Large scale biomass/carbon assessment using inventory plot data and growth & yield models

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Outline

• Background
  – Western States Fire Risk/Carbon
  – WA Biomass Assessment
  – US Biomass/Life Cycle Assessment

• Lessons/Conclusions
### Comparing Projects

<table>
<thead>
<tr>
<th></th>
<th>Western States (Fire Risk/Carbon)</th>
<th>WA Biomass</th>
<th>US Biomass/Lifecycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>States</td>
<td>11</td>
<td>1</td>
<td>49</td>
</tr>
<tr>
<td>Plots</td>
<td>16,607</td>
<td>6000</td>
<td>125,194</td>
</tr>
<tr>
<td>Variants</td>
<td>15</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>Simulations</td>
<td>166,070</td>
<td>~12,000,000</td>
<td>?</td>
</tr>
<tr>
<td>Data</td>
<td>FIA</td>
<td>GNN, WA DNR GIS, derived GIS</td>
<td>FIA, US GIS</td>
</tr>
<tr>
<td>Year</td>
<td>2009-2010</td>
<td>2011</td>
<td>2012</td>
</tr>
</tbody>
</table>
Western States Fire Risk/Carbon

- 11 Western States
  - AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY
- 16,607 FIA Plots [latest panel or last periodic (2)]
- 15 FVS Variants
- ~166,070 pathways
- Target Forest Types: DF, PP, S/F, H/C, OP, MC, HW, P/J
## Western States - FIA Inventory Database

<table>
<thead>
<tr>
<th>State</th>
<th>FIA Plots</th>
<th>Measured Plots</th>
<th>Candidate Plots</th>
<th>Correct Forest Type</th>
<th>FIA Plots Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ</td>
<td>25581</td>
<td>7383</td>
<td>2284</td>
<td>1645</td>
<td>1626</td>
</tr>
<tr>
<td>CA</td>
<td>19229</td>
<td>8586</td>
<td>3921</td>
<td>1758</td>
<td>1754</td>
</tr>
<tr>
<td>CO</td>
<td>13459</td>
<td>3709</td>
<td>2341</td>
<td>1833</td>
<td>1808</td>
</tr>
<tr>
<td>ID</td>
<td>12501</td>
<td>5060</td>
<td>1454</td>
<td>1143</td>
<td>1143</td>
</tr>
<tr>
<td>MT</td>
<td>23059</td>
<td>6070</td>
<td>2236</td>
<td>1735</td>
<td>1735</td>
</tr>
<tr>
<td>NM</td>
<td>21491</td>
<td>3829</td>
<td>2542</td>
<td>2252</td>
<td>2223</td>
</tr>
<tr>
<td>NV</td>
<td>16572</td>
<td>2101</td>
<td>407</td>
<td>331</td>
<td>331</td>
</tr>
<tr>
<td>UT</td>
<td>16002</td>
<td>5448</td>
<td>2578</td>
<td>1984</td>
<td>1984</td>
</tr>
<tr>
<td>WA</td>
<td>10875</td>
<td>6179</td>
<td>2424</td>
<td>1484</td>
<td>1483</td>
</tr>
<tr>
<td>WY</td>
<td>17834</td>
<td>2494</td>
<td>1981</td>
<td>1455</td>
<td>1441</td>
</tr>
<tr>
<td>Total</td>
<td>193806</td>
<td>58350</td>
<td>25964</td>
<td>18118</td>
<td>18025*</td>
</tr>
</tbody>
</table>

*Actual plots decreased because some plots do not simulate correctly in all scenarios.*
Western States – Simulation of FIA Plots

- States have one or more FVS variants required to simulation plots
- Developed map of plot locations to FVS variants.
- Extract FIA plot information and format for use with FVS.
- Simulate various management alternatives
## Western States – FIA Plots by FVS Variant

<table>
<thead>
<tr>
<th>State</th>
<th># FIA Plots</th>
<th>FVS Variants</th>
</tr>
</thead>
<tbody>
<tr>
<td>AZ</td>
<td>1626</td>
<td>CR (1626)</td>
</tr>
<tr>
<td>CA</td>
<td>1754</td>
<td>CA (441), NC (20), SO (200), WS (875)</td>
</tr>
<tr>
<td>CO</td>
<td>1808</td>
<td>CR (1807), UT (1)</td>
</tr>
<tr>
<td>ID</td>
<td>1143</td>
<td>CI (509), EM (4), KT (121), NI (402), TT (95), UT (12)</td>
</tr>
<tr>
<td>MT</td>
<td>1735</td>
<td>EM (965), KT (454), NI (315), TT (1)</td>
</tr>
<tr>
<td>NM</td>
<td>2223</td>
<td>CR (2223)</td>
</tr>
<tr>
<td>NV</td>
<td>331</td>
<td>CI (1), CR (291), WS (39)</td>
</tr>
<tr>
<td>OR</td>
<td>2497</td>
<td>BM (638), CA (138), EC (106), NC (62), PN (419), SO (557), WC (577)</td>
</tr>
<tr>
<td>UT</td>
<td>1984</td>
<td>CI (34), CR (13), UT (1937)</td>
</tr>
<tr>
<td>WA</td>
<td>1483</td>
<td>BM (30), EC (607), NI (185), PN (326), WC (335)</td>
</tr>
<tr>
<td>WY</td>
<td>1441</td>
<td>CR (793), TT (582), UT (66)</td>
</tr>
</tbody>
</table>
Western States –
Scenarios Simulated

• No Management (Base)
• Current Typical Management (different management for FS Plan, States, Private)
• Fire Reduction Scenarios
  – Fire1 through Fire5
• Active Management
• High Revenue
• Carbon Sequestration Scenario
• Wildfire (overlay – each scenario above run with stochastically scheduled wildfire)
Western States – Fire Reduction Scenarios

- Fire Risk: Crowning Index classified into High (CI<25), Moderate (25>CI<50), Low (CI>50)
- **Fire1** - When stand first classified as High (BA 45, from below); Mod (½ BA from below). Assumes follow up fuel treatments.
- **Fire2** - When stand classified as High (BA 45, from below); Mod (½ BA, from below). Treatments applied whenever stand at risk.
- **Fire3** - Same as Fire1, except thinning not done if < 40 TPA
- **Fire4** – When stand first classified as High (BA 40, proportional thin); Mod (½ BA, proportional thin)
- **Fire5** – When stand classified as High or Mod (Thin all trees <9”)


Treatment Effects

- Treatment effects on crowning index
- Treatment effects on standing and product carbon
Treatment Effects on CI

Mean Crowning Index for CA by Treatment

Year

- Base
- Fire1
- Fire2
- Fire3
- Fire4
- Fire5
- Typical
- Active
Treatment Effects on CI

Mean Crowning Index for WA by Treatment

- Base
- Fire1
- Fire2
- Fire3
- Fire4
- Fire5
- Typical
- Active
Results - Carbon

Mean Carbon: State=All States : 18025 plots represented

- Total Stand Carbon (mean)
- Products (mean)
- Landfill (mean)
Mean Carbon: State=OR : 2497 plots represented

- Total Stand Carbon (mean)
- Products (mean)
- Landfill (mean)
Mean Carbon: State=OR - Fire1: 2497 plots represented

- Total Stand Carbon (mean)
- Products (mean)
- Landfill (mean)
CORRIM Charts

• These charts depict forest carbon, products carbon, landfill carbon, displacement, and substitution

• They can be created for a plot, state, forest, ownership, or forest type
Gifford Pinchot NF - Base

Carbon in Forest, Products, and Landfill by Component

Metric Tons C

Year: 2007 - 2017

Components:
- Stem
- Root
- Crown
- Litter
- Dead
- House
- Chips
- Hogfuel
- Landfill Carbon
Gifford Pinchot NF - ActMgmt
Base – Standing Carbon 2007

Average Carbon Per Acre by County (Tons)

Legend
Western Counties
Carbon2007

- 7.200000 - 25.000000
- 25.000001 - 50.000000
- 50.000001 - 100.000000
- 100.000001 - 200.000000
- 200.000001 - 400.000000
ActMgmt – Forest Carbon 2007

Average Carbon Per Acre by County (Tons)

Legend

Western Counties
Carbon2007

- 4.300000 - 25.000000
- 25.000001 - 50.000000
- 50.000001 - 100.000000
- 100.000001 - 200.000000
- 200.000000 - 400.000000
ActMgmt – Forest Carbon 2107

Average Carbon Per Acre by County (Tons)

Legend:
- Western Counties
- Carbon2107
  - 0.566667 - 25.000000
  - 25.000001 - 50.000000
  - 50.000001 - 100.000000
  - 100.000001 - 200.000000
  - 200.000001 - 368.833333
WA Biomass Assessment

- 1 State
- 5,999 unique FCIDs
- 194,500,000 Pixels, 105,421,583 forested
- 5 FVS Variants
- ~12,000,000 pathways
WA Biomass - Background

• WA Department of Natural Resources RFP
• UW/TSS Awarded Contract
• Negotiation of timelines and deliverables
• Project Starts
  – Spatial Analysis and Inventory done by UW
  – Surveys done by TSS
• Participants: Jeff Comnick, Andrew Cooke, Todd Hanson, Tad Mason, James McCarter, Matt McLaughlan, Elaine Oneil, John Perez-Garcia, Luke Rogers
WA Biomass- Information Sources

• Spatial Information
  – GNN (vegetation map, non-forest mask)
  – WA DNR (operations layers, transportation layers, hydrology, etc.)
  – UW RTI (Landowner Database, Statewide DEM, ...)
  – USGS (elevation data, land cover types, etc.)
  – Other or derived (satellite imagery, fuel sheds, ...)

• Inventory Information
  – GNN (30m pixel resolution with tree list inventory associated, 2 analysis projects combined provide state wide coverage)
  – FIA (validation and check dataset)
  – WA DNR (validation and check dataset)

• Survey Information
  – TSS Generated
WA Biomass - Analytical Techniques

• Spatial Analysis
• Inventory Assessment
• Biomass Assessment
• Forest Operations Surveys
• Growth and Yield Simulations
• Combine spatial and inventory information for fuel shed, county, and statewide estimates
WA Biomass - Spatial Analysis

- Spatial analysis combines legal, transportation, hydrology, ownership, slope, forest type, buffers, etc.

```
  Facilities -> Network Analysis -> Haul Time
  Roads

  Hydrology -> Buffer Analysis

  Ownership -> Classify Owners

  GIS Analysis

  Slope

  Buffers

  Mgt. Plans

  Define Mgt. Areas

  GNN GIS

  GIS Overlay

  Mgt. Areas

  Mgt. Plans
```

University of Washington
WA Biomass –
Spatial Analysis - Input Layers

Source spatial data
- Roads
- Stream Buffers
- Streams, Lakes & Wetlands
- Ownership
- Forest Inventory
- Slope
- Satellite Imagery
- Elevation

Derived spatial data
- Time
- Transportation Economics
  - Transportation Distance/Time & Harvest Volumes
- Harvest Volumes
  - Timber Volume, Biomass Recovery Coefficients
- Harvest Economics
  - Harvest Scenarios, Equipment & Labor Costs
- Harvest Scenarios
  - Management Areas & Ownership & Inventory
- Management Areas
  - Buffers & Slope & Management Plans
- Inventory
  - CENM & Growth Model
All owner information and parcel geometry for the Biomass Database is derived from the 2009 Washington State Parcel Database (Parcel Database). The Parcel Database contains parcel data from 42 different source data providers, including Washington’s 39 Counties, The Washington State Department of Natural Resources (DNR), The Washington Department of Fish and Wildlife (WDFW), and the United State Bureau of Land Management (BLM).
WA Biomass - GNN Spatial Map
Stand Basal Area in 2006

Darker green is higher stand basal area.
WA Biomass - GNN Spatial Map
Stand Basal Area in 2006

Darker green is higher stand basal area.
WA Biomass - Spatial Analysis – Reserved (red) and Unreserved Acres

<table>
<thead>
<tr>
<th>Management Class</th>
<th>Unreserved Acres</th>
<th>Reserved Acres</th>
<th>Percent Reserved Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation</td>
<td>25,021</td>
<td>9,110</td>
<td>25%</td>
</tr>
<tr>
<td>DNR</td>
<td>1,164,072</td>
<td>1,116,777</td>
<td>48%</td>
</tr>
<tr>
<td>Forest Service</td>
<td>2,946,348</td>
<td>5,368,777</td>
<td>65%</td>
</tr>
<tr>
<td>Industrial</td>
<td>4,078,939</td>
<td>515,053</td>
<td>11%</td>
</tr>
<tr>
<td>Municipal Forestlands</td>
<td>31,084</td>
<td>4,325</td>
<td>13%</td>
</tr>
<tr>
<td>Municipal Watersheds</td>
<td>-</td>
<td>138,678</td>
<td>100%</td>
</tr>
<tr>
<td>Non-Industrial</td>
<td>3,559,492</td>
<td>222,606</td>
<td>6%</td>
</tr>
<tr>
<td>Other Federal</td>
<td>-</td>
<td>1,697,457</td>
<td>100%</td>
</tr>
<tr>
<td>Other Municipal</td>
<td>205,030</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>Other Private</td>
<td>17,380</td>
<td>-</td>
<td>0%</td>
</tr>
<tr>
<td>Other State</td>
<td>-</td>
<td>244,180</td>
<td>100%</td>
</tr>
<tr>
<td>Tribal Forestlands</td>
<td>1,233,895</td>
<td>355,660</td>
<td>22%</td>
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<tr>
<td>Unknown</td>
<td>-</td>
<td>128,811</td>
<td>100%</td>
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<tr>
<td>Total</td>
<td>13,266,077</td>
<td>9,799,401</td>
<td>42%</td>
</tr>
<tr>
<td>Grand Total</td>
<td>23,056,508</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Source road network datasets (left) and combined final network (right)
WA Biomass - Spatial Analysis – Forest Type by Stumpage Value Area

Forest Ecosystem Types by Stumpage Value Areas (SVA)
WA Biomass – Forest Inventory Assessment

• Start with initial GNN inventory (2000 eastside, 2006 westside).

• Update with harvest information 2000-2009 and apply growth and regeneration resulting in 2010 inventory.

• 2010 Inventory used as base for projecting management scenarios by ownership class to arrive at current and future estimates of biomass.
Harvest levels by ownership class and county were applied to update the inventory information to 2010. Future harvest level targets were established from 2009.
# WA Biomass – Forest Operations Survey

<table>
<thead>
<tr>
<th>FOREST ECOSYSTEM</th>
<th>OWNER CLASS</th>
<th>WESTSIDE OR EASTSIDE</th>
<th>HARVEST OR FOREST OPERATIONS SCENARIO</th>
<th>ESTIMATED PERCENT OF ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Douglas-fir</td>
<td>Industrial</td>
<td>West</td>
<td>RH remnant stands &gt;50 years</td>
<td>5% of stands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West</td>
<td>No PCT, RH at 45 years</td>
<td>70% of stands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West</td>
<td>PCT @ 15 years, RH at 45 years</td>
<td>20% plantations require PCT</td>
</tr>
<tr>
<td></td>
<td></td>
<td>West</td>
<td>No PCT, CT @ 25 years, RH @ 45 years</td>
<td>5% of stands</td>
</tr>
<tr>
<td>Federal</td>
<td>West</td>
<td>PC - thinning from above and below w/RH @ 65 years for PC @ 55 years</td>
<td>95% (90% PC/10% RH)</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCT, CT @ 45 years, RH at 65 years</td>
<td>10% plantations require PCT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PC - thinning from above and below</td>
<td>90% of stands</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RH remnant stands &gt;50 years</td>
<td>&lt;10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCT, RH at 45 years</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCT @ 15 years, RH at 45 years</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>PCT, CT @ 25 years, RH @ 45 years</td>
<td>45%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5%</td>
</tr>
</tbody>
</table>
WA Biomass –
Growth and Yield Simulations

• Simulation Challenges:
  – Multiple FVS variants required (BM, EC, NI/IE, PN, WC)
  – Habitat Types Assignment
  – Growth model constraint and calibration
    • Maximum SDI Adjustments
  – Plots that will not run
  – Regeneration

• Management Scenarios
WA Biomass –
Growth and Yield Simulations
Multiple FVS Growth Model Variants
The above management scenarios were applied depending on ownership, forest type, and management zone. Multiple simulations were run for each inventory so that the spatial database could select between management options.

<table>
<thead>
<tr>
<th>Harvest and Forest Operation Scenarios</th>
<th>Harvest and Forest Operation Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH remnant stands &gt; 50 years</td>
<td>PCT @ 6 years, RH @ 35 years</td>
</tr>
<tr>
<td>RH remnant stands &gt; 65 years</td>
<td>PCT @ 12 years, RH @ 45 years</td>
</tr>
<tr>
<td>No PCT, RH @ 35 years</td>
<td>PCT @ 15 years, RH @ 45 years</td>
</tr>
<tr>
<td>No PCT, RH @ 45 years</td>
<td>PCT @ 15 years, RH @ 50 years</td>
</tr>
<tr>
<td>No PCT, RH @ 50 years</td>
<td>PCT @ 15 years, RH @ 60 years</td>
</tr>
<tr>
<td>No PCT, RH @ 55 years</td>
<td>PCT @ 17 years, RH @ 55 years</td>
</tr>
<tr>
<td>No PCT, RH @ 60 years</td>
<td>PCT @ 15 years, CT @ 45 years, RH @ 65 years</td>
</tr>
<tr>
<td>No PCT, RH @ 65 years</td>
<td>PCT @ 15 years, CT @ 55 years, RH @ 85 years</td>
</tr>
<tr>
<td>No PCT, RH @ 70 years</td>
<td>PCT @ 20 years, PT @ 70 years - thinning from above and below</td>
</tr>
<tr>
<td>No PCT, RH @ 75 years</td>
<td>PCT - from above and below</td>
</tr>
<tr>
<td>RH @ 90 years</td>
<td>PC - from above and below</td>
</tr>
<tr>
<td>No PCT, CT @ 25 years, RH @ 45 years</td>
<td>PC - thinning from above &amp; below w/RH @ 55 yrs</td>
</tr>
<tr>
<td>No PCT, CT @ 30 years, RH @ 50 years</td>
<td>PC - thinning from above &amp; below w/RH @ 60 yrs</td>
</tr>
<tr>
<td>No PCT, CT @ 35 years, RH @ 65 years</td>
<td>PC - thinning from above &amp; below w/RH @ 65 yrs</td>
</tr>
<tr>
<td>No PCT, CT @ 40 years, RH @ 65 years</td>
<td>PC - thinning from above &amp; below w/RH @ 75 yrs</td>
</tr>
<tr>
<td>No PCT, CT @ 45 years, RH @ 65 years</td>
<td>PC @ 65 years - thinning from above and below</td>
</tr>
<tr>
<td>No PCT, CT @ 55 years, RH @ 85 years</td>
<td>PC @ 70 years - thinning from above and below</td>
</tr>
<tr>
<td>CT or PC @ 55 years</td>
<td>PC @ 75 years - thinning from above and below</td>
</tr>
</tbody>
</table>
WA Biomass – Growth and Yield Simulations

• Combination of ownership, GNN source pixels, FVS variant, etc. results in 550,288 unique FCIDs

• Applying the management alternatives, staggered by cycle results in ~12 million simulations (~4 days on 4 core computer)

• Simulation results summarized, biomass estimates calculated, and loaded into spatial database
WA Biomass - Putting It All Together
WA Biomass - What can you do?

Biomass processing facility locations
Example concentric service area rings around a facility
WA Biomass - What can you do?

Facility 2: Longview Fibre Biomass FuelsHeds in 2010

$35 per Ton

$40 per Ton

$50 per Ton

$60 per Ton
WA Biomass - What can you do?

Facility 6: Vaagen Brothers
Biomass Fuelsheds in 2010

- $35 per Ton
- $40 per Ton
- $50 per Ton
- $60 per Ton
WA Biomass - What can you do?

Biomass Fuelsheads in 2010 at $35 Per Ton
WA Biomass - What can you do?

Biomass Fuelsheeds in 2010 at $40 Per Ton
WA Biomass - Project Completion

• Report Published and made available by WA DNR:

• Online Biomass Calculator
  – http://wabiomass.cfr.washington.edu/
Select facilities to include in the analysis "

Quick pick groups "

- Existing
- Proposed
- Hypothetical
- All
- Clear

Selected Facilities competing for forest biomass "

- Aberdeen: Hypothetical
- Amboy: Proposed
- Bingen: Existing
- Camas: Existing
- Centralia: Hypothetical
- Chehalis: Hypothetical
- Colville: Existing
- Cosmopolis: Existing
- Ellensburg: Proposed
- Entiat: Hypothetical
- Everett: Existing
- Forks: Hypothetical
- Goldendale: Hypothetical
- Hoquiam: Existing
- Kettle Falls: Existing
- Kulzer: Proposed
- Lewiston: Existing
- Longview: Existing
- Longview West: Proposed
- Longview East: Proposed
- Morton: Hypothetical
- Mount Vernon: Existing
- Naselle: Hypothetical
- Olympia: Proposed
- Omak: Proposed
- Pe Ell: Hypothetical
- Peshastin: Hypothetical
- Port Angeles: Existing
- Port Townsend: Existing
- Raymond: Hypothetical
- Shelton Airport: Proposed
- Shelton Waterfront: Proposed
- Spokane: Hypothetical
- Tacoma: Existing
- Taholah: Proposed
- Usk: Existing
- Vancouver: Proposed
- Vancouver: Hypothetical
- Wallula: Existing
- Wonatech: Hypothetical
- White Swan: Proposed
- Winton: Existing
- Yakima: Proposed
Biomass Calculator

Select costs and prices

Biomass harvest costs

Cost model: Low

Forest health cost ($/BDT): $30.00
Mobilization cost ($/hr): $96.00
Load/unload cost ($/BDT): $21.00
Haul cost ($/hr): $75.00

Biomass price paid at facility

Biomass price ($/BDT): $35.00

Note that higher biomass prices increase the run-time of the calculator so please be patient.
Results (5 year planning period totals)

Hide Run Parameters

Run: Conservative Statewide Harvest
Year: 2010
Geography: County
Geographies: Clallam (5), Island (15), Jefferson (16), King (17), Skagit (29), Snohomish (31)
Facilities: Camas: Existing, Cosmopolis: Existing, Everett: Existing, Hoquiam: Existing, Longview: Existing, Mount Vernon: Existing, Port Angeles: Existing, Port Townsend: Existing, Tacoma: Existing, Winton: Existing
Cost: Low
Price: $35
Max Haul Time To Facility: 240 minutes
Reporting Fields: County, Stumpage Value Area, Facility, Owner Class
Field Options: Names
**Results (5 year planning period totals)**

- **Run:** Conservative Statewide Harvest
- **Year:** 2010
- **Geography:** County
- **Geographies:** Clallam (5), Island (15), Jefferson (16), King (17), Skagit (29), Snohomish (31)
- **Facilities:** Camas: Existing, Cosmopolis: Existing, Everett: Existing, Hoquiam: Existing, Longview: Existing, Mount Vernon: Existing, Port Angeles: Existing, Port Townsend: Existing, Tacoma: Existing, Winton: Existing
- **Cost:** Low
- **Price:** $35
- **Max Haul Time To Facility:** 240 minutes
- **Reporting Fields:** County, Stumpage Value Area, Facility, Owner Class
- **Field Options:** Names

<table>
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<tr>
<th>SVA</th>
<th>County</th>
<th>Facility</th>
<th>Owner Class</th>
<th>Scattered Biomass (BDT)</th>
<th>Roadside Biomass (BDT)</th>
<th>Market Biomass (BDT)</th>
<th>Residual Value ($)</th>
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US Biomass/Life Cycle Assessment

- 49 States
- 125,194 FIA Plots (119,010 with trees, 376 species)
- 148 Forest Types, 37 Provinces, 1160 Ecological Subsection Codes
- 20 FVS Variants
- ~3,129,850 pathways
US Biomass/Life Cycle Assessment
US Biomass/Life Cycle Assessment

- FIA Database Biomass: Total, Merch, NonMerch
Observations/Conclusions

• These projects require a lot of data!
• Incredible amount of data (information) is available and we are improving in our ability to use the information
• Care and knowledge required to use data sources properly
• Care and knowledge required when using models
• Large quantity of results can be difficult to interpret
Observations/Conclusions

• Biomass calculation method used critical
• Need to be sure analysis is not impacted by assumptions required for analysis
• Need fast computer, large hard drives, and increasingly fast networks:
  – Computer resources are CHEAP compared to analytical talent (2 TB Hard disk < $100, 4 Ghz 4 Core computer ~ $1000)
• Need to be using efficient techniques for analysis
Observations on Data Sources

• Not all FIA plots are FVS “friendly”
  – EM variant does not like large amounts of regeneration
  – CR variant is “somewhat fragile”, several math overflow errors exposed by running FIA plots.

• Large scale simulations are difficult
  – Which variant, what habitat code, variant differences, data differences, time, etc...

• Simulations take about 1 hour per state per scenario
Observations on Growth Models

- Some variation is the result of suspect growth projections from the FVS growth model.
- Different habitat types (in Western US) have different behaviors – which selected matters!
Growth and Yield Simulations
Habitat Type Matters

Basal Area Growth for Habitat Types

Year
FVS Variant = PN, Habitat Group = PSME
Growth and Yield Simulations
Habitat Type Matters

Basal Area Growth for Habitat Types
Growth and Yield Simulations

Maximum SDI

- Maximum SDI values are high for some habitat types (PN-PSME-2 DF MaxSDI=950, EC-PSME-34 MaxSDI=767)
- Maximum SDI values by habitat type and species extracted from FVS variants, then examined and adjusted based on habitat manuals and published max values by species
Growth Model Behavior

Typical stand development (range of site classes from DF yield tables – McArdle et al. 1949)
Growth Model Behavior

Most stands exhibit expected behavior with increase in younger stands and leveling off of older stands.

Stands above 600 are suspect. Maximum SDI for DF stands should not be above 600. Mixed stand with tolerant understory (hemlock, etc) can be higher.
Growth Model Behavior

Most stands exhibit expected behavior with increase in younger stands and leveling off of older stands.

Several suggest suspect behavior:

1) rapid increase and then crash,
2) sustained increase over entire period.
Most stands exhibit expected behavior with increase in younger stands and leveling off of older stands.

Several suggest suspect behavior:
1) rapid increase and then crash,
2) sustained increase over entire period.
Observations on Biomass Calculation

PSME - Stem Biomass

- Stem Biomass (lbs)
- DBH

Graph showing the relationship between stem biomass (in lbs) and DBH (diameter at breast height) for different models: Gholz, Jenkins, CORRIM1, CORRIM2, Browne, and Zhou.
Observations on Analysis Assumptions

• Regeneration is critical for biomass after harvest activities

• Some FVS variants have full establishment model
  – Rely on IE variant to provide regeneration
  – Is it correct for all habitat types?

• Developed establishment by variant and habitat type based on habitat manuals and existing young stands in inventory information
Observation – Efficient Techniques

- Using binary, pre-created, cached copy of inventory data results in a significant reduction in analysis time

<table>
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Data and Tools Used

- FIA (http://fia.fs.fed.us/)
- FVS (http://www.fs.fed.us/fmsc/fvs/)
- Python (www.python.org)
- R (http://cran.r-project.org/)
- ArcGIS (www.esri.com)
- MS Office (Access and Excel)
Sustainable Recovery of Forest Residuals – NE WA study

• ~ 50% is already removed from the woods, leaving 50% as residual biomass (tops, limbs, broken material) (Oneil and Lippke 2009)

• Of the residual biomass, 70% is accessible (meaning available for removal as the rest is left for soil building, wildlife, and habitat purposes) (35% of total harvested)

• Of the residual biomass, 42% is recoverable (21% of the total)