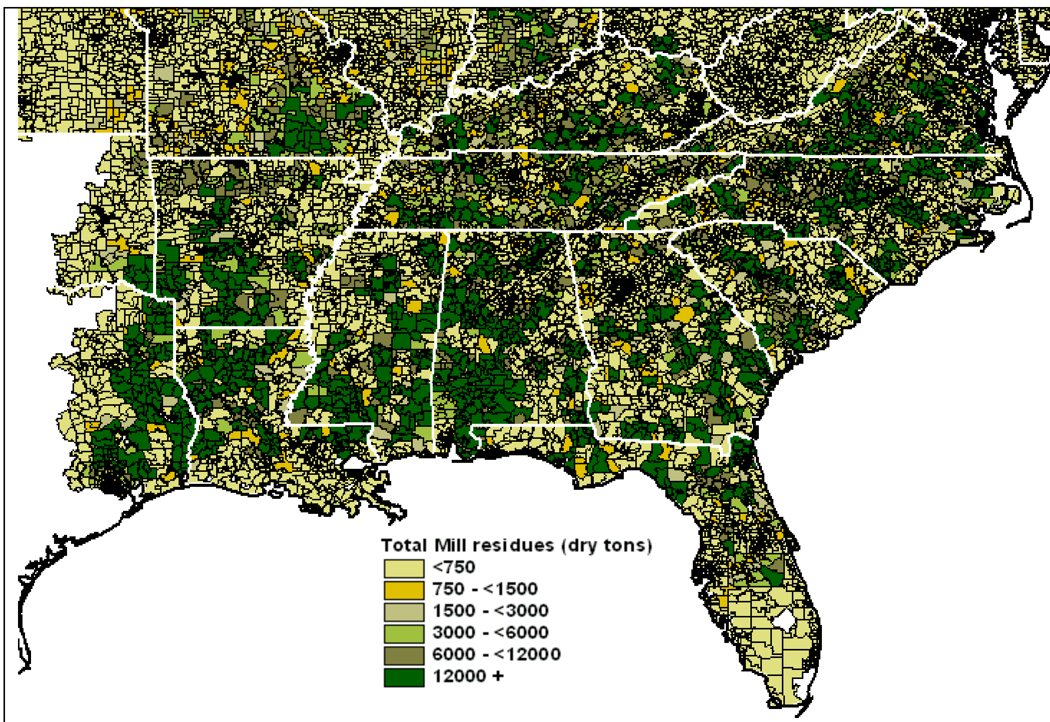

FIGURE 1. Mill residue density by ZCTA for southern U.S.

The trucking cost model component of the BioSAT model is used to generate total cost, average total cost, and marginal costs for up to 1.5 million dry tons of annual consumption of mill residues for 9,353 ZCTA demand points within the

13-state study region. Marginal cost curves for trucking costs only are also generated from the model by ZCTA (Figures 2 and 3).

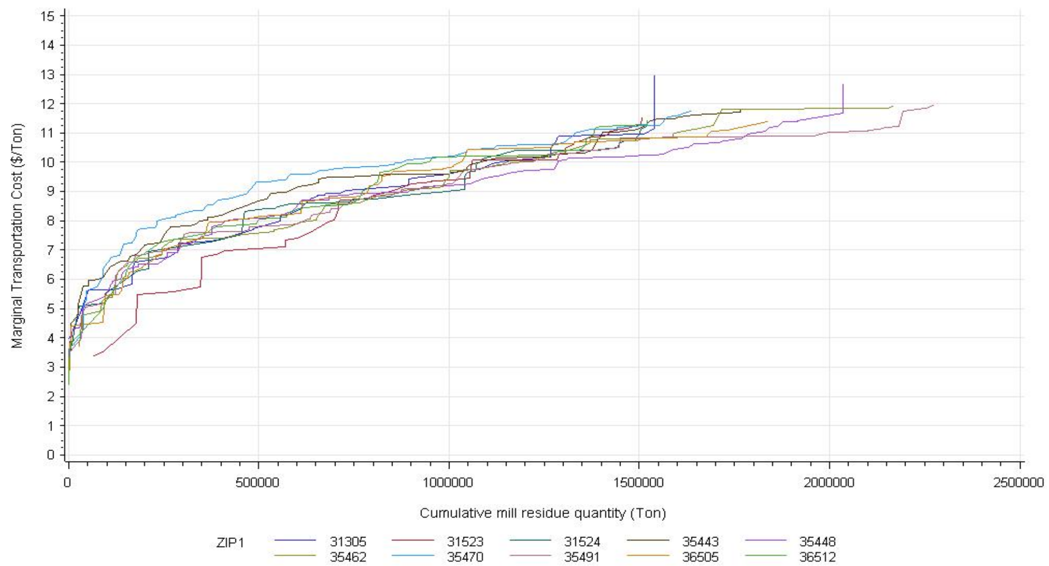

FIGURE 2. Marginal cost curves for trucking of mill residues by ZCTA in Alabama and Georgia for up to 1.5 million dry tons of consumption per year.

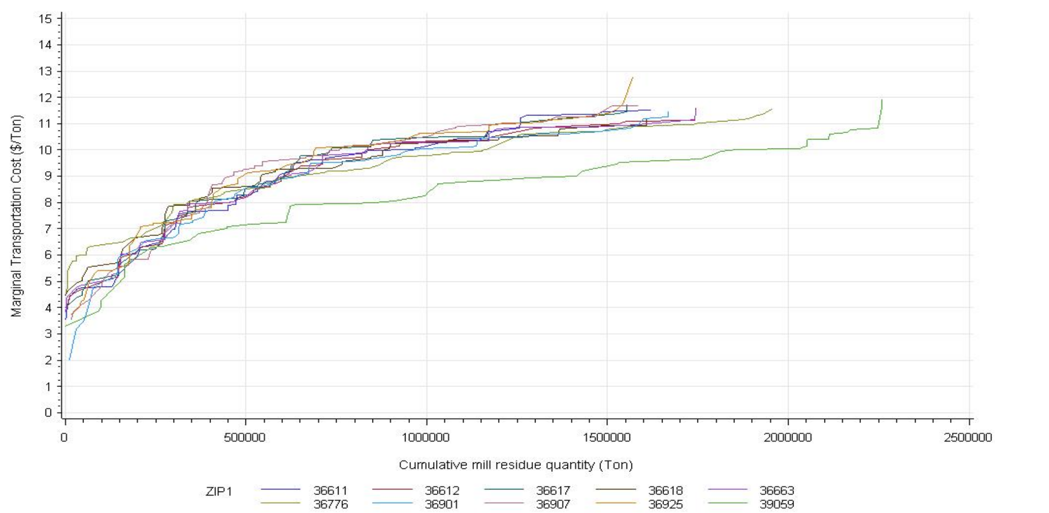

FIGURE 3. Marginal cost curves for trucking of mill residues by ZCTA in Mississippi and Louisiana for up to 1.5 million dry tons of consumption per year.

A comparison of the marginal curves in Figures 2 and 3 for trucking costs indicate significant differences in marginal costs for some demand ZCTAs due to trucking expenses. A key assumption of the BioSAT model is that transportation costs are a key cost factor in the location of biomass consuming facilities.

This is illustrated in Figure 4 in the marginal cost curves for ZCTA 31305 (Darien, GA) that includes trucking costs and TMS 2009 mill residue prices for that region. For an annual consumption of up to 1.5 million dry tons of mill residues the cost of procuring mill residues declined from $29.65 per dry ton in September 2008 (diesel price of $4.068 per gallon) to $28.67 per dry ton in January 2009 (diesel price of $2.228 per gallon). This differential of $0.98 per dry ton may be a significant cost for a biomass facility in a highly competitive market. The cost per ton for ZCTA 31305 (Darien, GA) for consumption between 500,000 and 1.5 million dry tons of consumption per year is given in Table 3. Note that ZCTA 31305 (Darien, GA) is ranked in the 13-state study region as a low cost demand point for mill residues.

There is more than 1.5 million dry tons of available mill residues in the bioshed for ZCTA 31305 (Darien, GA) but for illustration purposes only 1.5 million dry tons are presented in Figure 4. The distinct shifts in the marginal cost curve in Figure 4 occur from larger travel times between the demand $ZCTA_{(i)}$ and supply $ZCTA_{(j)}$ after mill residues are procured from the preceding lower cost supply $ZCTA_{(j)}$. It is assumed that mill residues are economically available if the demand $ZCTA_{(i)}$ buyer is willing to pay an additional price from the supplier. Given the 2008-2009 economic recession and the many mill curtailments and shutdowns of residue suppliers, the next version of the BioSAT model will allow the user to select a percentage of mill residues physically available before starting a cost estimation and search by ZCTA for a bioshed (e.g., 100%, 80%, 75%, 50%, etc.).

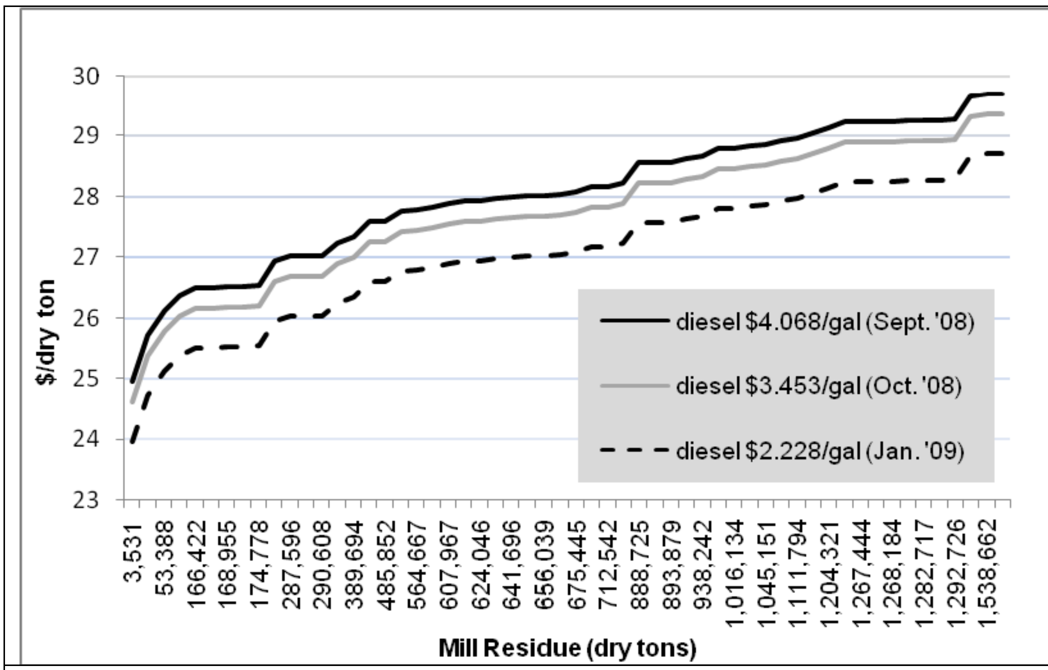

FIGURE 4. Marginal cost curves for trucking and mill residue costs for ZCTA 31305 (Darien, GA) for consumption up to 1.5 million tons per year.

TABLE 3. Cost of mill residues in dry tons for ZCTA 31305 (Darien, GA).

Dry Tons	diesel $4.068/gal (Sept. '08)	diesel $3.453/gal (Oct. '08)	diesel $2.228/gal (Jan. '09)
557141	$27.76	$27.43	$26.77
564667	$27.78	$27.45	$26.79
576221	$27.81	$27.48	$26.82
607967	$27.89	$27.55	$26.90
620670	$27.92	$27.59	$26.93
624046	$27.93	$27.60	$26.94
640828	$27.97	$27.64	$26.99
641696	$27.98	$27.65	$26.99
653744	$28.01	$27.68	$27.02
656039	$28.02	$27.69	$27.03
658074	$28.02	$27.69	$27.03
675445	$28.07	$27.74	$27.08
712447	$28.16	$27.83	$27.17
712542	$28.16	$27.83	$27.18
730901	$28.21	$27.88	$27.22
888725	$28.55	$28.22	$27.56
893656	$28.56	$28.23	$27.57
893879	$28.56	$28.23	$27.57
926886	$28.63	$28.30	$27.64
938242	$28.65	$28.32	$27.66
1009023	$28.78	$28.45	$27.80
1016134	$28.80	$28.47	$27.81
1029843	$28.82	$28.49	$27.83
1045151	$28.85	$28.52	$27.86
1080692	$28.91	$28.58	$27.92
1111794	$28.97	$28.64	$27.98
1151927	$29.04	$28.71	$28.05
1204321	$29.12	$28.79	$28.14
1266766	$29.22	$28.89	$28.23
1267444	$29.22	$28.89	$28.24
1268084	$29.22	$28.89	$28.24
1268184	$29.22	$28.89	$28.24
1278278	$29.24	$28.91	$28.26
1282717	$29.25	$28.92	$28.26
1286112	$29.26	$28.93	$28.27
1292726	$29.27	$28.94	$28.28

1512672	$29.65	$29.32	$28.67
1538662	$29.70	$29.37	$28.71
1539276	$29.70	$29.37	$28.71

Optimal Sites for Biomass Facilities that use Mill Residues

Twenty low cost demand ZCTAs of mill residues for the 9,353 ZCTAs in the 13-state study region are presented in Figure 5. Southern Mississippi is a low cost region for a facility that consumes mill residues up to 1.5 million dry tons per year (ZCTAs 39653, 39436, and 39059). There are also low cost ZCTAs for mill residue consumption of 1.5 million dry tons per year in southeast Georgia (ZCTA 31305), southeast Oklahoma (ZCTA 74737), and southwest Alabama (ZCTA 35448). East Texas has two low cost ZCTA locations (ZCTAs 75534 and 77657) for mill residue consumption up to 1.5 million dry tons per year.

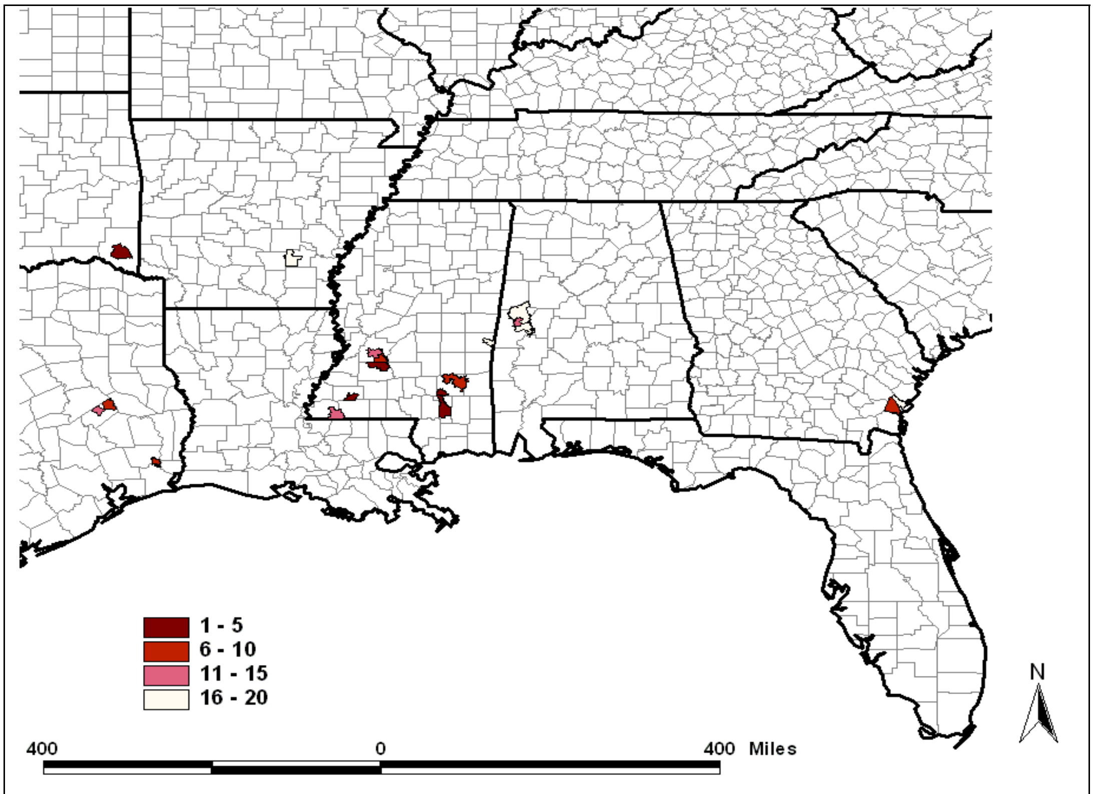

FIGURE 5. Top 20 ZCTA locations with county boundaries for mill residue consumption up to 1.5 million tons consumption per year in the 13-state study region.

A strength of the BioSAT model is that it estimates trucking costs as a function of the MapPoint® road network. This is illustrated in Figure 6 for ZCTA 31305 (Darien, GA) for annual consumption of mill residues of up to 1.5 million dry tons. Some ZCTAs are located in very close proximity (gray color) to the east of the demand ZCTA (highlighted in blue) but are excluded from the model given lack of mill residues and/or long travel-time road networks that incur high trucking costs.

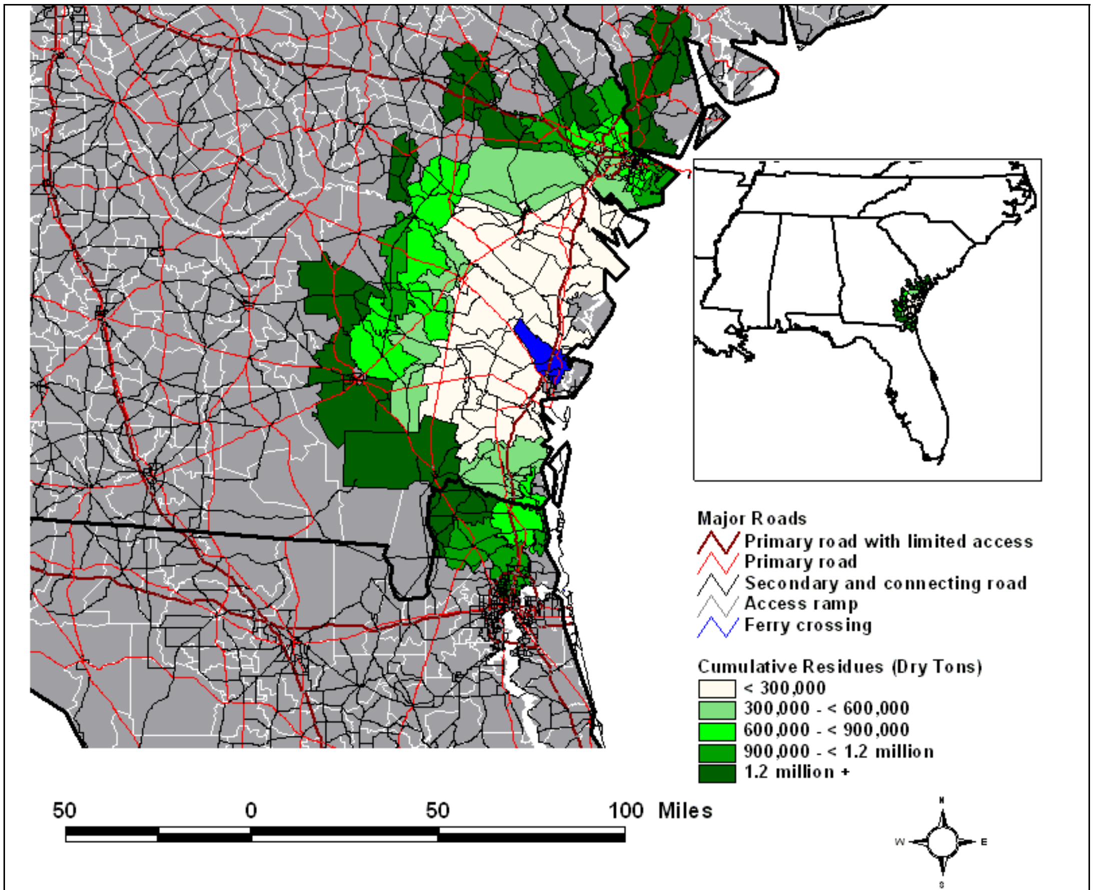

FIGURE 6. Bioshed for ZCTA 31305 (Darien, GA) with road network for consumption of mill residues up to 1.5 million tons per year.

CONCLUSIONS

A study using the Biomass Site Assessment Tool (BioSAT) model for procurement of mill residues for 13 southern U.S. states is presented in this paper. The BioSAT model for mill residues assumes truck transportation with dry-van storage for a maximum one-way haul distance of five hours. Mill residue prices are obtained from Timber Mart South.

BioSAT has a trucking cost model that estimates costs as a function of the road network provided by MapPoint®. Road networks in MapPoint® are a combination of the Geographic Data Technology, Inc. (GDT) and Navteq data. County level estimates of all-live total biomass, as well as average annual growth, removals, and mortality are obtained from the Forest Inventory and Analysis Database

(FIADB) version 3.0. The latest complete cycle of data for each state are used. Data in BioSAT are organized by 24,975 zip code tabulation areas (ZCTA) in 33 eastern U.S. states. ZCTAs are based on the U.S. Census Bureau 2000 census definition.
Confidence bounds of the resource supply in any given grouping of ZCTAs ("bioshed") does not offer improvement over existing studies which aggregate county-level resource supply data. However, using the ZCTA as a demand point may offer improvement in cost estimates when compared to studies which use the county centroid as a demand point. Counties can be large and have geographic/economic barriers that impact road networks (e.g., bridges over large waterways, mountains, large metropolitan areas, etc.). Such geographic/economic barriers can increase the travel time and costs for transportation.

Twenty low-cost ZCTA demand-points for annual consumption of mill residues up to 1.5 million dry tons are located in southern Mississippi, southeast Georgia, southeast Oklahoma, southwest Alabama, and east Texas. Costs for these ZCTAs range from $25 per dry ton to $38 per dry ton for up to 1.5 million dry tons of annual consumption.

Research on BioSAT is on-going and studies are forthcoming for 33 eastern U.S. states. These studies will include different types of woody and agricultural biomass (e.g., logging residues, pulpwood, corn stover, etc.). Additional cost models for transportation by truck with rail and barge intra-modal transfer will also be forthcoming.

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APPENDIX

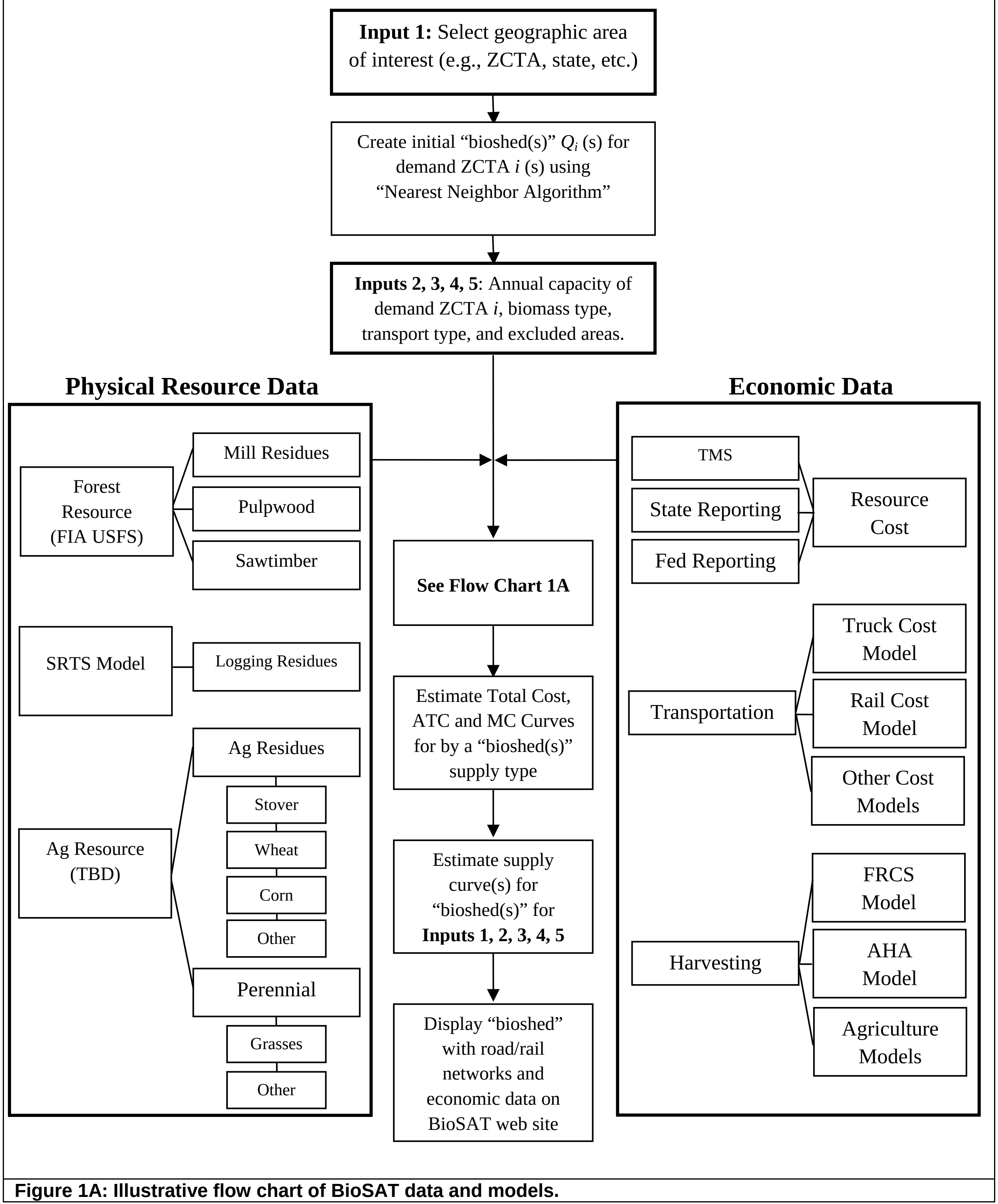

Figure 1A: Illustrative flow chart of BioSAT data and models.

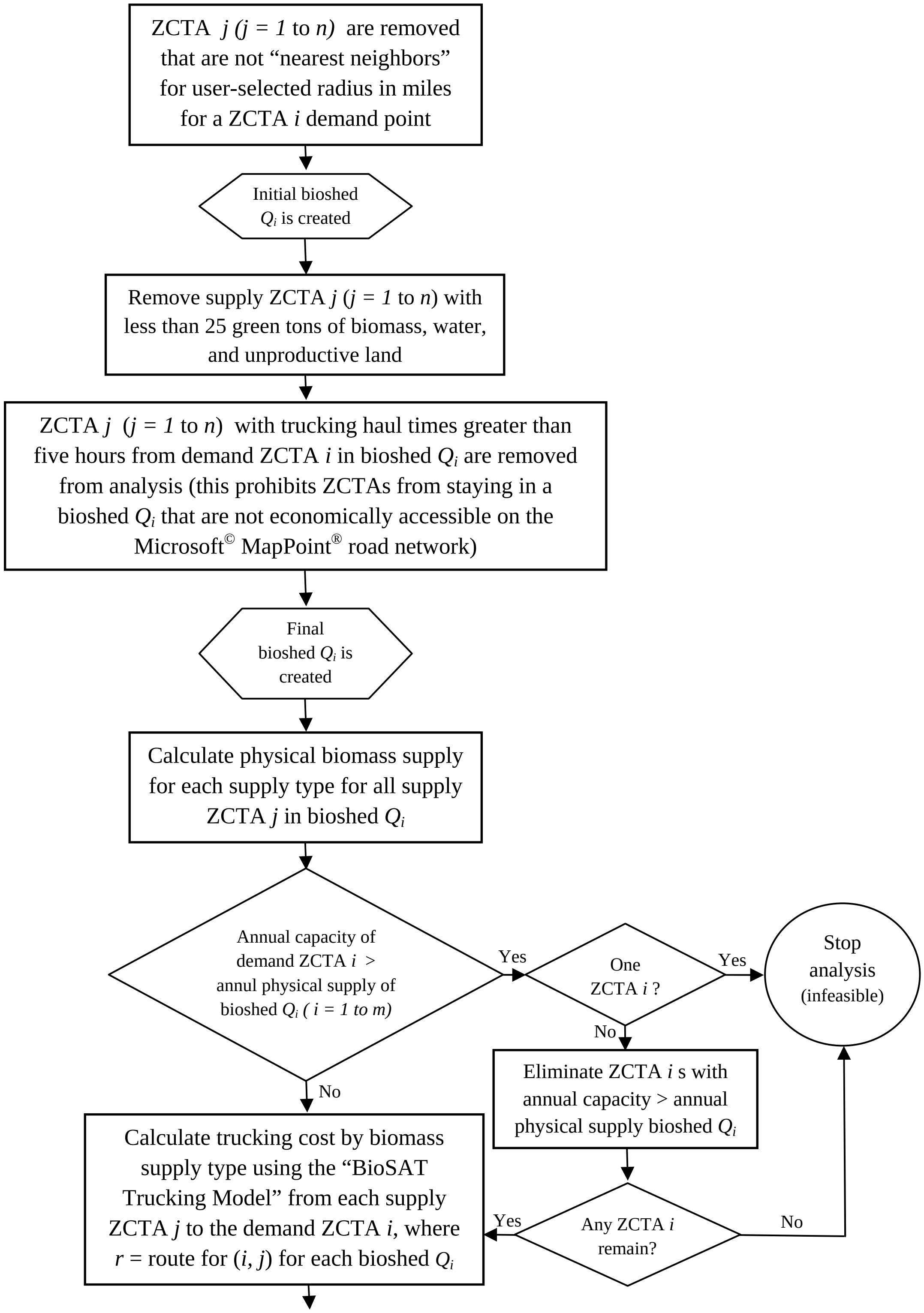

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Figure 2A. Flow Chart 1A, cost calculations for BioSAT model (trucking model only).

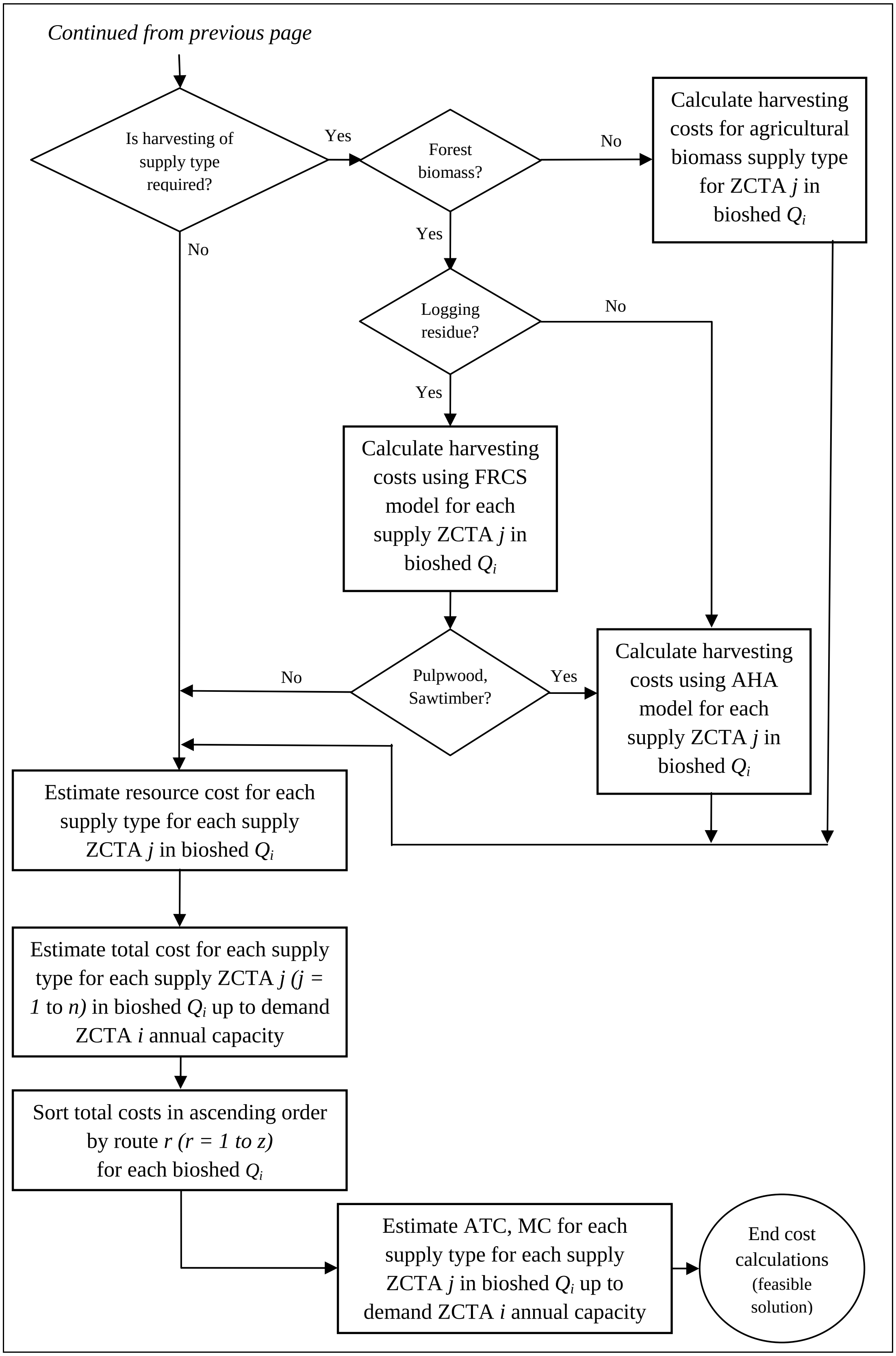
Continued from previous page
Is harvesting of supply type required?
Yes
No
Forest biomass?
No
Yes
Calculate harvesting costs for agricultural biomass supply type for ZCTA j in bioshed Qi
Logging residue?
No
Yes
Calculate harvesting costs using FRCS model for each supply ZCTA j in bioshed Qi
Pulpwood, Sawtimber?
No
Yes
Calculate harvesting costs using AHA model for each supply ZCTA j in bioshed Qi
Estimate resource cost for each supply type for each supply ZCTA j in bioshed Qi
Estimate total cost for each supply type for each supply ZCTA j (j = 1 to n) in bioshed Qi up to demand ZCTA i annual capacity
Sort total costs in ascending order by route r (r = 1 to z) for each bioshed Qi
Estimate ATC, MC for each supply type for each supply ZCTA j in bioshed Qi up to demand ZCTA i annual capacity
End cost calculations (feasible solution)

Figure 2A (cont). Flow Chart 1A, cost calculations for BioSAT model (trucking model only).

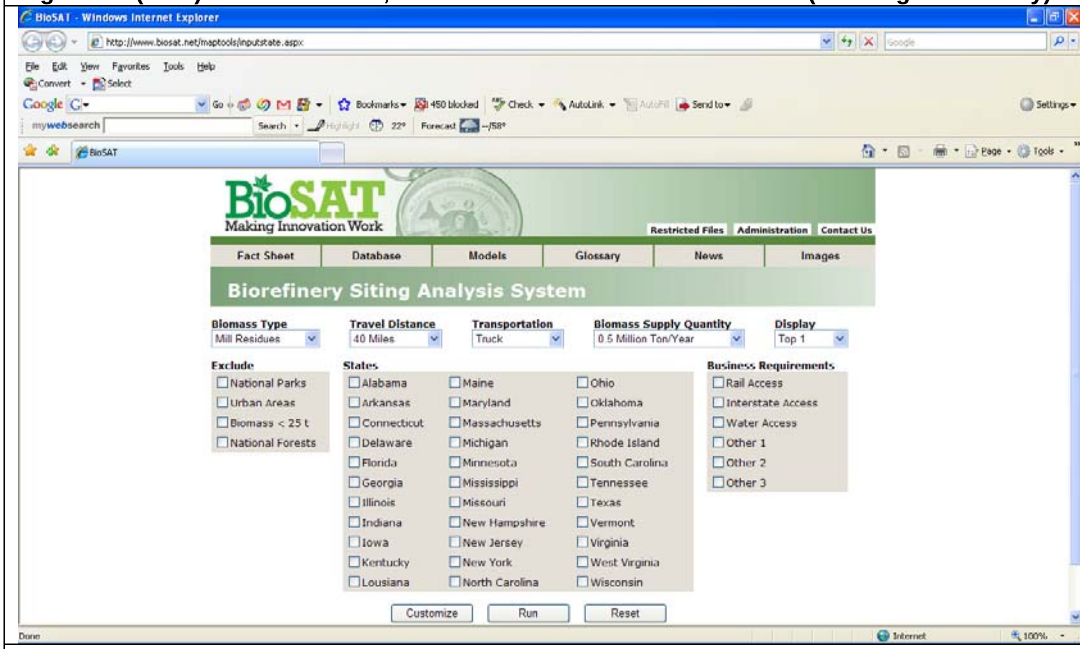

Figure 3A. Draft of BioSAT model input page (www.BioSAT.net)

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