Harvesting cost calculations on large rasters

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PhD title (Søvde, 2013):

Optimization of Terrain Transportation Problems in Forestry

Extraction trail layout – the network method

Cableway layout

Landing location

Why national harvesting cost calculations?

In the literature, forest planning is often categorized as either operational, tactical or strategical.

- National Forest Inventories estimate today's and the near future's resource availability, and harvesting cost has an impact.
- Public infrastructure models may rely on harvesting cost.
- A detailed map could also be interesting for forest owners and managers.

National calculations – WARNING

Many studies rely on expert assessment.

Experts walking around in the forest are expensive.

At a national level, this is hardly possible.

Parts of forest harvest models

The harvester (e.g. cost driver tree size) – basically lookup tables (and fast).

Forwarders (and skidders) – transport distance, not hard, but can be tricky.

The location of truck roads and skid roads are usually modeled as facility location problems (and hard to solve).

Cable yarding operations are usually modeled as facility location problems (and hard to solve).

Three approaches for solving difficult problems

1. solve a smaller instance (exact solver)

2. use a (meta-) heuristic

3. redesign the problen

Forwarding models

1. Average Skidding Distance (Matthews, 1942)

2. Network models, usually solved by Shortest Path Algorithms, several reports, e.g.

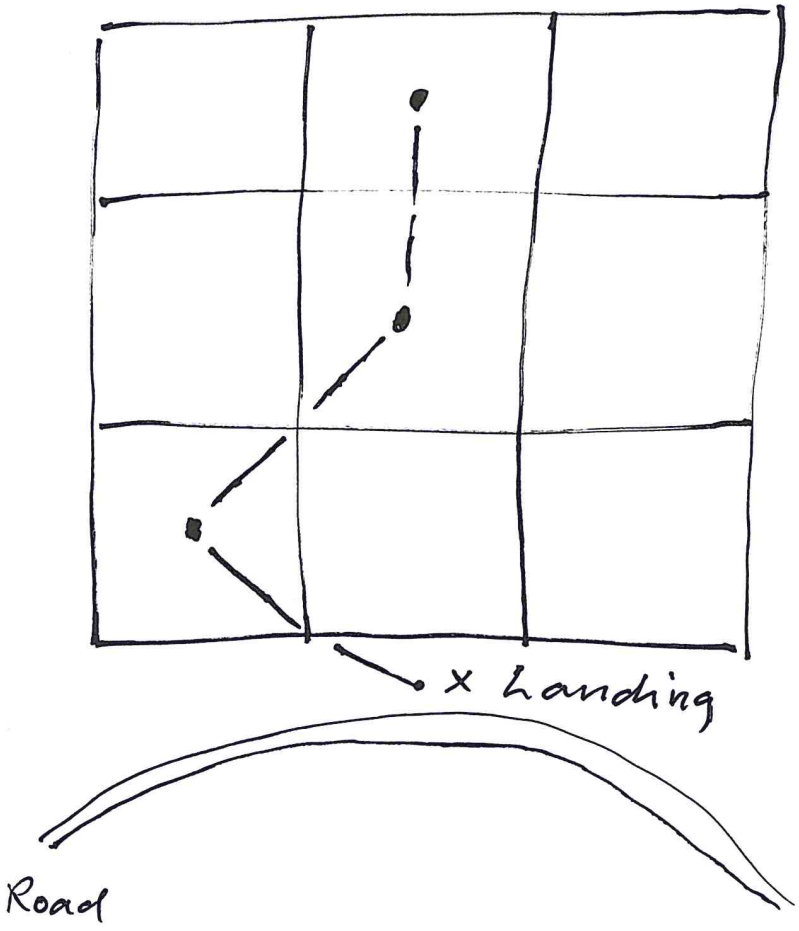
   Tan (1992)

   Contreras and Chung (2007)

   Chung et al. (2008)

   Contreras and Chung (2011)

   Søvde et al. (2013)



The Network method

Network model for forwarding – some observations

The cost of transport between neighbors depend on the micro topography (and resolution (i.e. distance)).

Shortest path models can be solved as $\mathcal{O}(n \log n)$.

Harvest by harvester and forwarder is cheap, and the most common in Scandinavia (probably more than 90 % by volume).

Shortest path models may be too simple if e.g. main extraction trails are required.

Case study

The infrastructure program (Kystskogbruket)

A study to optimize:

- location of quays
- upgrade of public road bottlenecks
- which forest roads to prioritize

in Coastal Norway.

Case study

The infrastructure program (Kystskogbruket)

Harvesting costs were calculated on a $16\,\text{m} \times 16\,\text{m}$ grid.

Available volumes in three cost classes were aggregated at municipality level.

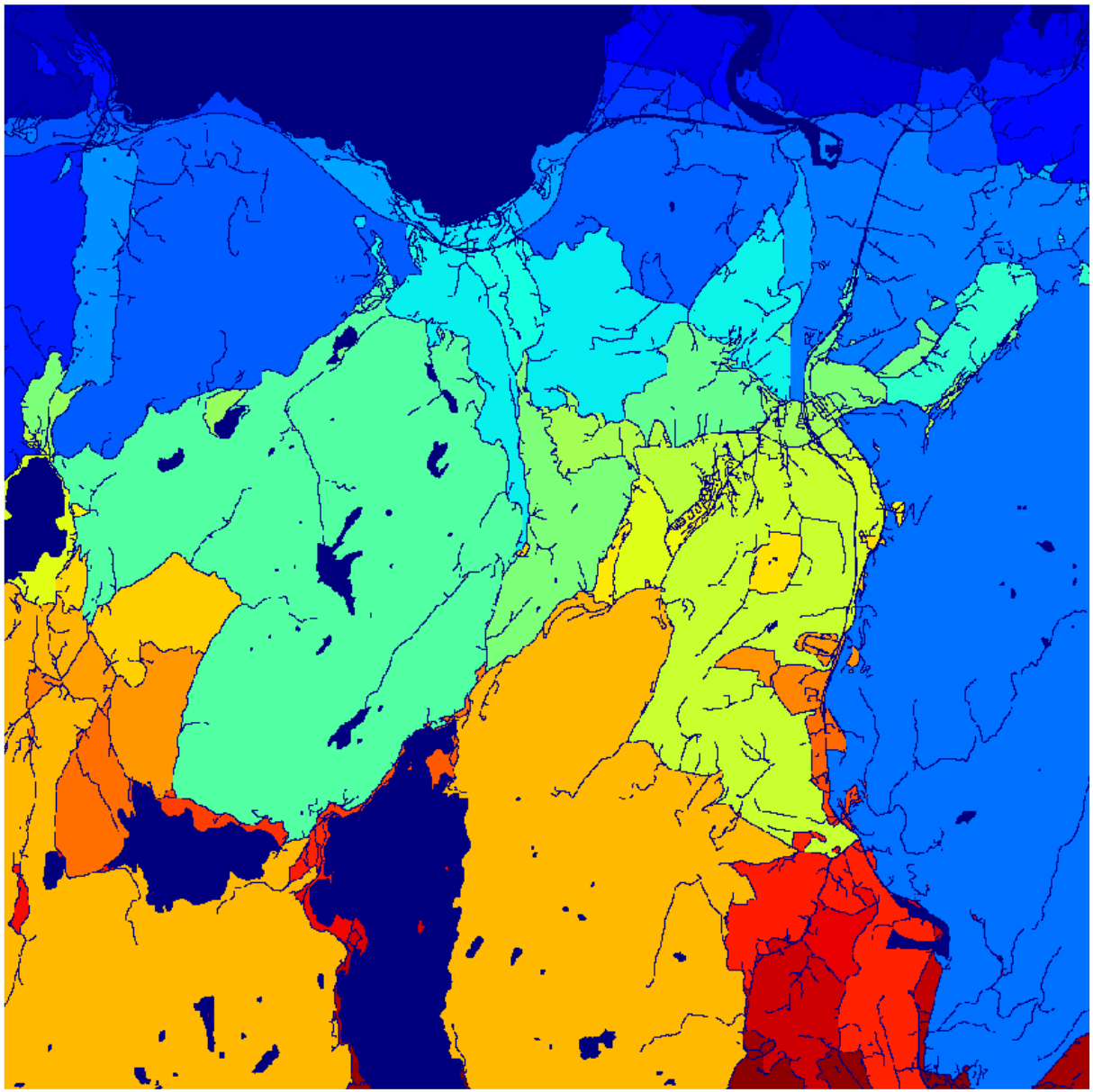
A report was published: Nørstebø et al. (2015).

(A scientific paper is forthcoming.)

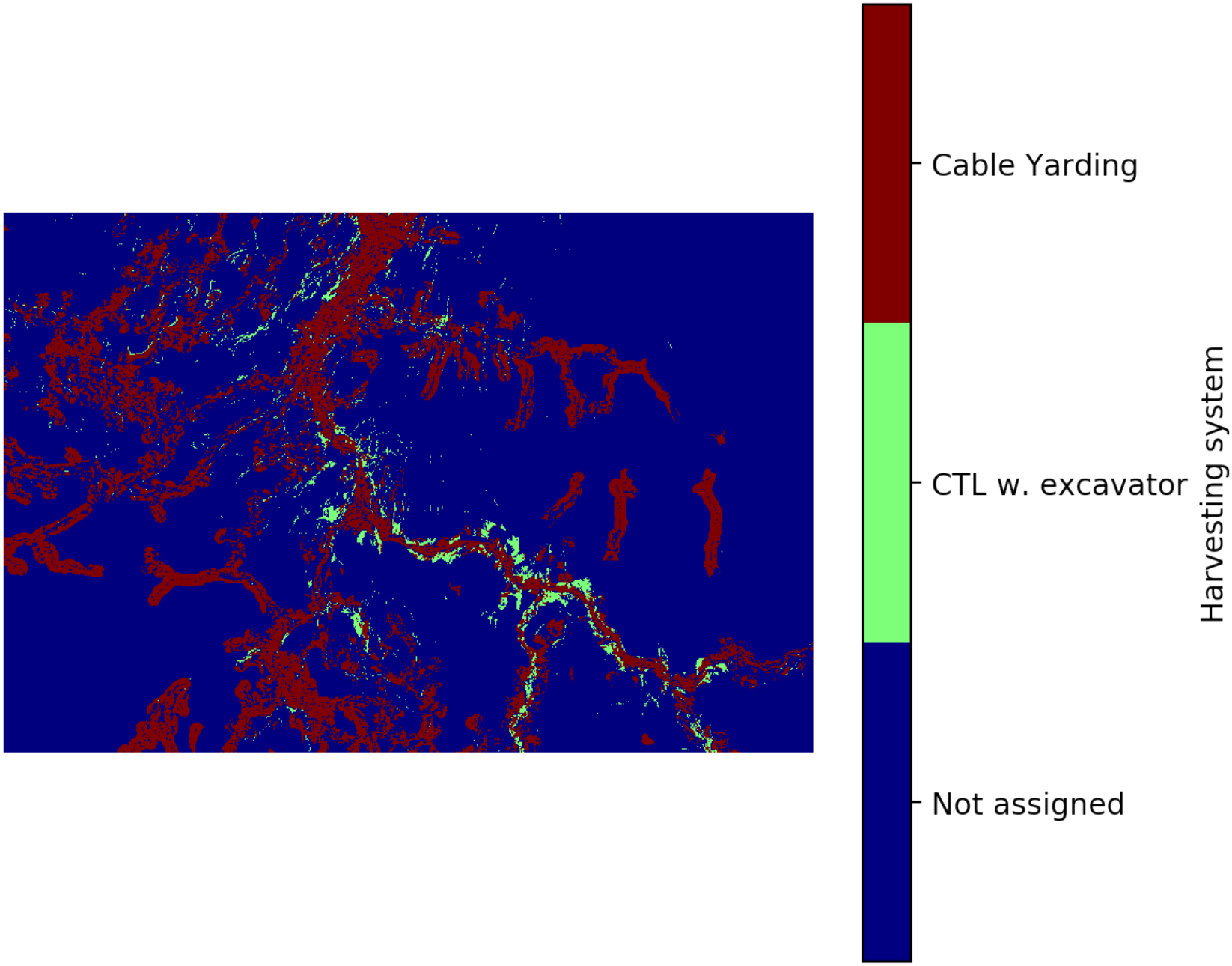
Some stats

- Number of labeled pixels: 476,765,258 (12 million ha)
- Number of pixles suitable for spur roads: 3,117,256 (78,000 ha)
- Number of pixles suitable for CYS: 95,566,910 (2.4 million ha)
- Number of pixles Variable forwarding cost $<$ \$ 40: 350,118,069 (9 million ha)

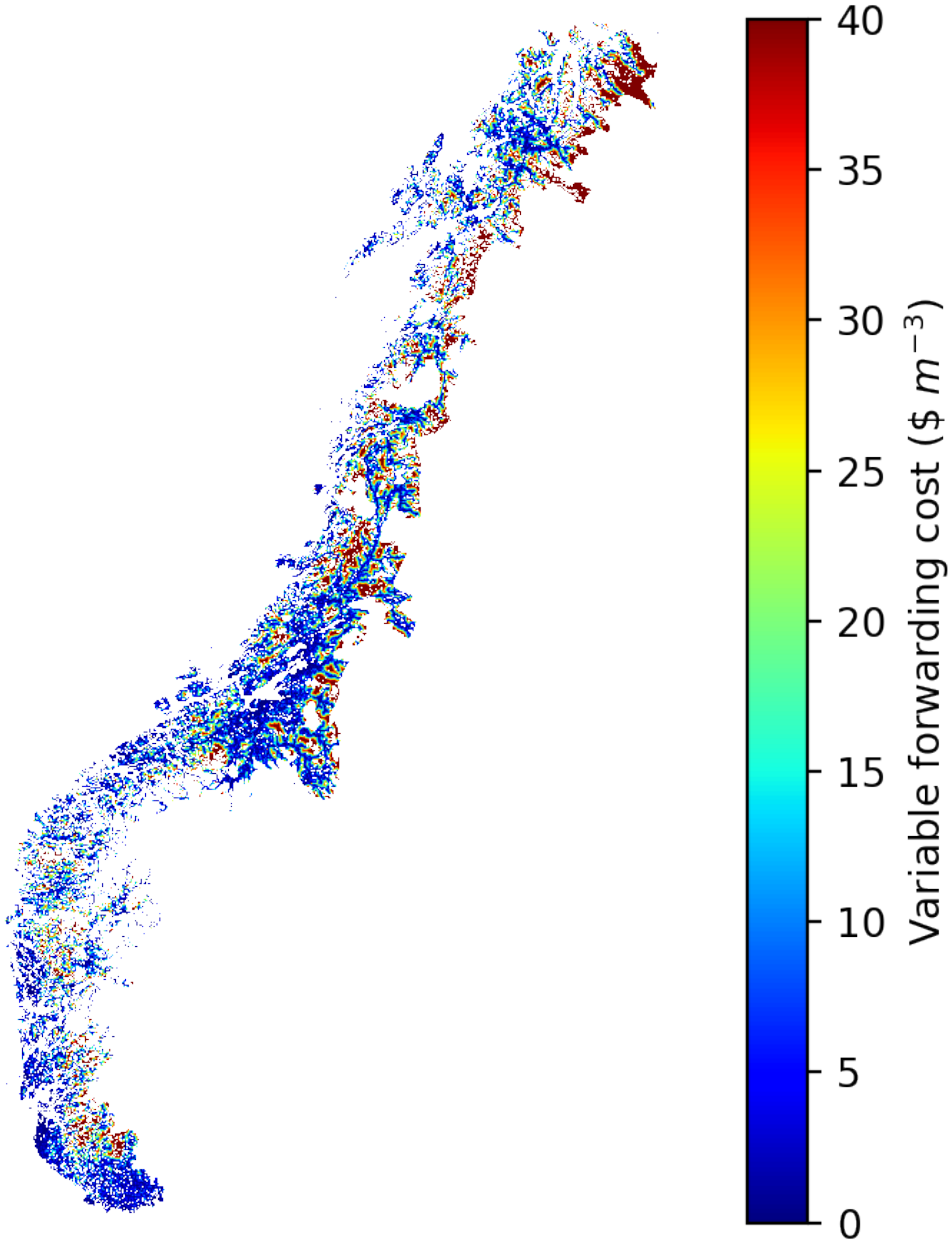
Polygons for Shortest Path Algorithm



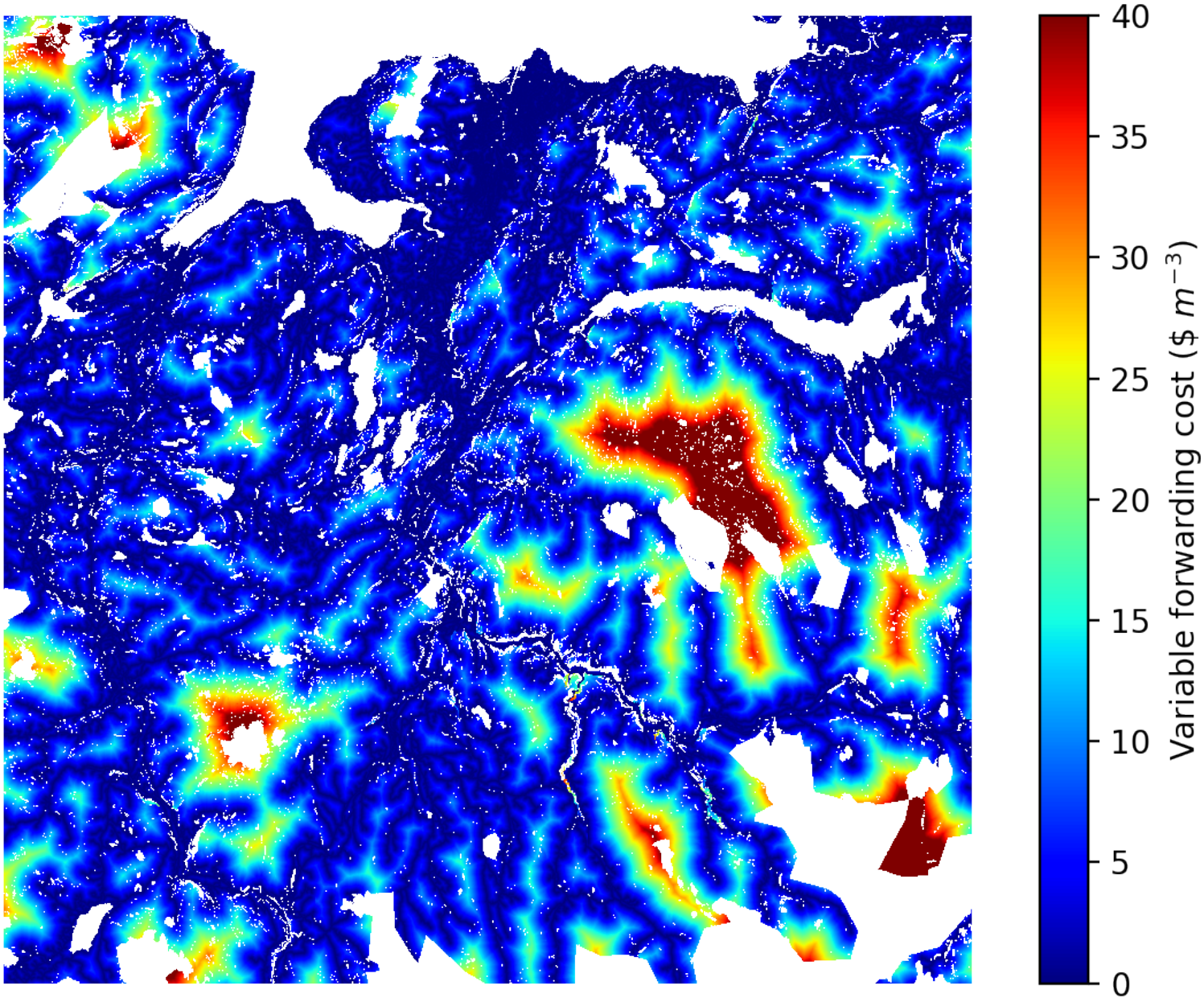
Possible harvesting system



Variable forwarding cost



Variable forwarding cost



Spur road model

In some areas, spur roads may reduce the cost of harvesting operations, but require soil that can be excavated.

Simple heuristic: Include all areas with soil, compare with shortest path and drop non-profitable areas.

This is basically one iteration of a drop-routine of (Feldman et al., 1966), e.g. used by Dykstra (1976).

Cable yarding model

Cable yarding operations are usually modeled as facility location problems (and hard to solve).

Here, the cable yarding model was simplified.

Cable way locations were not sought, but rather a cost based on shortest straight line distance to truck road.

Final observations

- Lookup tables are nice.
- Shortest path algorithms are fine (but need thoughtful programming (hacks)).

- What is the quality of the input data?
- Productivity functions at this level are hard to find.

Thanks for your attention.

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