Effects of moisture content on supply costs and CO\textsubscript{2} emissions for an optimized supply network

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Formec Symposium 2015
Forest Engineering: Making a positive contribution
48th International Symposium on Forestry Mechanization, 04. - 08. October 2015, Linz (Austria)
Background

Moisture content of energy wood has an impact on:

- Chip quality
- Heating value
- Demand
- Revenues
- Transport
- Storage
- Chipper performance
- ...
Background

• Natural drying to decrease water content and increase heating value is wanted

• Series of drying experiments have been done

• Savings on logistics in terms of emissions and costs have not been studies extensively
Study area

- Resources ~882,170 t*a⁻¹ represented by 9,984 resource points
- 228 heating & CHP with a demand of ~982,000 t*a⁻¹
- 356 possible terminal location
- 119 Railway shipping stations for round wood

Kanzian et al., 2013
Problems

✓ What terminal locations to chose?
✓ Should we transport solid or chipped?
✓ Where the chipping should be done?
✓ What *profit* and *emissions* can we expect?

- How sensitive is the optimal solution on changing moisture content?
Supply chains

Biomass Supply Network

Forest (P) → Shipping Station (S) → Plant (H) → Shipping Station (S) → Forest (P)

Harvesting

- Chipping
- Transport
- Transport
- Chipping
- Transport
- Transport
- Transport
- Chipping

Storing

- Chipping
- Transport
- Transport
- Chipping
- Transport
- Transport
- Chipping

SC 1, SC 2, SC 3, SC 4, SC 5
Multi-criteria optimization MOP

Weighted sum scalarization approach (*Ehrgott 2005*)

Basic idea is it to find Pareto optimal solutions by:

- Scaling different objectives (function) with non-negative weights

\[
\text{min}(x) = \lambda_p \times f_p + \lambda_e \times f_e
\]

Weigths

Objectives

*Kanzian et al., 2013*
MOP - Moisture content influences?

Weighted sum scalarization approach (Ehrgott 2005)

$$\max(f_p) = C^r - C^{\text{harv}} - C^{\text{trans}} - C^{\text{chip}} - C^{\text{var}} - C^{\text{fix}}$$

$$\min(x) = \lambda_p \times f_p + \lambda_e \times f_e$$

$$\min(f_e) = C^{\text{harv}} + C^{\text{trans}} + C^{\text{chip}} + C^{\text{var}} + C^{\text{fix}}$$
MOP - Moisture content influences?

\[ r_{j,k=0} = 60.273 + 36.105MC - 99.415MC^2 \]

\[ r_{j,k=1} = 81.346 + 30.558MC - 86.271MC^2 \]

\[ \max(f_p) = C^r - (C^{\text{harv}} + C^{\text{trans}} + C^{\text{chip}} + C^{\text{var}} + C^{\text{fix}}) \]

\[ c_{ijk} = \frac{((t_k^L + 2t_k^D + t_k^U + 2p_k^W t_k^D)c_k^h + 2c_{ij}^{\text{toll}})n_{ik}}{s_i} \]

Number of loads per site

\[ n_{ik} = \left[ \frac{s_i}{lv_k} \right] \]
Results

Increasing profit

Kanzian et al., 2013
Results – Revenue related

Profit and emission weighting values of 0.5

profit from 5 to 12 EUR\*t^{-1}
Results - Supply

Kanzian et al., 2013

Profit and emission weighting values of 0.5
Results - Distances

Profit and emission weighting values of 0.5

Kanzian et al., 2013
Results – relative supply & truck loads

Profit and emission weighting values of 0.5

Relative number of supply and loads (%) vs. Moisture content (%)
Results – specific distances and emissions

Profit and emission weighting values of 0.5
Conclusions?

10% decrease in moisture content means

- profit from 5.10 to 12.00 EUR\*t^{-1}
- save 4% of CO₂ emissions
- ~7% less truckloads
- ~3% less demand
- Decrease of specific transport distance from 2.9 to 2.5 km\*t^{-1}
Lessons learned
... or what is not written

- Adopting a model is not enough
  - Time periods are missing to find optimal storage
  - Include drying models
  - Consider changes of material over time
  - Uncertainty

- Used commercial solver platforms is powerful but costly for business users

- Still a long way to go, but who will be the user
Additional information

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The “full” paper will be published in the Croatian Journal of Forest Engineering (CROJFE), Issue 37(1), 2016.

www.infres.eu

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015) under grant agreement n°311881.

10/12/2015