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Effects of moisture content on supply costs and CO_2 emissions for an optimized supply network

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Background

Moisture content of energy wood has an impact on:

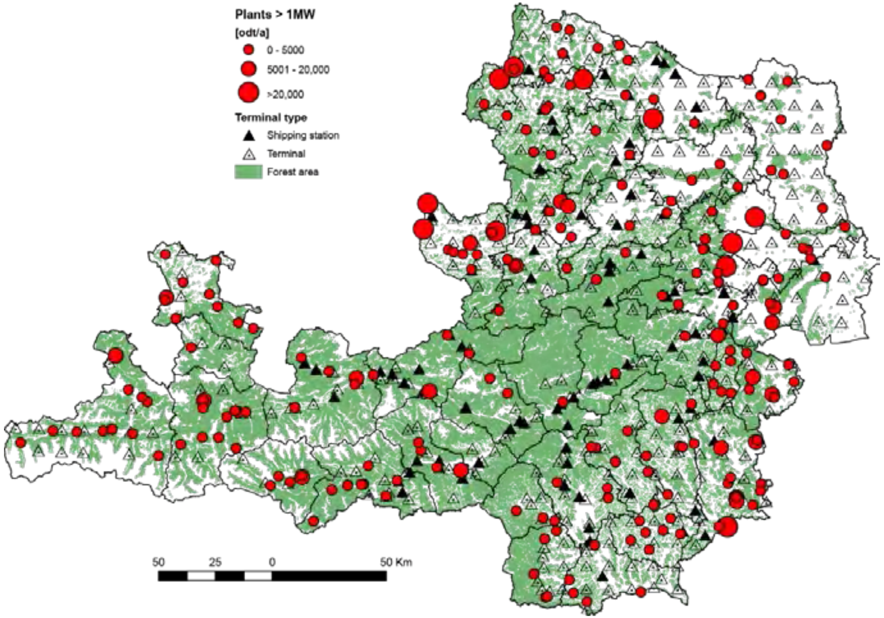
- Chip quality
- Heating value
- Demand
- Revenues
- Transport
- Storage
- Chipper performance
- ...

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



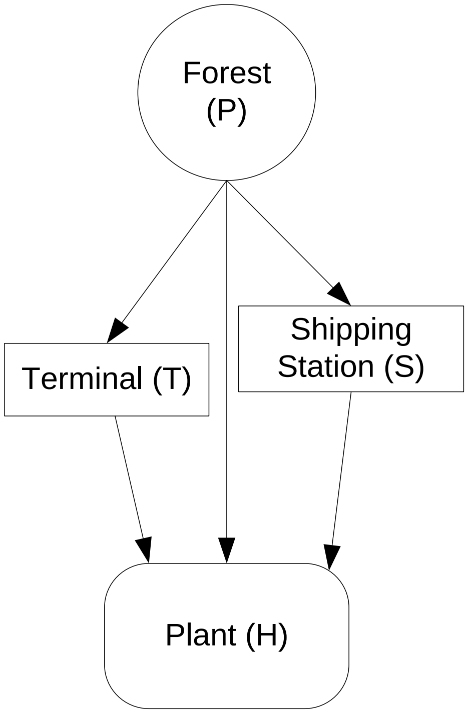
Kanzian et al., 2013

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?**

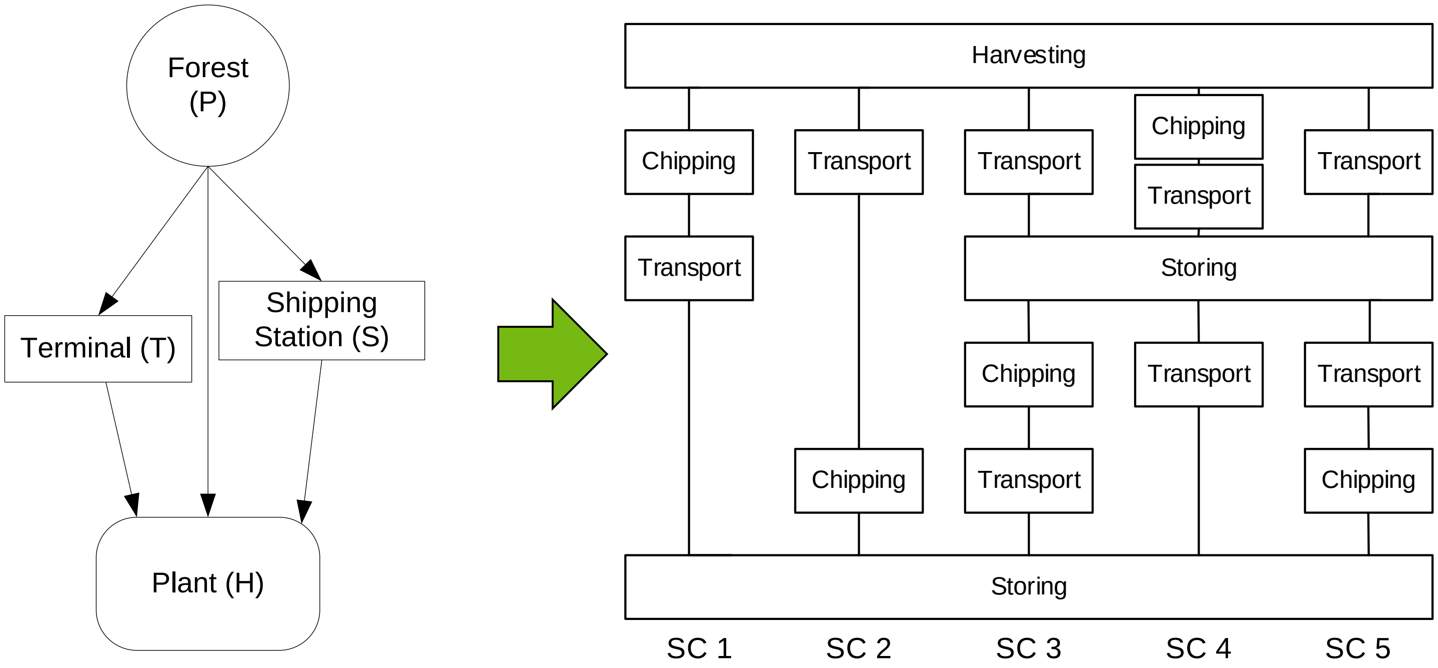
Biomass Supply Network



Kanzian et al., 2013

Supply chains

Biomass Supply Network



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

Objectives

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

Weights

Kanzian et al., 2013

MOP - Moisture content influences?

Weighted sum scalarization approach (*Ehrgott 2005*)

$$\max(f_p) = C^r - (C^{harv} + C^{trans} + C^{chip} + C^{l\,var} + C^{lfix})$$

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

$$\min(f_e) = C^{harv} + C^{trans} + C^{chip} + C^{l\,var} + C^{lfix}$$

MOP - Moisture content influences?

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

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

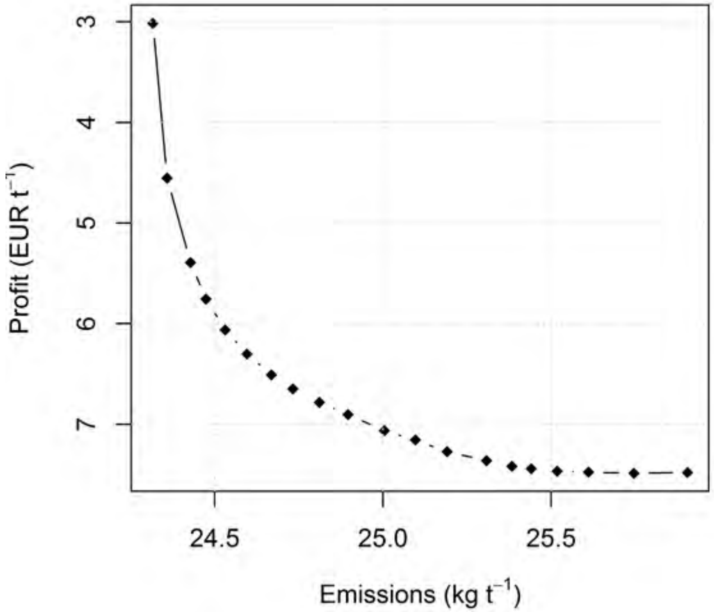
$$\max(f_p) = C^r - (C^{harv} + C^{trans} + C^{chip} + C^{l\,\mathrm{var}} + C^{lfix})$$

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

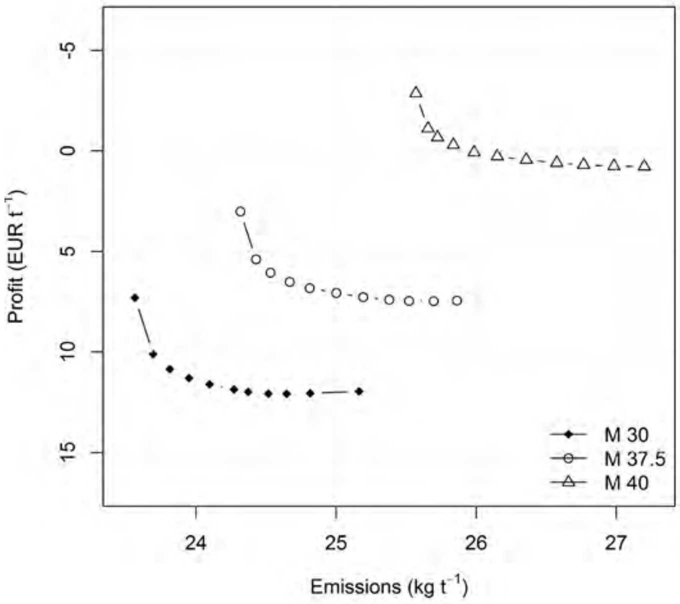
$$n_{ik} = \left\lceil \frac{s_i}{lv_k} \right\rceil$$

Number of loads per site

Results



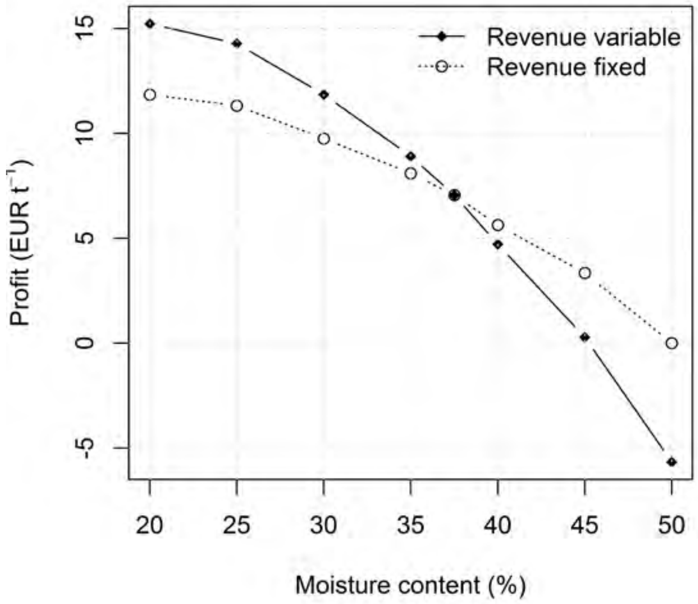
Increasing profit

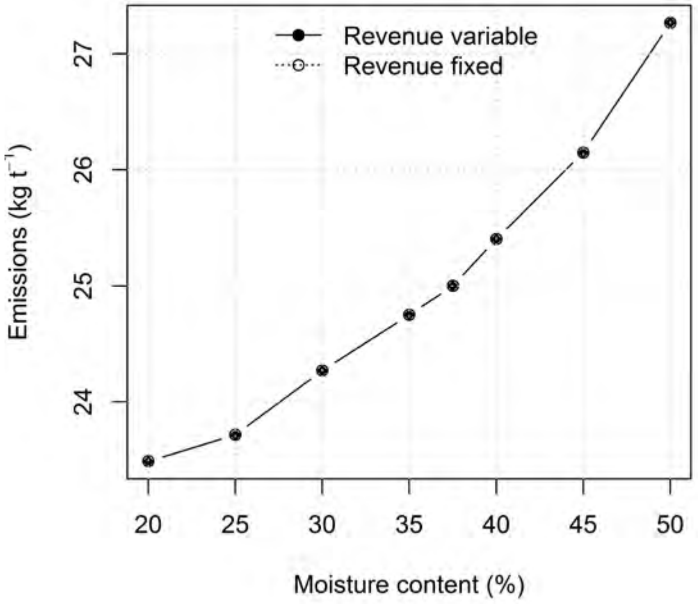


Kanzian et al., 2013

Results – Revenue related

Profit and emission weighting values of 0.5

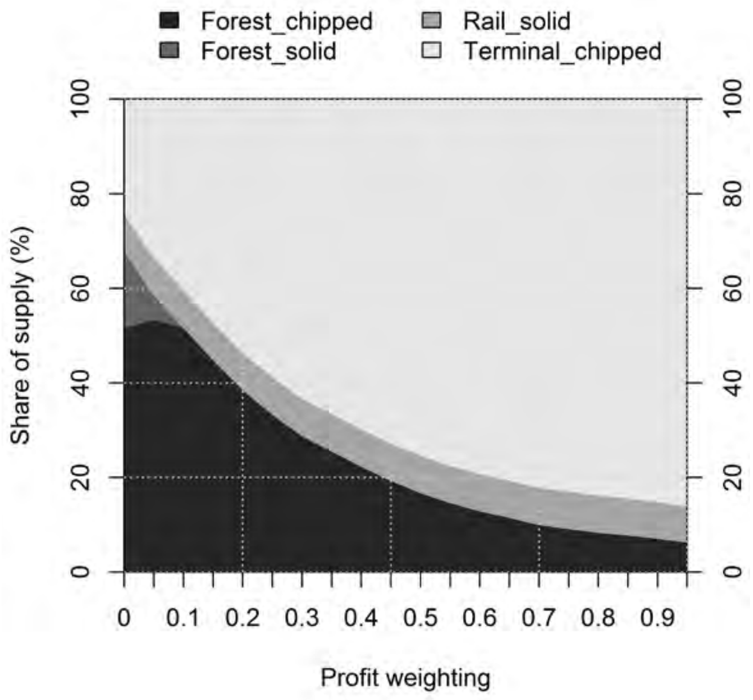


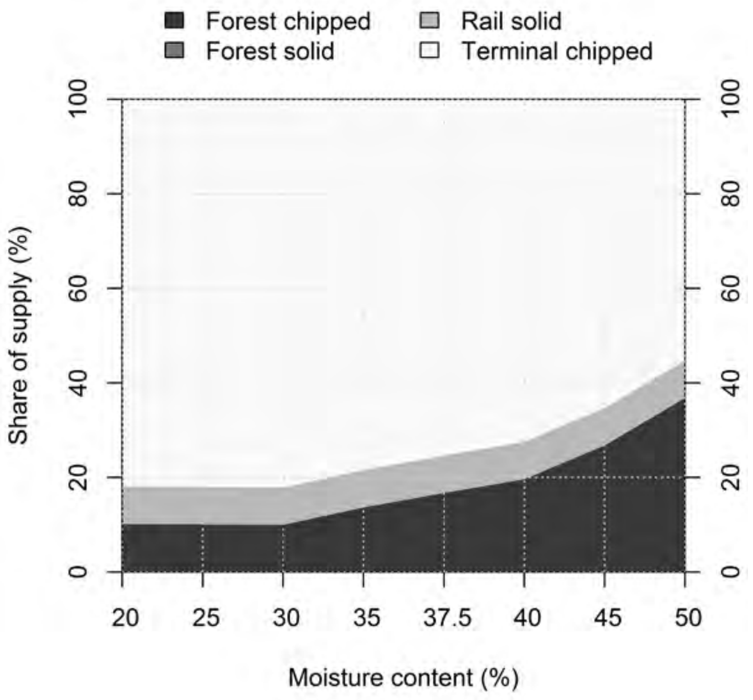


profit from 5 to 12 EUR$*t^{-1}$

Results - Supply

Profit and emission weighting values of 0.5

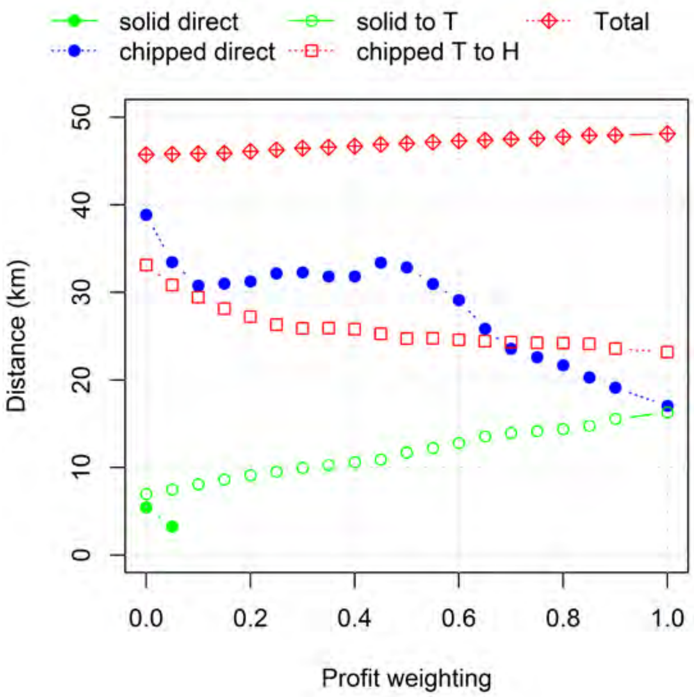


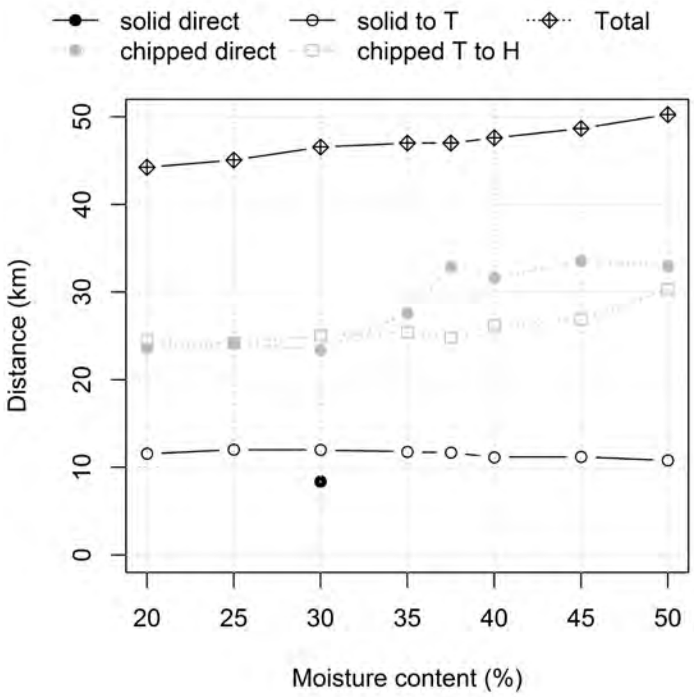


Kanzian et al., 2013

Results - Distances

Profit and emission weighting values of 0.5





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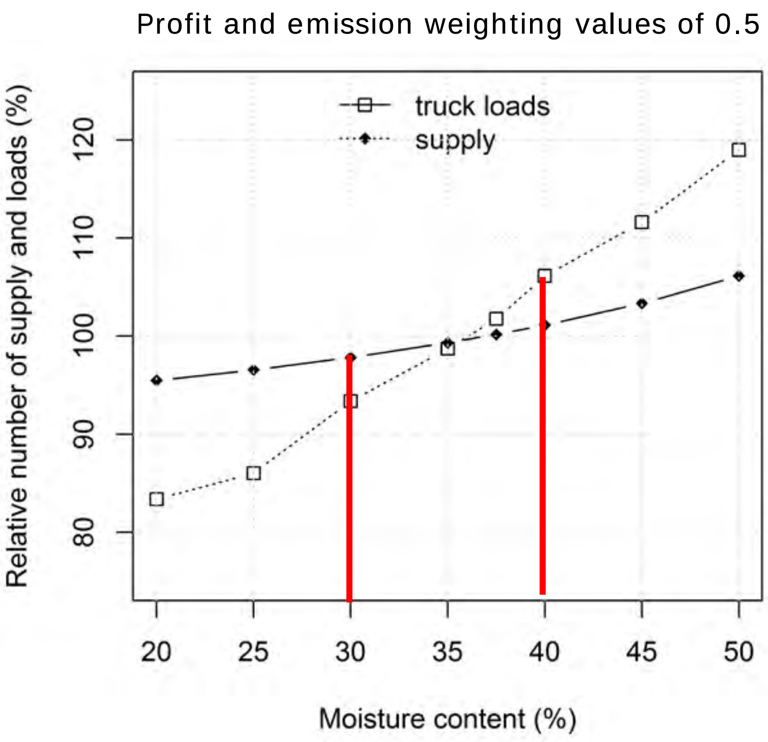
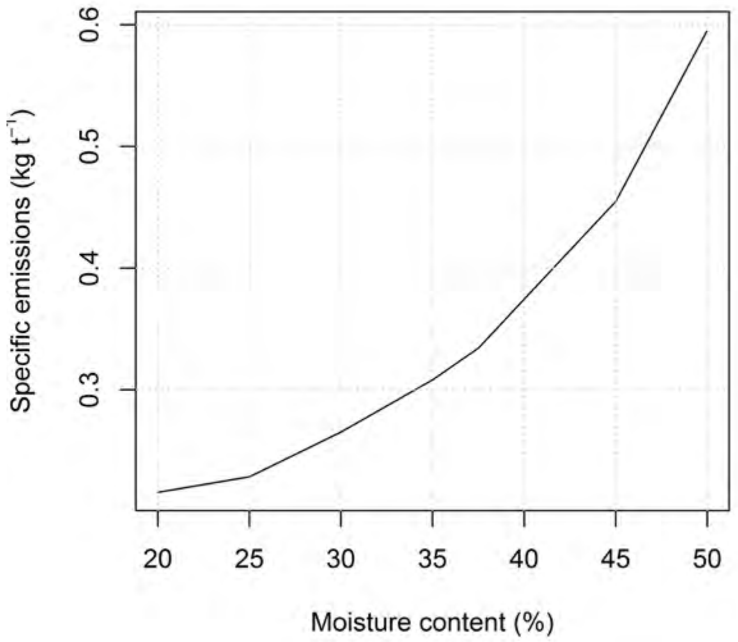
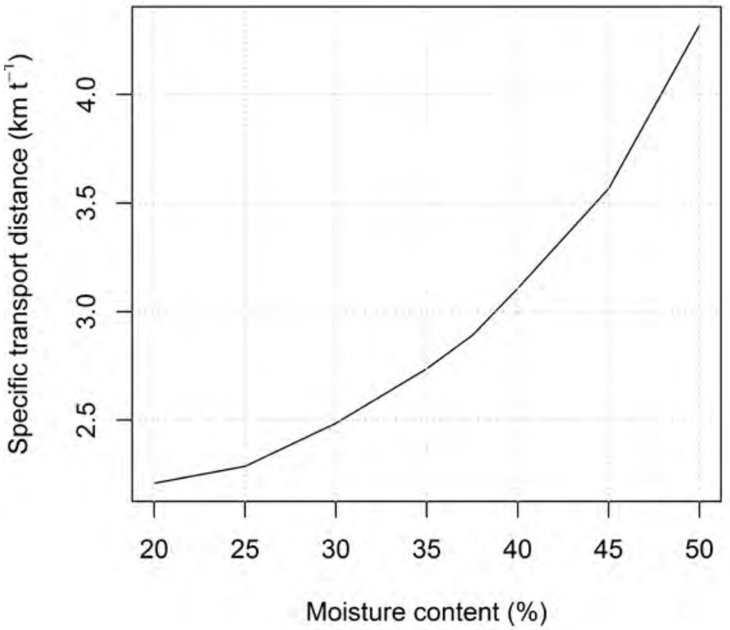
Results – relative supply & truck loads



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 CO_2 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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