A spatial geographic and socioeconomic index for identifying opportunity zones for biorefineries

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Motivation

• Replacing petroleum products with bio-based fuels and energy presents several technical, economic, and research challenges, one of which is availability of biomass feedstocks

• Lack of biomass production capacity, high relative costs of production, logistics, and transportation of feedstocks, are all potential constraints that need to better understood  

  Elbehri (2007)

• Assessing the economic capability and stability of the bioenergy supply chain infrastructure is essential for market organization of this emerging industry

  U.S. DOE (2011)
Biomass Site Assessment Tool


Phase II: stochastic-based site selection, ✓ constraint criteria, resource competition ✓

Phase III: Short Rotation Woody Crops *(planned)*
**Constraint Criteria - Research Problem & Objectives**

*Problem:*

Develop landscape suitability criteria to identify opportunity zones for potential biorefineries that use cellulosic resources as feedstocks

*Objective:*

1. Define landscape suitability characteristics in a spatial context
2. Define competition for the resource in a spatial context
3. Develop “disaster risk” index
4. Identify biomass opportunity zones

*Scope: 33 Southeastern United States – complete for 13 southeastern states*
Definitions

High suitability – lands suitable for forest or agricultural production only, e.g., agricultural land in Mississippi Delta, forests of northern Minnesota

Moderate suitability – lands that have moderate capability for being only in forest or agricultural production, e.g., some conversion between agricultural and forest land possible

Low suitability – lands that may be easily converted from agricultural production to forestland, e.g., marginal agricultural croplands in the Northern Lake States that may be converted to forestland

Unsuitable – land areas as defined by ecoregion classification that are not suitable for forest or agricultural production, e.g., desert in western Texas, mountain tops of Smoky mountains

Exclusion – land areas that will not support forest or agricultural production given socio-economic and/or legal constraints, e.g., national parks, military bases, urban areas with population density $> 150$ people/mile$^2$, etc.
Primary Exclusion Indicators and Unsuitable Ecoregions
**Exclusion Indicators**

**Federal Lands**

- Population Density > 150 people/mile² – Wear *et al.* 1999

**Slope > 40% (21.8°) – Kimsey *et al.* 2011**

**Unsuitable Ecoregions**
Total of 5,029, 5-digit ZCTAs excluded or
5,019/10,016=50.1%
Criteria - Forest Suitability ONLY

Start (10,016)

Exclusion (5,019)

Exclusion Indicators (4,293)

Factor 1: Federal Land
Factor 2: Population Density
Factor 3: Slope

Not suitable (726)

Factor 1: Ecoregions

Forest Suitability ONLY (4,997)

Agriculture Suitability ONLY
Unsuitable for Forest
(eliminate 2,251 ZCTAs)

**Forest Suitability ONLY**
- Factor 1: Population Density
- Factor 2: Income
- Factor 3: G/R Ratio + Forest Area Land Ratio
- Factor 4: Ecoregions
- Factor 5: Road Density
- Factor 6: Slope

**Agriculture Suitability ONLY**

**Not Suitable**
- ≥ 150 people/mile²
- Farm Net Income ≤ 0 or Median Family Income ≥ $49,445
- G/R ≤ 0 and Forest Area Ratio ≤ 0.1
- Highly Suitable for Cropland
- ≥3 km of road/km²
- ≥40%

**Low**
- Moderate
- High
High Suitability (987 ZCTAs)

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<tbody>
<tr>
<td>High</td>
<td>Income</td>
<td>G/R ≥1.5 and Forest Area Ratio ≥0.3</td>
<td>Suitable for Forests</td>
<td>≤3 km of road/km²</td>
<td>&lt; 40%</td>
</tr>
</tbody>
</table>

Population Density: < 100 people/mile²

Forest Suitability ONLY

Agriculture Suitability ONLY

Not Suitable

Low

Moderate

High

Map: Forest Suitability - High (987)
Forest Suitability - Possibly Suitable

Start

Exclusion

Ecoregions

Road Density

Slope
**Moderate Suitability (1,046 ZCTAs)**

<table>
<thead>
<tr>
<th>Forest</th>
<th>Population Density</th>
<th>Income</th>
<th>G/R Ratio + Forest Area Land Ratio</th>
<th>Ecoregions</th>
<th>Road Density</th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate</td>
<td>&lt;150 people/mile(^2)</td>
<td></td>
<td>G/R (\geq 1) and Forest Area Ratio &gt; 0.1</td>
<td></td>
<td>(\leq 3) km of road / km(^2)</td>
<td>&lt; 40%</td>
</tr>
</tbody>
</table>
## Low Suitability (713 ZCTAs)

**Forest Suitability ONLY**

**Factors:**
- **Factor 1:** Population Density
- **Factor 2:** Income
- **Factor 3:** G/R Ratio + Forest Area Land Ratio
- **Factor 4:** Ecoregions
- **Factor 5:** Road Density
- **Factor 6:** Slope

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</tr>
</thead>
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<tr>
<td>Low</td>
<td>&lt;150 people/mile²</td>
<td></td>
<td>0 &lt; G/R &lt; 1</td>
<td></td>
<td>≤ 3 km of road / km²</td>
<td>&lt; 40%</td>
</tr>
</tbody>
</table>
Constraint Criteria – Forest Suitability

Forest Suitability ONLY

- High (987)
- Moderate (1,046)
- Low (713)
- Not Suitable (2,251)
- Exclusion (5,019)
Constraint Criteria – Forest Suitability with Competition

- Criterion to measure the competition intensity using primary wood-using mills in the marketplace.

- Competition = \( f (\text{Percent Capacity Utilized, Growth, and Removals}) \)

- Function is expressed as a percentage of the summed demand capacity within a certain driving distance (40 miles, 80 miles, 120 miles) over the supply net growth for each 5-digit ZCTA, and the value then is adjusted by the annual net growth, and G/R ratio
Primary wood-using mills in southeast

Woody-using Facilities with Capacity (dry ton)
i.e., Bioenergy, Biopower, Biofuels,
Primary Mills, Pulp and Paper Mills, Wood Pellets for Energy
- Small (0 - 772)
- Medium (>772 - 519,600)
- Large (>519,600 - 2,600,000)
Competition Index within 40 mile one-way driving distance

1: Least Competitive - No Capacity Consumed, Growth > 10,000 dry ton/year, G/R > 1.5
2: Less Moderate Competitive - [0,50%] Capacity Consumed, Growth > 0 dry ton/year, G/R >= 1.0
3: Moderate Competitive - [0, <100%] Capacity Consumed, Growth > 0 dry ton/year, G/R >= 1.0
4: More Moderate Competitive - [0, <100%] Capacity Consumed, Growth > 0 dry ton/year, G/R <= 1.5
5: Most Competitive - >100% Capacity Consumed
6: No or Negative Growth, or G/R = 0
Competition Intensity – 80 mile haul distance

Competition Index within 80 mile oneway driving distance

1: Least Competitive - No Capacity Consumed, Growth>10000 dry ton/year, G/R>1.5
2: Less Moderate Competitive - [0,50%] Capacity Consumed, Growth>0 dry ton/year, G/R>=1.0
3: Moderate Competitive - [0, <100%] Capacity Consumed, Growth>0 dry ton/year, G/R>=1.0
4: More Moderate Competitive - [0, <100%] Capacity Consumed, Growth>0 dry ton/year, G/R<=1.5
5: Most Competitive - >100% Capacity Consumed
6: No or Negative Growth, or G/R = 0
Constraint Criteria – Forest Suitability with Competition

- Adjust by Competition Index (80-mile)

- High (592)
- Moderate (558)
- Low (835)
- Not Suitable (3,012)
- Exclusion (5,019)
Biomass Site Assessment Tool

“Landscape and socio-economic suitability criteria for identifying opportunity zones”
Model Logic

SQL Database

MC Curve

Quantity (dry tons) per Year

$/dry ton
BioSAT Cost Model – Mimics Supply Chain

“Woody Residues and Roundwood”

USFS FIA

Mill Residues

Growth/Removals

Logging Residues
SRTS “Econometrics”

Roundwood
“5 Eco-Regions & Stand Types”

“Ag Residues”

USDA NASS
BioSAT Cost Model – Mimics Supply Chain

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“5 Eco-Regions & Stand Types”

Resource Costs (TMS, TMN, ST)

“Ag Residues”

USDA NASS

Nutrient Replacement Cost (Literature)
BioSAT Cost Model – Mimics Supply Chain

"Woody Residues and Roundwood"

USFS FIA

Mill Residues

Growth/Removals

Logging Residues
SRTS "Econometrics"

Roundwood
"5 Eco-Regions & Stand Types"

Resource Costs (TMS, TMN, ST)

Harvesting Costs (FRCS)

Harvesting Costs (AHA)

Nutrient Replacement Cost (Literature)

"Ag Residues"

USDA NASS

Harvesting Costs
(Literature)
BioSAT Model
Current Feedstocks

**Woody Residues & Merchantable Wood**
- Logging Residues
  - Softwood/Hardwood
    - At the landing/In the woods
- Mill Residues
  - Softwood/Hardwood
    - Clean/Unclean
- Roundwood
  - "Pulpwood"
    - Softwood/Hardwood
- Roundwood
  - "Sawtimber"
    - Softwood/Hardwood

**Ag Residues**
- Barley Straw
- Corn Stover
- Oat Straw
- Sorghum Straw
- Wheat Straw (Winter)
- Wheat Straw (All)
Focus on Opportunity Zone in Mississippi

- Adjust by Competition Index (80-mile)
  - High (592)
  - Moderate (558)
  - Low (835)
  - Not Suitable (3,012)
  - Exclusion (5,019)
Marginal Cost Curve Development

Aggregate Supply Curve
ZCTA 39090 (Kosciusko MS) – Pine Pulpwood

Marginal Cost Curve Development

Marginal Cost ($/dry ton)
- 48 - 52
- >52 - 62
- >62 - 66

Cumulative Quantity (dry ton)

Marginal Cost ($/dry ton)

45.00
50.00
55.00
60.00
65.00
70.00

17,313
74,676
233,067
295,406
366,333
401,194
444,103
458,543
493,189
521,372
547,216
587,987
628,538
664,827
701,088
773,096
Aggregate Supply Curve
Elasticity and Increased Demand

User must assess the intersection with supply curve
Aggregate Supply Curve
Elasticity and Increased Demand

What is impact of increased demand?
What is impact on elasticity?
The BioSAT Project

BioSAT “Terms of Use Agreement”

Update Notice: BioSAT is a research project in progress. The system has update capabilities combined with additional research targeted to continuously adding innovation and utility. From time to time you will see updates and new features.

The BioSAT Final Report is available

Cost Updates
Harvesting Costs for Logging and Mill Residues have been updated and now reflect 03/28/2011 Diesel price.
Trucking costs for all Biomass Types except Merchantables Trees have been updated and now reflect 05/07/2012 Diesel price and May 2011 Truck Drivers’ hourly median wage.

BioSAT stands for Biomass Site Assessment Tools.

www.BioSAT.net
Conclusions

- Criteria for landscape, socio-economic, and resource-competition constraints is important for identifying opportunity zones – spatial context is important

- Used in conjunction with BioSAT model provides decision tool for identifying cost scenarios for mills interested using cellulosic feedstocks

- Website www.BioSAT.net in public domain
Questions?

“All Models are Wrong, Some are Useful”

George Box (U of Wisconsin)