Fuelwood forestry and biodiversity conservation
A focus on the European case study

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Contents

Context

1. Fuelwood and forest environment
2. Fuelwood and saproxylic biodiversity
3. Fuelwood and non-saproxylic biodiversity

Conclusion
CONTEXT

- Concerns over climate change mitigation activities, peak oil and energy security

- Use of renewable and alternative energies and forest-based bioenergy
WOOD-DERIVED FUELS

3 sources of forest biomass material:

**Wood waste**
- packaging materials, construction and demolition waste, tree trimmings, pallets

**Wood energy crops**
- stands of fast-growing trees

**Forest residues**
- tree tops, smaller limbs, small thinned trees, stumps
I

Fuelwood and forest environment
Potential changes in forest practices induced by fuelwood development

- extension of traditional fuelwood collection
- changes in harvesting practices
  - whole-tree harvesting
  - post-harvest recovery of residues
    - small trees
    - slash
    - logging residues
    - logs of low quality
    - stumps
Other changes related to forestry intensification

- ↑ density of cutting areas
  - extensive thinning and clearing
  - felling of previously unmanaged forests (protected, abandoned...)

- road construction > ↑ forest access

- ↓ forestry cycle duration

- conversion of native forests into short-rotation coppices
Regional contrasts in pressing issues

<table>
<thead>
<tr>
<th>Forestry</th>
<th>Boreal</th>
<th>Temperate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics</strong></td>
<td>- Industrial forest companies</td>
<td>- Fine-grain fragmented ownership and management</td>
</tr>
<tr>
<td></td>
<td>- Large scale</td>
<td>- High proportion of poorly-managed forests</td>
</tr>
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<td></td>
<td>- Environmental regulation</td>
<td>- Fuzzy environmental rules</td>
</tr>
<tr>
<td><strong>Main fuelwood-driven changes</strong></td>
<td>- ↑ post-harvest recovery of residues (FWD and stumps)</td>
<td>- ↓ % unmanaged forests = ↑ density of fellings</td>
</tr>
<tr>
<td></td>
<td>- ↑ whole-tree harvests</td>
<td>- ↑ forest roads and access</td>
</tr>
<tr>
<td></td>
<td>- ↑ traditional fuelwood collection?</td>
<td>- ↓ forestry cycle duration and ↑ old tree harvesting</td>
</tr>
<tr>
<td></td>
<td>- ↑ conversion of forests into short-rotation coppices?</td>
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</tbody>
</table>
Key constraints to fuelwood development

- Accessibility
- Environmentally sensitive areas
- Environmental regulations
- Federal funding for forestry programs
- Labor availability / skilled forestry workers
- Availability of specialized equipment
- Transportation costs
- …Bioenergy values and market stability
Potential environmental effects of bioenergy-related forest practices

**SOIL**
- ▼ organic matter and nutrients
- ▲ risk of soil acidity
- ▼ protective mats of harvesting residues
- ▲ soil compaction and rutting by machinery

**GHG BALANCE**
- ▼ GHG
- ▼ soil carbon storage

**WATER**
- ▼ infiltration
- ▲ movement
- ▲ water turbidity and [nutrient]

**FIRE RISK**

**PEST RISK**
Potential environmental effects of bioenergy-related forest practices

- Changing conditions for biodiversity
  - Habitat loss and fragmentation
    - Changes in deadwood volume and profile
    - ↓ density in old stands and veteran trees
  - Changes in soil conditions
  - ↑ internal edges and ↓ forest interior habitats
  - Enhanced disturbance to fauna
    - ↑ access roads: barrier effects, casualties
Reduction of deadwood availability

- General forest management
  - In Swedish managed forests:
    - CWD ↓ 2-10% of the amounts in natural forests
    - Spruce FWD has increased by 75% since 1920
      - Caruso (2008)

- How many snags, down CWD and FWD actually remain after intensified woodfuel harvests?
DW volume at the plot scale

- whole-tree harvesting
- post-harvest recovery of residues (FWD, stumps…)
- ↑ destruction of deadwood pieces by machinery
- ↓ natural input of deadwood due to the shortening of forestry cycle duration and harvesting of older trees
**DW volume at the plot scale: empirical studies**

- **Quantitative data are scarce in temperate forests**
  - Arnosti et al., 2008, USA

- **In boreal forests**

<table>
<thead>
<tr>
<th>Reference</th>
<th>Removal during residue harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ericsson, 2003</td>
<td>75% of existing deadwood and residues from final harvesting</td>
</tr>
<tr>
<td>Rudolphi and Gustafsson, 2005</td>
<td>75% of existing deadwood and residues from final harvesting</td>
</tr>
<tr>
<td>Rudolphi and Gustafsson, 2005</td>
<td>40% of the decomposing logs present before</td>
</tr>
<tr>
<td>Allmér, 2005</td>
<td>6% of deadwood and 45% of FWD</td>
</tr>
</tbody>
</table>
DW volume at the landscape scale: modelling studies

Scenarios with an intensification of log biomass removal

- In Nordic landscapes
  - An overall reduction?
  
  - Ranius et al. (this workshop)

- In temperate landscapes
  - Compensation processes?
    - (-) ↑ recovery of residues
    - (+) ↑ density of cutting areas (some with DW retention)

- At the European level
  - 2005<>2030: ↓ 5.5% DW volume
  
  - Verkerk et al. (2011)
II - Fuelwood and saproxylic biodiversity

1. Response to decreased density of old trees
2. Response to decreased DW volume
3. Response to logging residues harvesting
4. Response to stump harvesting
Response to decreased density of old trees
Response to decreased density of old stands and veteran trees

- Positive relationship between species richness of saproxylic beetles and 
  - trunk diameter  
    - Ranius & Jansson, 2000  
  - basal area of large trees  
    - Grove, 2002  
  - tree age  
    - Branquart, 2005

- Risks in temperate forests:
  - Decrease in forestry cycle rotations  
  - Harvests in natural-like forests
A peculiar case study: pollard trees

- In agricultural landscapes structured by hedgerows and orchards
- Pollard trees
  - fuelwood
  - alternative habitats for saproxylic beetles inhabiting mature trees
    Ex. Osmoderma eremita
Response to decreased DW volume
Response to decreased DW volume

In boreal forests, many saproxylic species
- adapted to large-scale disturbances and sun-exposed substrates
- Important populations in clearcut residues on a landscape level

Plot scale
- Unclear relationship btw local DW volume and biodiversity
- Better correlations in boreal than in temperate forests
  - Meta-analysis: Lassauce et al. (this workshop)

Landscape scale
- A few results on broad scale positive effects of DW
  - Franc et al., 2007, Gibb et al., 2006, Okland et al., 1996…

Literature meta-analysis, Lassauce et al. (2011) Ecol. Indicators
Response to logging residue harvesting
What are harvesting residues?

- Small fallen trees from precommercial thinning operations
- Tree tops from logging operations
- Lying branches
- Fine Woody Debris (<10cm)
What life in the FWD?

Lichens, bryophytes
Kruys & Jonsson, 1999; Caruso & Rudolphi, 2009; Caruso & Thor, 2007

Saproxylic beetles
Nitterus et al., 2004, Manak, 2007, Gedminas et al., 2007, Jonsell et al., 2007, Jonsell, 2008, Ferro et al., 2009, Brin et al., 2011, Lassauce & Bouget (subm.)

Fungi

Saproxylic Diptera
Gedminas et al., 2007
Ecological drivers of biodiversity in logging residues (FWD)

- Deadwood quality
  - Diameter
  - Tree species
  - Decay stage

- Environment
  - Sun exposure
  - Soil moisture
  - Local species pool
What’s different between FWD and larger CWD?

- **Differences in species composition**
  - Beetles
    - Jonsell et al., 2007, Brin et al., 2011, Lassauce & Bouget, subm.
  - Lichens
    - Caruso & Thor, 2007; Caruso et al., 2008

- **FWD specialists**
  - twig assemblages are not just nested subsets of bole assemblages
Are there twig beetle specialists?

Methods to investigate twig beetle specialists:

- Dissection
- Emergence
- Beating and collecting

(Jonsell and Hansson, 2007; Grove, 2009)
What’s different between FWD and larger CWD?

- Differences in species density
  - but…
    - standardization mode: area, volume, no of elements?
      - Schiegg, 2001
    - diameter range

- Rare species in FWD
  - Lichens
    - Caruso & Thor, 2007
    - Caruso et al., 2008
  - Beetles
    - Jonsell et al., 2007
    - Brin et al., 2011
Ecological processes underlying the difference between FWD and CWD

(Brin et al., 2011)

1. substrate heterogeneity
   - number of feeding niches
2. microclimatic stability
3. life span
4. quantity of available resources per DW piece
5. bark thickness
6. decay pathways
Importance of FWD tree species

- More species and red-listed species in deciduous than in coniferous residues

- Fungi
  - Norden et al., 2004

- Beetles
  - Jonsell et al., 2007
  - Lassauce and Bouget, subm.
Comparison between lying and hanging dead branches

Suspended dead branches = potential alternative substrates for all the FWD species?

- Microclimate vertical stratification (moisture…)
- A significant inter-strata dissimilarity
- Stratum-specialist taxa
  - Exclusive canopy species = 20 - 40%
    - (Bouget et al., 2011)
- Arboreal saproxylic beetle communities
  - = not just nested subsets of ground assemblages
What about the effects of delayed extraction?

- **Delayed extraction for nutrient retention**
  - in situ “drying” to limit extraction of nutrients from needles/leaves
  - (Cacot et al., 2006)

- **Assemblages and decay dynamics**
  - Especially for deciduous tree species
  - Jonsell et al., 2007; Lassauce & Bouget (subm.) – saproxylic beetles
  - Species richness in residues: decayed > fresh
  - Decay class > important factor for sp. composition

- Delayed extraction might be **counterproductive!**
Ecological trapping by log piles

Woodpiles may act as ecological traps!

- Harvested wood stored in piles and allowed to dry for one summer
- Aggregations of fresh dead wood attract laying beetle females
- Mitigate the negative effects of piles:
  - remove the piles before the insects colonize them
  - retain the top layer of the piles (preferred by most beetles)

(Hedin et al., 2008)
Impact of slash removal on saproxylic biodiversity

Comparison of saproxylic beetle biodiversity in sites with (FW) or without (nFW) fuelwood harvesting

- Grove, 2009
  - ↓ abundance and ≠ assemblages in FW vs nFW

- Bouget (unpublished)
  - ↓ species (esp. secondary xylophagous) in FW vs nFW
Response to stump harvesting
Stump harvesting in Europe

- In Sweden and Finland
  - Stump harvesting in the 1970s and 80s for use as pulp wood and abandoned
  - expansion since 2002 in Finland, and since 2009 in Sweden

- in GB?

- In South-western France?
Stumps as « trivial dead wood »?

Stump = a common, widespread deadwood type

- Overlooked in ecological studies
  - Pioneer studies on pine stumps
    - Wallace, 1953 (GB), Elton et al., 1964 (NL)

- Not considered in deadwood estimates

<table>
<thead>
<tr>
<th>Stump volume</th>
<th>Managed/unmanaged mature oak forests</th>
<th>Temperate France</th>
<th>Bouget, unpublished</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 %CWD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 %CWD</td>
<td>Managed pine plantations</td>
<td>Temperate France</td>
<td>Brin et al., 2009</td>
</tr>
<tr>
<td>28 %CWD</td>
<td>managed forests</td>
<td>Boreal Sweden</td>
<td>Jonsell, unpublished</td>
</tr>
<tr>
<td>Stumps=3x [logs/high stumps]</td>
<td>clearcuts</td>
<td>Boreal Sweden</td>
<td>Hjältén et al., 2010</td>
</tr>
<tr>
<td>80 %CWD</td>
<td>clearcuts</td>
<td>Boreal Sweden</td>
<td>Caruso et al., 2008</td>
</tr>
</tbody>
</table>
Are stumps as species-rich as downed logs and snags?

### Beetle sp richness

<table>
<thead>
<tr>
<th></th>
<th>Temperate</th>
<th>Boreal</th>
</tr>
</thead>
<tbody>
<tr>
<td>spruce</td>
<td>Hjältén et al., 2010</td>
<td>=</td>
</tr>
<tr>
<td>birch, aspen,</td>
<td>Jonsell et al., subm</td>
<td>=</td>
</tr>
<tr>
<td>pine, spruce</td>
<td></td>
<td>=</td>
</tr>
<tr>
<td>oak</td>
<td>Bouget, unpubl</td>
<td>&lt;</td>
</tr>
</tbody>
</table>

= Indicates equivalence.
< Indicates inequality.

II - Fuelwood and saproxylic biodiversity
Importance of low stumps for biodiversity

Are beetle assemblages in stumps different from those in logs and snags?

**Beetle sp composition**

<table>
<thead>
<tr>
<th>Species</th>
<th>Temperate</th>
<th>Boreal</th>
<th>Logs</th>
<th>Stumps</th>
<th>Snags</th>
</tr>
</thead>
<tbody>
<tr>
<td>spruce</td>
<td>Hjältén et al., 2010</td>
<td>≠</td>
<td>≠</td>
<td>≠</td>
<td></td>
</tr>
<tr>
<td>birch, aspen, pine, spruce</td>
<td>Jonsell et al., subm</td>
<td>≠</td>
<td>≠</td>
<td></td>
<td></td>
</tr>
<tr>
<td>oak</td>
<td>Bouget, unpubl</td>
<td>=</td>
<td>=</td>
<td>≠</td>
<td></td>
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</tbody>
</table>
Importance of low stumps for biodiversity

Beetle dissimilarity btw stumps and logs:

- Tree species?
  - ≠ stronger for coniferous (pine, spruce) than deciduous (aspen, birch) trees
    - Jonsell et al., subm.

- Deadwood age?
  - ≠ stronger for fresh than decayed wood
    - Jonsell et al., subm.

- Species common in spruce low stumps also reported from other substrate types
  - Hjältén et al., 2010
Importance of low stumps for biodiversity

- Man-made stumps as key micro-habitats
- more homogeneous than logs
- but LT continuity and decay diversity
- = alternative micro-habitats
  - beetles
    - Pine plantations in SW France (Brin, unpubl.)
  - Bryophytes
    - French oak forests (Gautrot, unpubl.)

What original habitat for stump-associated species?

- low stumps ≠ snag basis
  - beetles: Abrahamsson & Lindbladh, 2006
  - parasitoids: Hedgren, 2007
### Importance of low stumps for biodiversity

Do rare species occur in stumps?

<table>
<thead>
<tr>
<th></th>
<th>Rare species in stumps</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosses</td>
<td>-</td>
<td>Caruso &amp; Rudolphi, 2009</td>
</tr>
<tr>
<td>Lichens</td>
<td>+/-</td>
<td>Caruso &amp; Rudolphi, 2009</td>
</tr>
<tr>
<td>Saproxylic fungi</td>
<td>-</td>
<td>Hottola, 2009</td>
</tr>
<tr>
<td>Saproxylic beetles</td>
<td>+</td>
<td>Jonsell et al., subm. Bouget, unpubl.</td>
</tr>
</tbody>
</table>
III

Fuelwood and non-saproxylic biodiversity
Residue removal and wildlife

- Meta-analysis of impact of FWD harvest on biodiversity in North America

- FWD is not only a direct substrate but an important habitat feature for many types of wildlife

Riffell et al., 2011
Residue removal and non-saproxylic biodiversity

Piles of slash and residues used by Vertebrates as:
- means of traversing their home range
- protective cover
- nesting sites
- feeding areas

- Wildlife response to changes in FWD (Riffell et al., 2011)
  - mice, voles and shrews
    Ecke et al., 2002; Manning and Edge, 2008
  - marten
    Bunnell et al., 2002
  - small birds
    Hanowski et al., 2003
  - amphibians
Piles of slash and residues > changes in substrate and micro-climate for soil arthropods

<table>
<thead>
<tr>
<th>Group</th>
<th>Variable</th>
<th>Time scale</th>
<th>Effect of slash removal</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mites and springtails</td>
<td>Density Composition</td>
<td>Short-term</td>
<td>(-) ns</td>
<td>Bird &amp; Chatarpaul, 1986</td>
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<tr>
<td>Mites</td>
<td>Density/diversity</td>
<td>Short-term</td>
<td>(-)</td>
<td>Battigelli et al., 2004</td>
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<tr>
<td>Spiders</td>
<td></td>
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<tr>
<td>Enchytreids, Nematodes, springtails</td>
<td>Density</td>
<td>Long-term</td>
<td>ns</td>
<td>Bengtsson et al., 1997</td>
</tr>
<tr>
<td>Ground beetles</td>
<td></td>
<td></td>
<td>(-) ns</td>
<td>Nitterus et al., 2007</td>
</tr>
<tr>
<td>Spiders</td>
<td>Composition</td>
<td>Short-term</td>
<td>(-)</td>
<td>Castro and Wise, 2009</td>
</tr>
<tr>
<td>Soil-dwelling beetles</td>
<td>Sp. Richness</td>
<td></td>
<td>(-)</td>
<td>Gunnarson et al., 2004</td>
</tr>
<tr>
<td>Nematodes</td>
<td>Density</td>
<td>Mid-term</td>
<td>(-)</td>
<td>Sohlenius, 1996</td>
</tr>
<tr>
<td></td>
<td>Composition</td>
<td></td>
<td>(+)</td>
<td></td>
</tr>
</tbody>
</table>
Residue removal and soil acidification

- **Fauna**
  - Soil decomposer and microbial activity
    - Baath et al. (1980)
  - Amphibians as bioindicators of acidification
    - (Wyman and Jancola, 1992)

- **Flora**
Residue removal and flora

Piles of slash and residues > physical and geochemical changes for vascular flora

- **Short-term mulching effect**
  - ↓ herbaceous cover
    - Olsson & Staaf, 1995
    - Brakenhielm & Liu, 1998
    - Deconchat & Balent, 2001
    - Aström et al., 2005

- **Physical protection from browsing**
  - Bergquist, 1998
Bioenergy-related practices and soil compaction

- Soil compaction
  - Flora
    - Species adapted to hypoxic conditions
      - Godefroid and Koedam, 2004
  - Soil fauna
    - Mite density and diversity
      - Battigelli et al., 2004
    - Biological activity
      - Radford et al., 2001

- Logging trails with retained woody material to reduce forest machine ground pressure
Conclusion
Cautionary statements to mitigate ecological damage on biodiversity

- Incorporate regional wildlife management guidelines into biomass production systems
- Development of environmentally friendly collecting practices
- Complete Life Cycle Analysis (LCA) of fuelwoods
  - incl. fossil fuels used in production and transport
Recommendations to minimize negative impacts on biodiversity

- Harvest recommendations
  - account for the context (region/forest/biome)
  - difficult to set an appropriate level of extraction/retention
    - Area specialization strategy
      - site classification based on conservation values
      - restrict/concentrate residue harvesting in stands with high/low values
  - safeguarding principles
    - threshold frequency of residue harvesting per rotation
Research requirements

Further research:

- Manipulative experiments
- Large-scale experiments
- Landscape analyses
  landscape-level effects
- Long-term studies
  delayed impacts of fuelwood harvesting
  (decay dynamics/extinction debt)
- Multi-taxonomical approaches
- Adaptive management
Thanks for your attention!

Thanks for initial debates to Frédéric Gosselin, Marion Gosselin and Guy Landmann

Next workshop...