

# Potentials of possible machine systems for directly loading logs in cut-to-length harvesting

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# Outline

- Integration approaches
- Analytical objective
- Methods & assumptions
- Results: system potentials
- Conclusions



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# Work tasks in CTL harvest

**Harvester**

Felling and processing

**Stem size**

**Forwarder**

Empty transport

**Distance, speed**

Loading

**Stand density, speed**

Full transport

**Distance, speed**

Unloading

**Assortments**



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# Direct loading of logs - *Integration of work tasks*

- Work tasks combined to be done at the same time and place:  
in sequence or simultaneously
- Results
  - Reduction of work tasks
  - Shorter lead time
  - Reduction of stocks (buffers)
- Technical or organizational



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Direct loading = logs are processed directly to load space of transporting vehicle

Technical approach:  
1 machine (*harwarder*)



Organizational approach:  
Co-operating machines (*Besten*)



# Harwarder

- 1 machine harvests and forwards
- Tested from 1950:ies
- Potentials
  - Lower relocation costs
  - Simple planning
  - Faster production
  - Clean lumber



# Co-operating machines

- Harvester process directly to forwarders' bunk
- Potentials:
  - Faster production
  - Clean lumber



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*Integrated Forwarder Loading (IFL)*

*Conventional*

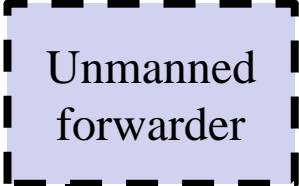
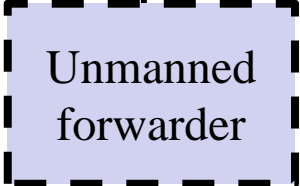
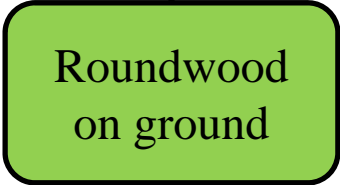
*Harwarder*

*Autonomous  
Load Change  
(ALC)*

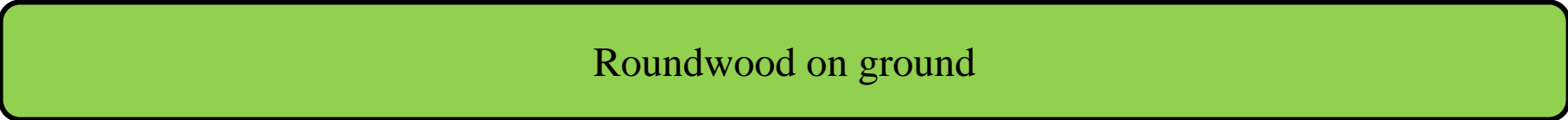
*Autonomous  
Direct Loading  
(ADL)*

*Remote controlled  
Direct Loading  
(RDL)*

*Forest stand*



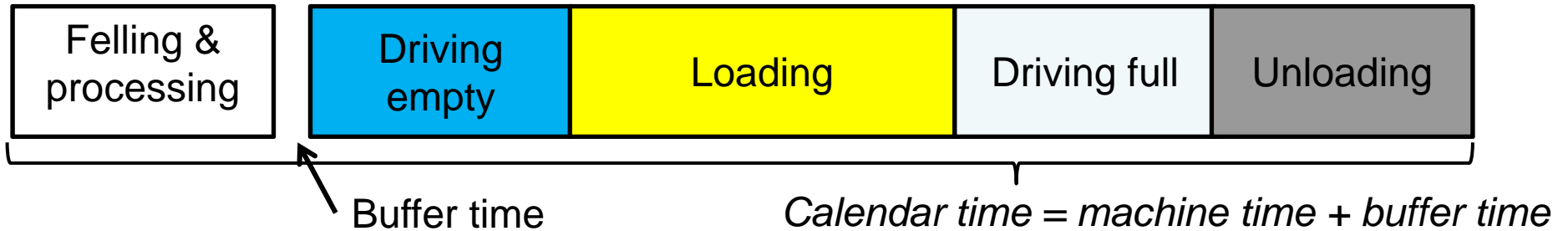
*Road side*



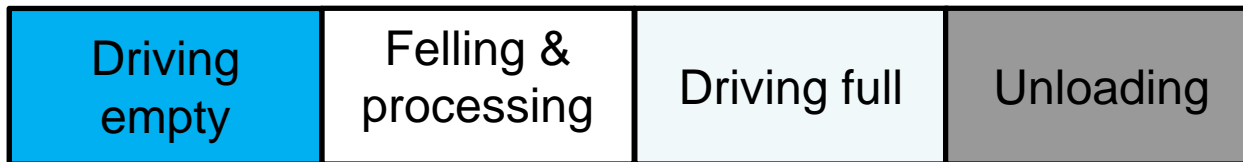


# Time gain

## Conventional CTL



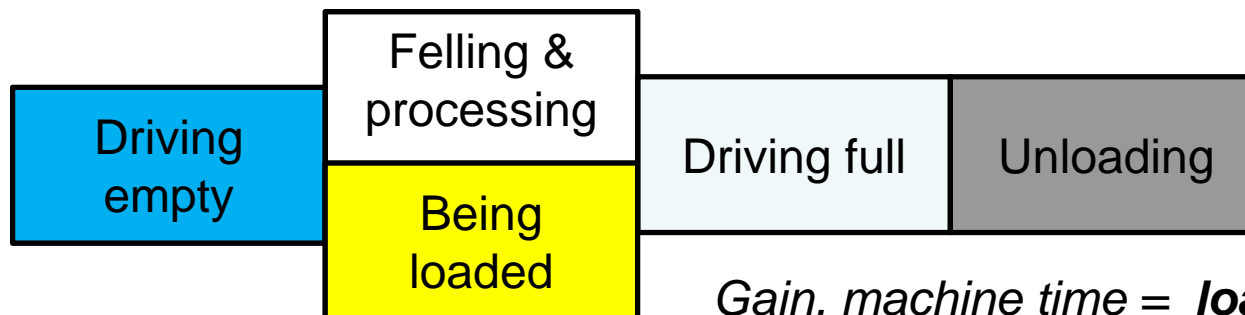
## Harwarder



*Gain, machine time = loading*

*Gain, calendar time = loading + buffer time*

## Co-operating machines

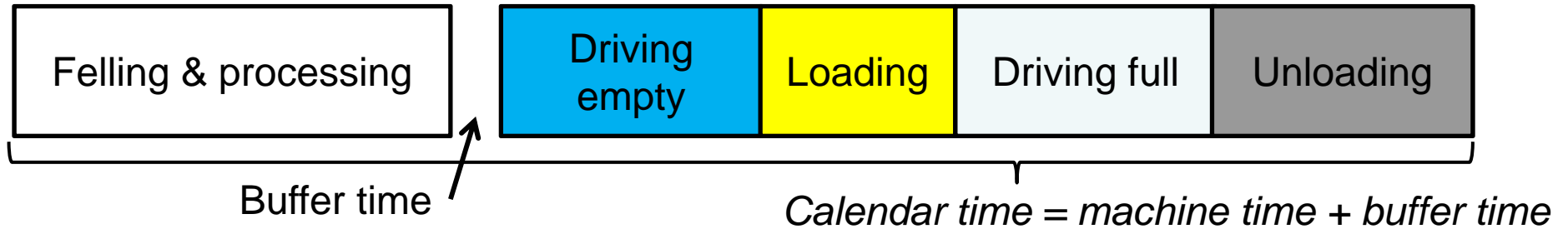


*Gain, machine time = loading - fell & process*

*Gain, calendar time = loading + buffer time*

# Time gain

## Conventional CTL



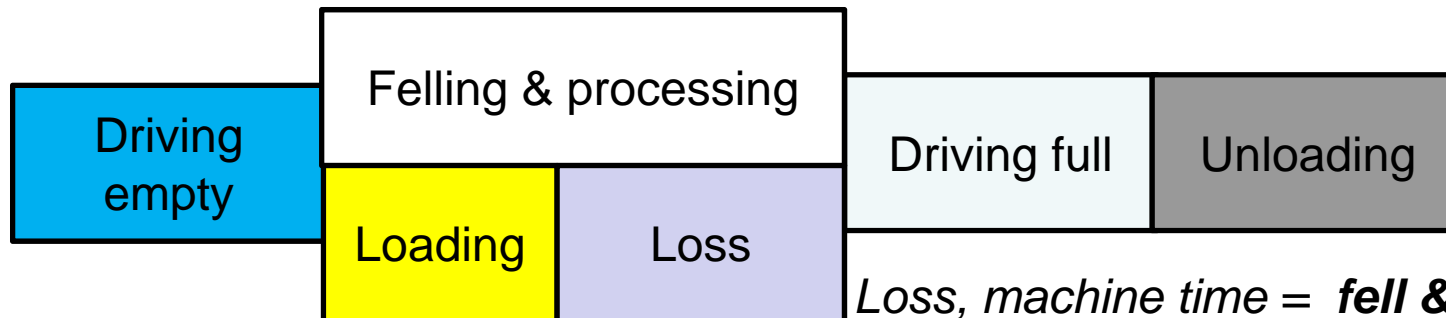
## Harwarder



*Gain, machine time = loading*

*Gain, calendar time = loading + buffer time*

## Co-operating machines



*Loss, machine time = fell & process - loading*

*Gain, calendar time = loading + buffer time*

# Co-operating machines

- Balance (suitable distance)



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# Co-operating machines

- Too short distance

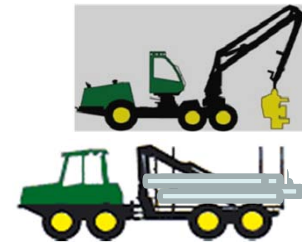


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# Co-operating machines

- Too long distance



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# Objective

- Analyze the theoretical potentials of the four direct loading machine systems in final felling
- *What machine system should be prioritized?*



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# Methodology

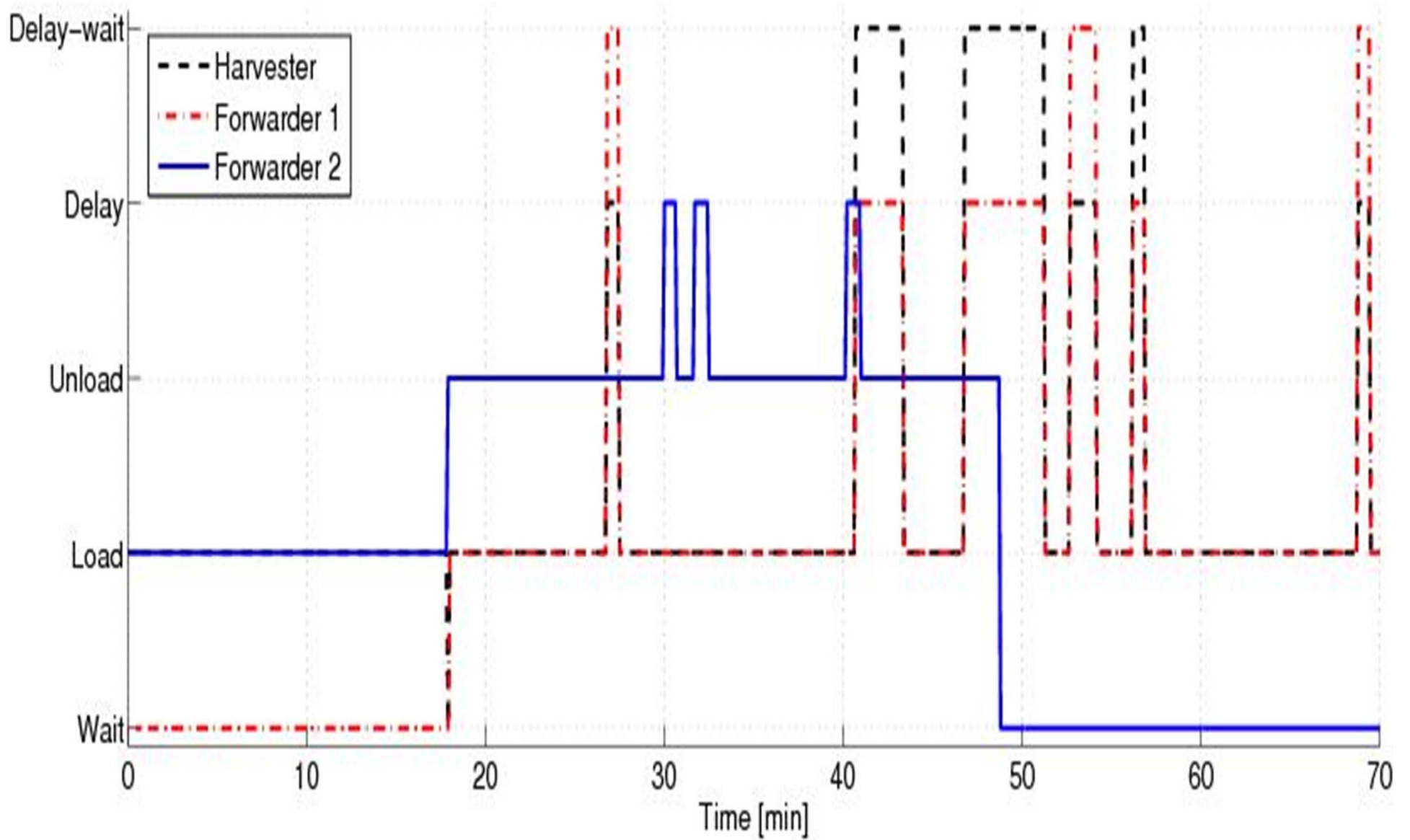
- Discrete event simulation of time consumption for harvest of >1000 stands (ca 1.6 million m<sup>3</sup>)
- Required productive machine time defined by stand characteristics
- Random delay occurrence and duration during work
- Variation in forwarding distance within stands
- Queuing due to random delays and mismatches between the work of interdependent machines



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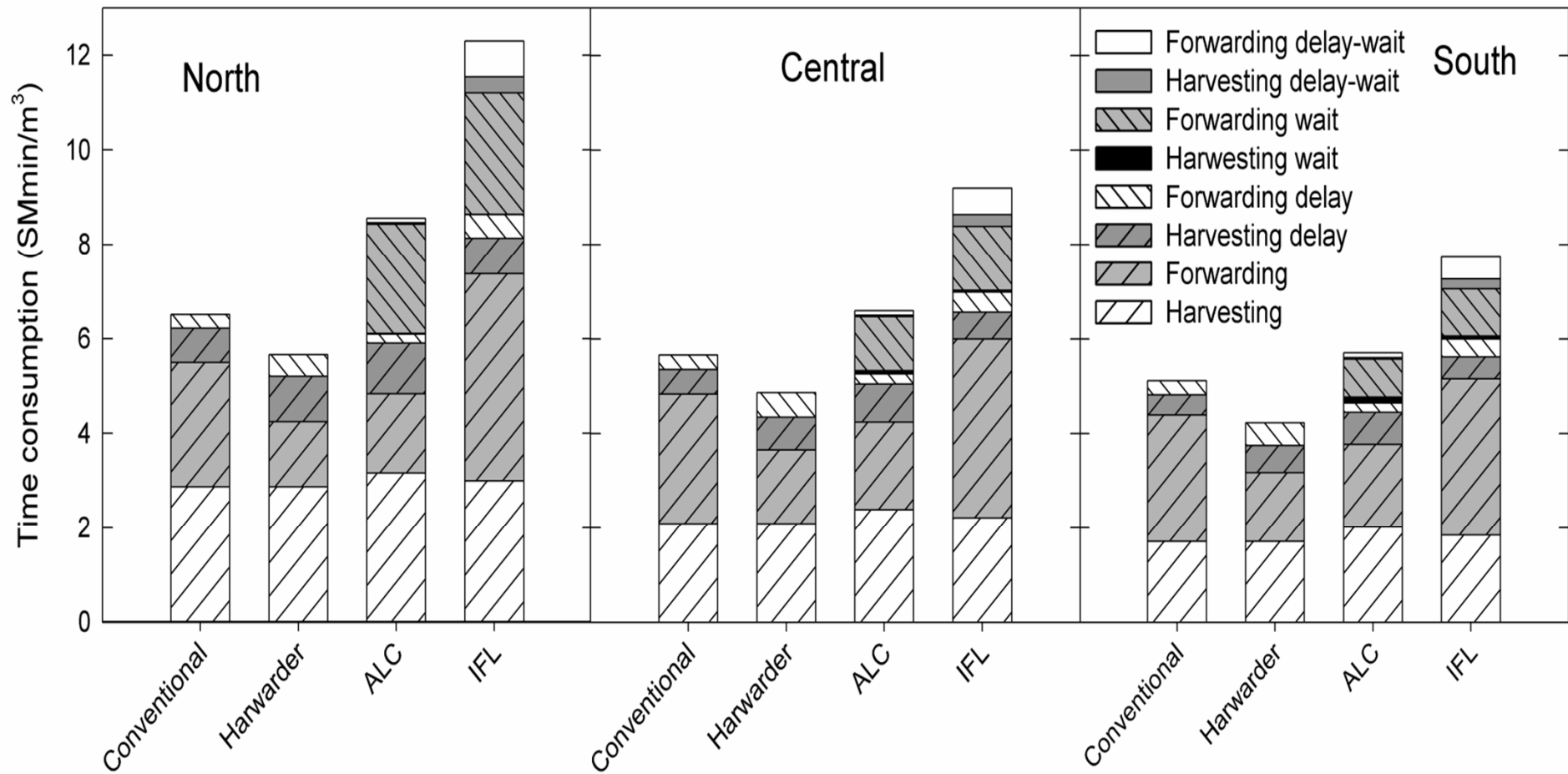
# Simulation example – time in different states





# Results 1: Time consumption

(Mean of 35 simulation runs)



## Cost assumptions:

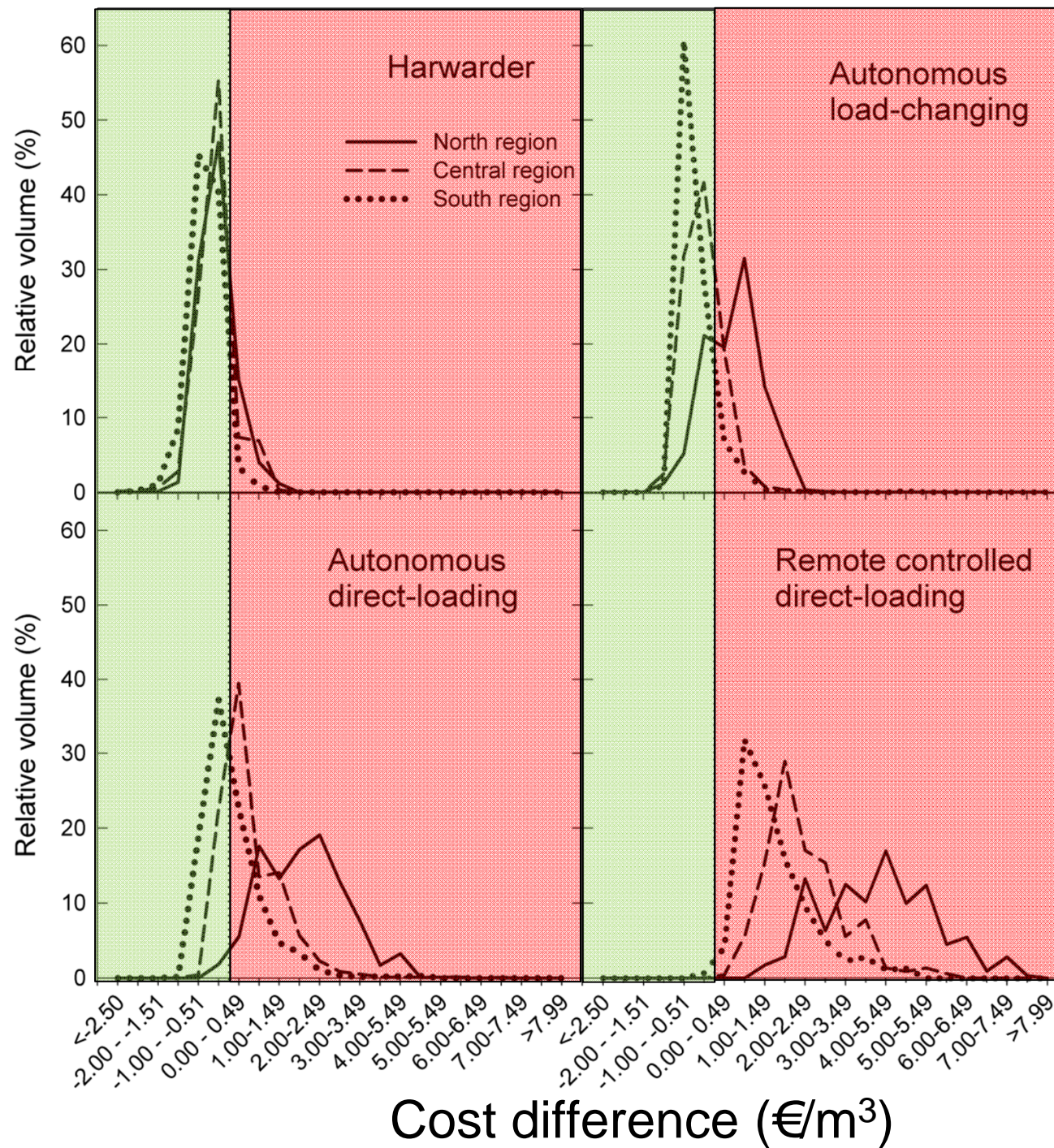
- Fixed cost harwarder: is **+17%** than a conv. harvester (*harvester head-grapple, rotatable bunk*)
- Fixed cost ALC harwarder: **+20%** than a conv. harvester (*harvester head-grapple, rotatable and switchable bunk*)
- Fixed cost autonomous forwarder: **+5%** than a conv. forwarder (*requires rotatable or switchable bunk, but no cabin*)
- Fixed cost RDL harvester: **-20%** than a conv. harvester (no cabin).
- Fixed cost RDL forwarder: **+17%** than a conv. forwarder (requires remote control gear and rotatable bunk).
- Fuel consumption when idling is **21%** of the consumption in normal operation (idle when being loaded, delay & waiting)
- Relocation cost per machine



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# Results 2: Costs



# Conclusions

- High potential in technical integration (*harwarder*)
  - Technical limitations
- Low potential in organizational integration (*best with ALC*)
  - Organizational limitations



## ***Further reading:***

Ringdahl, O., Hellström, T. and Lindroos, O. Potentials of possible machine systems for directly loading logs in cut-to-length harvesting. (resubmitted manuscript).

Lindroos, O. (in press). Evaluation of technical and organizational approaches for directly loading logs in mechanized CTL harvesting. *Forest Science*.

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