Developing biomass supply systems for forested marginal lands in Sweden

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Introduction

Demand for small-diameter trees will increase if a bio-economy develops (biorefineries).

Logging residues one of the main raw material for wood chips.

Forest industries by-products (bark, sawdust, other chips...): fully utilized.

Biomass-dense thinning forests (non-commercially thinned stands): main source of small-diameter trees, 4.3 M OD t/yr.

Forest ed marginal land: large amounts of small-diameter trees too, 1.1-2.2 M OD t/yr (5-10 TWh/yr).

Primary forest biomass for wood chips in Sweden:
- Stumps, 0.3 TWh
- Small-diameter (whole, undelimbed) trees, 2.3 TWh
- Roundwood, 6.9 TWh
- Logging residues (tops and branches), 10.6 TWh
Introduction

Roadsides 0.8 TWh/yr

Overgrown pastures 2.3 TWh/yr

Power line corridors 0.8 TWh/yr

Overgrown arable land 1.6 TWh/yr

Edges of arable land 0.7 TWh/yr

Cut-away peatlands, edges of railways...

(potentials from Emanuelsson et al. 2014. Nationwide harvest of small trees and bushes – potential, opportunities and obstacles)
### Aim of the study

1. Characterize typical sorts of marginal land in northern Sweden;
2. Study the productivity of conventional & innovative systems on these lands;
3. Compare the cost of wood fuel delivery using different supply systems.

### Introduction

Harvests of marginal lands VS. energy thinnings in young dense forests:

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>= Heterogeneous and small tree sizes;</td>
<td>😊 Sometimes, higher productivities and volumes (work as in clear-cut);</td>
</tr>
<tr>
<td>= High stock densities;</td>
<td>😊 Easy accessible from existing road networks;</td>
</tr>
<tr>
<td>= Similar, existing, techniques (accumulating harvester/felling heads);</td>
<td>😊 Land must be cleared anyway, regularly;</td>
</tr>
<tr>
<td>= High harvesting and transport costs.</td>
<td>😊 Stand area small;</td>
</tr>
<tr>
<td></td>
<td>😊 Scattered in the landscape;</td>
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<td></td>
<td>😊 Work safety regulations;</td>
</tr>
<tr>
<td></td>
<td>😊 Large variation amongst marginal lands (case to case);</td>
</tr>
</tbody>
</table>

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**FRST SLU**
M&M: Inventory

50 km around Umeå, four types of predominantly marginal lands: farmland, edge areas and peri-urban sites.

<table>
<thead>
<tr>
<th>Stand</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of marginal land</td>
<td>Industrial site</td>
<td>Edges of arable land</td>
<td>Arable land</td>
<td>Roadside</td>
</tr>
<tr>
<td>Typical stand size (ha)</td>
<td>1</td>
<td>0.5</td>
<td>4</td>
<td>Up to road length</td>
</tr>
<tr>
<td>Density (all trees/ha)</td>
<td>16 446</td>
<td>20 105</td>
<td>4 341</td>
<td>2 450</td>
</tr>
<tr>
<td>Mean DBH (cm)</td>
<td>7.0</td>
<td>10.6</td>
<td>14.9</td>
<td>14.9</td>
</tr>
<tr>
<td>Mean height (m)</td>
<td>8.4</td>
<td>8.7</td>
<td>12.9</td>
<td>11.1</td>
</tr>
<tr>
<td>Mean stem volume (dm³)</td>
<td>23</td>
<td>54</td>
<td>140</td>
<td>128</td>
</tr>
<tr>
<td>Biomass (OD t/ha)</td>
<td>52.5</td>
<td>97.0</td>
<td>70.6</td>
<td>38.2</td>
</tr>
<tr>
<td>Volume whole tree (m³/ha)</td>
<td>123</td>
<td>199</td>
<td>134</td>
<td>91</td>
</tr>
<tr>
<td>Forwarding distance (m)</td>
<td>206</td>
<td>196</td>
<td>180</td>
<td>0</td>
</tr>
<tr>
<td>Driving conditions (GYL)</td>
<td>2.1.1.</td>
<td>3.1.1.</td>
<td>3.1.1.</td>
<td>1.1.1.</td>
</tr>
</tbody>
</table>

More biomass-rich!

Bearing capacity (G) limited during periods of high ground moisture (spring when snow and ground frost is melting)
M&M: Harvesting systems

“Logmax” (edges of arable land)

Harvester EcoLog 560D

AHH Log Max 5000D “Bio” (modified knives for rough-delimbing)

“Fixteri” (overgrown arable land)

Bundler Fixteri FX15a

Harwarder Logman 811FC

AFH Nisula 285E+
M&M: Harvesting systems, terrain transport

Forwarder Komatsu 865

Farm tractor with timber trailer, derived from the forwarder: same load sizes and 35% longer time loading & unloading

"Logmax" ➔ rough-delimbed tree sections (full load 3.3 OD t)

"Fixteri" ➔ bundles (full load 5.1 OD t, 22 bundles)

(Gullberg, T. 1997. Time consumption model for off-road extraction of shortwood)
M&M: Comminution and road transport systems

A: Container-truck (rough-delimbed tree sections)

B: Conventional timber truck (bundles)

C: Forwarder-mounted, Bruks 805 CT (rough-delimbed tree sections)

(Bergström D., Di Fulvio F. 2014. Comparison of the cost and energy efficiencies of present and future biomass supply systems for young dense forests)
Results

Based on productivity and biomass concentration on overgrown arable land (4 ha, 70.6 OD t/ha, DBH 14.9 cm, stem volume 140 dm³). Equivalent productivity Logmax.

Total harvesting cost (including relocation cost)

Based on productivity and biomass concentration on overgrown arable land (4 ha, 70.6 OD t/ha, DBH 14.9 cm, stem volume 140 dm³). Equivalent productivity Logmax.
Results

Total delivery cost of wood chips, 3 supply systems
(chipping cost at power plant included, in order to allow comparisons)

- Logmax+forwarder+truck+chipped factory: *Most expensive >60 km*
- Logmax+forwarder+chipped forest+chip-truck: *Most expensive <60 km*
- Fixteri+forwarder+truck+chipped factory: *Cheapest >20 km*

Bundler system most cost-effective alternative! (7%-5% comp. lower at 100 km)
Results

Total delivery cost of wood chips, 6 supply systems
(chipping cost at power plant included, in order to allow comparisons)

For all systems, using a farm tractor, cost could be reduced by 4-5% (low operational cost)
Discussion

→ Assuming a high price, the 3 alternatives were profitable with a large margin;

→ If price fall from a high to a medium level, the bundle-harvester system can still deliver the biomass far away from the forest;

→ Low prices at industry gate can put at risk supply chains that have required years to set up;
Discussion and Conclusion

→ Analyses with the farm tractor based on assumptions, to be verified in the field;

→ Limited use of forest machines if bearing capacity decreases; better winter!

→ The case study marginal land: lower costs than the equivalent biomass harvesting of a dense first thinning → Higher concentration of biomass, work as in clear-cutting and relatively large tree size (more typical pulpwood sizes!);

→ Higher costs in other marginal land with smaller tree sizes, sites and longer terrain driving distances. Conditions can vary greatly, difficult to generalize for all!

→ More expensive harvest but savings during transportation and comminution at the factory/terminal by large-scale chippers, rather than at the forest roadside; Handling bundles easier than tree sections or logging residues;

→ Integrated transportation of bundles and roundwood (same timber trucks).

→ Further development and integration of harvesting marginal land with conventional forest land can decrease the delivery costs of small-diameter trees!
Thanks for your attention!

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