Forest Structure & Spatial Restrictions: Interactions & How They Affect Harvest Goal Achievement

Karl R. Walters
Forest Planning Manager

Forest Technology Group

Spatially explicit harvest scheduling

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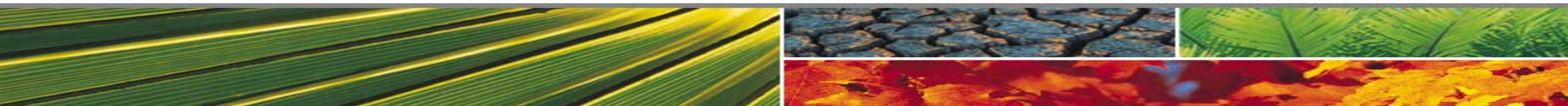
Stands are not spatially configured the way we would prefer them:

- Stands are smaller than harvest blocks
  - Harvest blocks must exceed minimum size to be economical
- Stands are larger than harvest blocks
  - Harvest blocks must not exceed some regulatory maximum opening size
- Forest structure is too dispersed
  - Costs are minimized by harvesting large tracts in close proximity
- Forest structure is too concentrated
  - Diversification of activities across a landscape is needed

Social and political limitations

- Societal demands lead to legal remedies or self-regulation
- Spatial restriction rules on opening size, adjacency, green-up



Stanley

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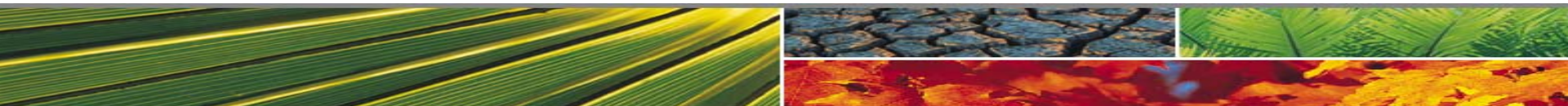
Based on a hierarchical approach to planning

- Solve strategic harvest schedule first
- Allocate subset of harvest schedule tactically
- Iterate as needed

Area-restriction model approach

- Block configuration is not an input but part of solution

Heuristic solution methodology



Stanley input parameters

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Opening size limitations on harvest blocks

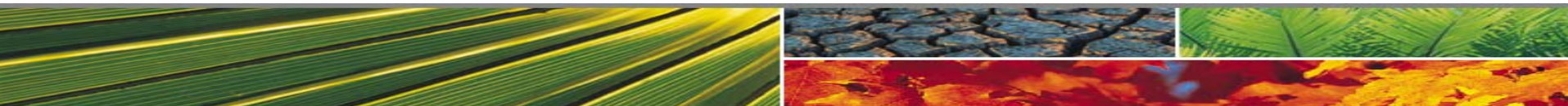
- Minimum feasible block size (economic considerations)=MINPARM
- Maximum allowable block size (BMP's, SFI, state law)=MAXPARM

Adjacency restrictions on harvest blocks

- Minimum buffer distance (proximity to contemporary blocks)=PROX
- Greenup (period to elapse before cutting adjacent block)=GREENUP

Adjustments to strategic plan for spatial feasibility

- Deviations from strategic timing choices=TIMEDEV
- % Variation relative to optimal flow profile=FLOWPARM



Stanley Input Parameters

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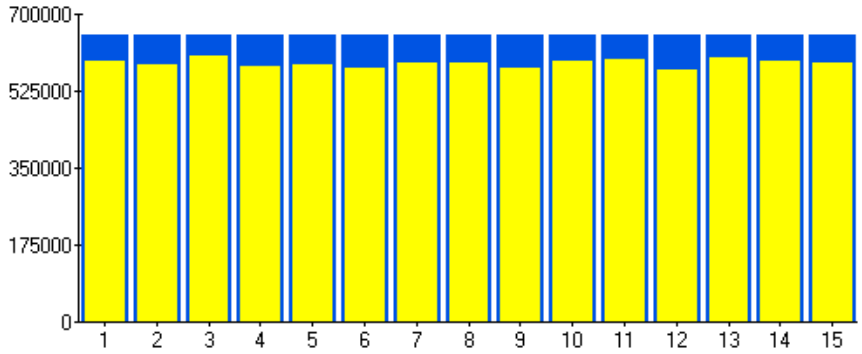
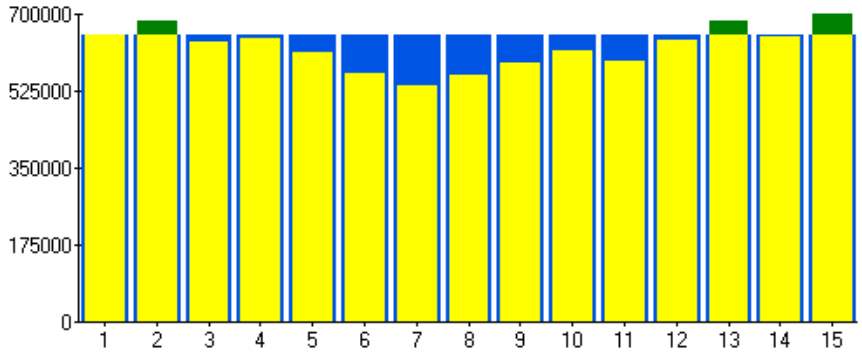
FlowParm

- Blue bars = strategic objective
- Yellow bars = achieved volume



Maximum % variation is lowest achieved % minus highest achieved %



Study Objectives

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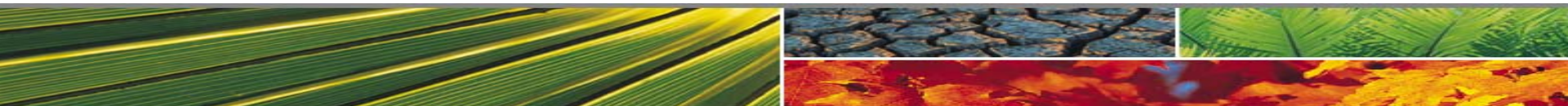
To quantify how forest structures interact with spatial restrictions

- Why is there such variety in results in the literature?
- Is there a reproducible metric that will predict how much of an impact spatial restrictions will have in a given forest?

To gain a better understanding of the process so as to improve implementation and/or affect policy

- How much difference would it make to increase minimum block size from 5ha to 10 ha? What is the impact of increasing the green-up interval by 1 year?

Today, we will examine how GREENUP, PROX, TIMEDEV and MINPARM together affect harvest level achievement



Experimental Design

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Forest structure

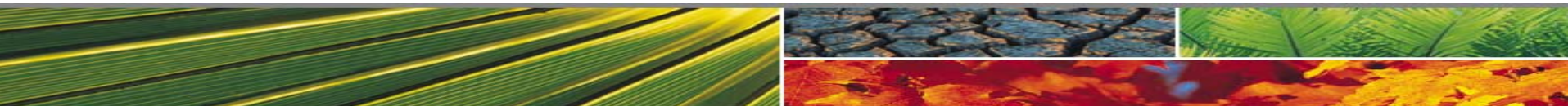
- 32,000 ha, uniform site quality, single species
- Uniform age-class distribution (1-40), 800 ha each
- Volume objective, non-declining flow constraint
- Minimum harvest age = 19

Planning horizon

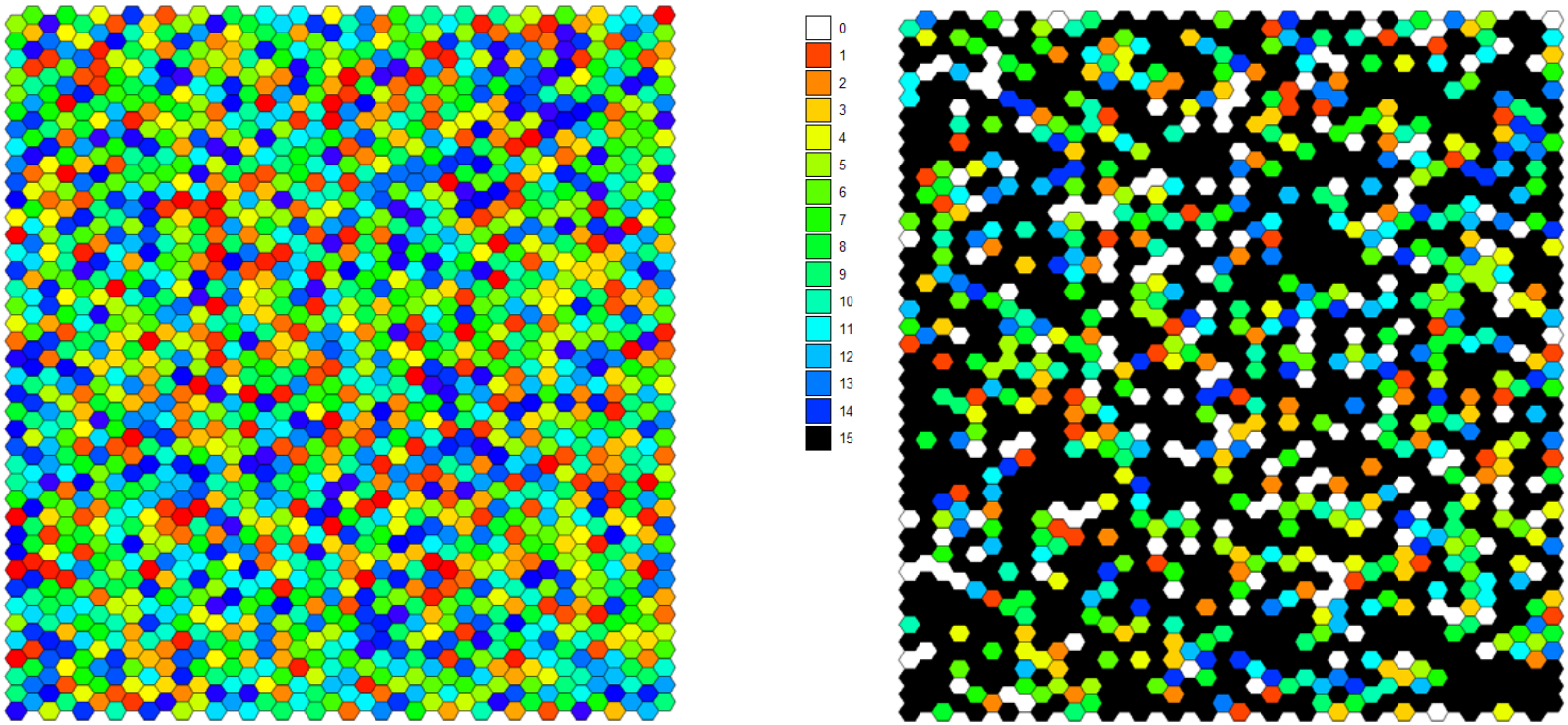
- Strategic = 80 yrs, tactical = 15 yrs

Varied spatial distribution of stands

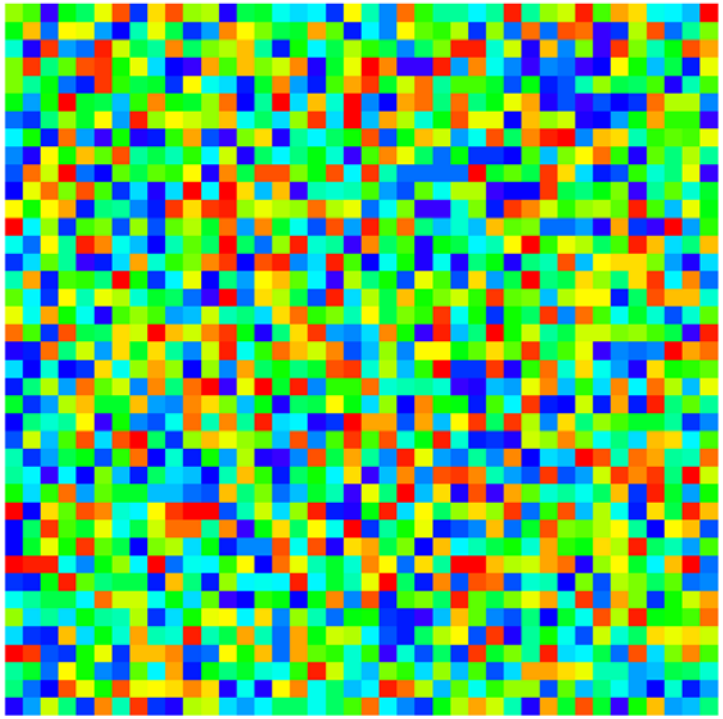
- Square or hexagon grids
  - 20 ha cells (1600 cells in a 40x40 grid of squares & hexagons)
  - 5 ha cells (6400 cells in a 80x80 grid of squares)

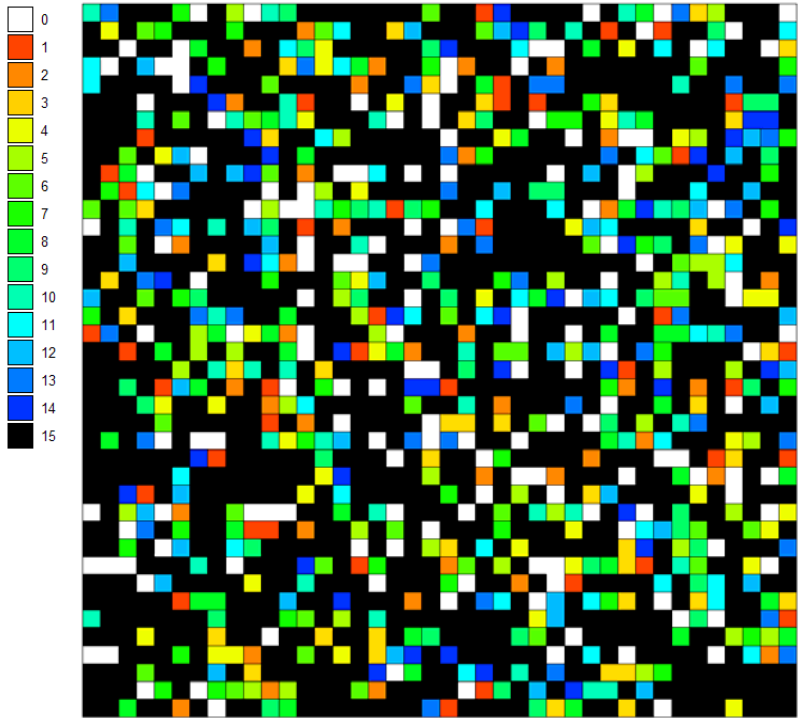


HX40R – 20 ha, random

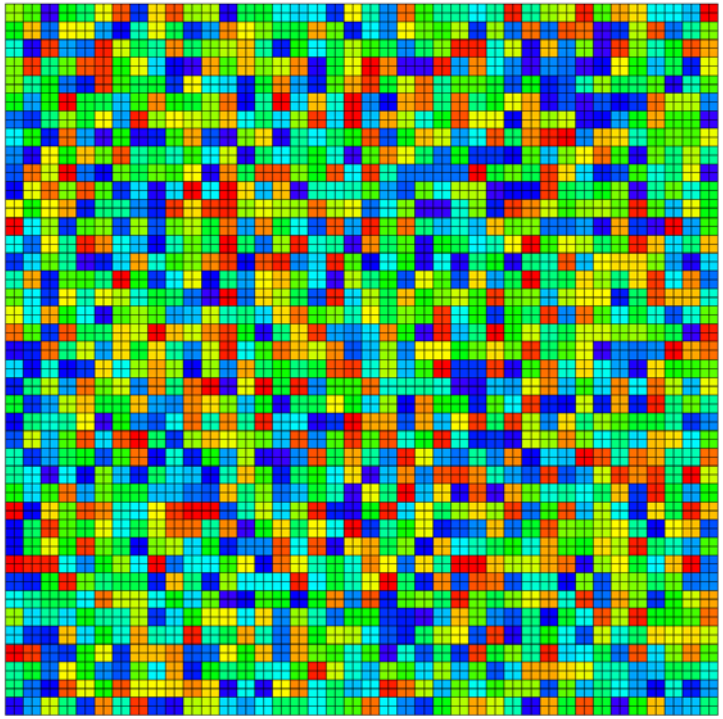


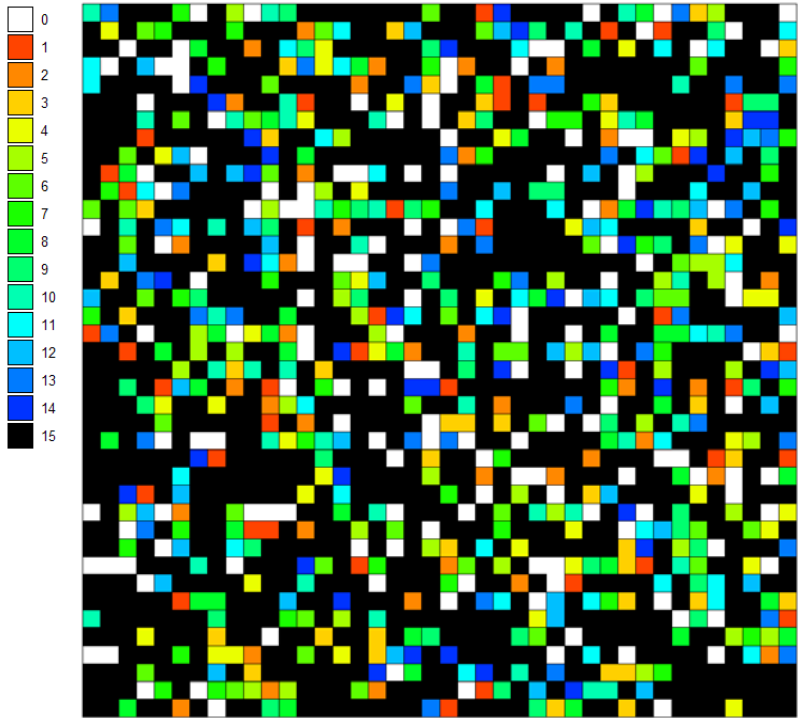
SQ40R – 20ha, random





SQ80R – 5ha, random





SQ40S – 20 ha, systematic-random

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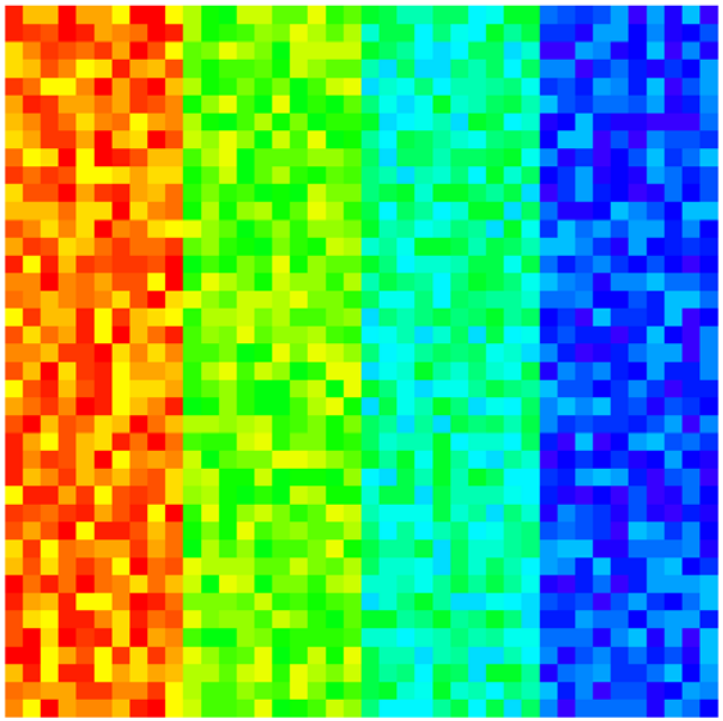
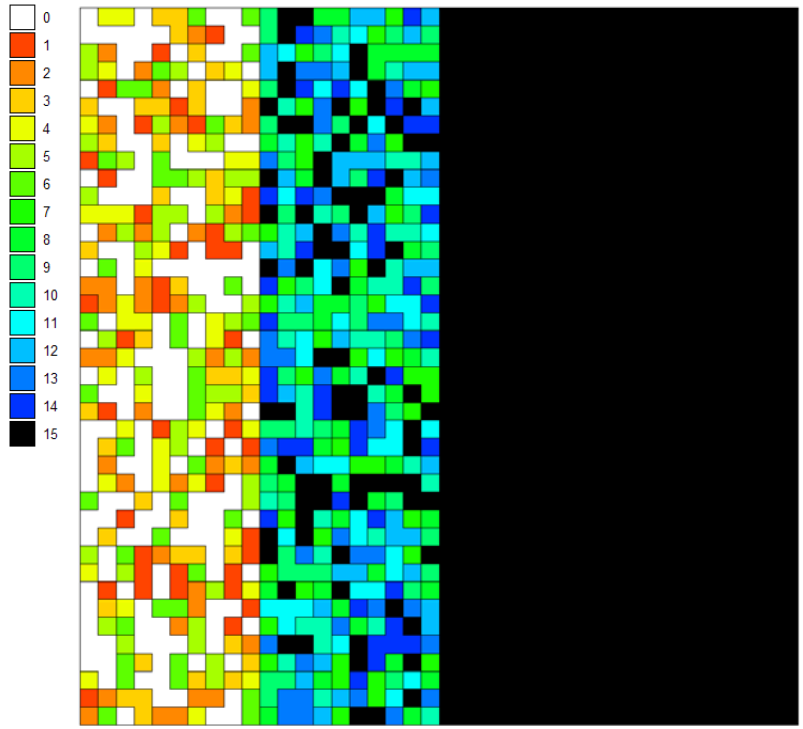
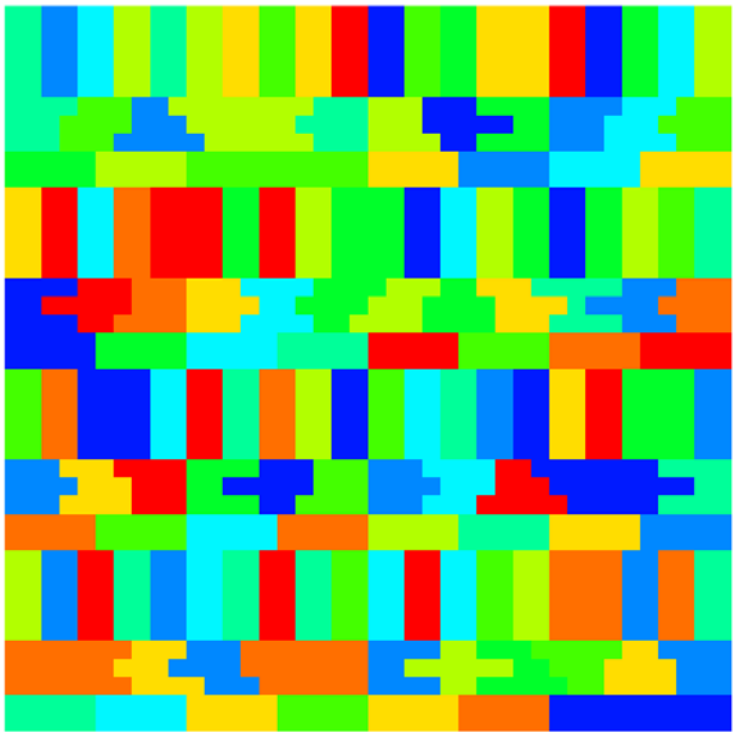
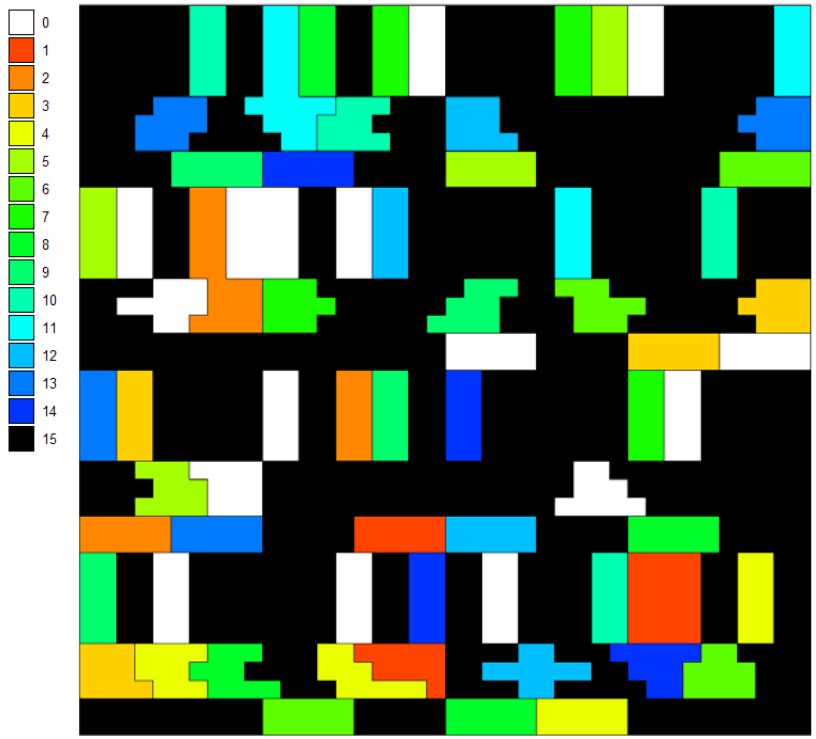


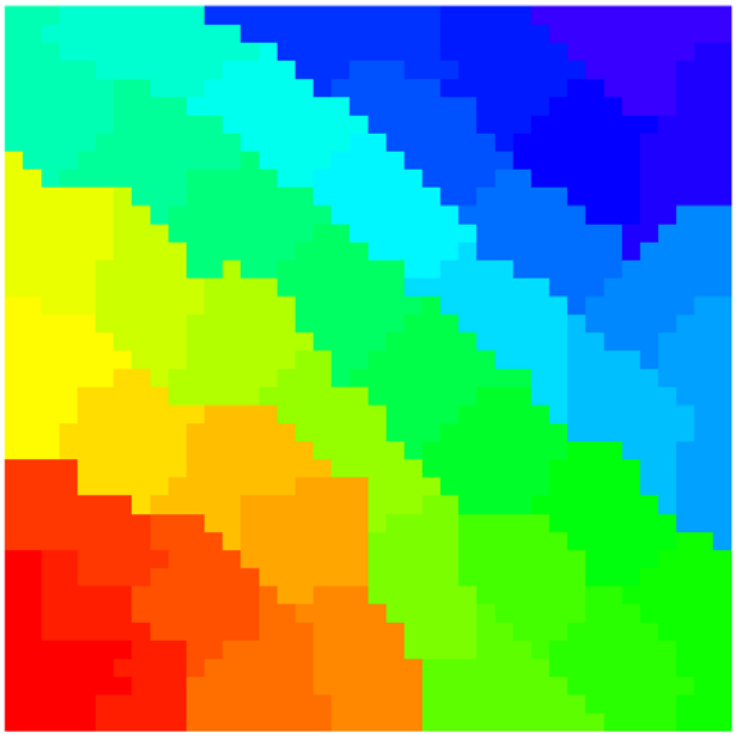


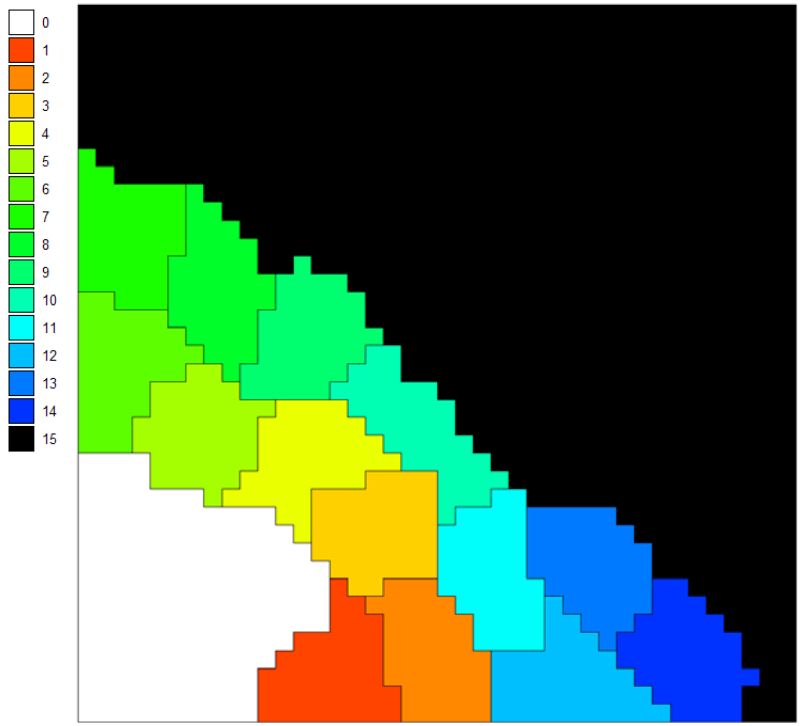
SQ40C – 20ha, clustered





SQ40CS – 20 ha, systematic-cluster





Experimental Design

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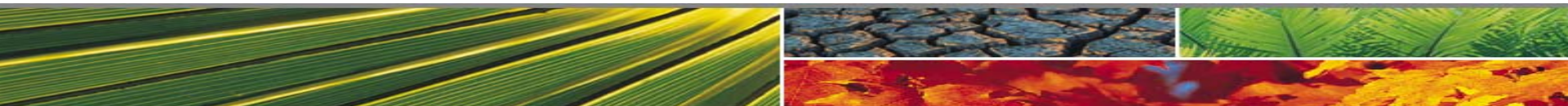
Stanley blocking and scheduling software, 15 year planning horizon

- PROX – 3 levels of proximity (adjacents, 2nd ring, 3rd ring)
- GREENUP – 3 levels of greenup interval (3, 4 & 5 years)
- MINPARM – 2 levels (minimum 20 and 40 ha blocks)
- MAXPARM – 3 levels (maximum 120, 180 and 240 ha blocks)
- TIMEDEV – 3 levels (±5, ±10, ±15 yr deviations from timing)
- FLOWPARM – 2 levels (5% & 10% variation about flow)

Factorial experiment

- 3888 obs. (6 factors x 54 levels x 2 replicates x 6 forests)



Ranking of Solutions

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Highest average harvest volume
- HX40R

Lowest periodic harvest volume
- SQ40CS

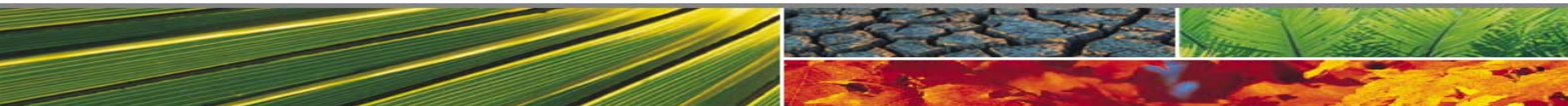
Highest periodic harvest volume
- HX40R

Largest average blocks
- SQ40CS

Smallest average blocks
- HX40R

	AvgVol	MinVol	MaxVol	BlockAvg
SQ80R	0.684180	0.658666	0.711808	56.71373
SQ40CS	0.539730	0.511570	0.575562	117.53030
SQ40C	0.692941	0.672847	0.718571	97.61975
SQ40S	0.550097	0.521164	0.575552	99.33364
HX40R	0.703730	0.676697	0.730613	55.82006
SQ40R	0.656411	0.629567	0.683752	64.03164

	AvgVol	MinVol	MaxVol	BlockAvg
SQ80R	3	3	3	5
SQ40CS	6	6	5	1
SQ40C	2	2	2	3
SQ40S	5	5	6	2
HX40R	1	1	1	6
SQ40R	4	4	4	4



ANOVA – 20 ha cell configurations

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Null hypothesis: no differences in average harvest due to spatial configuration

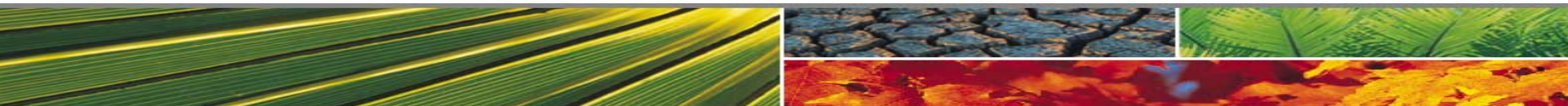
- Rejected, alpha = 1%

All parameters significant at 1%

Significant interaction

- GREENUP & PROX
- MPFD & MINPARM
- MINPARM & TIMEDEV

FACTOR	F Value	Pr(F)
PROX	2261.404	0
GREENUP	1410.437	0
TIMEDEV	540.237	0
MINPARM	241.224	0
MPFD	240.700	0
GREENUP:PROX	185.640	0
FLOWPARM	135.775	0
MAXPARM	117.744	0
MINPARM:MPFD	112.221	0
PROX:MPFD	71.509	0
MINPARM:TIMEDEV	52.115	0
GREENUP:MPFD	40.881	0
PROX:MAXPARM	27.184	0.0000002
PROX:FLOWPARM	26.202	0.0000003
PROX:TIMEDEV	17.775	0.0000256
MINPARM:TIMEDEV:MPFD	17.355	0.0000318
GREENUP:PROX:TIMEDEV	14.720	0.0001272
FLOWPARM:MPFD	11.714	0.0006285
GREENUP:FLOWPARM	9.747	0.0018124
MINPARM:FLOWPARM	8.721	0.0031699
FLOWPARM:TIMEDEV	8.521	0.0035367
PROX:MINPARM	8.259	0.0040816
MAXPARM:MPFD	4.919	0.0266416
PROX:MAXPARM:TIMEDEV	4.333	0.0374717
GREENUP:MINPARM:MPFD	4.123	0.0423895



Response of AvgVol to Greenup:Prox

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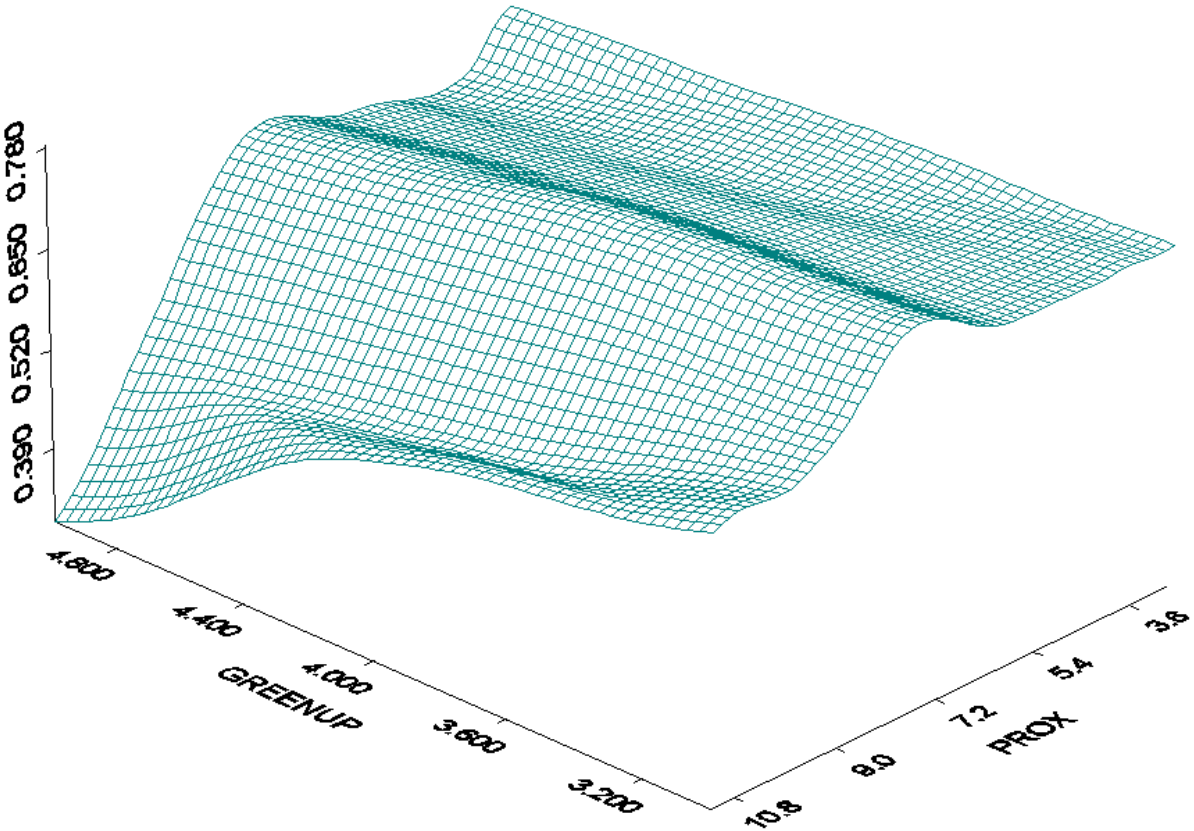
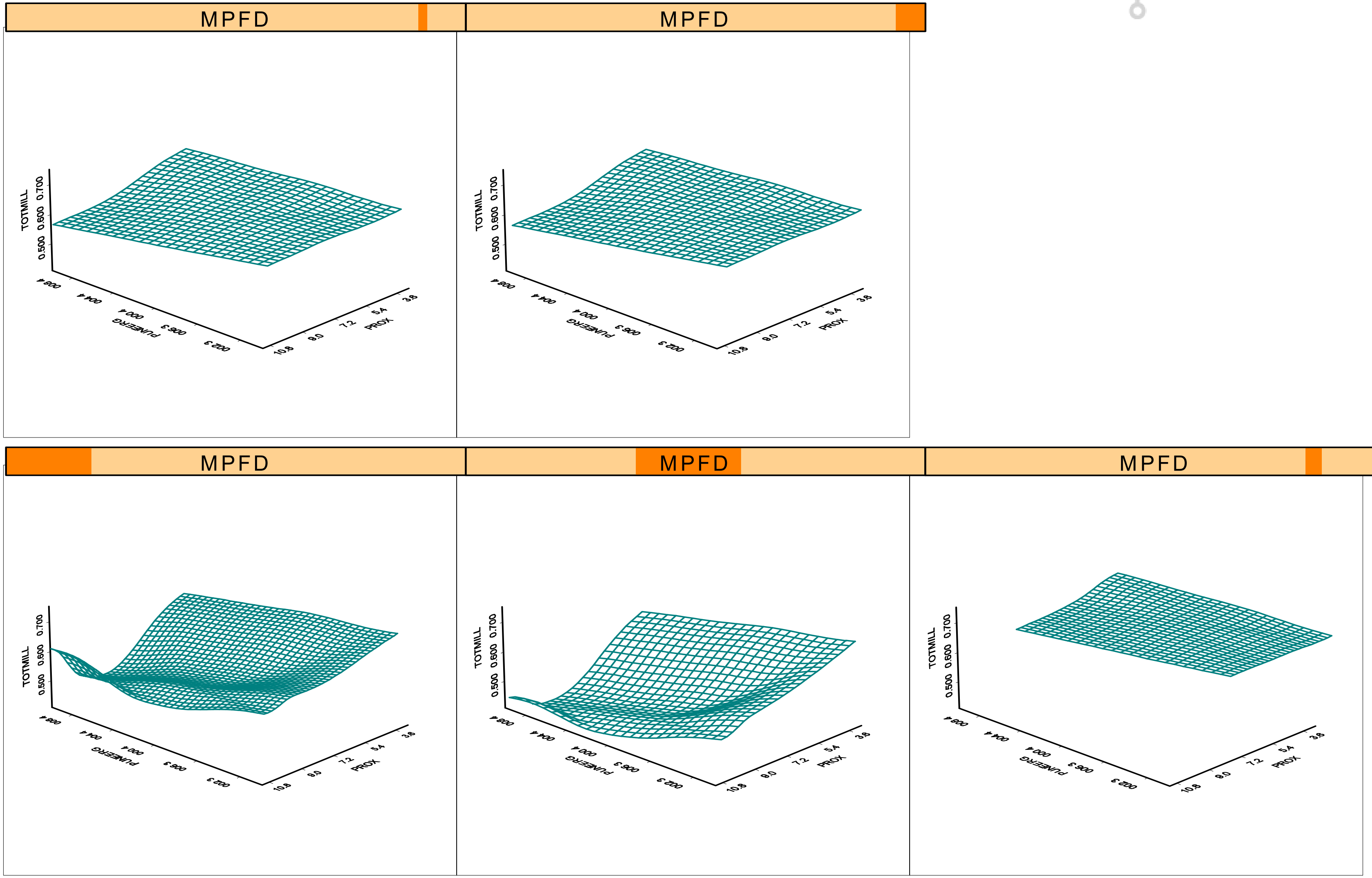
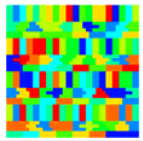


Response conditioned by MPFD



SQ40C



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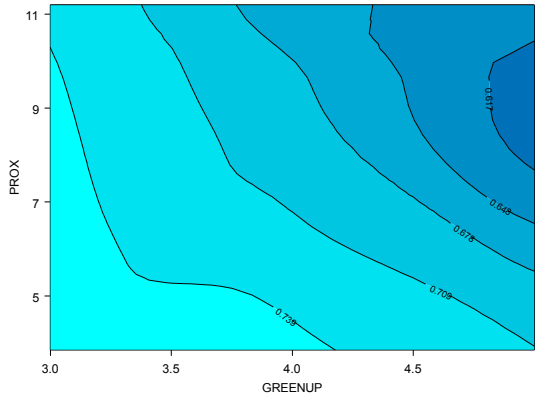
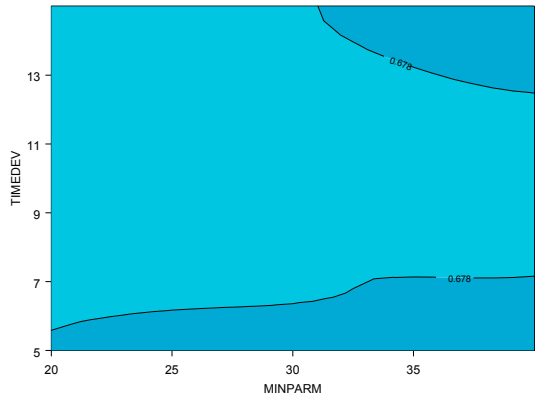
Clustered age classes

- Sensitivity to proximity distance increases with greenup interval
- Relatively insensitive to proximity at greenup = 3
- Relatively insensitive to timing choice deviations for smaller minimum blocks
- Deviations initially help by allowing more area to be harvested
- Blocks become more heterogeneous in composition





SQ40CS

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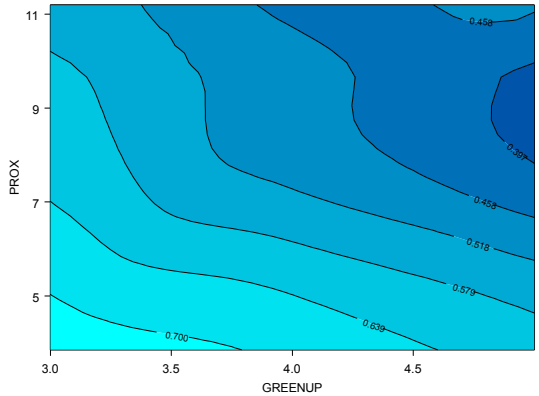
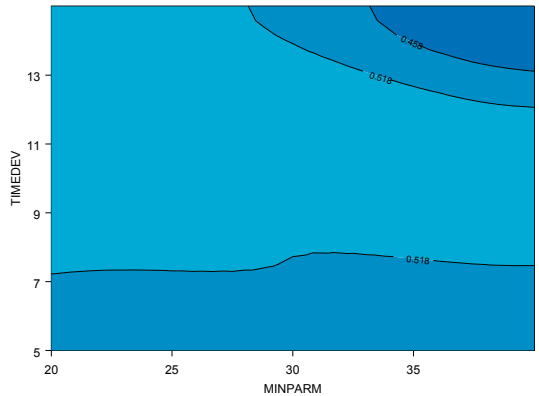
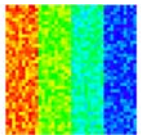
Clustered, systematic age classes

- Sensitivity to proximity distance increases with greenup interval
- Sensitivity to proximity distance is higher at short greenup intervals than SQ40C
- More sensitive to timing choice deviations for smaller minimum blocks than SQ40C
- Deviations initially help by allowing more area to be harvested
- Blocks become more heterogeneous in composition





SQ40S



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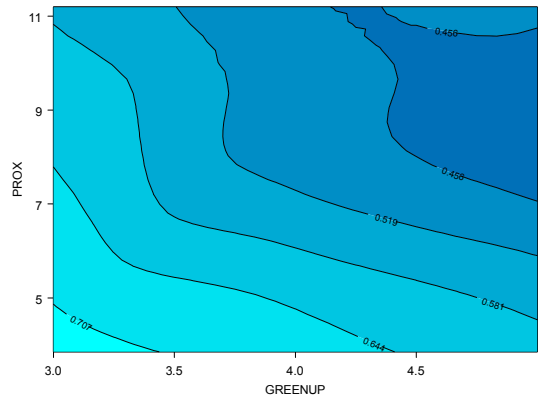
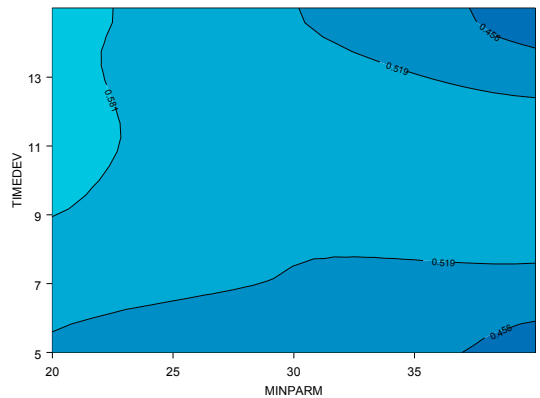
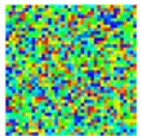
Systematic, random age classes

- Sensitivity to proximity distance increases with greenup interval
- Sensitivity to proximity distance is higher at short greenup intervals
- Relatively insensitive to timing choice deviations for smaller minimum blocks
- Deviations initially help by allowing more area to be harvested
- Blocks become more heterogeneous in composition; more pronounced than in clustered age classes





SQ40R



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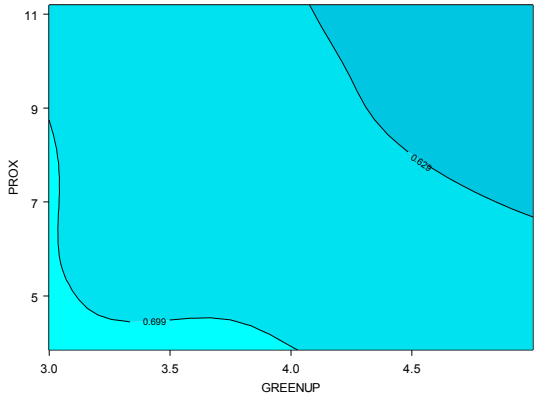
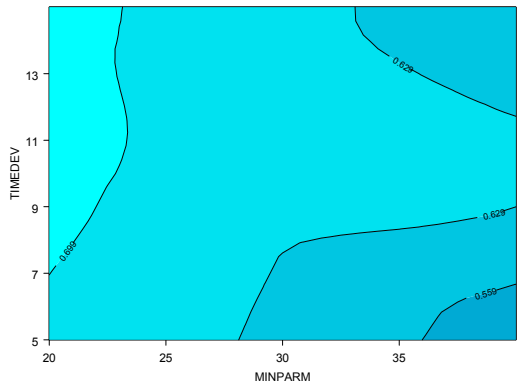
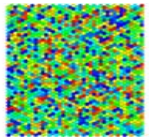
Random age classes

- Much lower sensitivity to proximity at all greenup intervals
- Relatively more sensitive to timing choice deviations than clustered age classes
- Blocks become more heterogeneous in composition; more pronounced than in clustered age classes





HX40R



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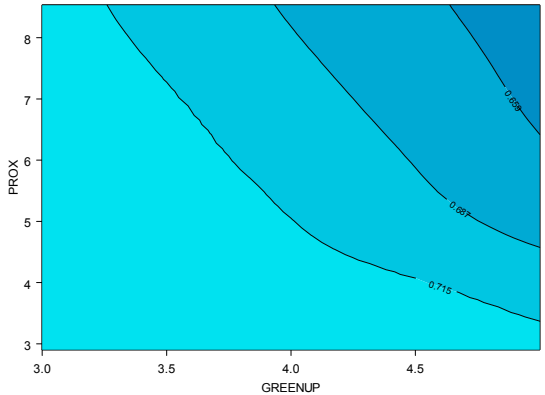
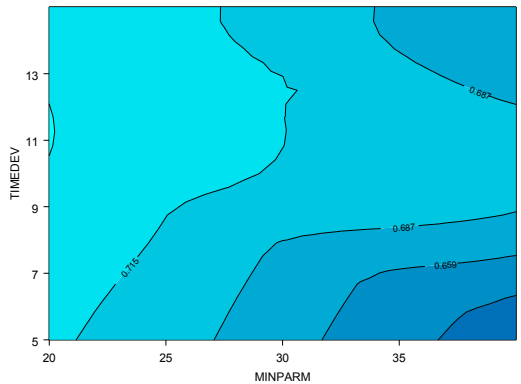
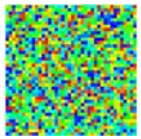
Random age classes

- Insensitive to proximity at short greenup intervals
- More sensitive to proximity at higher greenups than SQ40R
- More sensitive to timing choice deviations than clustered age classes and SQ40R



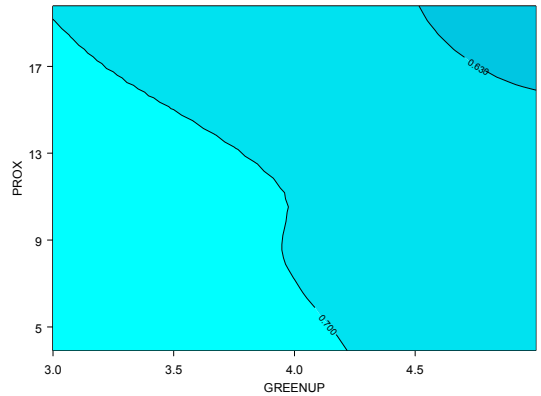


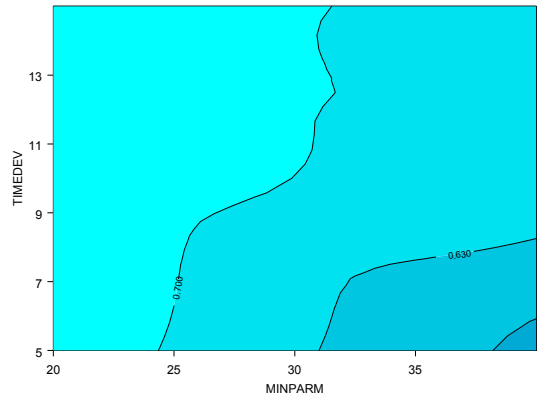
SQ80R



Random age classes

- Relatively insensitive to proximity at short greenup intervals
- Less sensitive to proximity at higher greenup intervals than SQ40R
- Decreasing sensitivity to timing choice deviations at higher minimum block sizes





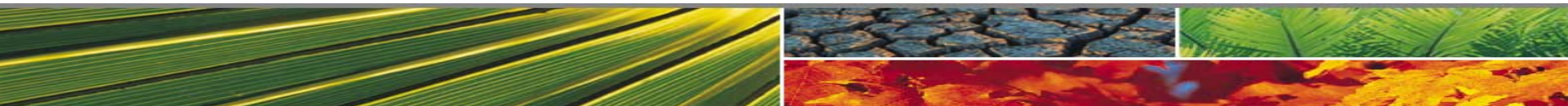
Summary

Identical forests from a strategic standpoint

- Yielded very different outcomes under spatial restrictions
- Forest structure was significant determinant

Although contrived, forests have analogs in the real world

- SQ40C – similar to disturbance dominated natural forests
- SQ40CS – similar to plantation management of the US southeast
- SQ40R – similar to forests of the Northeast (small, heterogeneous stands)



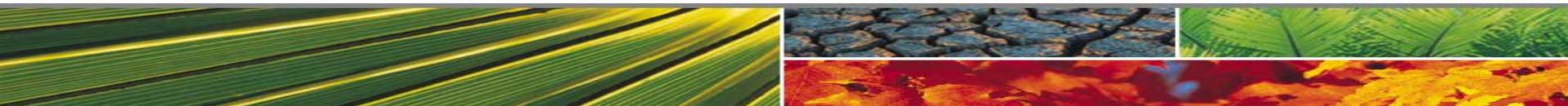
Summary

Forest fragmentation

- Highly fragmented forests are less sensitive to greenup interval
  - Neighboring stands are not likely to be harvested in same period anyway
- In non-fragmented forests, sensitivity to proximity distance increases with greenup interval
  - Neighboring stands are of similar age, and therefore likely candidates for harvesting in same period; proximity distance determines how much of this area is made unavailable during greenup

Allocation units

- Substands (SQ80R) yielded better solutions than stands (SQ40R)
  - Smaller allocation units present more alternative block configurations



Summary

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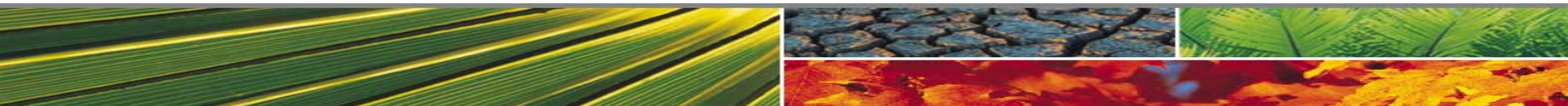
Block size

- Minimum block size can be much more limiting on volume achievement than maximum block size
- Maximum block size is limiting only in non-fragmented forests
  - Mean block size is much smaller than maximum allowed
  - Mean approaches maximum only in clustered forests (SQ40CS, SQ40C)

Timing choice deviations

- Mitigate shortfalls by allowing for the creation of larger harvest blocks (sensitive to minimum block size)
- Significant deviations from original timing can nullify gains arising from increased harvest area



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Knowledge for Growth