Defining Adequately the Decision Space for Maximizing Carbon Removals in Eucalyptus Industrial Plantations

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DecisionES 2025
Porto Seguro
Jun 30th *to* Jul 4th BR
Symposium on Ecosystem Services, Forest Management and Decision Making

atrium Forest Consulting

PennState

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1) Introduction

Our Symposium is about:

- Decision Making
- Ecosystem Services

Guiding Question:

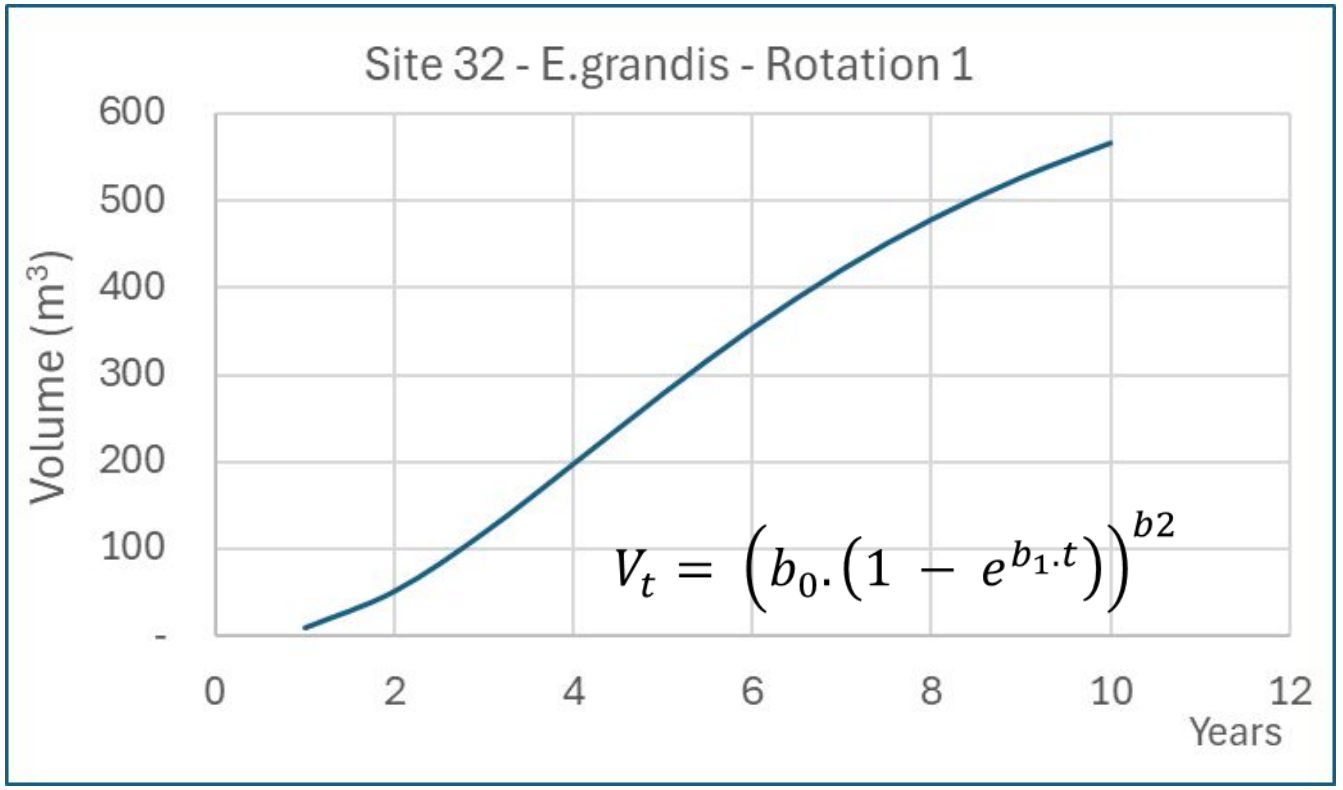
How can we design a mathematical model to guide forest management decisions aimed at maximizing carbon sequestration?

Hypothesis:

The more accurately our set of alternatives reflects reality, the closer we get to the true optimum.

2) Our example:

- *E.grandis and E.saligna*
- Site index 24, 28, 30, 32, 34



- 500 ha
- 6 management unit,
  - ages from 1 to 6
- Regular costs and prices
- Discount Rate 7%

3) Scenarios

Three scenarios:

- Growth1, Growth2, Growth3
- Varying decision space density (i.e., number of management alternatives)
- Objective: Maximize Current Annual Increment (CAI)

  → used as a proxy for carbon sequestration

Intervention Types	**Description**
ni	No Intervention node
CR	Clear cut and Renewal
CS	Clear cut and Sprouting from stumps

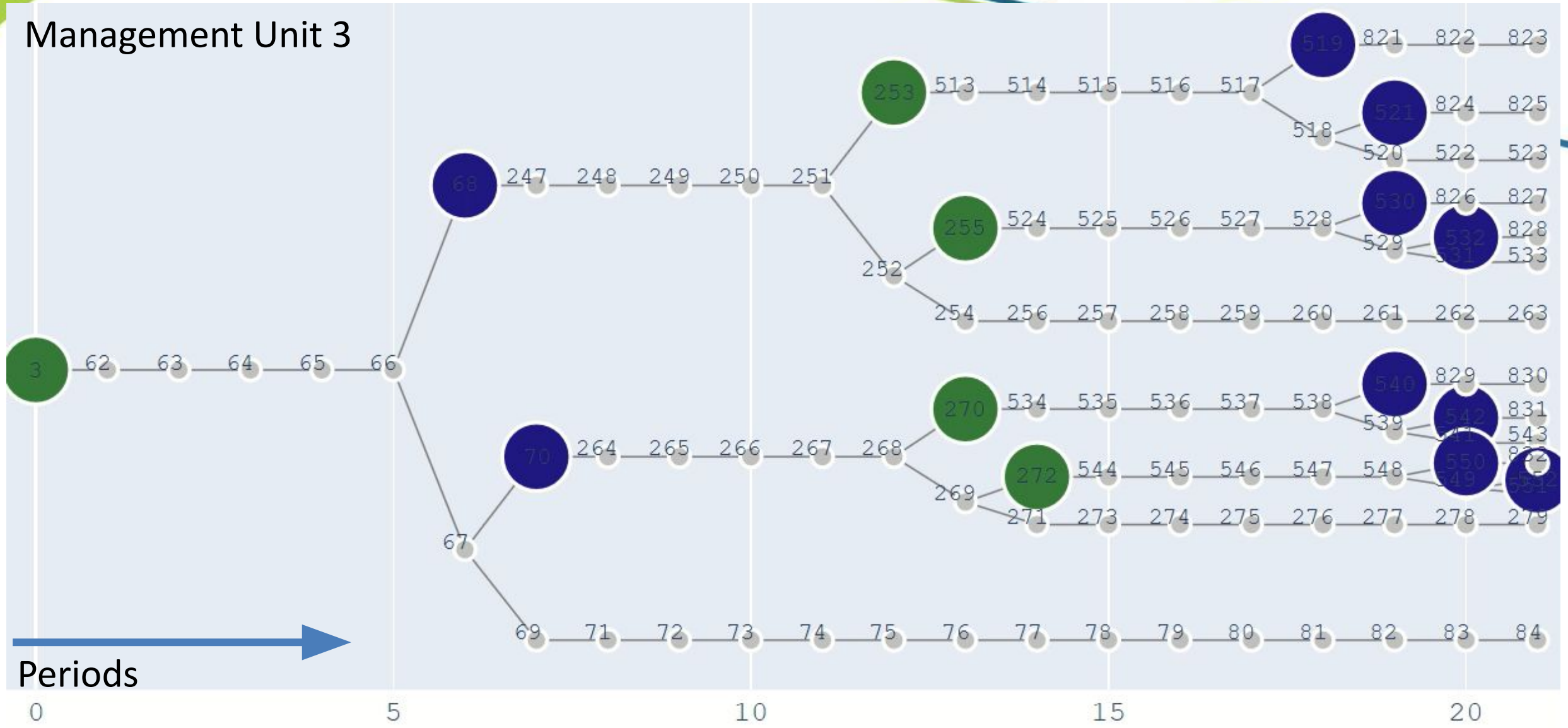
Scenario Growth1

Only cycles with two rotations

Rules	
Last Intervention	**Next Intervention**
CR →	CS
CS →	CR

Rule Variable	Rule Expression
Age	If (:Age >= 6 and :Age <= 7)

__	Growth 1	Growth 2	Growth 3
Decision Space Density (nodes)	954		
Possible Interventions inside the Horizon	106		
Management Alternatives	112		


Management Unit 3
3
62
63
64
65
66
68
247
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821
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82
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84
Periods
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5
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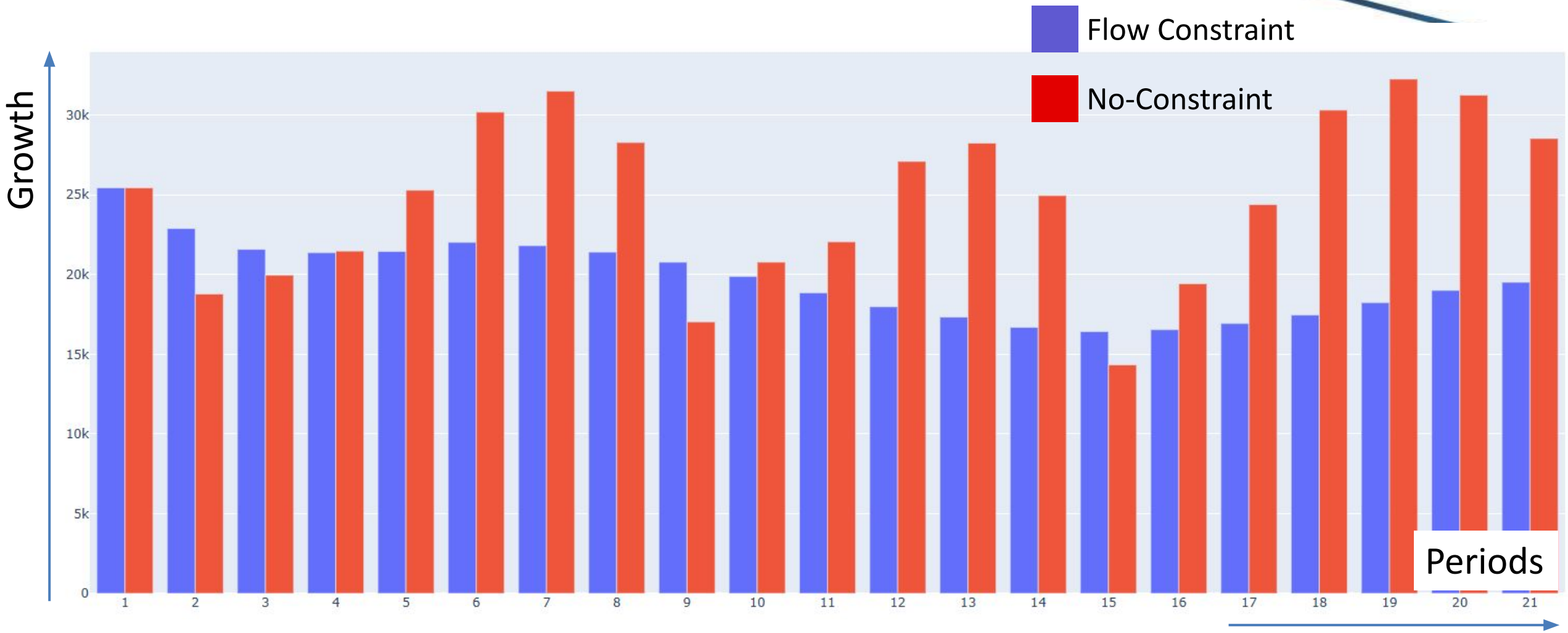
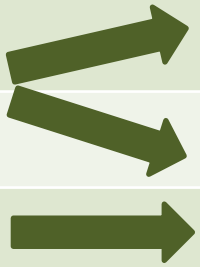
15
20

Growth 1 Scenario



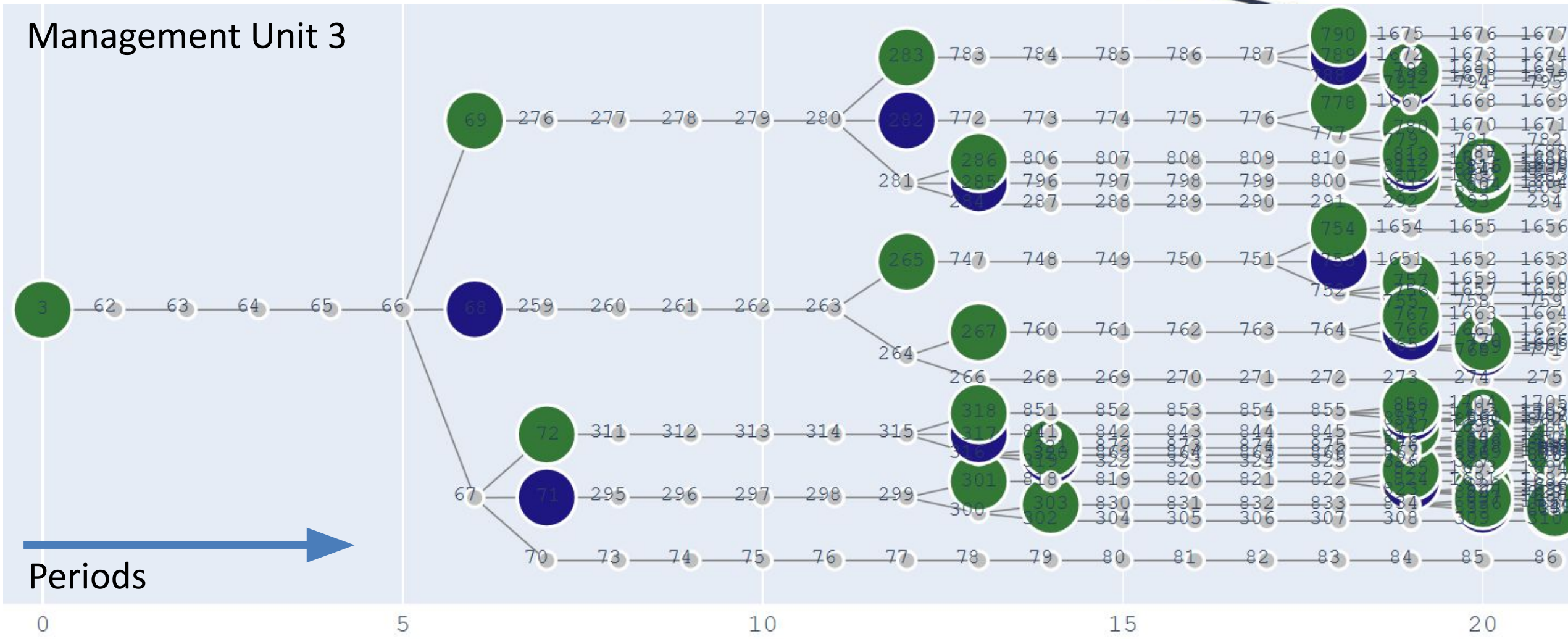
Scenario Growth2

Cycles with one or two rotations	
Rules	
Last Intervention	**Next Intervention**
CR	CS
CR	CR
CS	CR

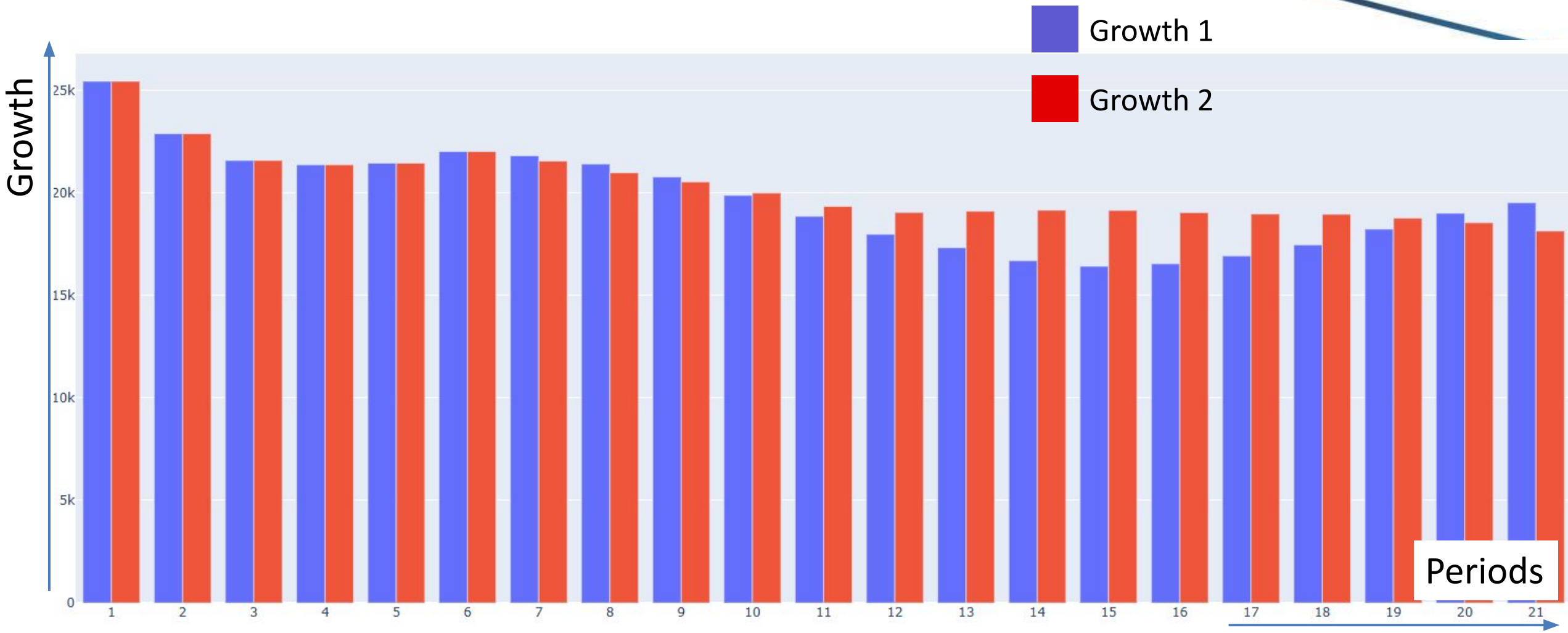


Rule Variable	Rule Expression
Age	If (:Age >= 6 and :Age <= 7)

__	Growth 1	Growth 2	Growth 3
Decision Space Density (nodes)	954	2210	
Possible Interventions inside the Horizon	106	373	
Management Alternatives	112	379	


Management Unit 3
Periods
0
5
10
15
20

Scenarios Growth 1 and 2

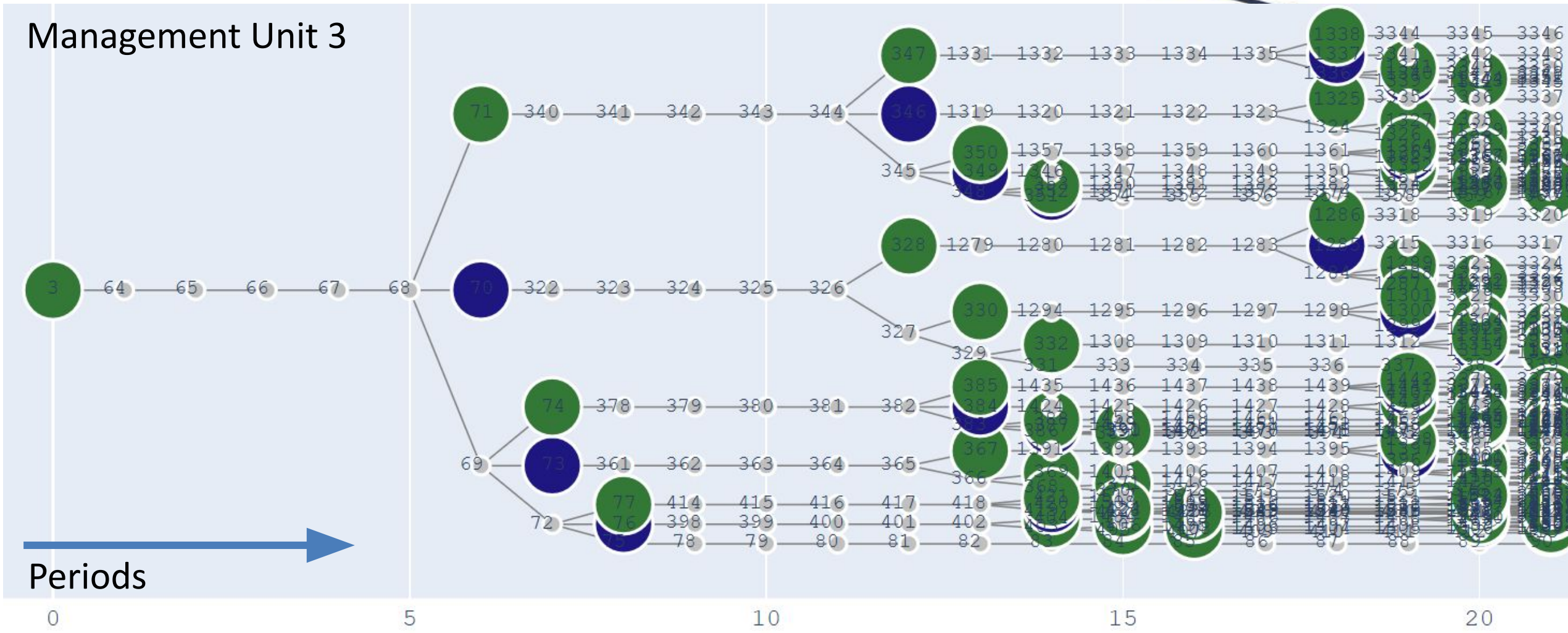


Scenario Growth3

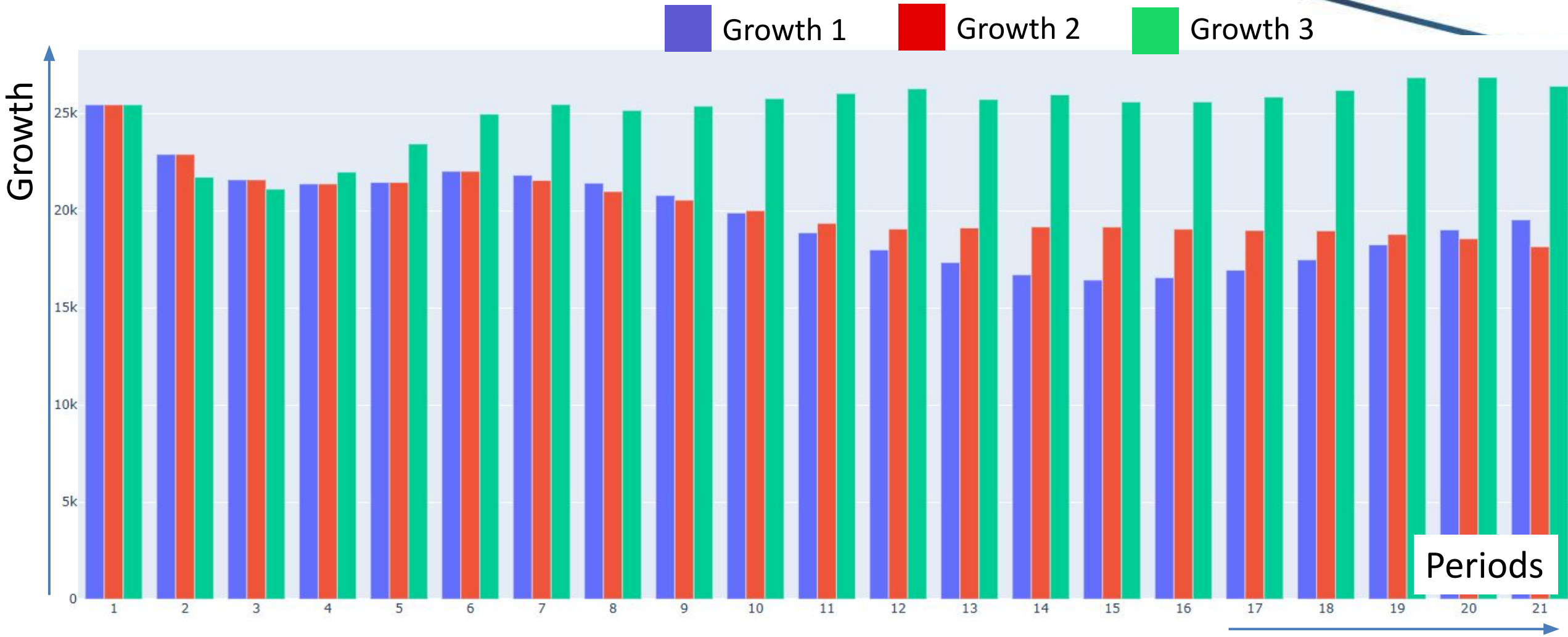
Cycles with one or two rotations	
Rules	
Last Intervention	**Next Intervention**
CR	CS
CR	CR
CS	CR

Rule Variable	Rule Expression
Age	If (:Age >= 6 and :Age <= 8)

__	Growth 1	Growth 2	Growth 3
Decision Space Density (nodes)	954	2210	4425
Possible Interventions inside the Horizon	106	373	536
Management Alternatives	112	379	842


Management Unit 3
Periods
0
5
10
15
20

Scenarios Growth 1, 2, and 3



Scenarios Growth 1, 2, and 3

Area (ha)	Scenario	Additional Area (ha)	Capital (R$) to buy additional Area
500	From Grow1 to Grow2	15	596,503
	From Grow2 to Grow3	118	4,729,774
10,000		301	12,029,428
		2,385	95,383,350

4) Conclusions

- Increasing the density of the decision space—by generating and evaluating more alternatives—leads to better solutions. Despite the higher computational costs and modeling efforts, the benefits clearly outweigh the additional cost.

- Advancing our modeling capabilities brings tangible benefits. Let’s give models, methods, and mathematics the credit they deserve in decision-making.

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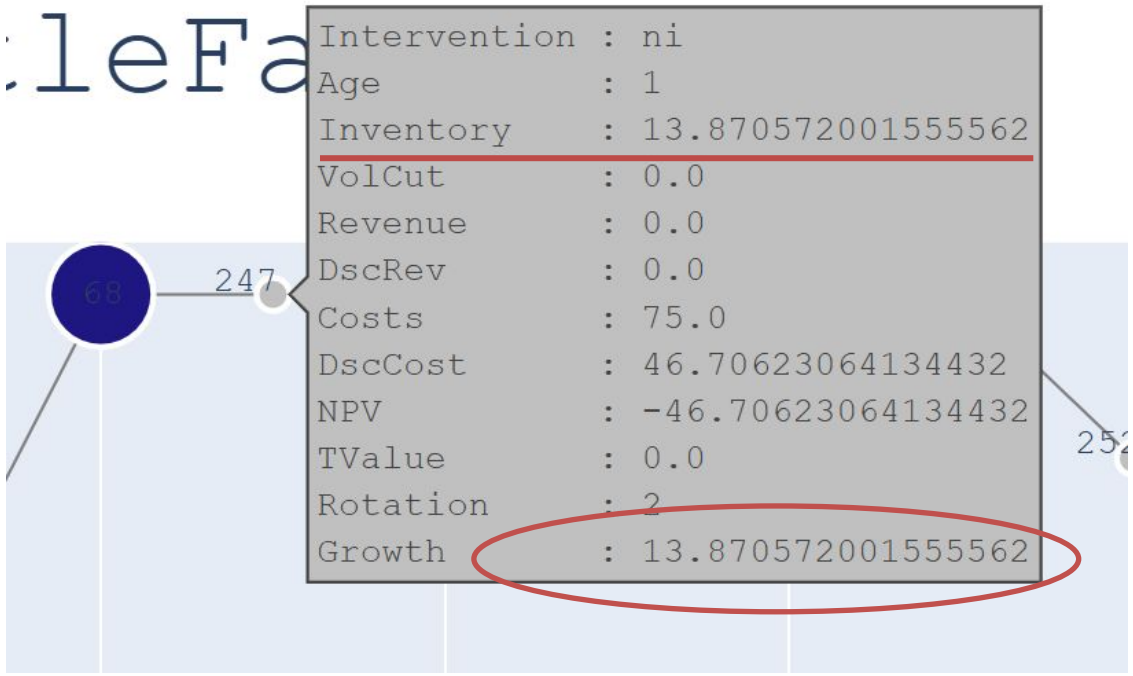
Our results show that increasing the density of the decision space—by generating and evaluating more alternatives—leads to significantly better solutions. Despite the higher computational or logistical costs, the gains in solution quality justify the effort

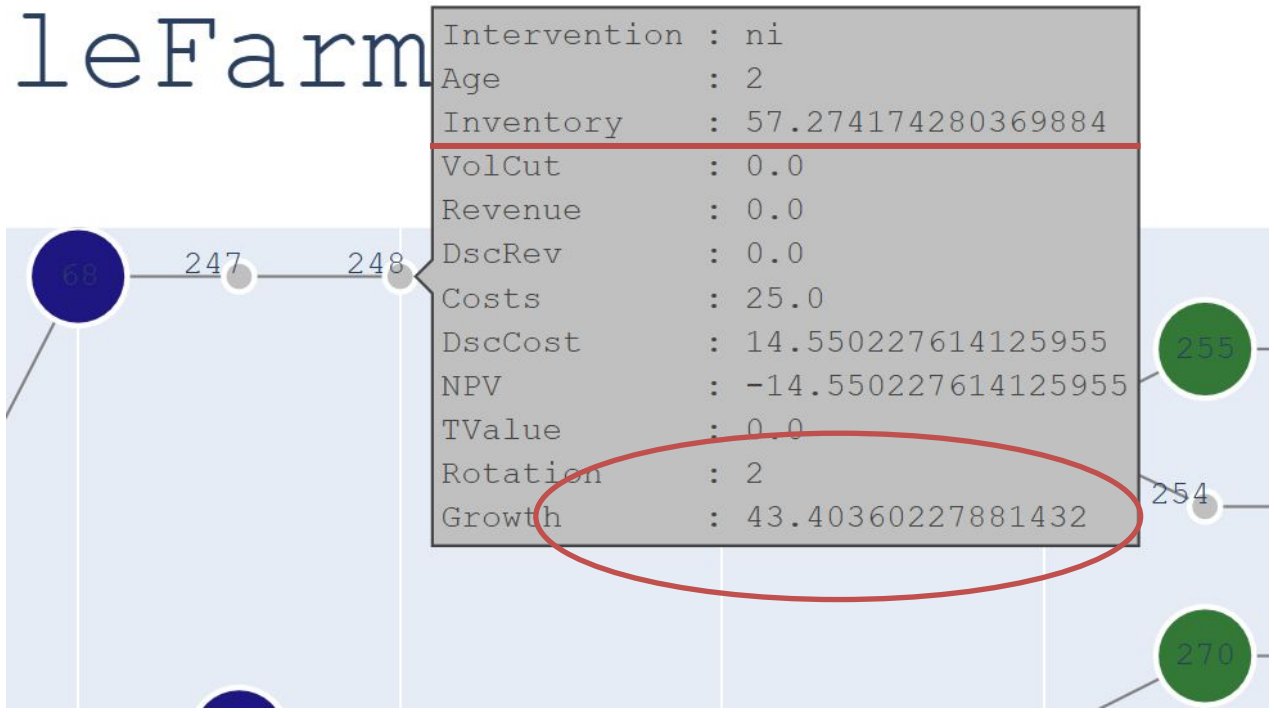
"These findings highlight the importance of trusting in well-designed models and rigorous analytical methods. The value they bring in guiding complex decisions should not be underestimated."

"This study reinforces two key messages: first, that expanding the decision space improves solution quality; and second, that decision-makers should place greater trust in models and mathematical approaches, which are essential tools in addressing complex challenges."

"Better solutions come from exploring more alternatives. We need to stop fearing complexity and start trusting the models and methods designed to manage it."

"Increased effort in modeling pays off. It's time we give models, methods, and mathematics the credit they deserve in decision-making processes."


leFa
Intervention : ni
Age : 1
Inventory : 13.870572001555562
VolCut : 0.0
Revenue : 0.0
DscRev : 0.0
Costs : 75.0
DscCost : 46.70623064134432
NPV : -46.70623064134432
TValue : 0.0
Rotation : 2
Growth : 13.870572001555562
68
247


leFarm
Intervention : ni
Age : 2
Inventory : 57.274174280369884
VolCut : 0.0
Revenue : 0.0
DscRev : 0.0
Costs : 25.0
DscCost : 14.550227614125955
NPV : -14.550227614125955
TValue : 0.0
Rotation : 2
Growth : 43.40360227881432
68
247
248
255
254
270