Modeling Biomass Availability at Regional & Local Scales

Jeremy S. Fried, USFS PNW Research Station
Inventory Simulation Paradigm

- Is tied to facts on the ground, measured at real places
- Informs as to mix of products produced at landscape scale under a range of assumptions, objectives and constraints
- Provides a **representative** sample of the entire landscape,
- For any …
  - Constellation of existing and potential processing facilities,
  - Set of performance objectives and landowner motivations,
  - Constraints
- the user can estimate …
  - Yields of products by type and generated revenue
  - Harvest costs
  - Haul costs
  - Goal achievement
  - Best places to site bioenergy facilities
FIA BioSum vs. $10^9$ ton Report

- Both are founded on systematic forest inventory data
- Both apply prescriptions and estimate treatment costs
- BioSum models many treatments per plot
  - Can pick “best” treatment via a rule set for an assumed bioenergy facility network or
  - Jointly optimize treatments and the configuration of the bioenergy facility network
- BioSum is implemented as a modeling framework so that anyone can set their own assumptions concerning
  - Objectives, constraints, costs, prices, bioenergy facility size, what constitutes the available land base
- Analyses differ in what is measured, modeled, assumed
FIA BioSum Objectives

- Explore how alternative silvicultural prescriptions, objectives and constraints play out with respect to:
  - Location of “hot spots” of potential biomass accumulation
  - The mix of wood products (merchantable & “dirty chips”)
  - Economic feasibility of landscape scale fuel treatment that leaves robust, resilient forests
- Evaluate the upper bound of potential production
  - as if all non-roadless area can be plausibly treated
- Assess potential for cross-subsidization among acres
  - Acres that make money can subsidize more expensive to treat acres on the same ownership to expand area treated and product yields
Why bother with spatial representation?

- Obtain realistic haul cost piece of the bioenergy puzzle
- Obtain representative range of yarding distances to feed the harvest cost model
- Get a ballpark idea of potential for bioenergy development
  - An extremely sparse network of bioenergy sites could leave carbon-emitting biomass rotting in the woods
  - An excessively dense network would likely not be supportable via sustainable forestry
- Don’t expect the best solution for a given acre or exact location of where to build a bioenergy facility
  - We’re working with representative samples of the forested landscape and siting guidance is not precise
FIA BioSum model framework

- Forest Inventory Plots (FIA)
  - Representative sample of forest vegetation
- Forest Vegetation Simulator (FVS)
  - Silvicultural treatment engine – NO projection
- Fire and Fuels Extension (FFE)
  - To evaluate crown fire potential
- Fuel Reduction Cost Simulator (FRCS)
  - To evaluate cost of fuel treatments
- Travel Times Calculator (TTC)
  - Calculate haul time, apply truck rental rate; Sample of accessibility relative to mills & power plants
- Treatment Selection Engine (TSE)
  - Via rule sets (with a fixed facility network)
  - Via optimization (facility sites & treatments jointly selected)
Designated & potential facility sites & FIA plots for the ORCA analysis

- 6200 plots accounted for
- 221 potential bioenergy sites
- Merch. wood to existing mills
- Many plots excluded because
  - Roadless/wilderness areas & parks
  - Steep (>40%) slopes and >2000’ from a road
  - Insufficient basal area for any prescription
- 9 crown and ladder fuel reduction prescriptions evaluated
- FVS used only to map prescriptions onto plot tree lists
- FFE estimates crown fire potential before and after treatment
- FRCS calculates harvest cost for each treatment-plot combo

**After Ladder Reduction Treatment**  
Residual BA=80 sq ft/ac

**After Crown Reduction Treatment**  
Residual BA=125 sq ft/ac
Travel time calculator

- Computes accumulated travel time radiating out from each facility location along road network
- Plots overlaid on accumulated travel time
- Travel time converted to haul cost using a truck rental rate per hour
Arizona/New Mexico model
15 bioenergy sites, with rail transit option

Road and rail topologies make working “circles” that are **not** round
Scenario builder enables easy comparison

At most, 22% of forest would be treated; <5% more likely

millions of acres

0 5 10 15 20 25

Private
Public

NR+ High Effec./10’ max
NR+ Mod. Effec. 16’ max
NR+ Mod. Effec./Min Merch
Mod. Effective
NR+ Mod. Effective
Accessible
High Hazard
All forest land
Your mileage varies by assumptions

<table>
<thead>
<tr>
<th># Scenario</th>
<th>Net Revenue (billion $)</th>
<th>Acres (million)</th>
<th>Dirty Chips (million gr. Tons)</th>
<th>Merch (million gr. Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MaxNR, ModEffect</td>
<td>8.9</td>
<td>4.5</td>
<td>83</td>
<td>309</td>
</tr>
<tr>
<td>2 MaxNR, HighEffect</td>
<td>7.1</td>
<td>2.8</td>
<td>61</td>
<td>235</td>
</tr>
<tr>
<td>3 MaxNR, ModEffect, ALL</td>
<td>5.6</td>
<td>8.1</td>
<td>138</td>
<td>350</td>
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<tr>
<td>4 MaxTI Improvement, HighEffect</td>
<td>4.7</td>
<td>3.9</td>
<td>85</td>
<td>241</td>
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<td>2.8</td>
<td>3.2</td>
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<td>142</td>
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<td>0.3</td>
<td>0.9</td>
<td>20</td>
<td>27</td>
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<tr>
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<td>4.8</td>
<td>71</td>
<td>51</td>
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<tr>
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<td>-2.8</td>
<td>3.4</td>
<td>33</td>
<td>0</td>
</tr>
</tbody>
</table>

MaxNR=Maximize net revenue  
MaxTI=Maximize torching index improvement  
ModEffect=Allow treatments that don’t improve torching index  
HighEffect=Allow only treatments that improve torching index  
ALL=Allow all treatable acres regardless of costs and revenues  
21” Max=Allow only treatments that do not cut trees larger than 21” diameter
## AZ/NM Outcomes

<table>
<thead>
<tr>
<th>Which acres</th>
<th>Objective</th>
<th>Acres millions</th>
<th>Net revenue billion $</th>
<th>Merch. volume billion ft(^3)</th>
<th>Dirty chip weight million tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Effective</td>
<td>Max NetRev</td>
<td>11.2</td>
<td>-1.6</td>
<td>4.4</td>
<td>80</td>
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<tr>
<td>NR+ only</td>
<td>Max NetRev</td>
<td>1.6</td>
<td>0.96</td>
<td>2.2</td>
<td>17</td>
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<td>Stewardship Contracts</td>
<td>Max NetRev</td>
<td>7.7</td>
<td>0.034</td>
<td>3.3</td>
<td>48</td>
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<tr>
<td>All Effective</td>
<td>Min Merch</td>
<td>11.2</td>
<td>-2.3</td>
<td>3.1</td>
<td>73</td>
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<tr>
<td>NR+ only</td>
<td>Min Merch</td>
<td>1.6</td>
<td>0.73</td>
<td>1.9</td>
<td>15</td>
</tr>
<tr>
<td>Stewardship Contracts</td>
<td>Min Merch</td>
<td>4.9</td>
<td>0.025</td>
<td>1.4</td>
<td>22</td>
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</table>
### Years of Supply for 50/5 MW Power Plants

At the best locations

<table>
<thead>
<tr>
<th>Processing Sites</th>
<th>15 Processing Sites</th>
<th>6 Processing Sites</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
<td>NR+</td>
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<tr>
<td>Flagstaff</td>
<td>15/87</td>
<td>5/30</td>
</tr>
<tr>
<td>Reserve</td>
<td>12/73</td>
<td>2/12</td>
</tr>
<tr>
<td>Grants</td>
<td>11/63</td>
<td>1/9</td>
</tr>
<tr>
<td>Springerville</td>
<td>11/63</td>
<td>3/19</td>
</tr>
<tr>
<td>Snowflake</td>
<td>10/59</td>
<td>2/11</td>
</tr>
<tr>
<td>Almogordo</td>
<td>8/46</td>
<td>1/4</td>
</tr>
<tr>
<td>Chama</td>
<td>6/36</td>
<td>1/5</td>
</tr>
</tbody>
</table>
Key findings from ORCA

- Apart from the economics, must usually cut merchantable trees to get effective hazard reduction
  
  \[
  \frac{\text{Merchantable Weight}}{\text{Chip Weight}} \quad \text{ranges from 1 to 4}
  \]
  
  \[
  \frac{\text{Merchantable Value}}{\text{Chip Value}} \quad \text{ranges from 3 to 12}
  \]

- Over 10 years, the 8 million acres of treatable forest has capacity to produce, entirely via fuel treatment thinnings and without mill residues,
  
  - $500-$700 million/yr in net revenue (mostly from merch)
  - 2-8 million green tons/yr of dirty chips,
    - To enable 1009 megawatts of carbon-neutral generating capacity
  - 0.5 to 8 million tons/yr of carbon to solid wood mills
More findings & lessons

- Small trees add to treatment costs but are a relatively small fraction of the energy wood extracted
  - most is tops and limbs of larger sized trees and entire trees of noncommercial species, such as tanoak
- BioSum identifies the ‘low-hanging fruit’—places where fire hazard reduction will be effective and produce enough revenue to at least cover treatment costs
- Energy-wood fueled bioenergy facilities <15 MW can’t compete with larger facilities except where wood yield is too low to support even 15 MW
  - Local factors such as alternative biomass sources may mitigate this finding
Caveats

- Treatment costs charged to the big wood; energy wood is a residual that gets tagged only with haul cost
- Without merch to subsidize, it could rarely be justified
- Assumes all roaded acres available and that all owners want to reduce fire hazard to maintain resilient forests
- Management/administrative/litigation/regulatory/planning costs not considered
- Re-treatment costs not considered
- Carbon offsets not considered
FIA BioSum Deployments/Uses

- CA Board of Forestry policy analysis of diameter limit for fuel treatments
- Supported sizing decision for a bioenergy plant in Lakeview, OR
- Supported forest plan development at Shasta Trinity NF
- Supported evaluation of siting a plant at Chemault, OR
- Supported decisions in USFS Region 3 about long term NF biomass supply contracts (e.g., White Mountain)
- Learn more about BioSum (and download articles and eventually, the software) at http://biosum.info
Extras
Product mix varies

<table>
<thead>
<tr>
<th>#</th>
<th>Scenario</th>
<th>Dirty Chips (million gr. Tons)</th>
<th>Chip Value (billion $)</th>
<th>Capacity (MW)</th>
<th>Merch: Chip Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MaxNR, ModEffect</td>
<td>83</td>
<td>1.5</td>
<td>630</td>
<td>11</td>
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<tr>
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<td>MaxNR, HighEffect</td>
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<td>12</td>
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<td>3</td>
<td>MaxNR, ModEffect, ALL</td>
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<tr>
<td>4</td>
<td>MaxTI Improvement, HighEffect</td>
<td>85</td>
<td>1.5</td>
<td>644</td>
<td>8</td>
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<tr>
<td>5</td>
<td>MaxNR, ModEffect, 21&quot; Max</td>
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<tr>
<td>6</td>
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<td>71</td>
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<td>1</td>
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<td>33</td>
<td>0.6</td>
<td>248</td>
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</tbody>
</table>
Plant Size Assumptions

- Plant requirements were taken from 2002 Oak Ridge National Laboratory report
- Minimum biomass set at a 10-year supply, assuming 300 days of operation per year
- Minimum plant size was varied in models:
  - 5 MW – 690 thousand gtons
  - 20 MW – 2,457 thousand gtons
  - 40 MW – 4,914 thousand gtons
Biomass plants (40 MW min)

Biomass Plants (40MW min)

Size_MW

- 15 - 20
- 21 - 25
- 26 - 35
- 36 - 45

Biomass Plants (heuristic)

Biomass Plants

Heuristic location

Southern Cascades

Klamath Mountains

Eastern Cascades

Modoc Plateau

17 plants

4 plants
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  - 5 MW – 690 thousand gtons
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OR/CA case used two prescription approaches

- Cut & scatter all 0-3” trees
- Cut & remove all 3-5” trees
  - Scatter on slopes >40%
- For trees >5 inches DBH:

**Crown Reduction**
- Thin across all diameter classes to target residual basal area.
- 70% of BA cut is in trees 5-14”
- 30% of BA cut is in trees >14” (up to max DBH for the Rx)

**Ladder Reduction**
- Thin from below to target residual basal area (*unless DBH max reached first*).
Applied 9 treatments in FVS

<table>
<thead>
<tr>
<th>Rx:</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>J</th>
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<tbody>
<tr>
<td>Type</td>
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<tr>
<td></td>
<td>Crown reduction</td>
<td>Ladder reduction</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Target Resid. BA</td>
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<td></td>
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<td></td>
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<tr>
<td>125</td>
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<td>90</td>
<td>90</td>
<td>90</td>
<td>80</td>
<td>60</td>
<td>60</td>
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<tr>
<td>No cut if dbh &gt; X inch</td>
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<tr>
<td>21</td>
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<td>21</td>
<td>16</td>
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<td>21</td>
<td>21</td>
<td>21</td>
<td>NA</td>
<td>10</td>
</tr>
</tbody>
</table>

Tolerant species cut first, then hardwoods, then high-value species.
Harvest cost & revenue model

- **Logging assumptions**
  - Whole tree or cut-to-length on slopes ≤40%
  - Cable systems and manual felling on slopes >40%, bucked and limbed in the woods

- **Processing & pricing assumptions**
  - Biomass: boles of 3–7” trees, limbs and tops of all trees, all hardwoods; utilized if contributes to net revenue; burned in air curtain destructor if transport detracts from net revenue
    - Valued at $18 per green ton delivered
  - **Merchantable:** Bole of trees >7” to a 5” top
    - Priced by diameter class and species
Indices of crown fire potential

- Torching Index (TI)—wind speed to initiate torching
- Crowning Index (CI)—wind speed that sustains crown spread
- Increasing either will reduce fire hazard; however both important, and neither should be decreased
If any of these criteria are met, we call the treatment effective (wrt to TI or CI)

- Pre-treatment index < 25, Post-treatment index ≥ 25, Change in index ≥ 10 mph
- Pre-treatment index < 25, Change in index ≥ 20 mph
- 50 > Pre-treatment index ≥ 25, Change in index ≥ 15 mph
- Pre-treatment index > 50, Change in index ≥ 20 mph
For OR/CA case we combined TI & CI to determine treatment effectiveness

- **High: one criteria met--**
  - TI effective, $\Delta CI > -10$, Post-treatment CI $> 25$
  - CI effective, $\Delta TI > -10$, Post-treatment TI $> 25$

- **Moderate: one criteria met--**
  - TI effective, $\Delta CI > -10$, Post-treatment CI $> 25$
  - CI effective, $\Delta TI > -10$
Specifying treatment effectiveness in FIA BioSum

This analyst-friendly tool now in Beta