Economic impacts of harvesting with spatial and size constraints

Mauricio Acuna
AFORA, USC, Australia
macuna@usc.edu.au

Glen Murphy
G.E. Murphy & Associates

Outline

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Background – Sustainable forest operations

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1. Many challenges exist for the harvest of industrial plantations (mechanisation, public perception, etc.)
2. Increasing social pressure to reduce clearfelling as one of the strategies to balancing the social, economic, and environmental use of the land
3. In some countries, this balance has been achieved by new voluntary regulations promoted by certification systems, which involve spatial and size constraints to harvesting.

Background – Limits to clearfelling

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1. National limits to clearfelling areas:
   - USDA Forest Service: Oregon (49 ha), Washington (50 ha), California (8.1 ha), South (no limits)
   - Canada: 40 ha (BC), 260 ha (Quebec)
   - Tasmania: 50 ha (slope > 20%), 20 ha (slope < 20%)
   - Chile, Brazil: 0 ha
2. Limits established by certification systems:
   - SFI: maximum avg. size (48.5 ha) with green-up periods of 3 years or 1.5 m height
   - It varies with FSC: Southern USA (avg. 16.2 ha, max. 32.4 ha)
   - Forest company must propose a limit (Chile, Brazil)

Background – ARM and URM models

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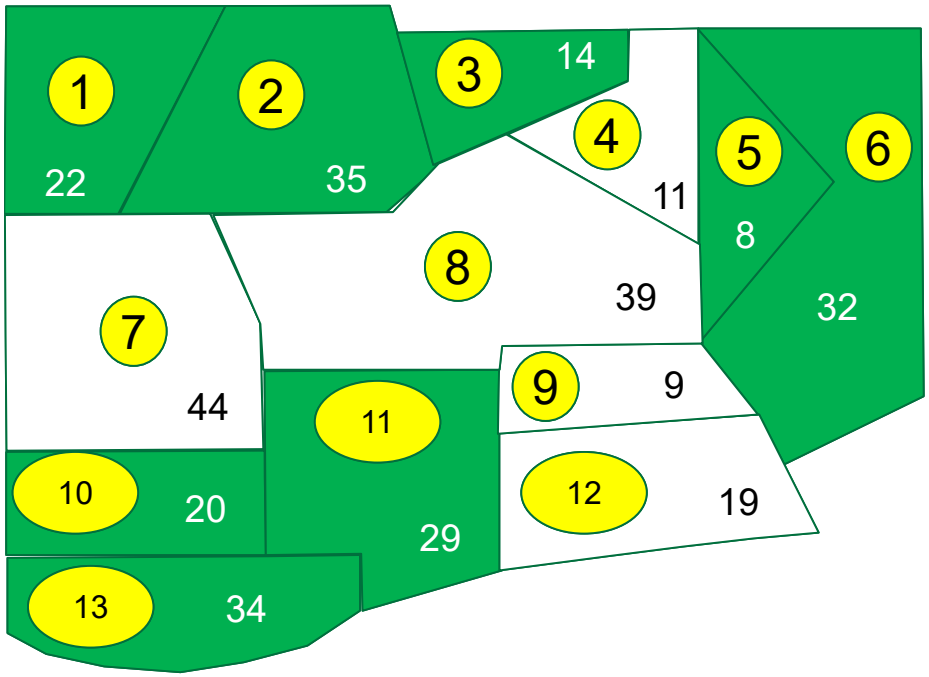
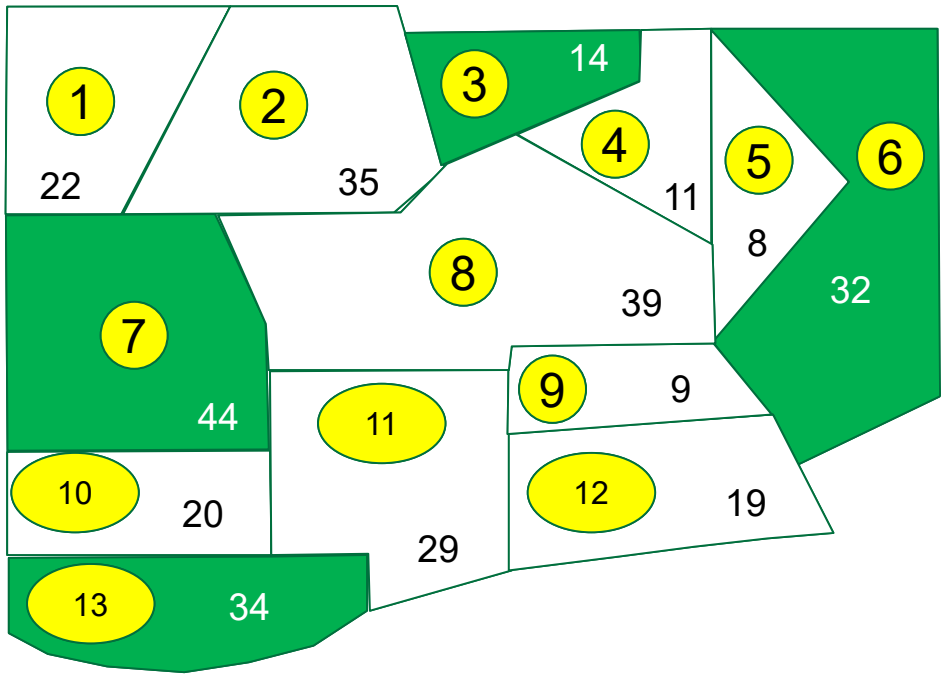
Area restricted model (ARM)



Max. opening area (MOA) = 100 ha
Optimal solution = 194 ha (40, 71, 83 ha)

Unit restricted model (URM)



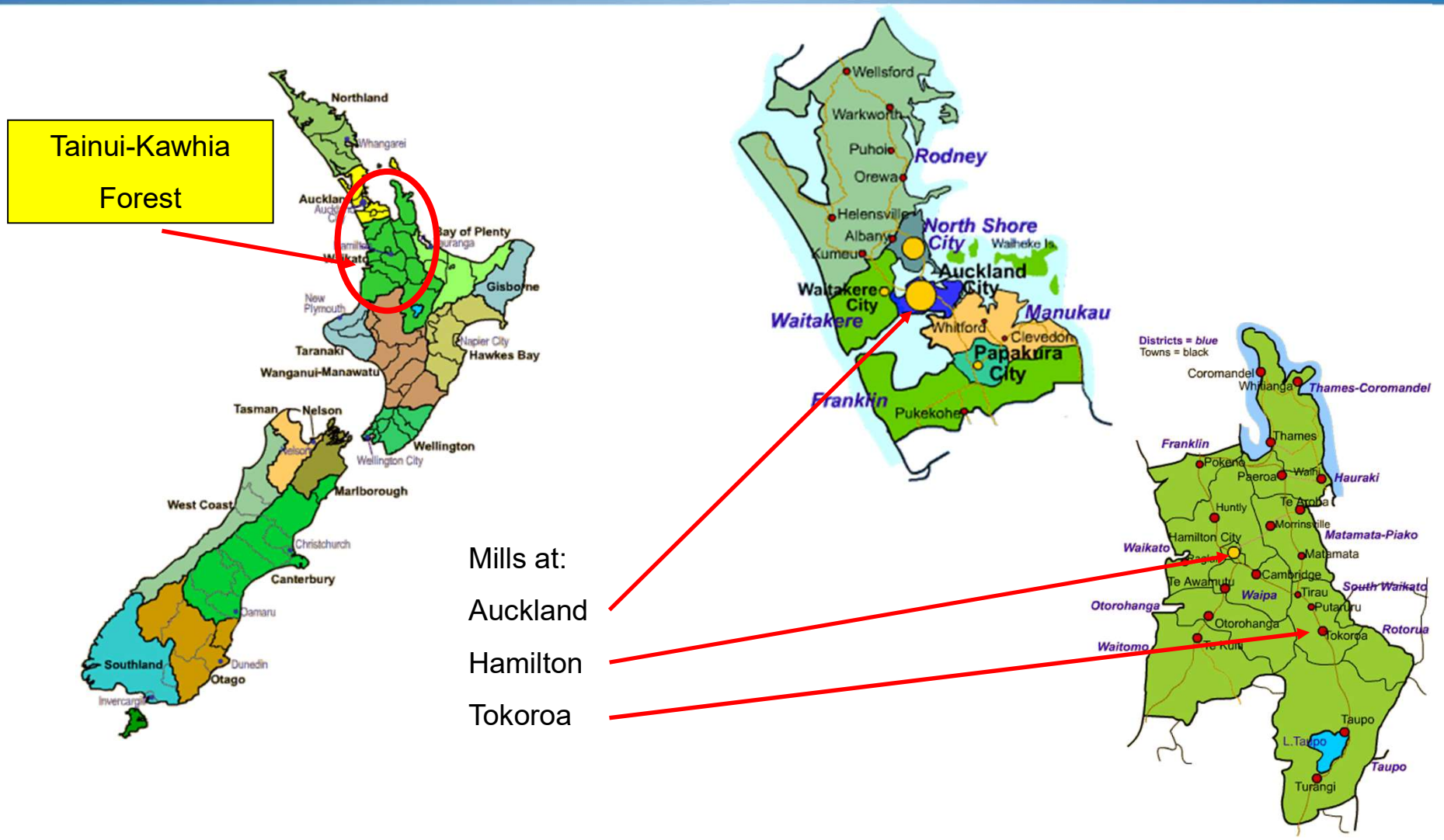
Optimal solution = 143 ha

Source: Acuña & Niklitscheck (2015)

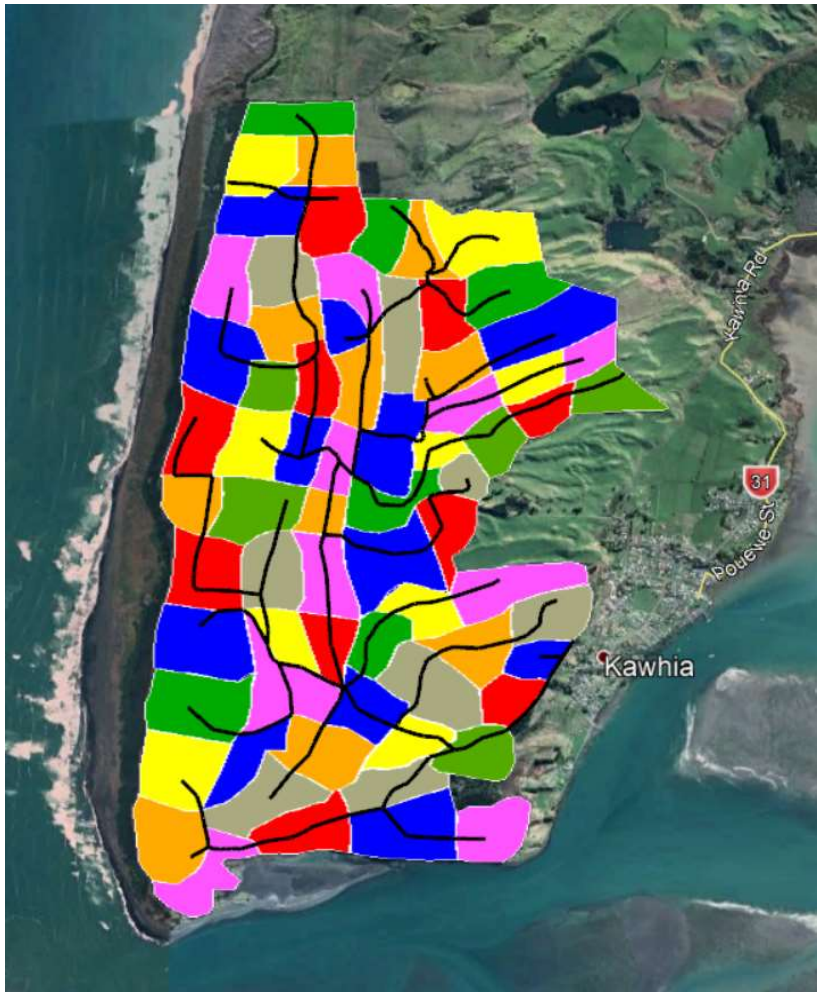
Objectives

1. Develop a tactical optimisation tool to quantifying the impact of spatial and size (MOA and green-up) constraints to harvesting on:
   - The financial value of industrial plantations (NPV)
   - Harvest areas and volumes
   - Harvest and road scheduling
   - Coupe aggregation
   - Product distribution (not presented here)
   - Harvesting productivity and equipment relocation costs (next task, not presented here)

Methodology – Location of the study (North Island of NZ)

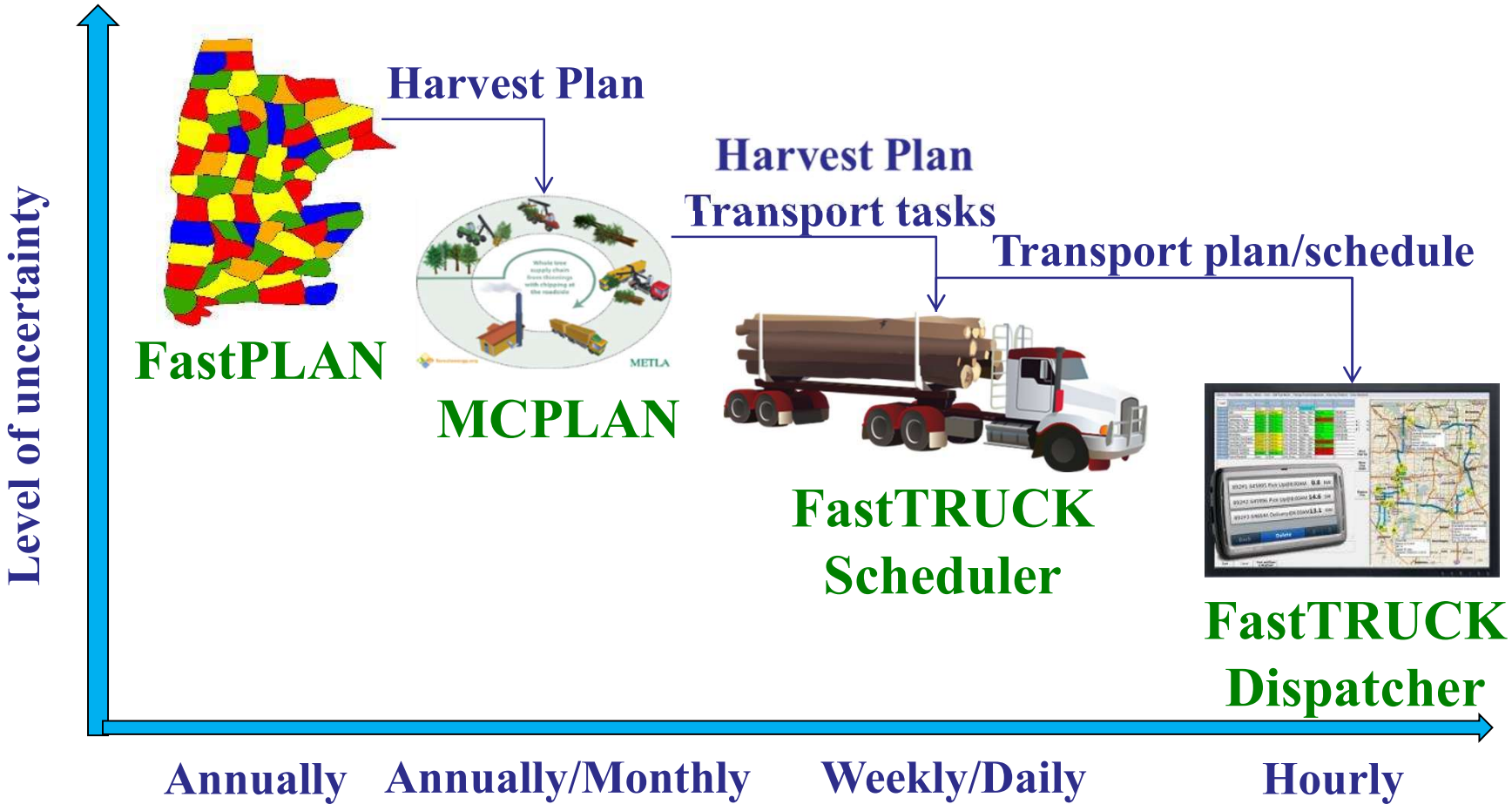


Methodology – Data set & analysis

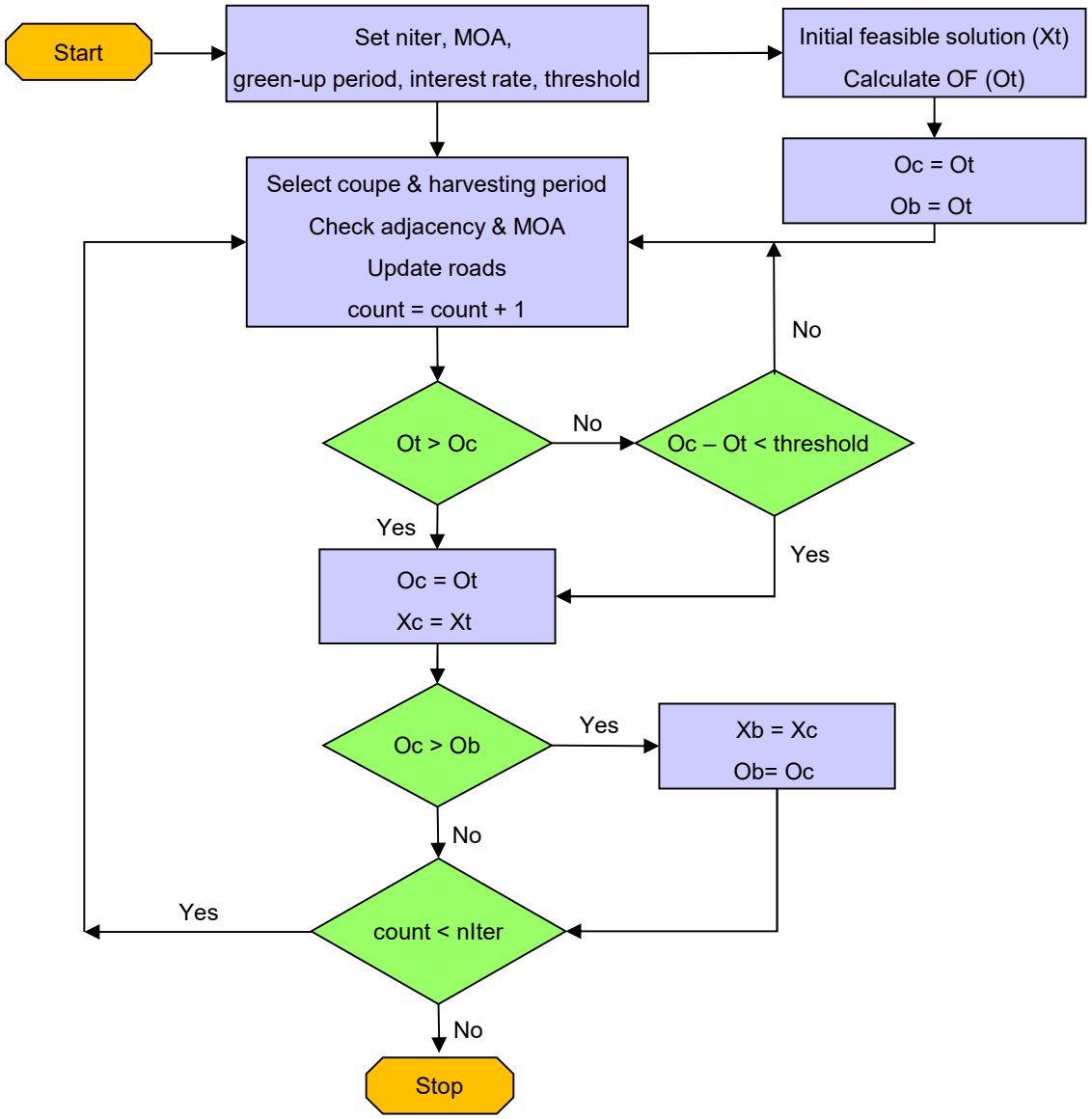


1. 70 forest coupes (Radiata pine) – area & volume per product per period (5 planning periods)
2. 95 road links - variable & fixed costs
3. Logging and landing costs
4. 4 products (veneer logs, pruned sawlogs, sawlogs and pulplogs) & their price per m^3
5. Adjacency list
6. 18 Scenarios (combinations of 6 MOA and 3 green-up periods)
7. Spatial analysis in ArcMap

Methodology – Implementation (FastPLAN optimisation tool)



Methodology – Optimisation algorithm (threshold accepting TA)



TA algorithm implemented in FastPLAN with C++ and Qt.

Objective function: Max. NPV (profits)

Subject to: MOA and green-up constraints

Includes decisions about when to harvest units and build/improve road links

Out of the scope: Water quality, visual and other environmental constraints

Results – Impact on harvest scheduling

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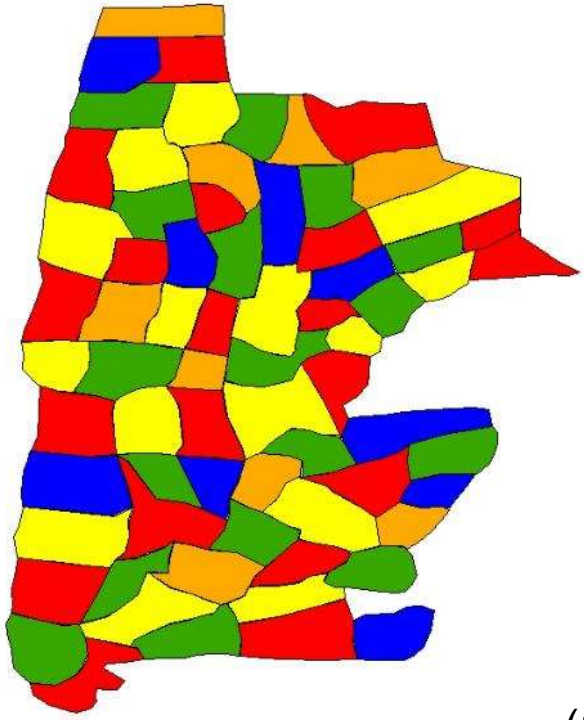
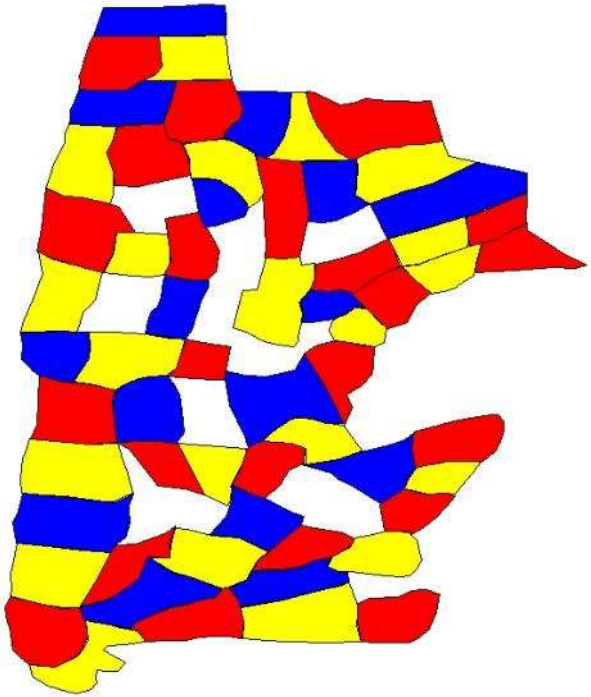
Green-up = 1 period

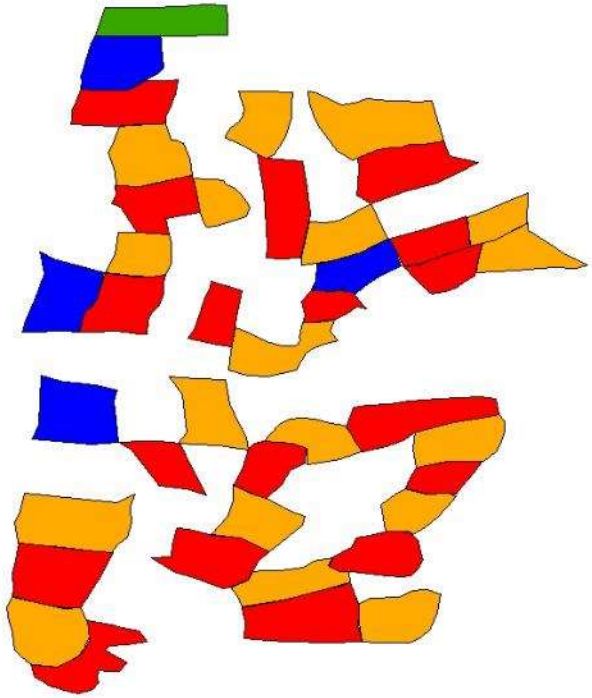


Green-up = 2 periods



(10 units not harvested – 14.2%)

Green-up = 3 periods



(29 units not harvested – 41.4%)

Period 1 Period 2 Period 3
Period 4 Period 5

MOA = 21 ha

Results – Impact on harvest scheduling

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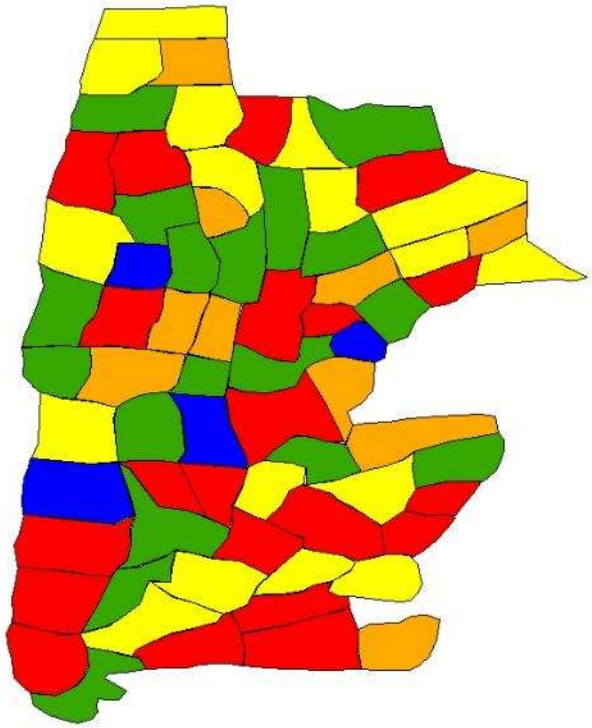
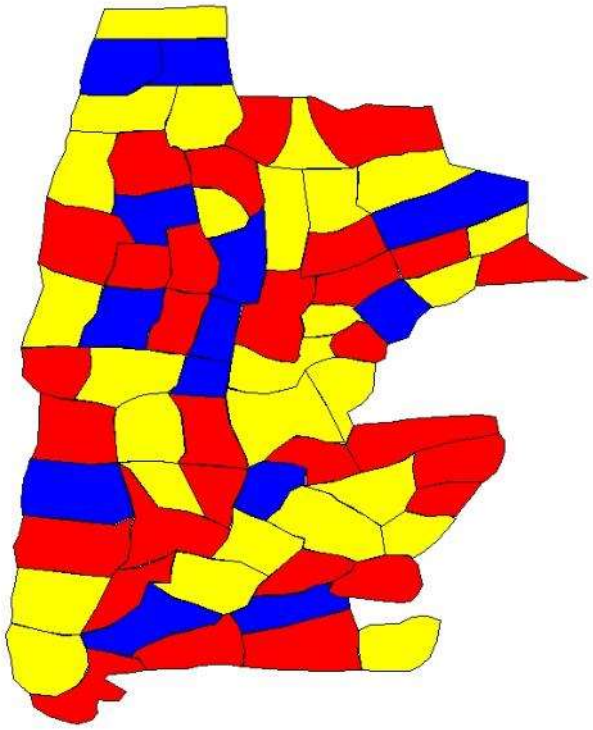
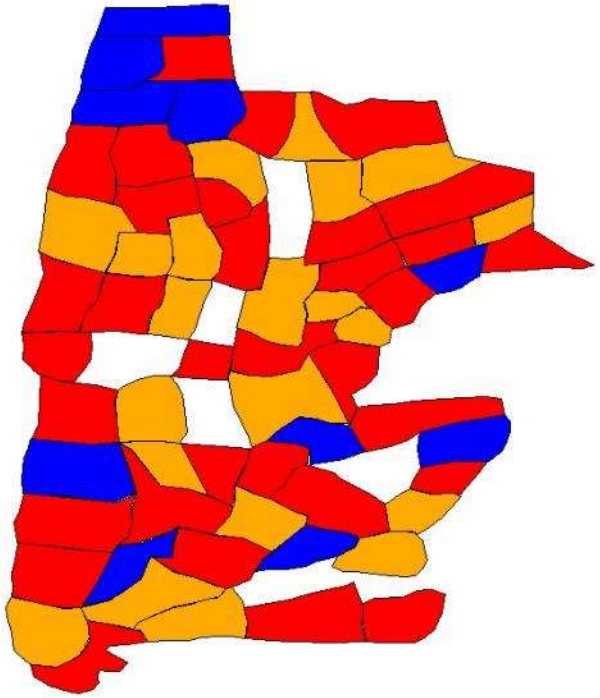
Green-up = 1 period



Green-up = 2 periods



Green-up = 3 periods



(6 units not harvested – 8.5%)

Period 1 Period 2 Period 3
Period 4 Period 5

MOA = 60 ha

Results – Impact on harvest scheduling

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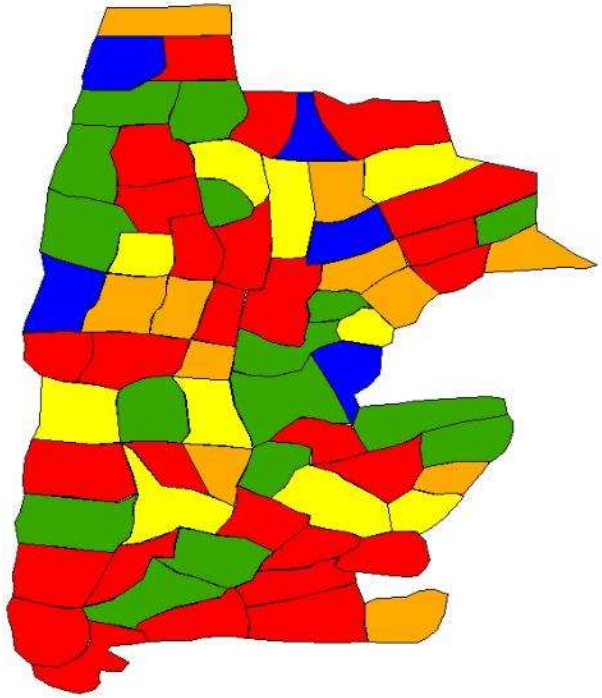
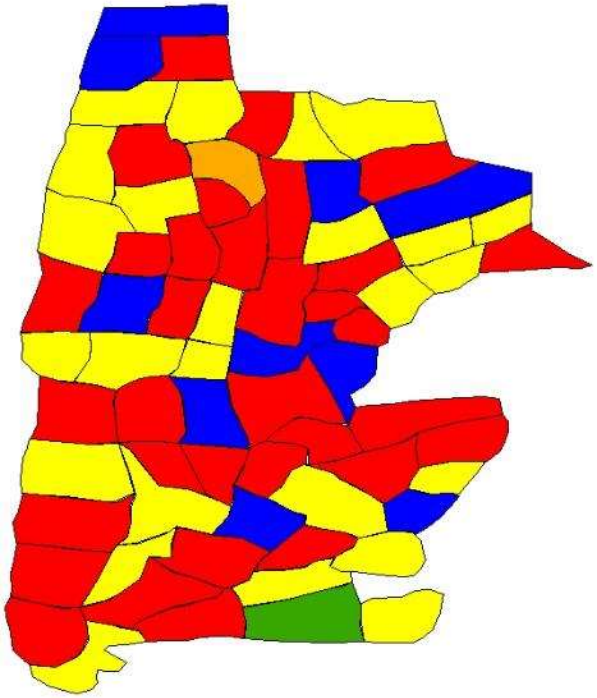
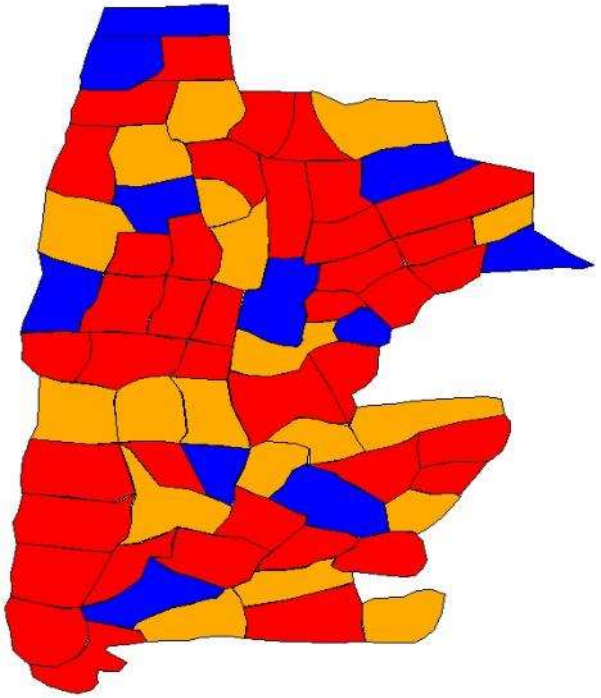
Green-up = 1 period



Green-up = 2 periods



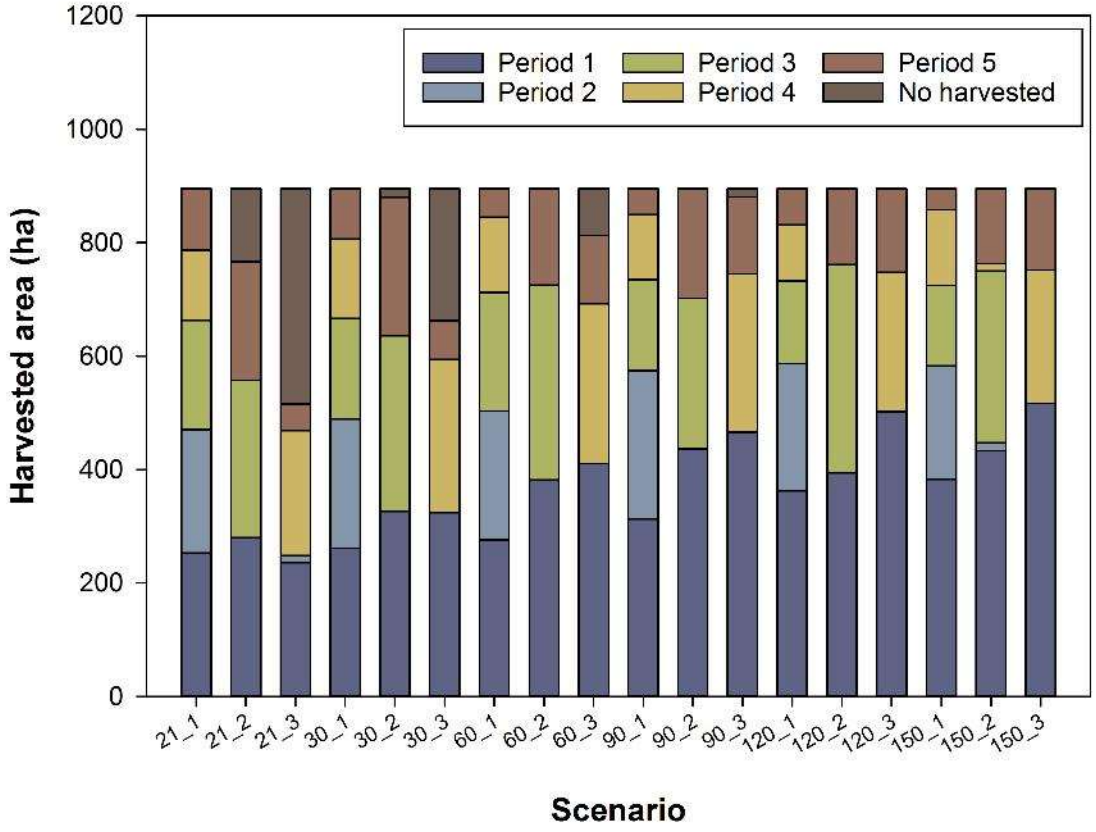
Green-up = 3 periods



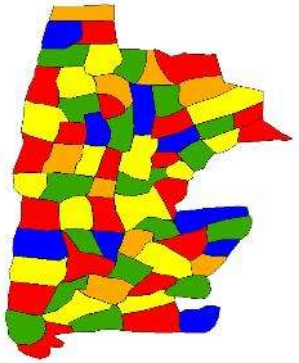
Period 1 Period 2 Period 3
Period 4 Period 5

MOA = 150 ha

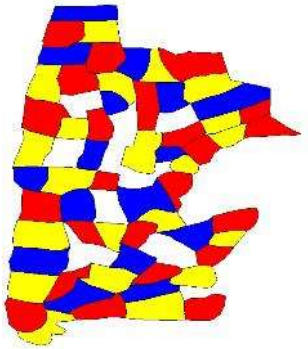
Results – Impact on harvest area per period



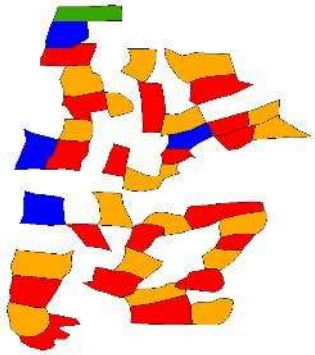
MOA = 21 ha
Green-up = 1 period



MOA = 21 ha
Green-up = 2 periods

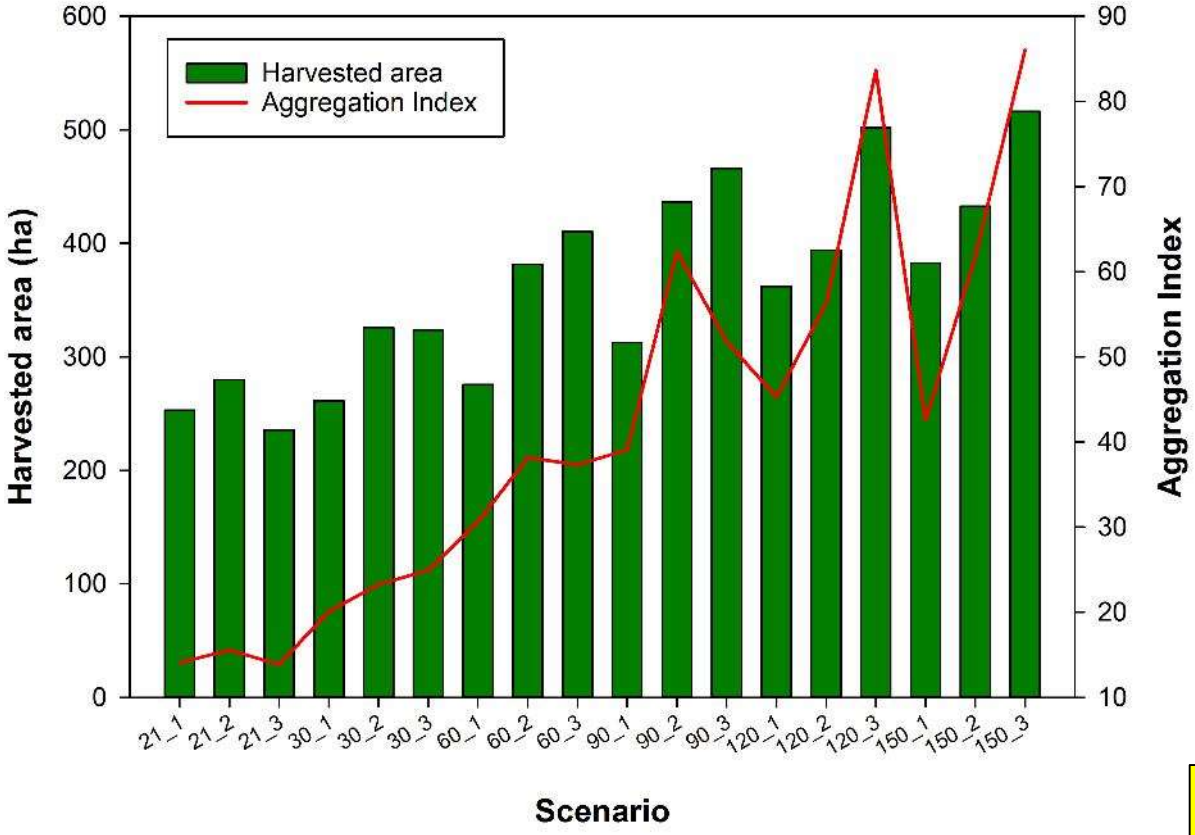


MOA = 21 ha
Green-up = 3 periods

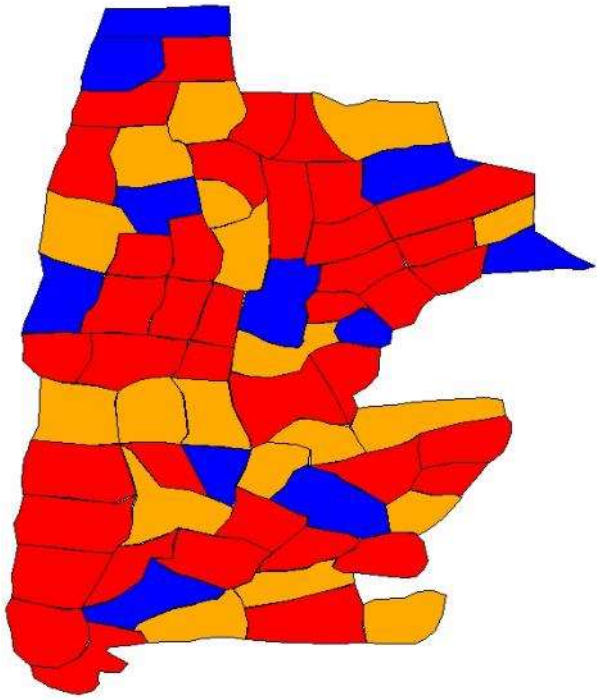


On average 40% of the area is harvested in Period 1 (ranging from 26% in Scenario 21_3 to 57% in Scenario 150_3)

Results – Impact on coupe aggregation (Period 1)

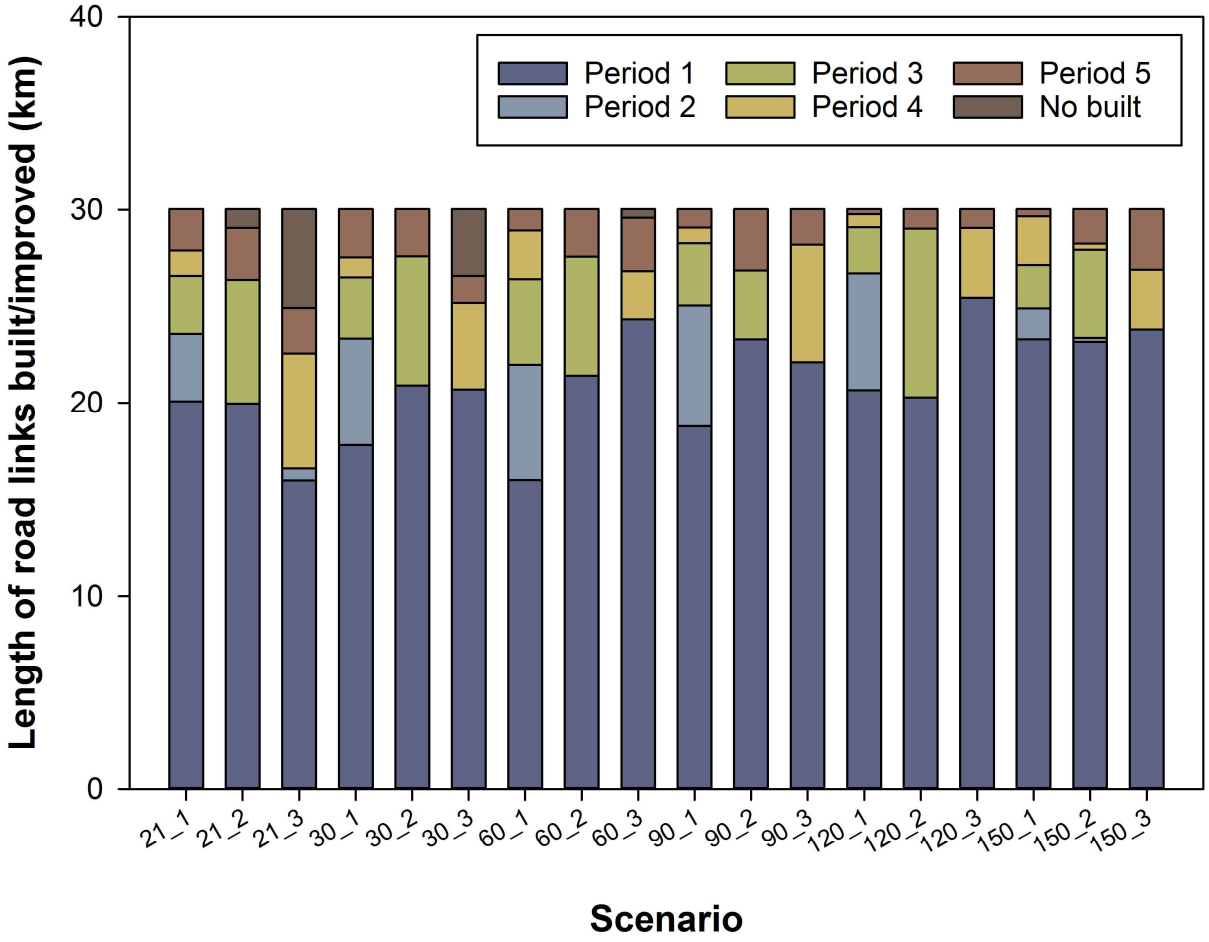


MOA = 150 ha
Green-up = 3 periods



Harvested area = 516 ha
Adjacent groups = 6
Aggregation Index = 86

Results – Impact on road scheduling



Road network: 30 km

On average 70% of the road links are built/improved in Period 1 (ranging from 53% in Scenario 21_3 to 85% in Scenario 120_3)

In some scenarios, some road links are never built/improved

21_2: 1.0 km
21_3: 5.1 km
30_3: 3.5 km
60_3: 0.5 km

Results – Impact on road scheduling (MOA = 21 ha)

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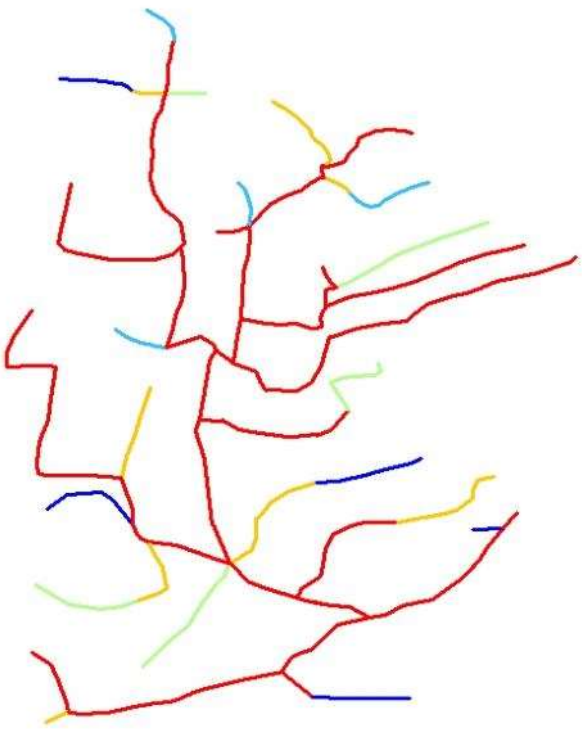
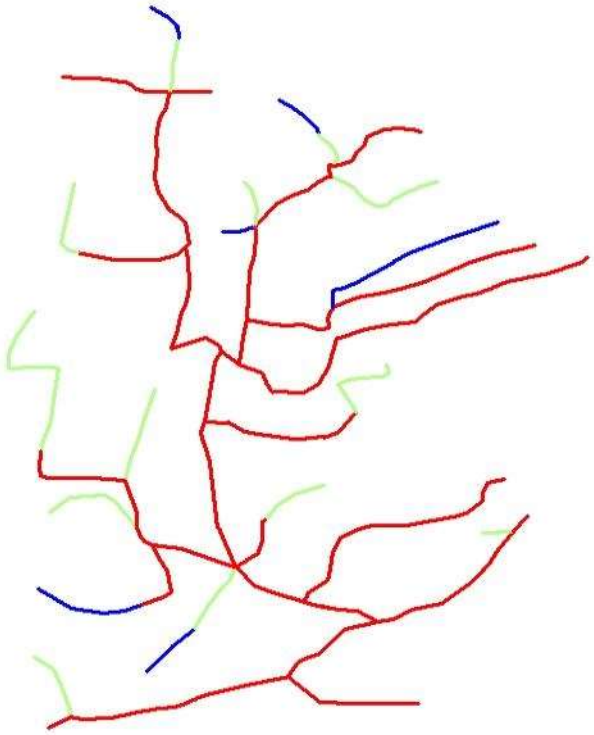
Green-up = 1 period



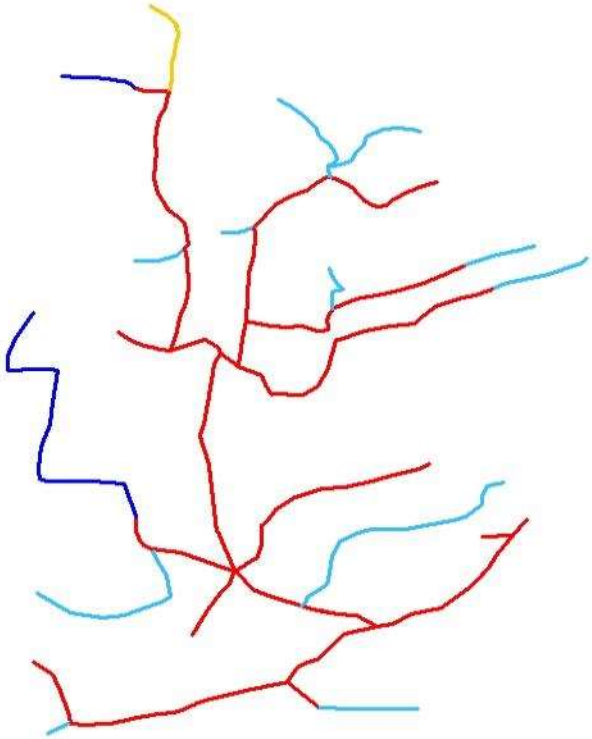
20.1 km (67%) in Period 1

Green-up = 2 periods



20.0 km (66%) in Period 1

Green-up = 3 periods

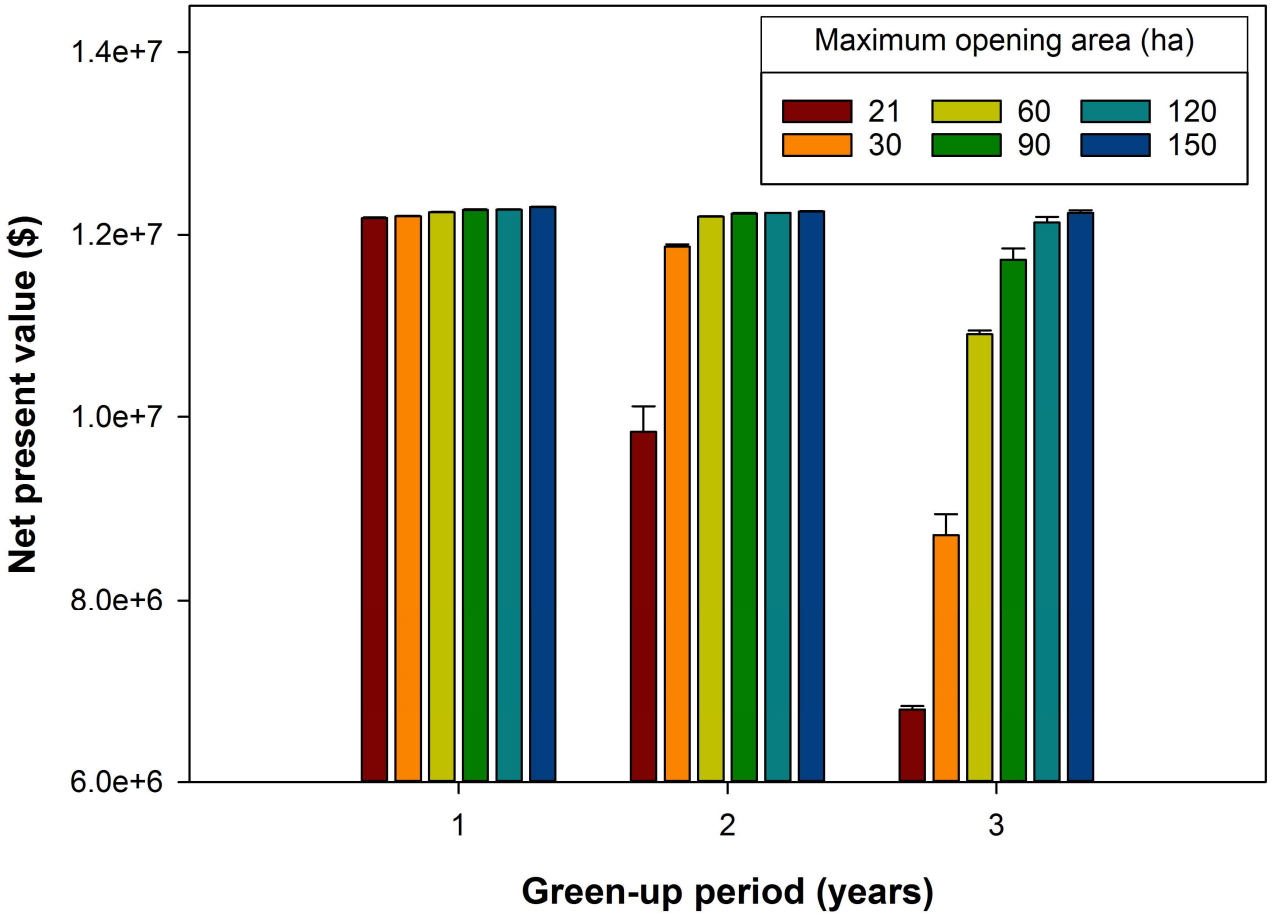


16 km (53%) in Period 1

Period 1 Period 2 Period 3

Period 4 Period 5

Results – Impact on NPV

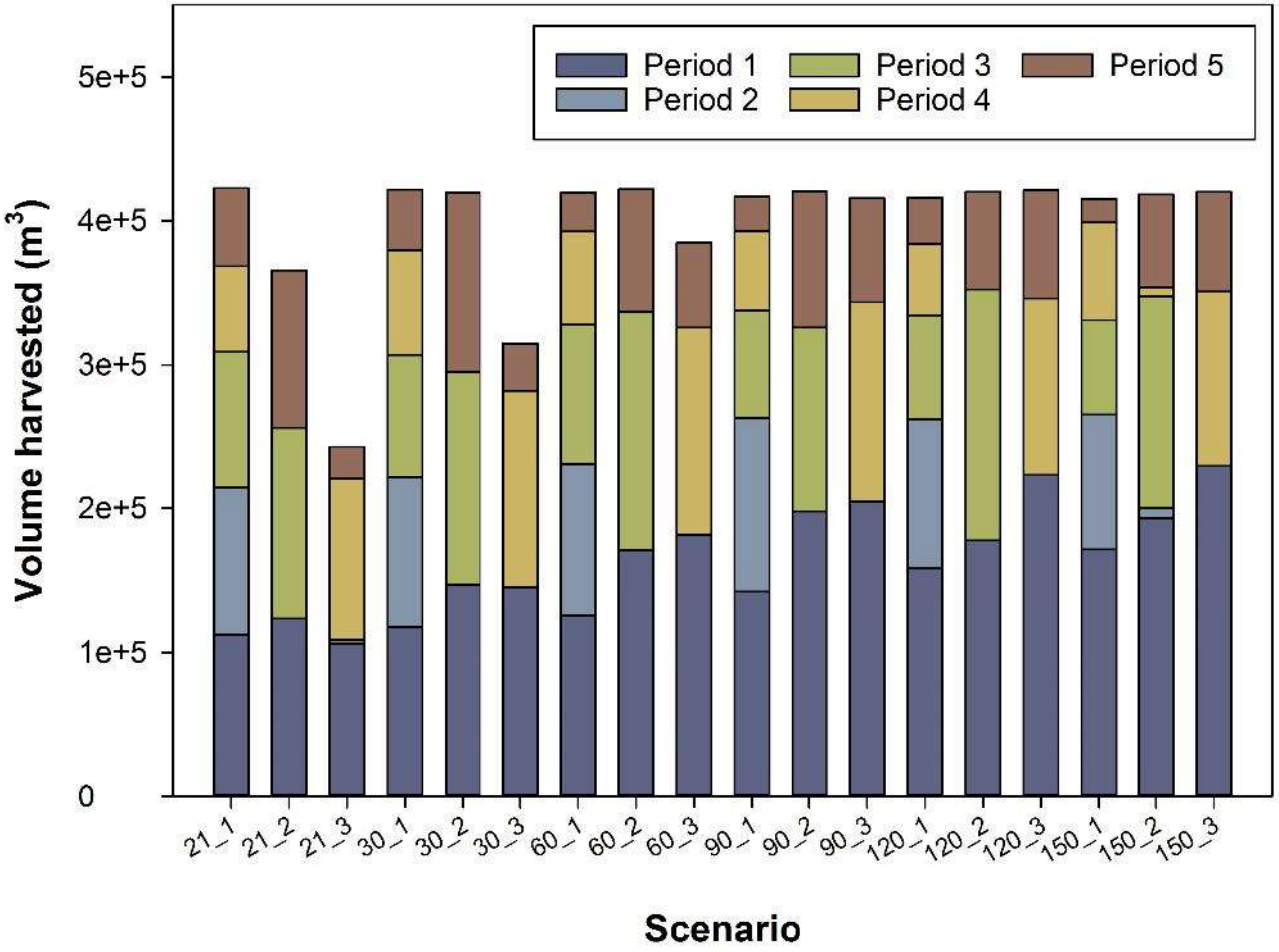


Minor impact on NPV across MOA scenarios when green-up = 1 period

Regardless of the green-up period, there is a minor impact on NPV when MOA > 90 ha

Major impacts on NPV occur when MOA < 90 ha and the green-up period > 1 period (up to 43.6% reduction in NPV)

Results – Impact on harvest volume per period



On average, the total volume harvested per scenario was about 399,000 m^3 (ranging from 243,290 m^3 in Scenario 21_3 to 422,500 m^3 in Scenario 21_1)

About 40% of the total volume was harvested in Period 1, and only 8% in Period 2

Substantial reductions in volume harvested in Scenarios 21_3 and 30_3

Summary

1. The addition of spatial and size constraints to harvesting may have substantial financial impacts, specially when MOA is < 90 ha (reductions in NPV of up to 43.5%). This is the result of reduced harvested areas and volumes.
2. The aggregation of harvest units increases with MOA and green-up period (this effect might have important effects on the economics of the harvesting operations)
3. Future research will include other values (e.g. water quality, visual impacts), other landscapes, and implications of spatial and size constraints at operational level (e.g. machine relocation costs)

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