USFWS- Brent Lawrence. "Diablo Lake in the Northern Cascades" Flickr, 3 November 2023, https://www.flickr.com/photos/52133016@N05/53545062751/

Forest Carbon Modelling Results

November 13, 2024

ESSA

Outline

- Introduction
- **Part 1**: Methods Refresher
- **Part 2**: Full Landscape Results w/Q&A
- **Part 3**: Climate Change Results w/Q&A

Study Objective

"Support the Work Group in examining relationship between forest management and carbon in DNR-managed forests"

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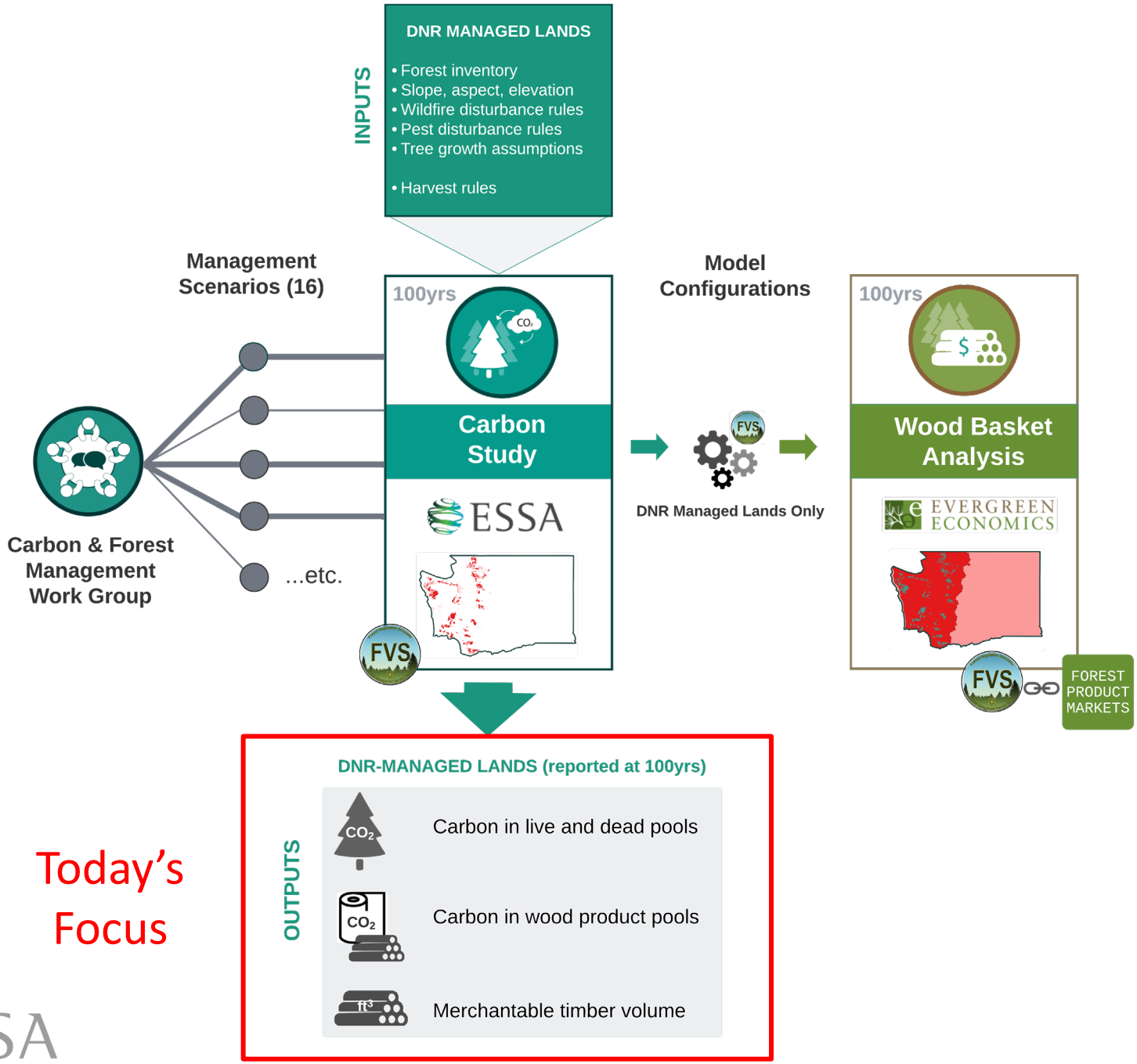
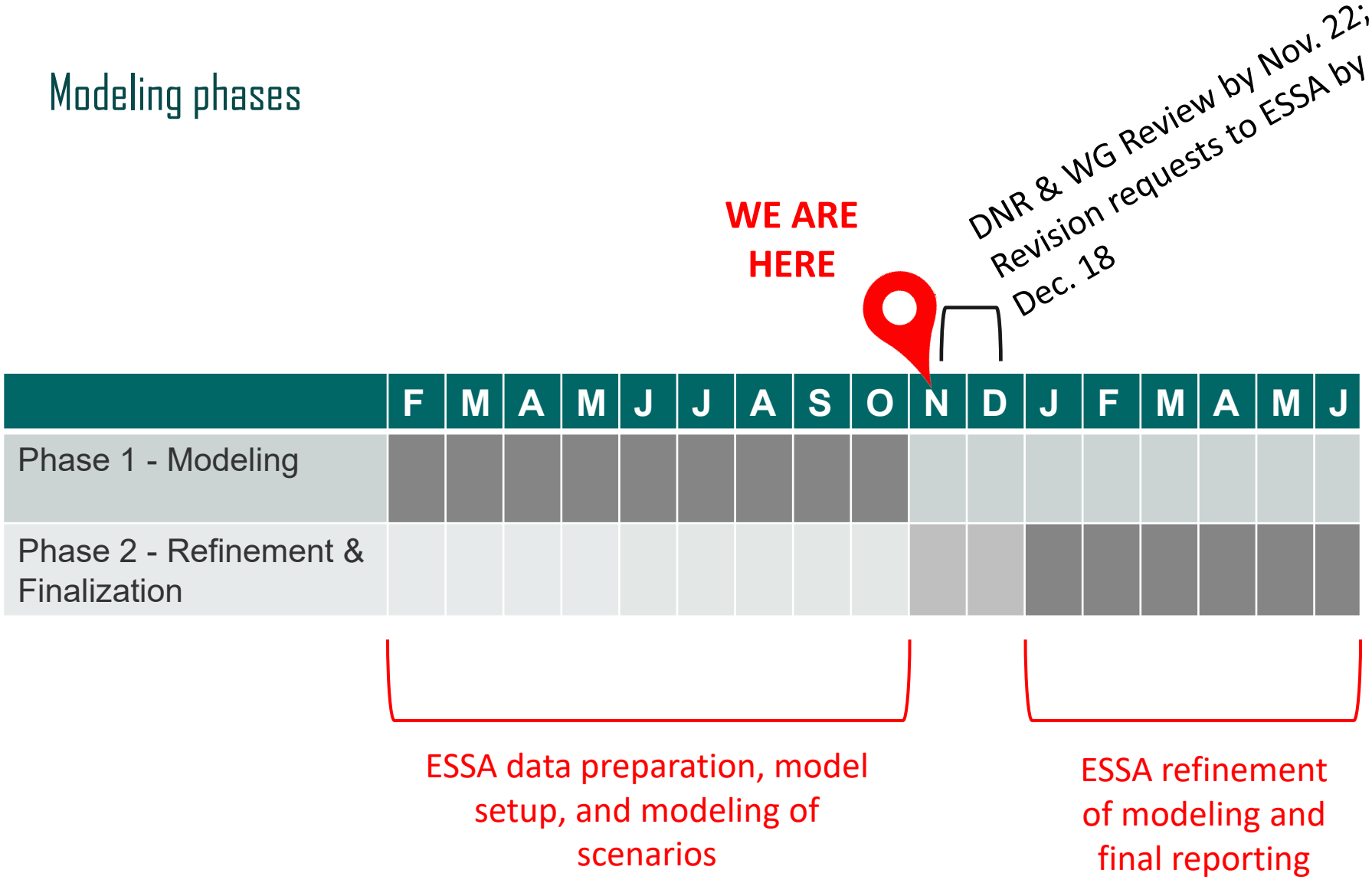
"Support the Work Group in examining relationship between forest management and carbon in DNR-managed forests"

How much carbon in DNR managed forests under different management scenarios?



Today's Focus

Modeling phases



Adopted Scenarios

Scenario number	Component (s)		
1	DNR current operations		
Single-dial scenarios			
2	Lengthen harvest rotation		
3	Shorten harvest rotation		
4	Significantly increase thinning		
Multi-dial scenarios			
5	Lengthen harvest rotation	Significantly increase thinning	
6	Lengthen harvest rotation	Significantly increase thinning	Increase deferrals
7	Increased emphasis on Silviculture	Significantly increase thinning	
8	Increased emphasis on silviculture	Significantly increase thinning	Shorten harvest rotation

Part 1: Methods Refresher

see also

https://www.dnr.wa.gov/publications/bc_cfm_m6_model_ppt.pdf

Basic model process

PREPARATION	MODELING		RESULTS
Prepare Inputs	Stand Initialization	Simulation	Outputs and Post-processing

Preparation data icon by monkik

- Growth
- Carbon fluxes
- Disturbance
- Harvest
- Silviculture

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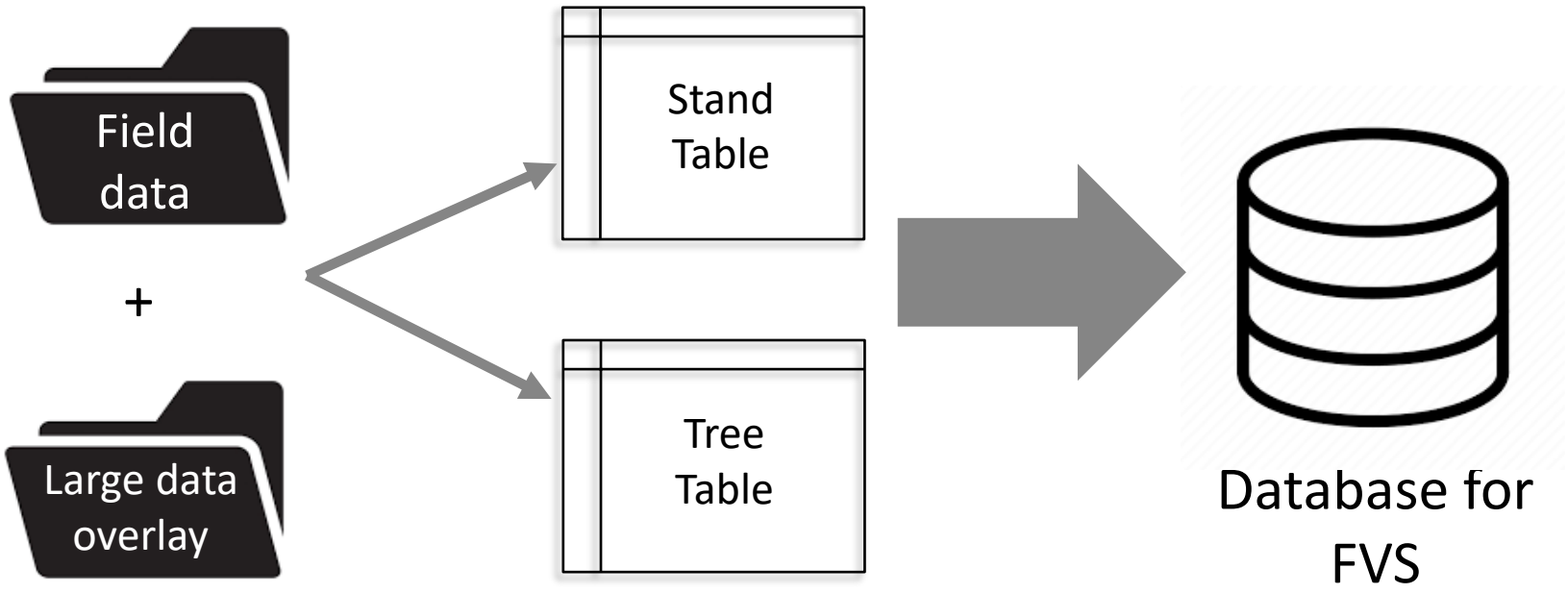
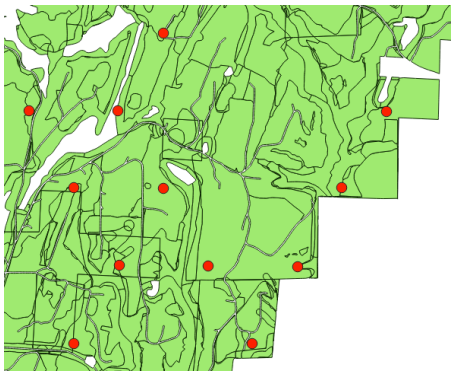
Spatial processing happens outside FVS



Spatial Units: What is a "Stand" in FVS?

Field plots data (DNR): trees and woody debris

+



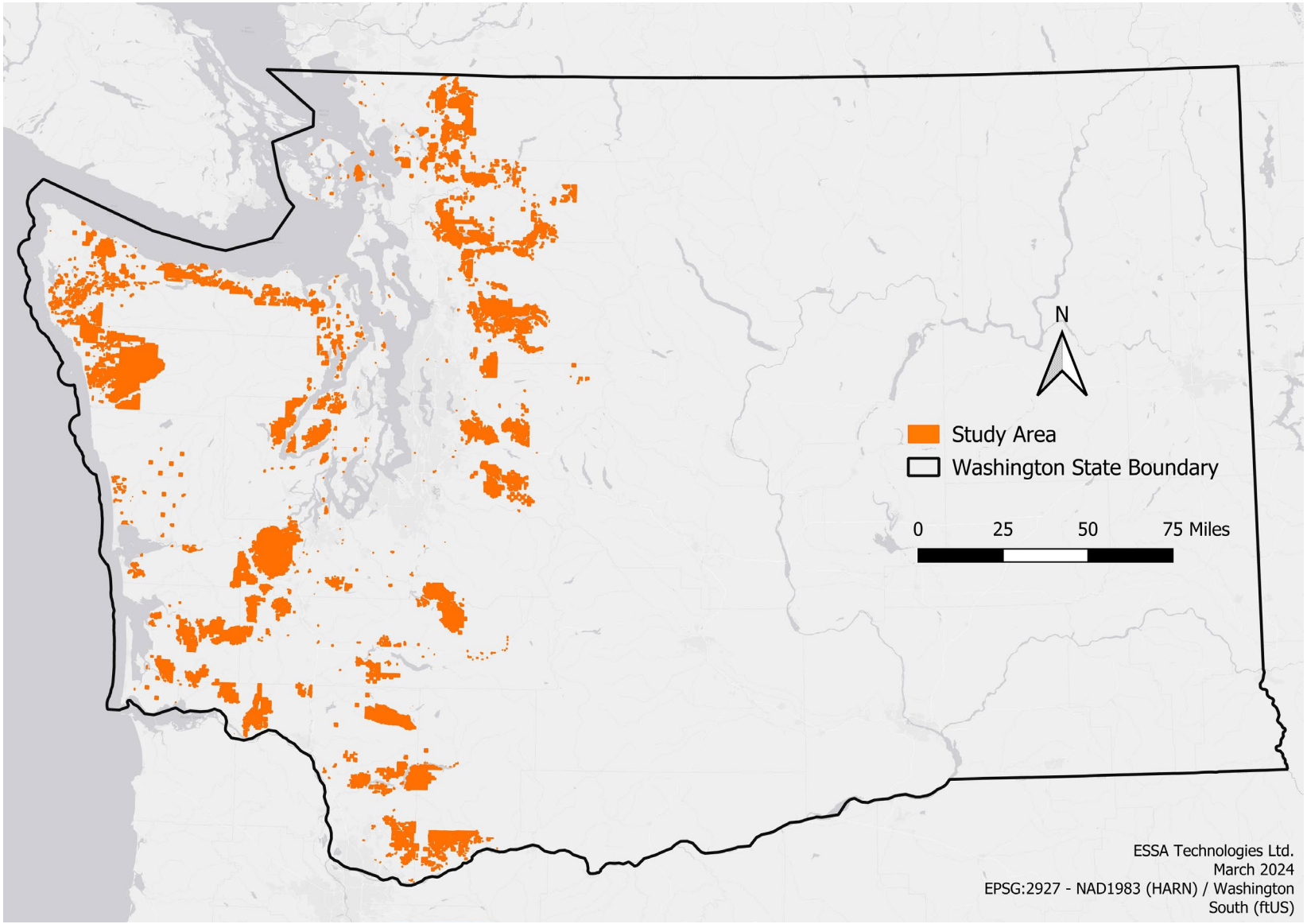
Forest stand mapping (DNR): ecological attributes and land management classes

=

	STAND_CN	STAND_ID	SITE_INDE	DT_SI
1	1_Clallam	e0979e12-0343-4cba-877a-1c578e07e59d	109	CONIF
2	2_Clallam	d7c953be-fbb9-4ed1-8cfa-3e0bfe527bca	131	CONIF
3	3_Clallam	e62b42b0-fa40-4099-adf2-173eac05142e	95	ALDER
4	4_Clallam	3d289bb2-b0cb-4760-a69e-3f8af146da66	133	CONIF
5	5_Clallam	421596ff-0374-40db-bf12-4df2960effff	134	CONIF
6	6_Clallam	c093ea2e-9f24-477b-980d-fd34a32a9061	134	CONIF
7	7_Clallam	c093ea2e-9f24-477b-980d-fd34a32a9061	134	CONIF
8	8_Clallam	c093ea2e-9f24-477b-980d-fd34a32a9061	133	CONIF
9	9_Clallam	421596ff-0374-40db-bf12-4df2960effff	134	CONIF
10	10_Clallam	421596ff-0374-40db-bf12-4df2960effff	134	CONIF

Final model input

Spatial Units: Landscape



Output Units

Total stored carbon

Live/dead forest biomass

MtCO2e

Harvested wood products

MtCO2e

CO2 equivalent *(CO2e) is the metric used to compare and report on the impact of greenhouse gases on global warming via a common scale*

1 mega ton (Mt) Carbon **x** **3.67** = 1 Mt CO2e

Output Units

Total stored carbon

Live/dead forest biomass

MtCO2e

Harvested wood products

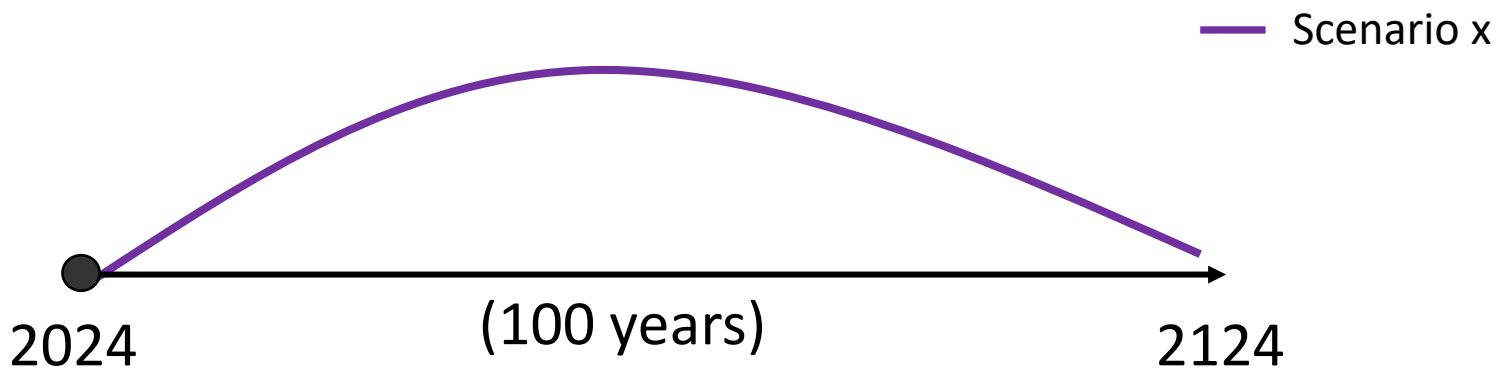
MtCO2e

Harvested merchantable timber volume

MBF

Scenario performance metric:

Mean of total $MtCO_2e$ across simulation time steps



Scenario performance metric:

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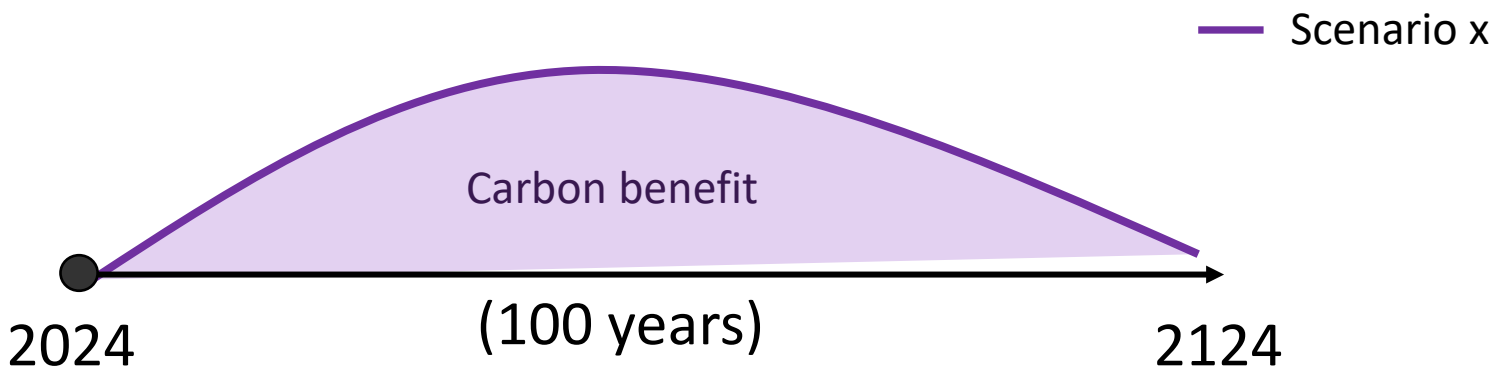

Scenario performance metric:

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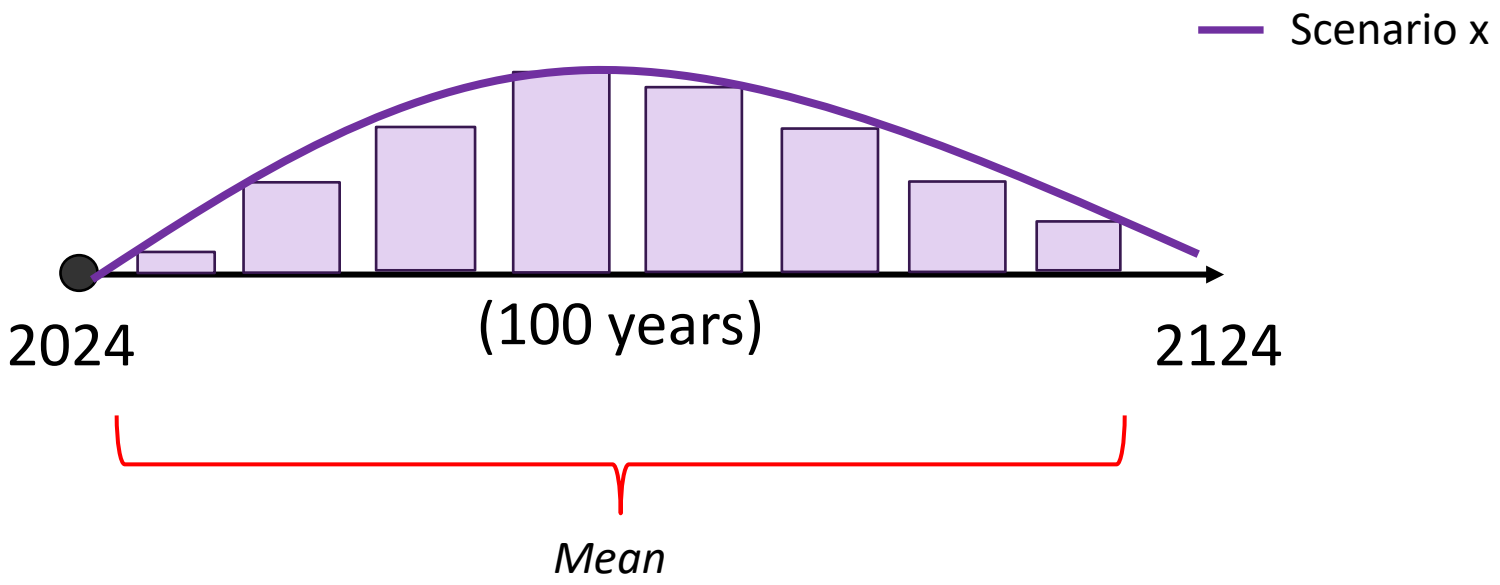
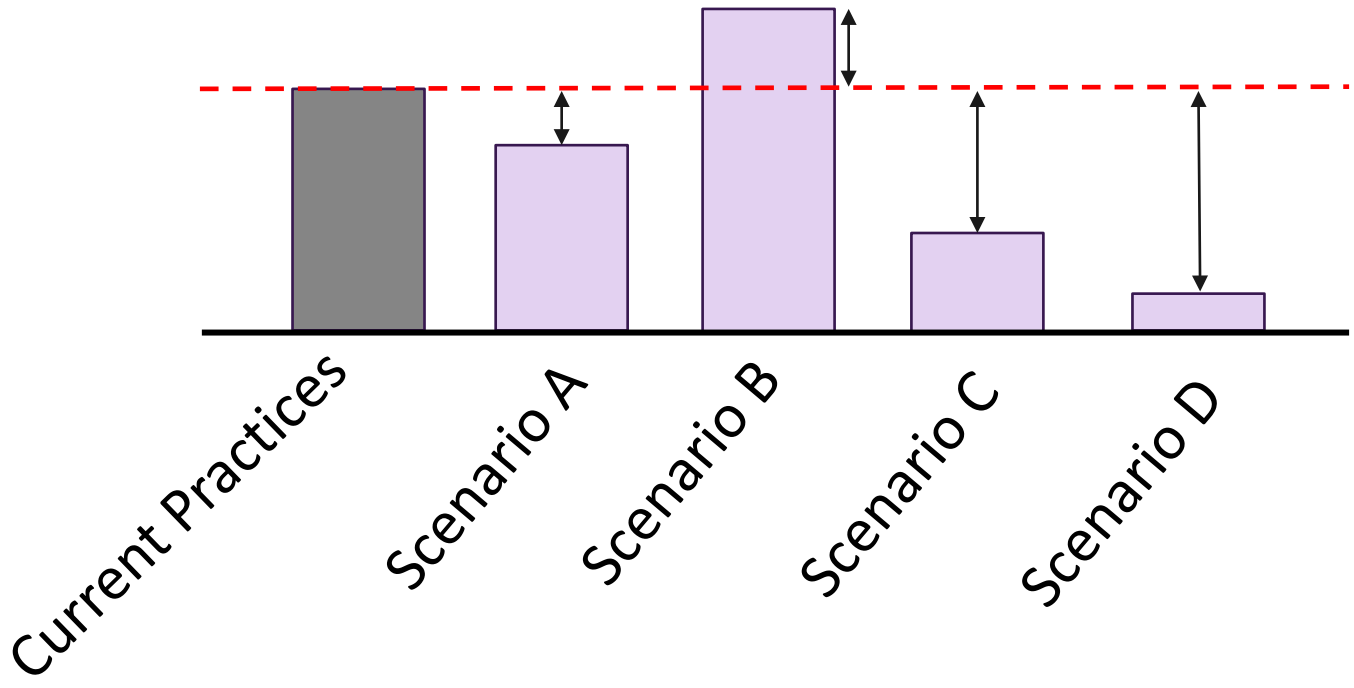


Scenario performance metric:

% difference in mean of total $MtCO_2e$ across simulation time steps



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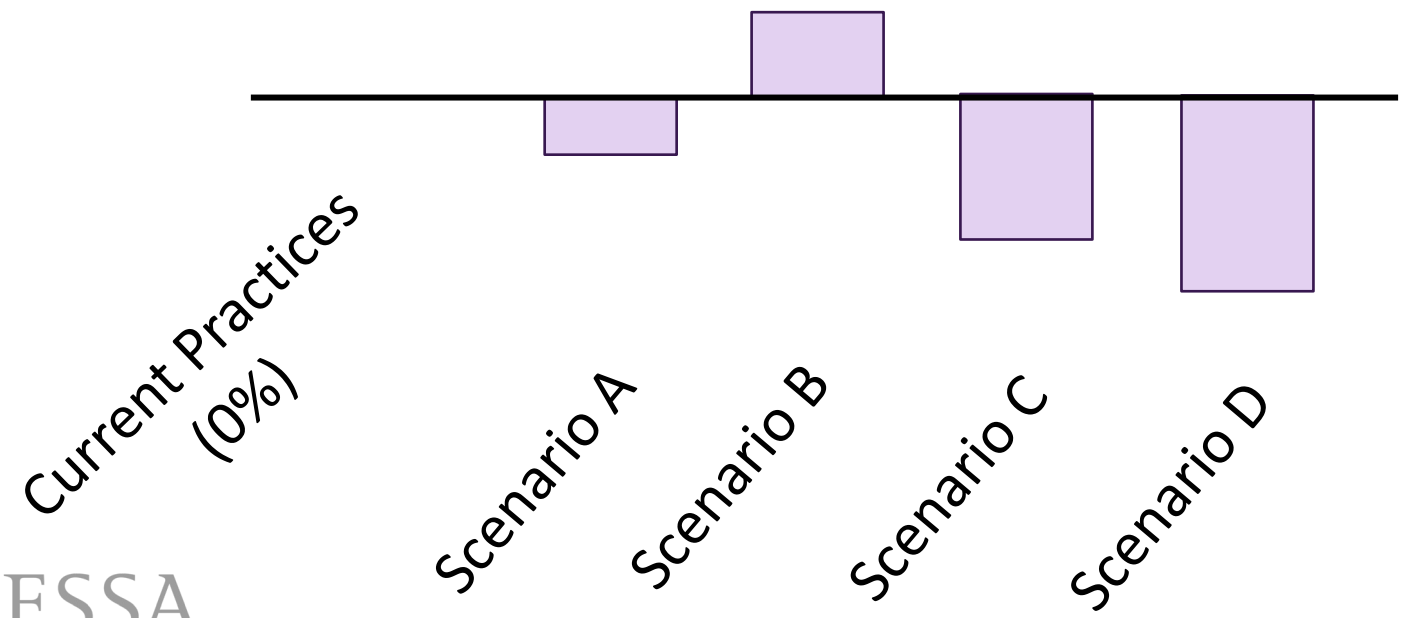


Temporal Units

Time Steps

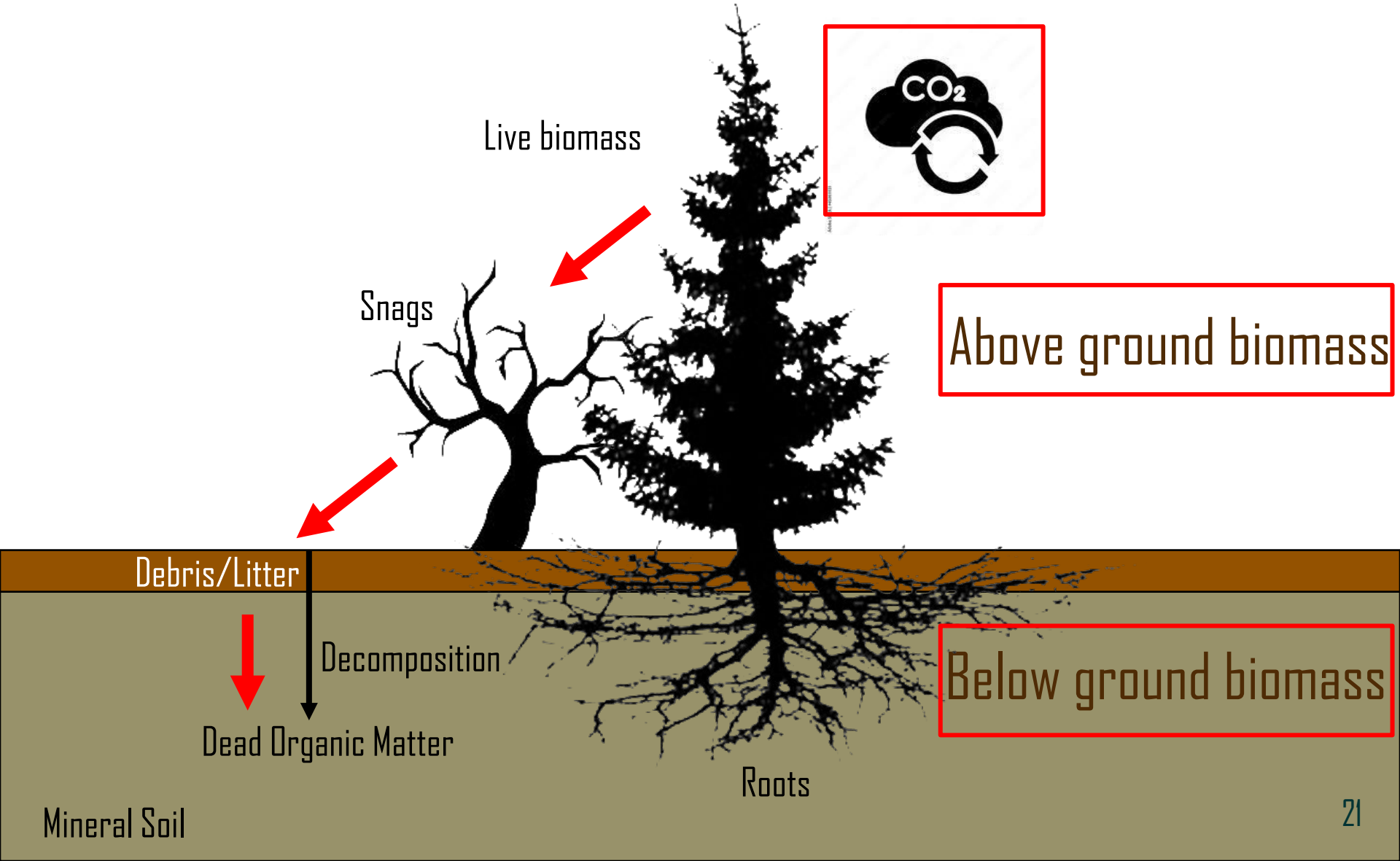
5

Time Horizon

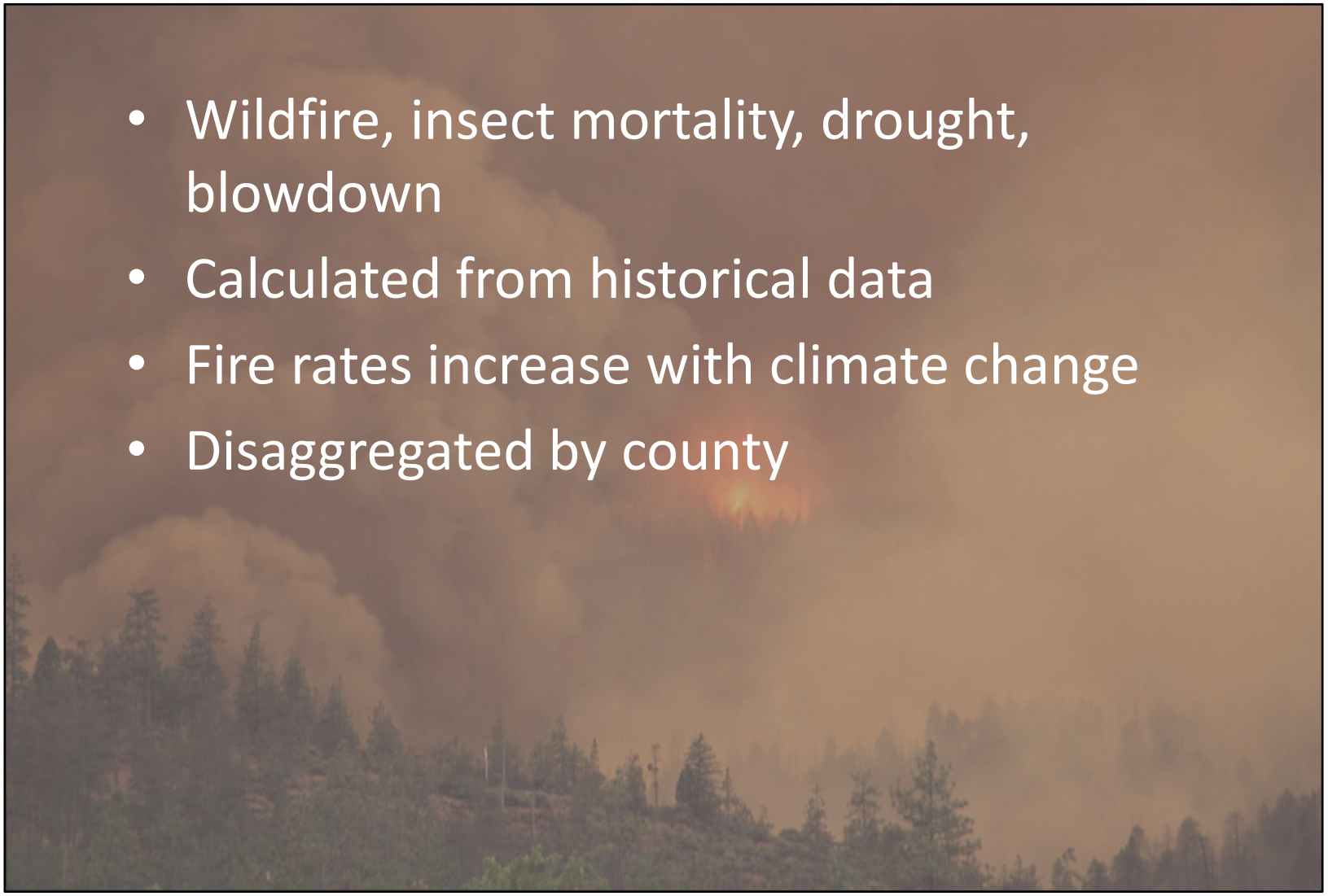
100

Years

Carbon Dynamics



Natural Disturbance



- Wildfire, insect mortality, drought, blowdown
- Calculated from historical data
- Fire rates increase with climate change
- Disaggregated by county

Photo Credit: Bureau of Land Management Oregon and Washington

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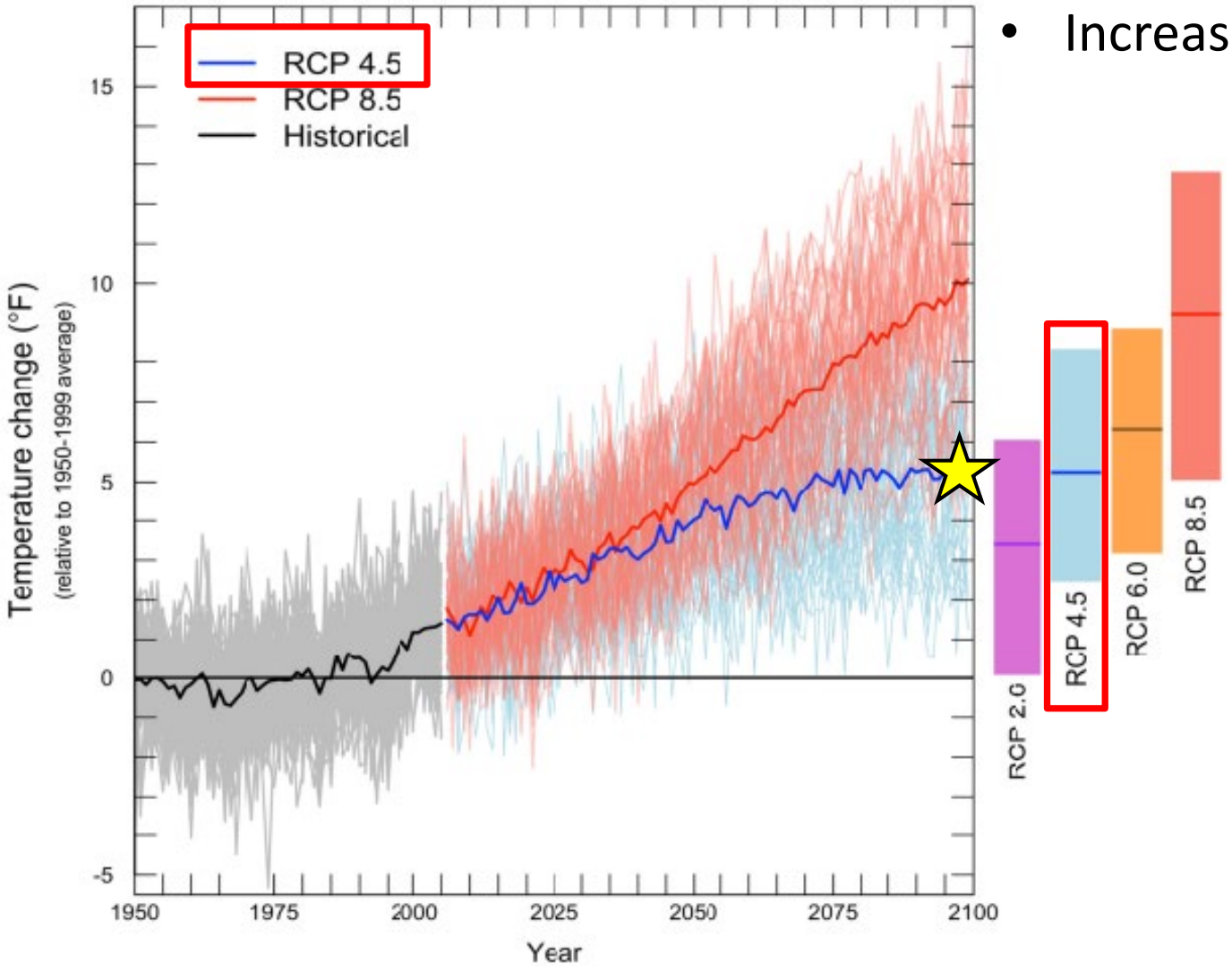
Climate Change

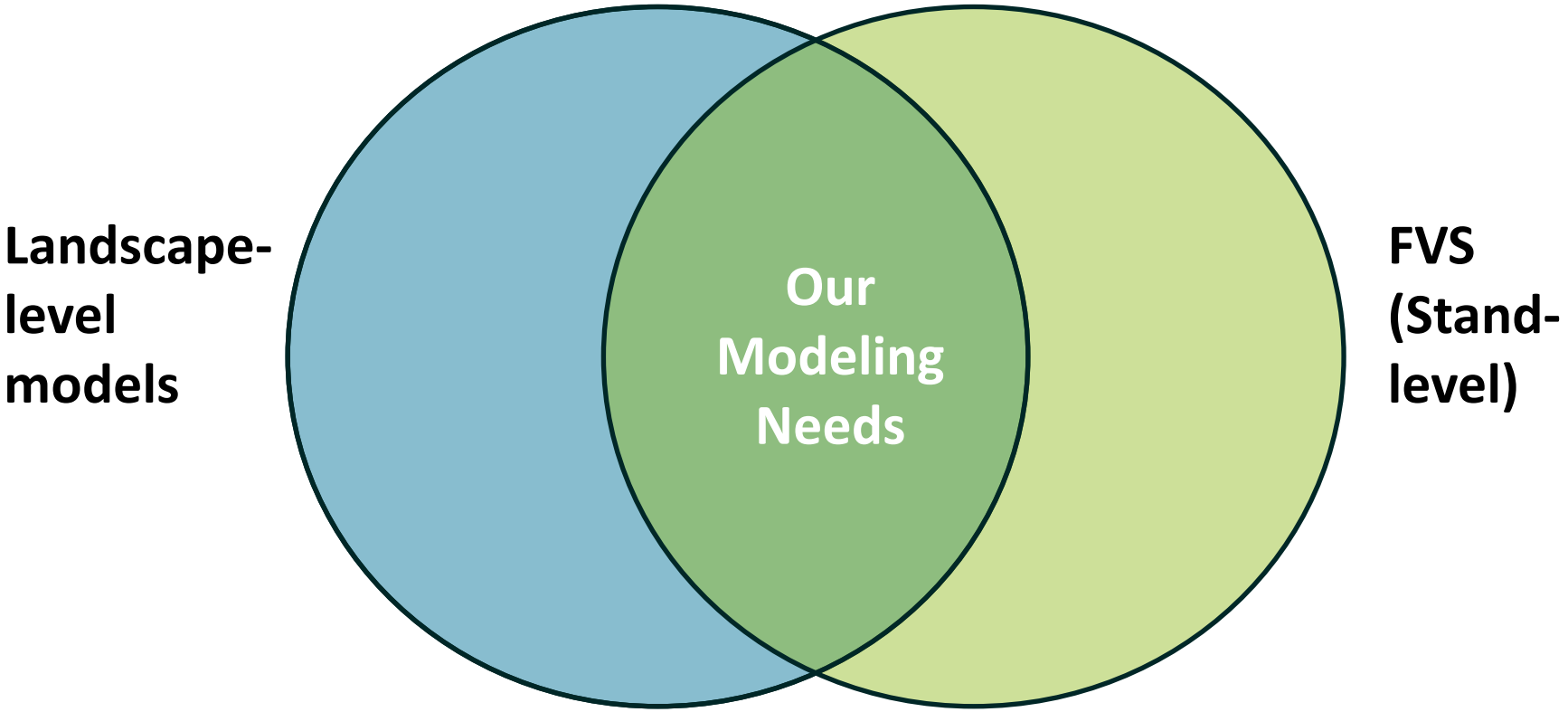
- 17 GCM ensemble
- Increased wildfire



ESSA Innovations

- **Custom Management Actions**: Couldn't do pre-commercial thinning, commercial thinning or site preparation without teaching FVS new tricks
- **Need for Speed**: Couldn't run the model over all stands and still meet project timeline

Our modeling needs were a hybrid between landscape-level modeling and FVS's stand-level capabilities



ESSA Innovations

Landscape-level Models	FVS
Landscapes (forest cover)	Stands (plot data)
Generalized growth/yield curves	Not curve dependent *uses site characteristics and stand history to predict growth*
Harvest even flow at landscape	Harvest based on stand triggers

Our Modeling Needs

☞ Stand and landscapes

ESSA Innovations

Landscape-level Models	FVS
Landscapes (forest cover)	Stands (plot data)
Generalized growth/yield curves	Not curve dependent *uses site characteristics and stand history to predict growth*
Harvest even flow at landscape	Harvest based on stand triggers

Our Modeling Needs

Stand and landscapes

Tree growth across diverse sites, silvicultural treatments, and stand histories

ESSA Innovations

Landscape-level Models	FVS
Landscapes (forest cover) Generalized growth/yield curves	Stands (plot data) Not curve dependent *uses site characteristics and stand history to predict growth*
Harvest even flow at landscape	Harvest based on stand triggers

Our Modeling Needs

FVS challenges

- Stand and landscapes
  Tree growth across diverse sites, silvicultural treatments, and stand histories
- Teach FVS to harvest even flow at landscape

ESSA Innovations

Many thanks to:

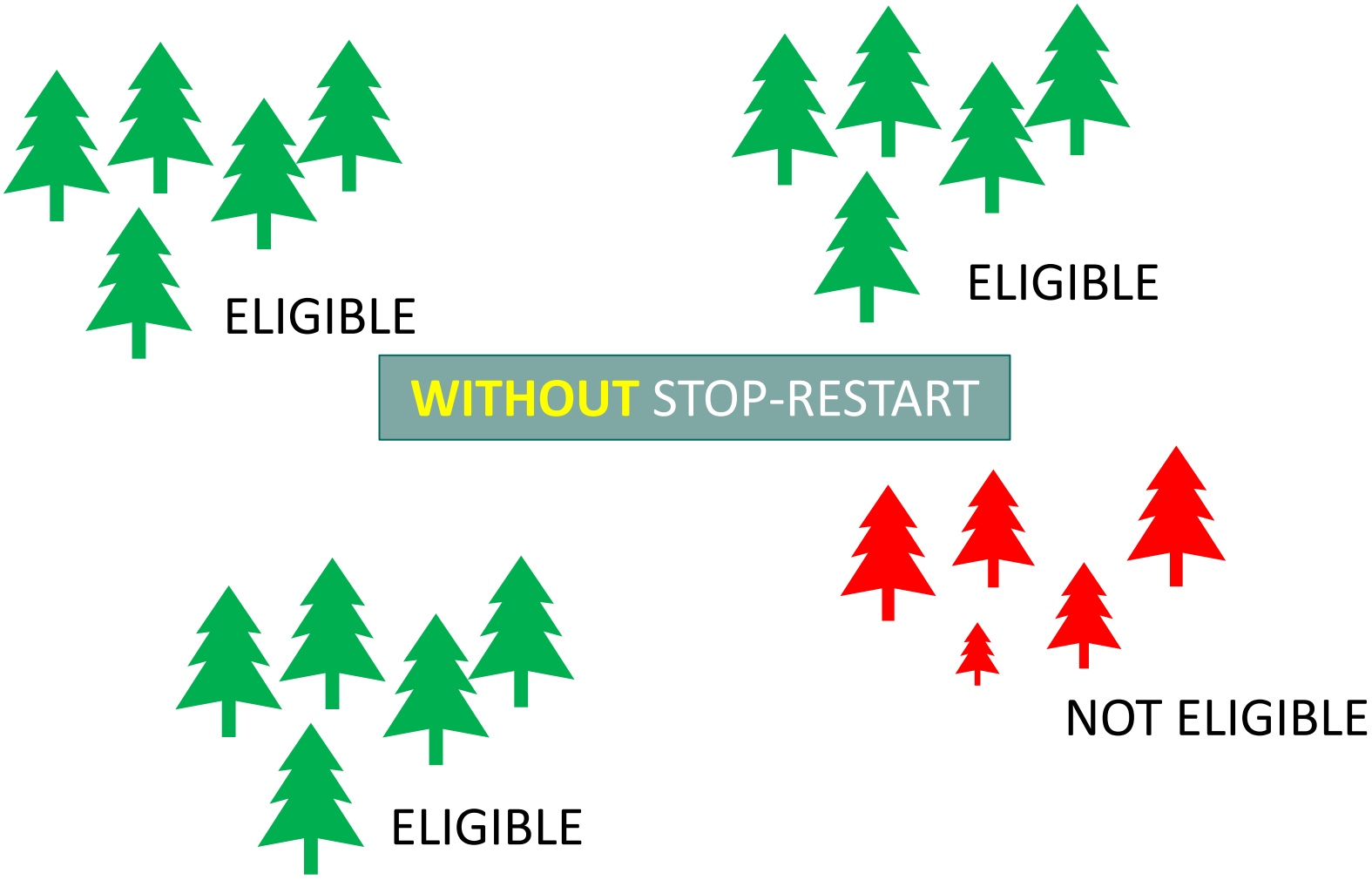
- **Lance David**
- **Nick Crookston**
- **Erin Smith-Mateja**

In addition to our own **Don Robinson** who worked closely with these folks

ESSA Innovations

Problem	Solution
Custom Management Actions	• Stop-restart Functionality
Need for Speed	• Cloud Computing & Parallel Processing • Clustering Stands for Speed

ESSA Innovations: "Stop-Restart" Functionality

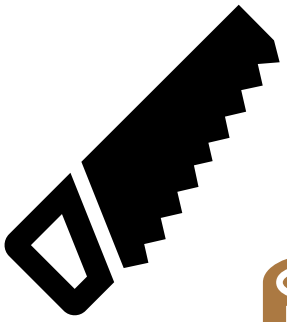


ESSA Innovations: "Stop-Restart" Functionality

ELIGIBLE

ELIGIBLE

WITHOUT STOP-RESTART



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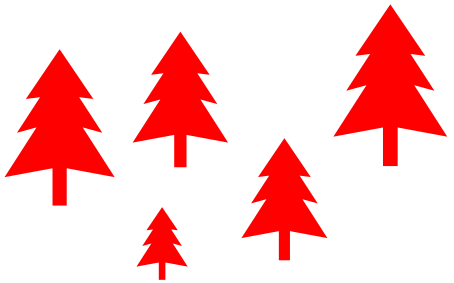


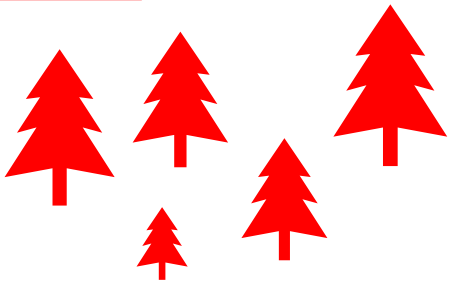
NOT ELIGIBLE

ESSA Innovations: "Stop-Restart" Functionality

ELIGIBLE

ELIGIBLE

WITH STOP-RESTART



NOT ELIGIBLE

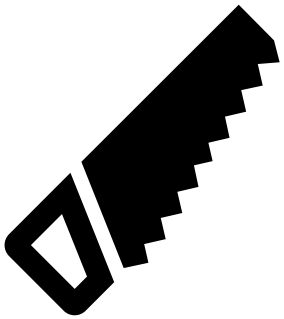
ELIGIBLE

ESSA Innovations: "Stop-Restart" Functionality

ELIGIBLE

ELIGIBLE

WITH STOP-RESTART



ELIGIBLE

NOT ELIGIBLE

Extra Methods Detail to Support Working Group Review of Slide Deck

Yield Target Implementation using Stop-Restart

- The **yield target** is based on the historical harvest 2013-2023 on a county-level basis
- The yield target is the same across all scenarios
- The simulated yield is the amount of volume estimated by FVS model simulations
- The simulated yield can only be equal to or less than the yield target. It cannot exceed

Commercial Thinning Implementation using Stop-Restart

- A **commercial thin** (CT) removes 30% of basal area starting with the smallest trees first
- In each 5-year time step, we identify the stands with MBF > commercial thinning threshold
- Next, we identify the volume available in these stands
- Next, we identify which stands to commercially thin first up to:
  - 4% of eligible **area** per 5-year time step (based on the historical rate of CT) for scenarios that don't include significantly increased thinning
  - 100% of eligible **area** for significantly increased thinning scenarios
- In both cases, we sort the stands and select the stands with highest trees per acre to thin first

Stand Replacement Harvest Implementation using Stop-Restart

- A **stand replacement harvest** removes all trees in a stand except for eight large leave trees
- The amount of total simulated yield is limited to not exceed the historical harvest (2013-2023) per county
  - This prevents FVS from harvesting all eligible stands in the first 5-year time step
- We calculate the remaining unmet yield (historical yield minus yield from commercial thinning)
  - Increased commercial thinning can thus lead to reduced stand replacement harvest
- We identify eligible stands as those with MBF > stand replacement harvest threshold
  - Eligible stands can also be those with an age > 80 in site class 3 or > 90 in site class 4 for scenarios 6 and 7
- Next, we sort eligible stands and select the stands with highest MBF to harvest first
- We harvest eligible stands as needed to obtain the yield not yet met by commercial thinning
  - The model may not find enough volume to meet county level targets

Site Preparation Implementation using Stop-Restart

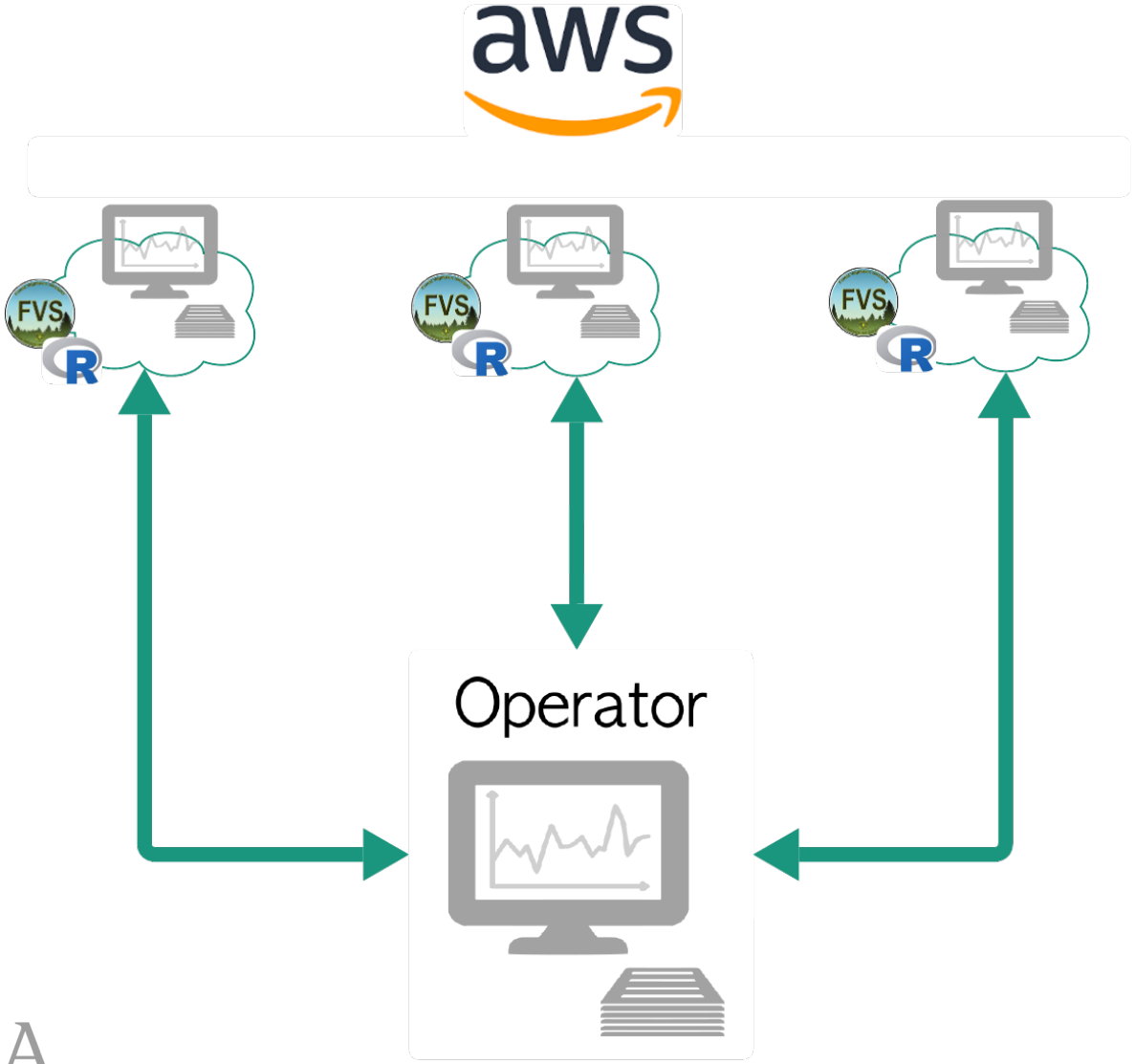
- **Site preparation** enhances seedling survival and growth through removal of competing vegetation
  - Modeled as a 63% increase in volume after 10 years (Rose et al. 2006)
- Stands that are < 10 years old are eligible for site preparation
  - In enhanced silviculture scenarios, site prep can occur on 100% of eligible stands vs. only 75% in all other scenarios
  - We sort the stands and select those with highest trees per acre to apply site preparation

Seedling Improvements (Stop-Restart not Required)

- **Seedling improvements** are a growth boost that results from planting seedlings bred for improved growth
  - Modeled as a 2% increase in volume in the first ten years of stand growth
- In the enhanced silviculture scenarios, all stands are planted with improved seedlings
- Improved seedling growth boost is additional to that from site preparation where site preparation was applied

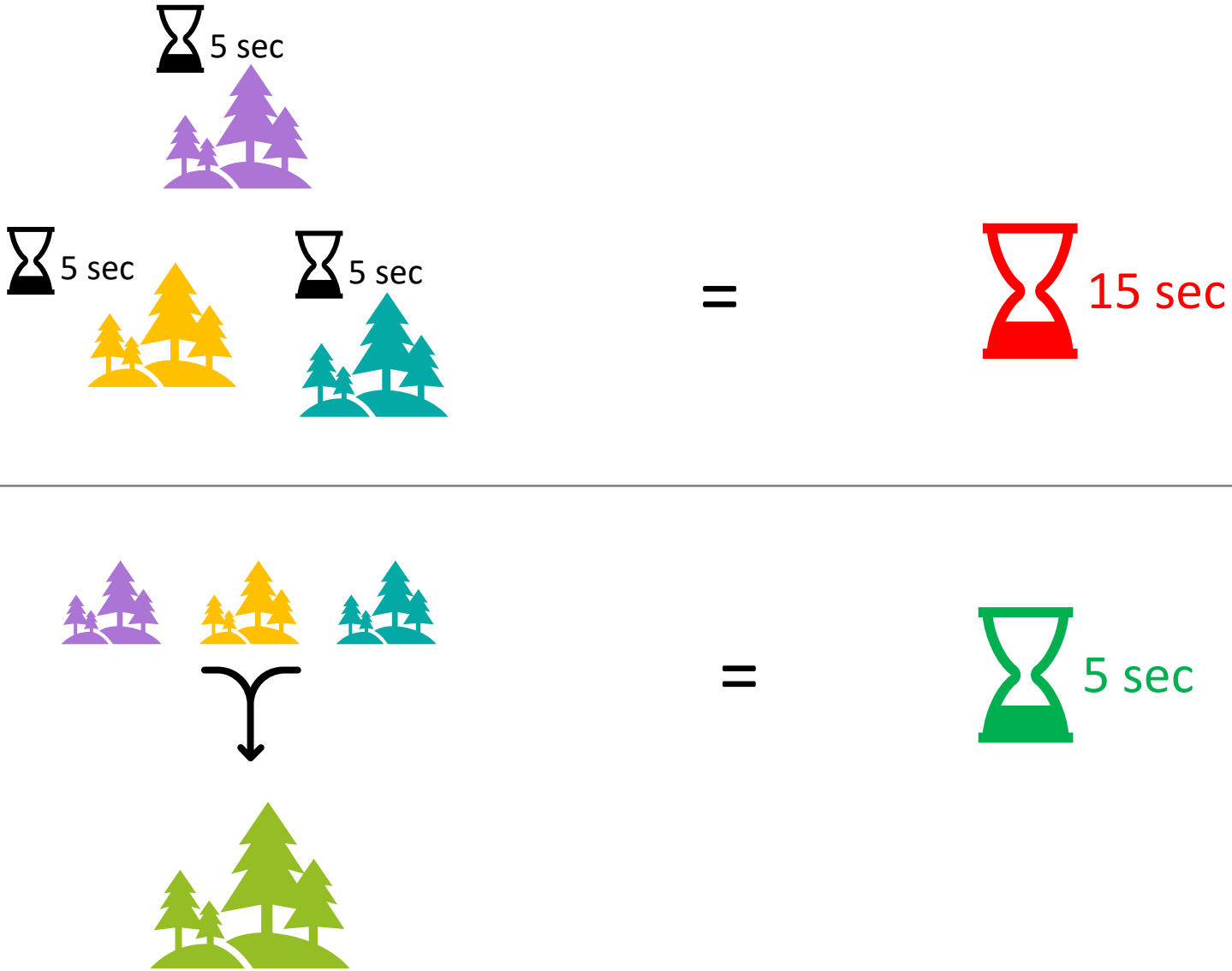
End of Extra Methods Detail

ESSA Innovations: Cloud Computing and Parallelization of FVS

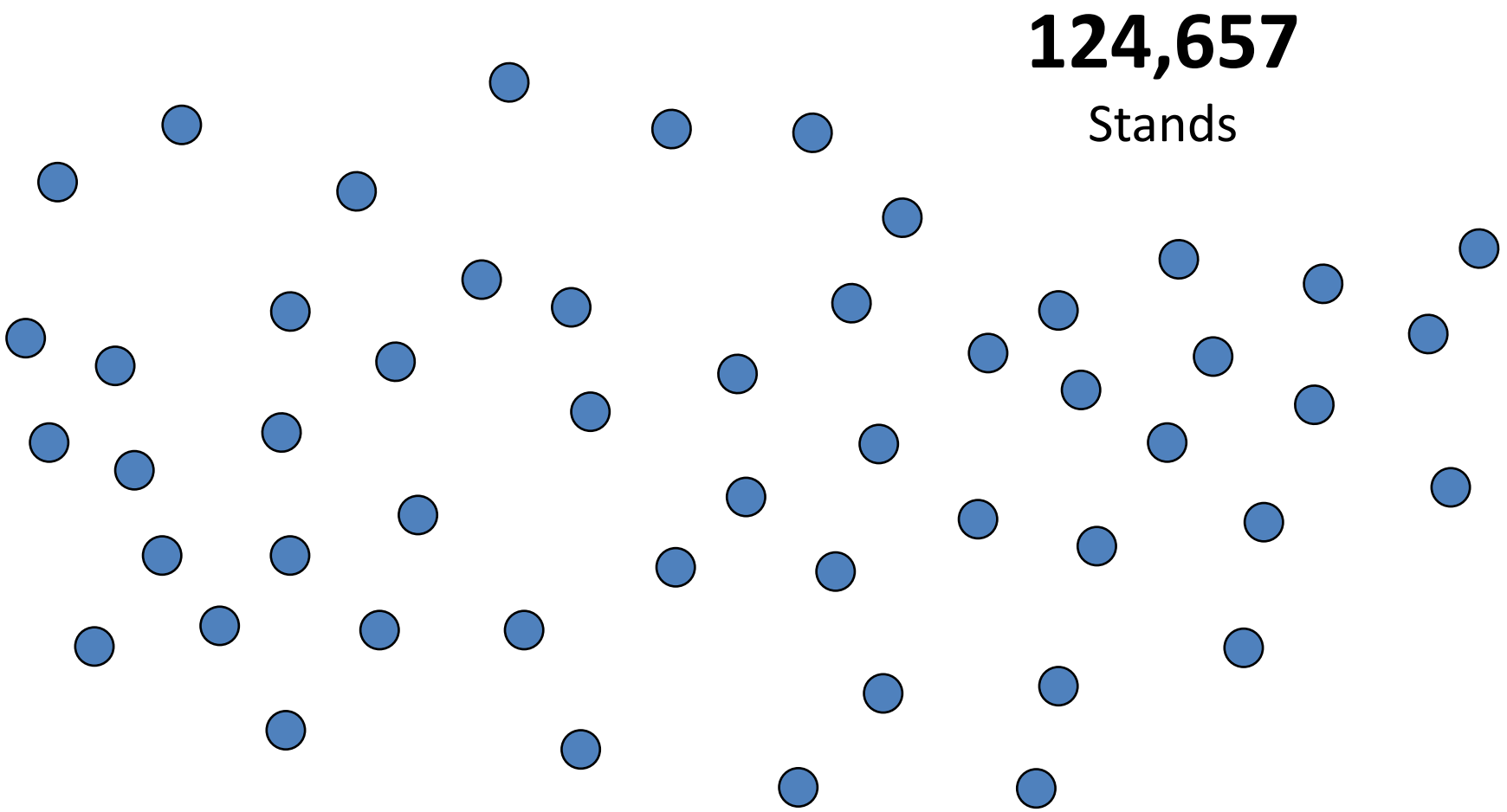


100 virtual computers

ESSA Innovations: Clustering Stands for Speed



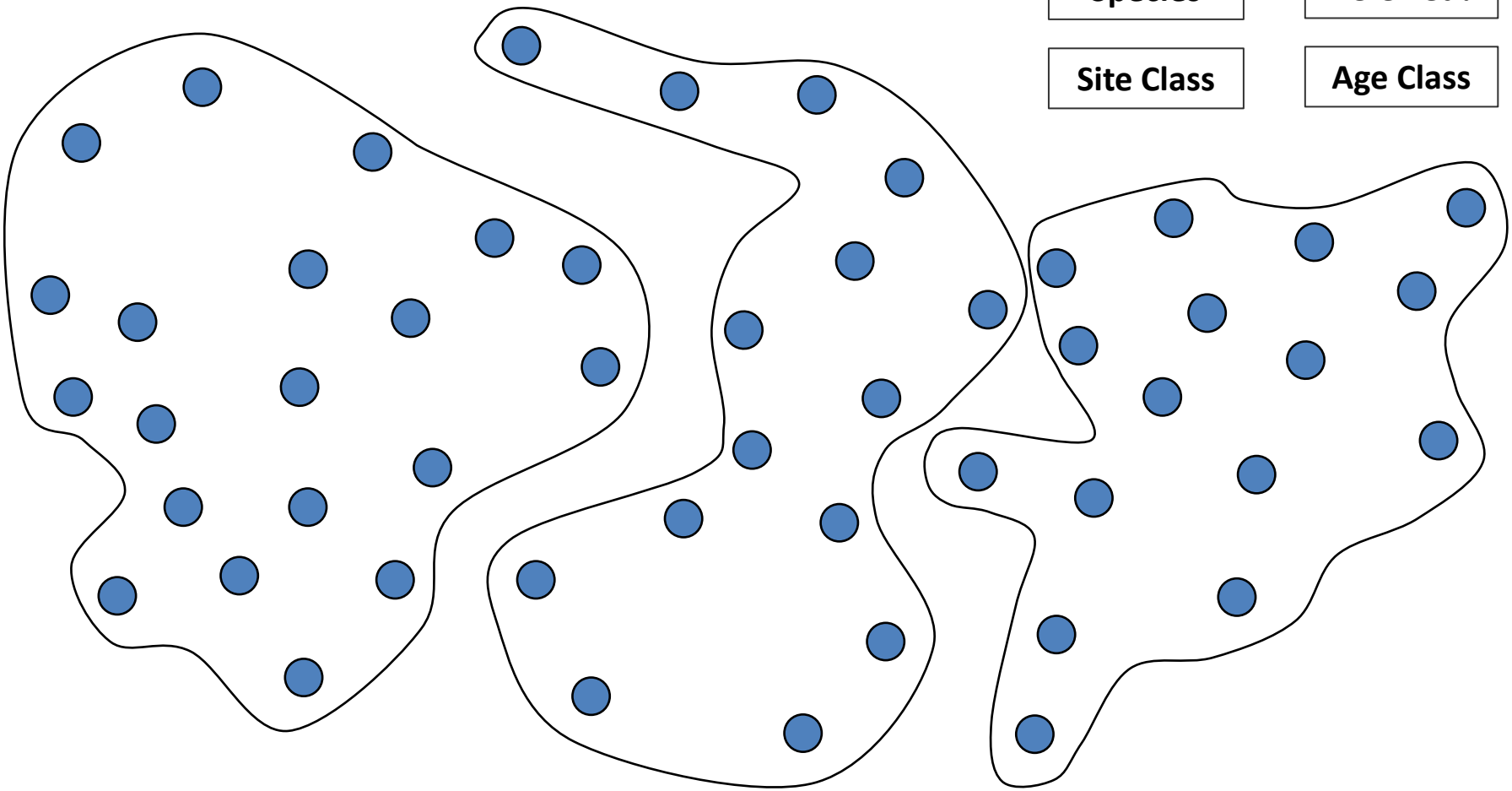
ESSA Innovations: Clustering Stands for Speed



ESSA Innovations: Clustering Stands for Speed

Initial Grouping Variables

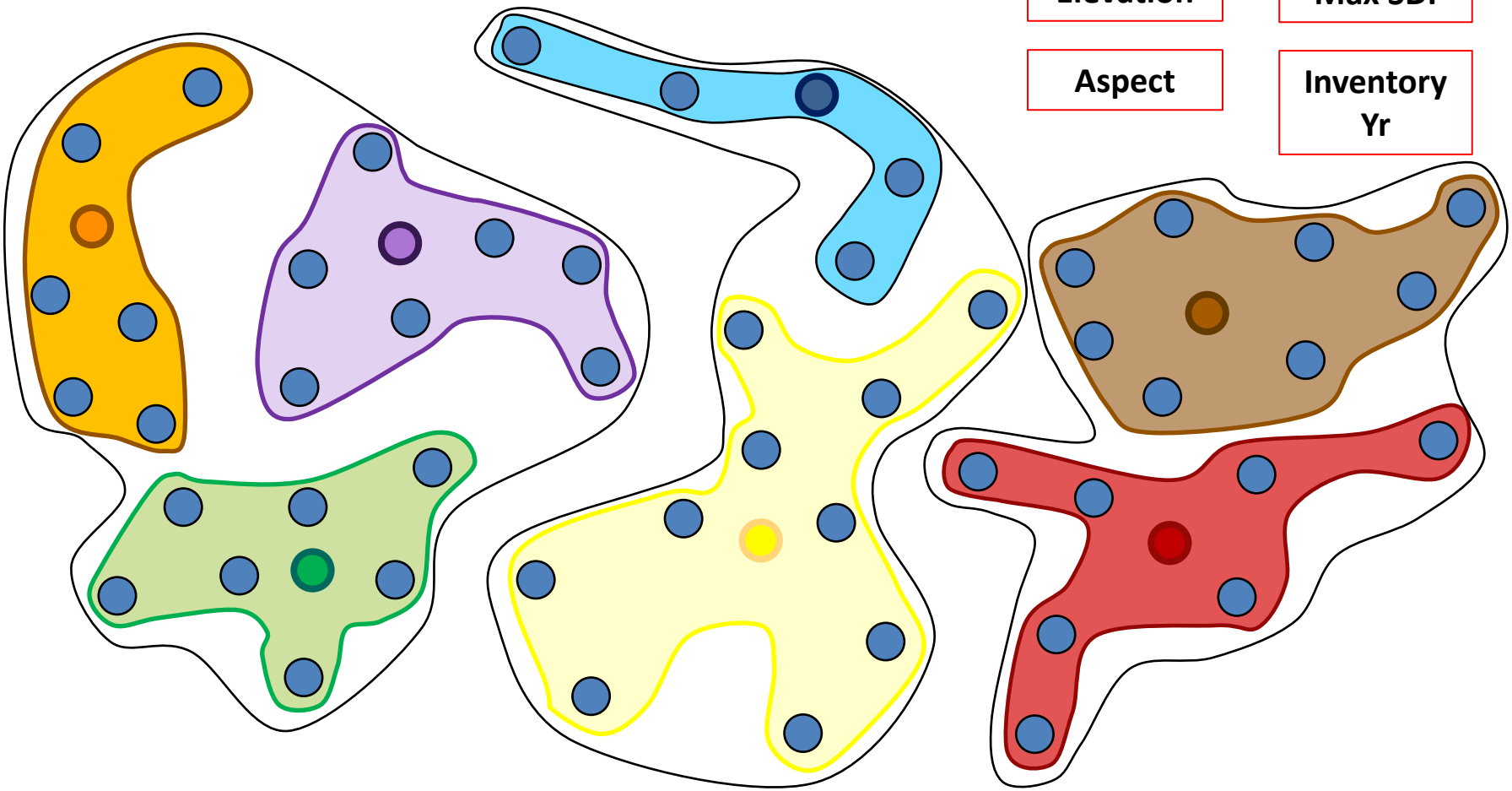
- Land Class
- County
- Species
- Deferred?
- Site Class
- Age Class



ESSA Innovations: Clustering Stands for Speed

Clustering Variables

- Slope
- Site Index
- Elevation
- Max SDI
- Aspect
- Inventory Yr



ESSA Innovations: Clustering Stands for Speed

Slope | Site Index
Elevation | Max SDI
Aspect | Inventory Yr

9,221

Clusters became “stands” in FVS
allowing us to simulate an entire landscape based on site specific attributes without relying on generalized yield curves

General Model Performance

	# Unique Stands (GEM only, non-deferred)	**Total run time per scenario (avg. est.)**	**Total run time all scenarios (est.)**
Single computer (all stands)	46,540	17 days 22 hours 23 mins	9 months 16 days 22 hours 4 mins

General Model Performance

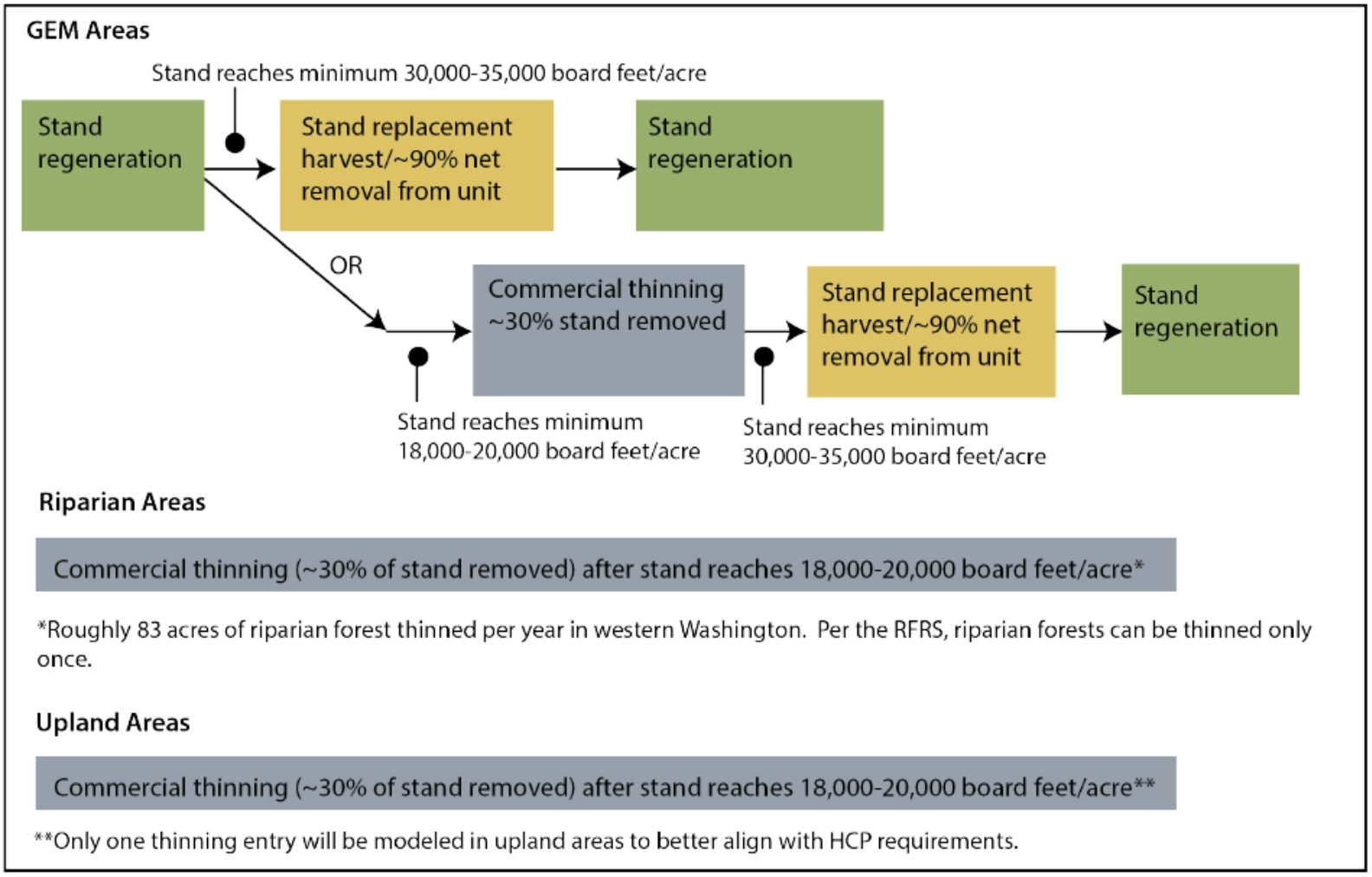
	# Unique Stands (GEM only, non-deferred)	Total run time per scenario (avg. est.)	Total run time all scenarios (est.)
Single computer (all stands)	46,540	17 days 22 hours 23 mins	9 months 16 days 22 hours 4 mins
Cloud system (all stands)	46,540	2 days 1 hour 19 mins	2 days 20 hours 34 mins

General Model Performance

	# Unique Stands (GEM only, non-deferred)	Total run time per scenario (avg. est.)	Total run time all scenarios (est.)
Single computer (all stands)	46,540	17 days 22 hours 23 mins	9 months 16 days 22 hours 4 mins
Cloud system (all stands)	46,540	2 days 1 hour 19 mins	2 days 20 hours 34 mins
Cloud system (clustering)	2,206	1 hour 12 mins	3 hours 15 mins

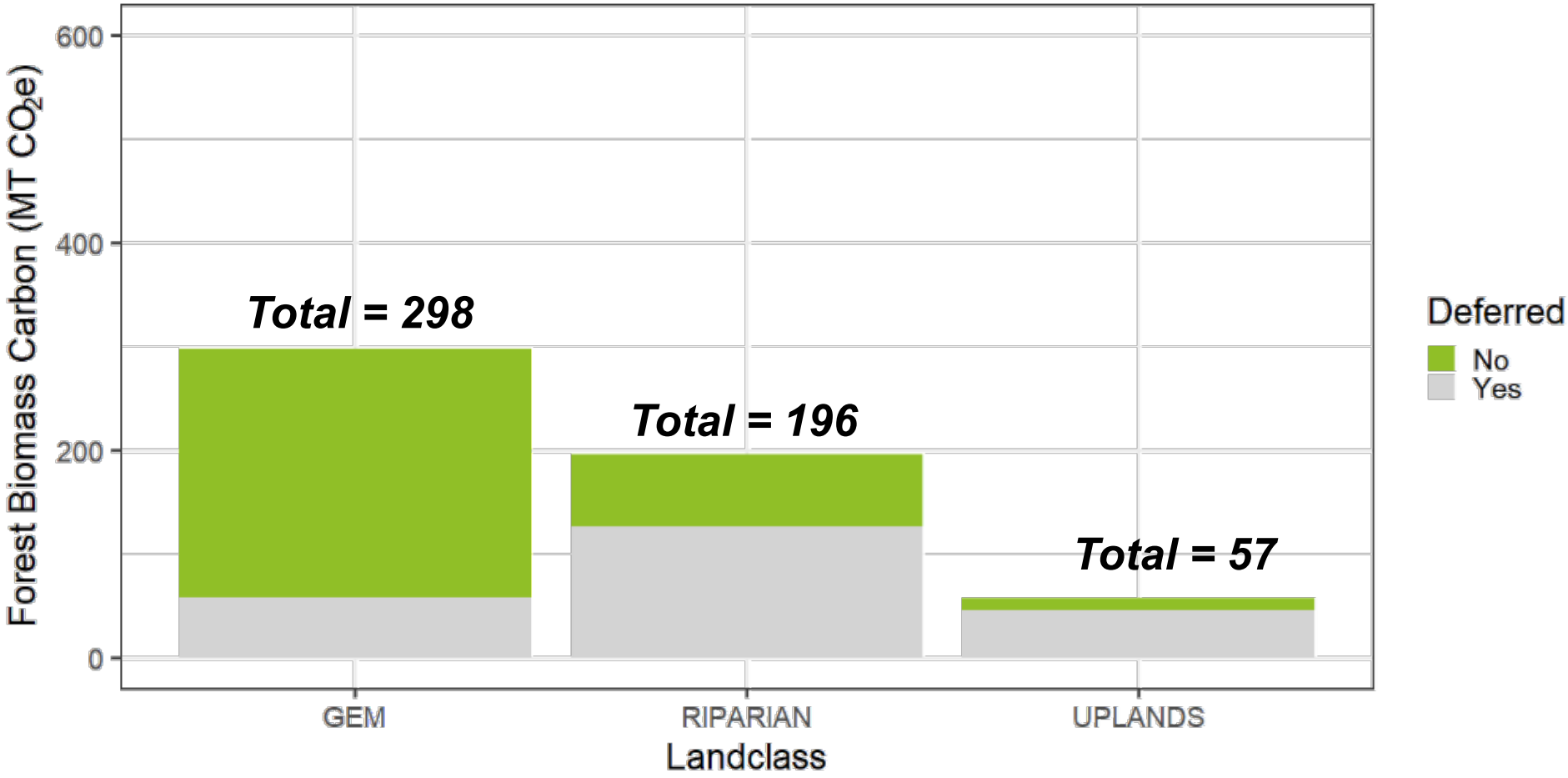
Part 1: Landscape-level Results

Scenario 1: Current Practices



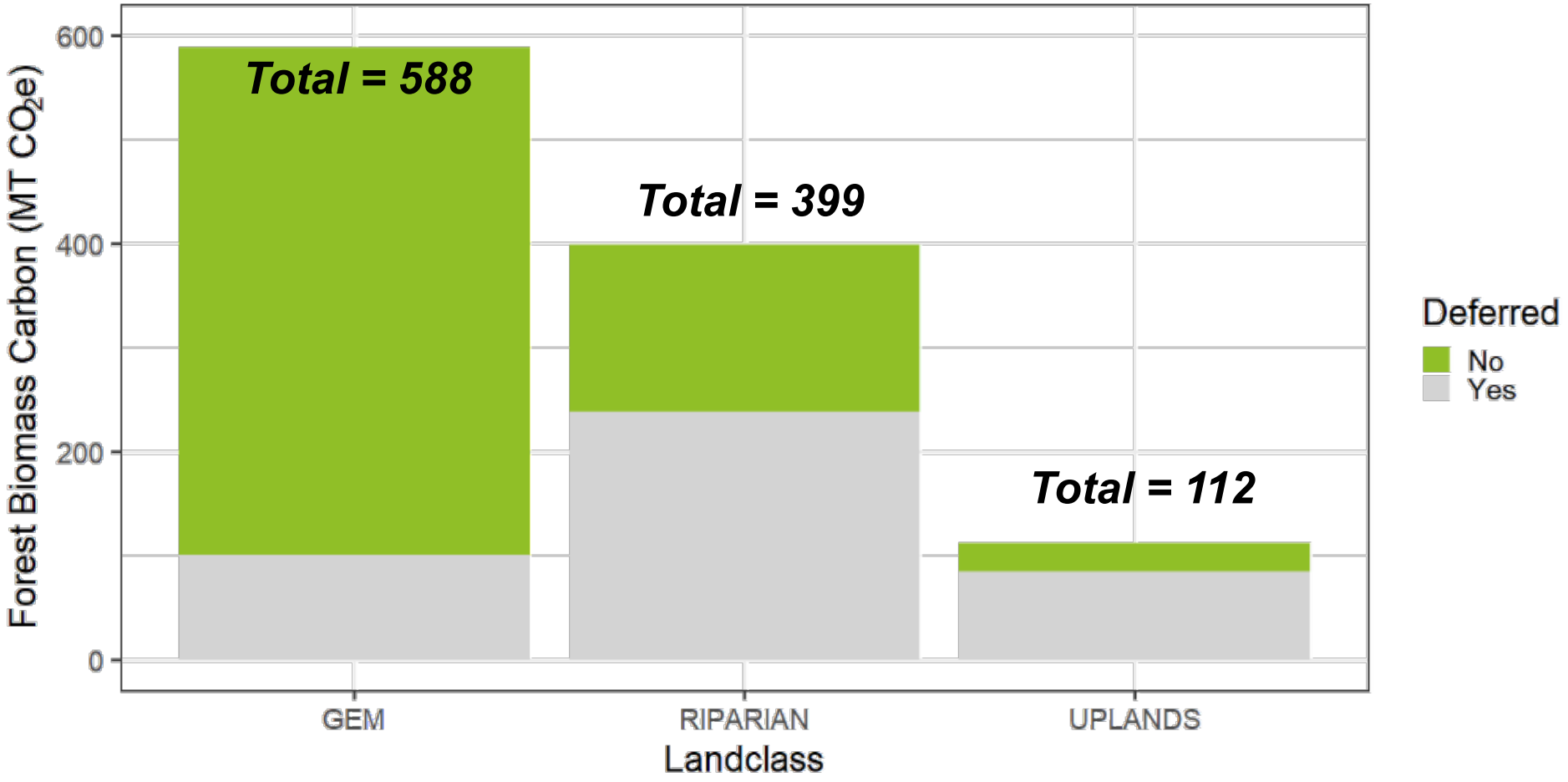
Baseline for Comparison: Scenario 1 Current Practices

551 Mt CO2e in 2024

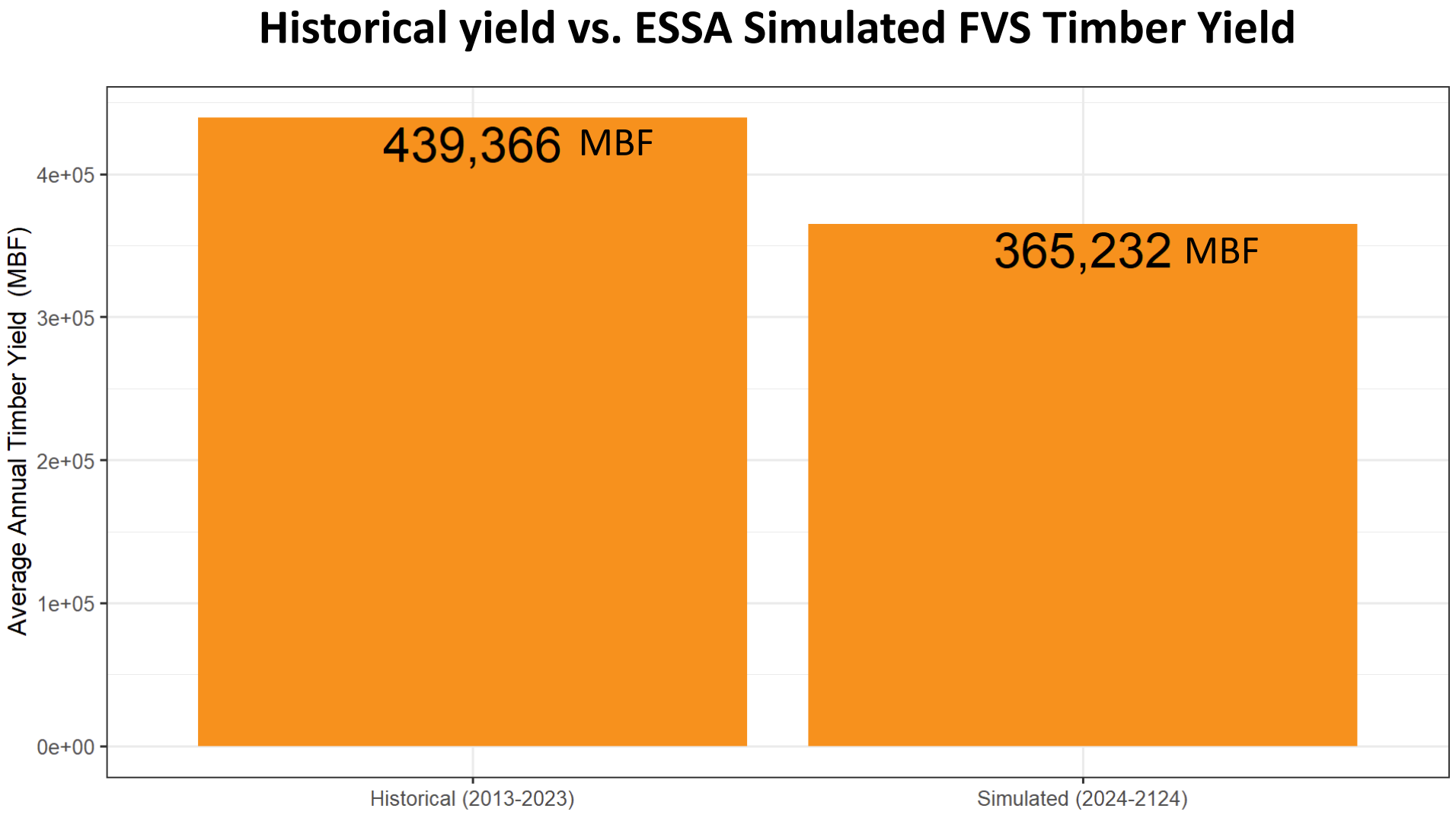


Baseline for Comparison: Scenario 1 Current Practices

1,099 Mt CO2e in 2124

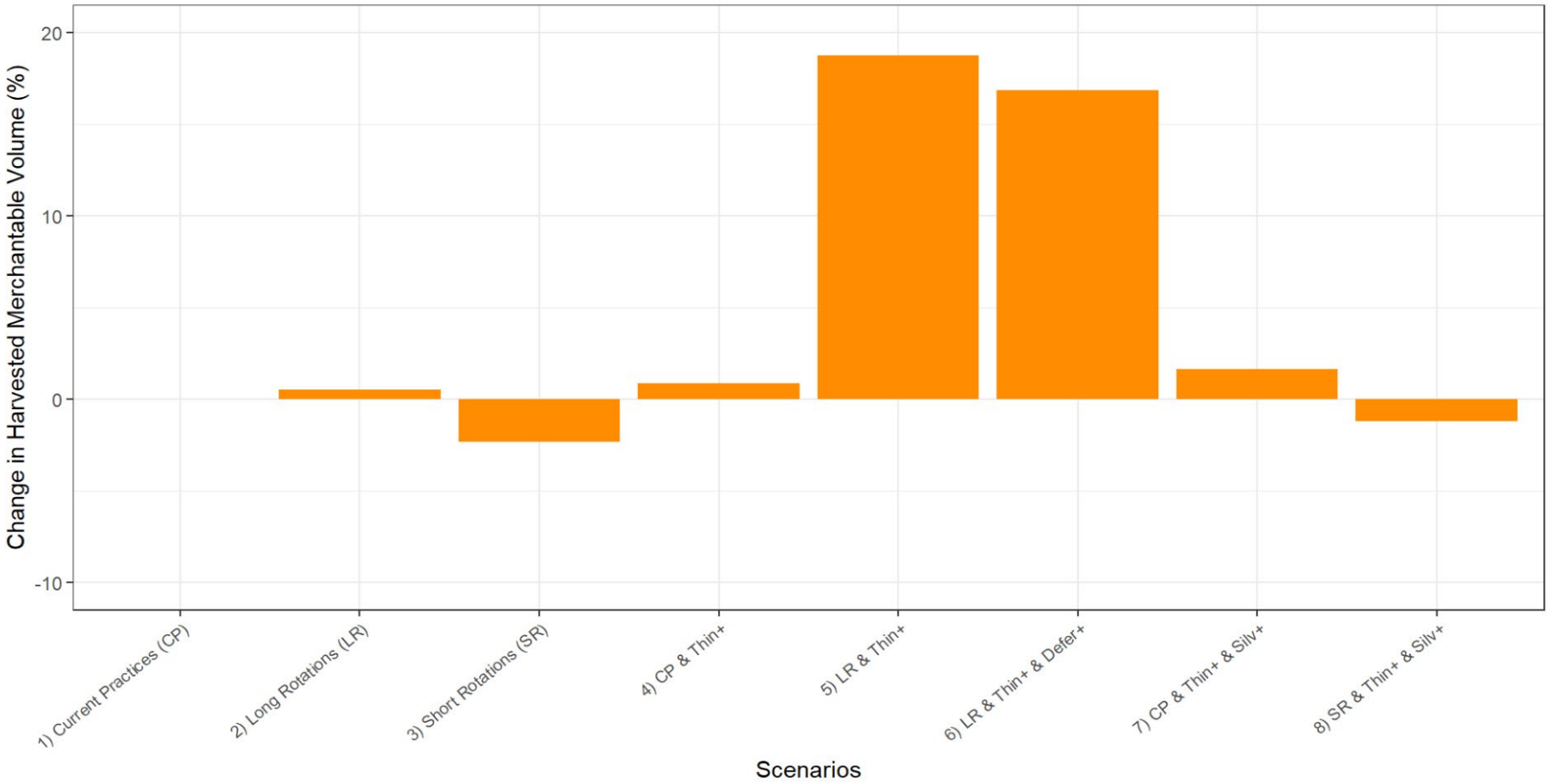


Baseline for Comparison: Scenario 1 Current Practices (no Climate Change)



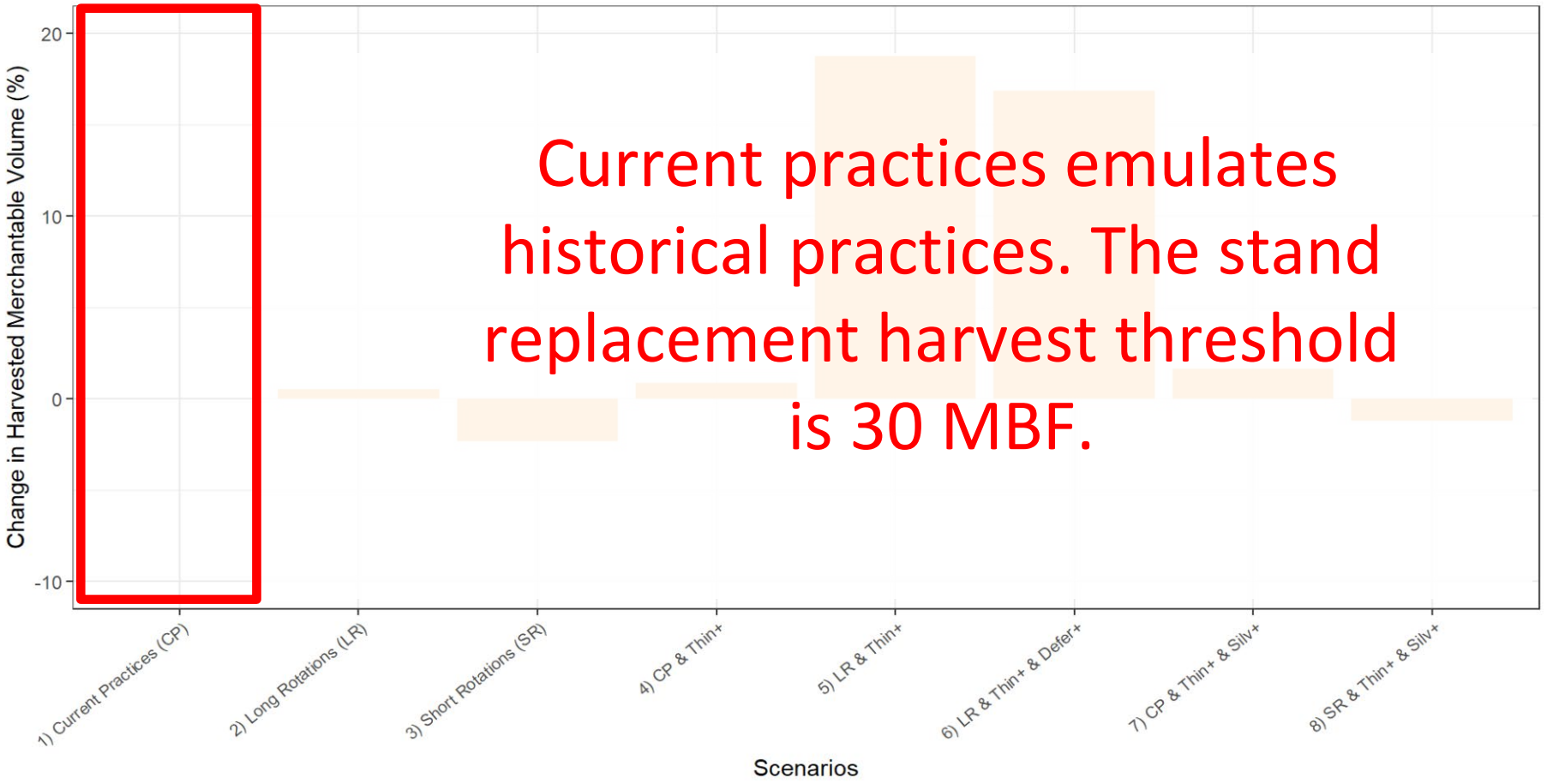
Scenario Results - Landscape Level

Simulated Timber Yield



Scenario Results - Landscape Level

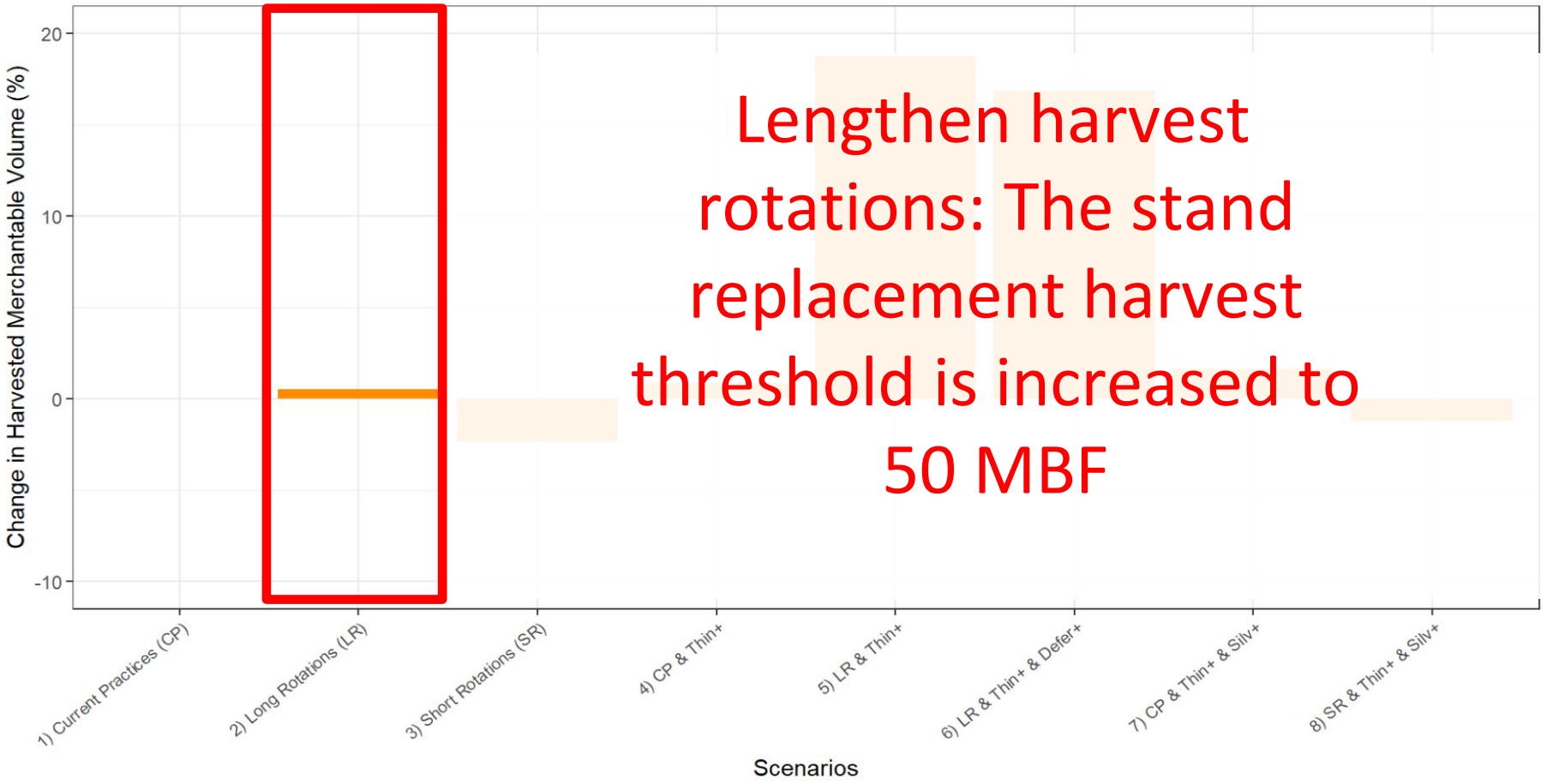
Simulated Timber Yield



Current practices emulates historical practices. The stand replacement harvest threshold is 30 MBF.

Scenario Results - Landscape Level

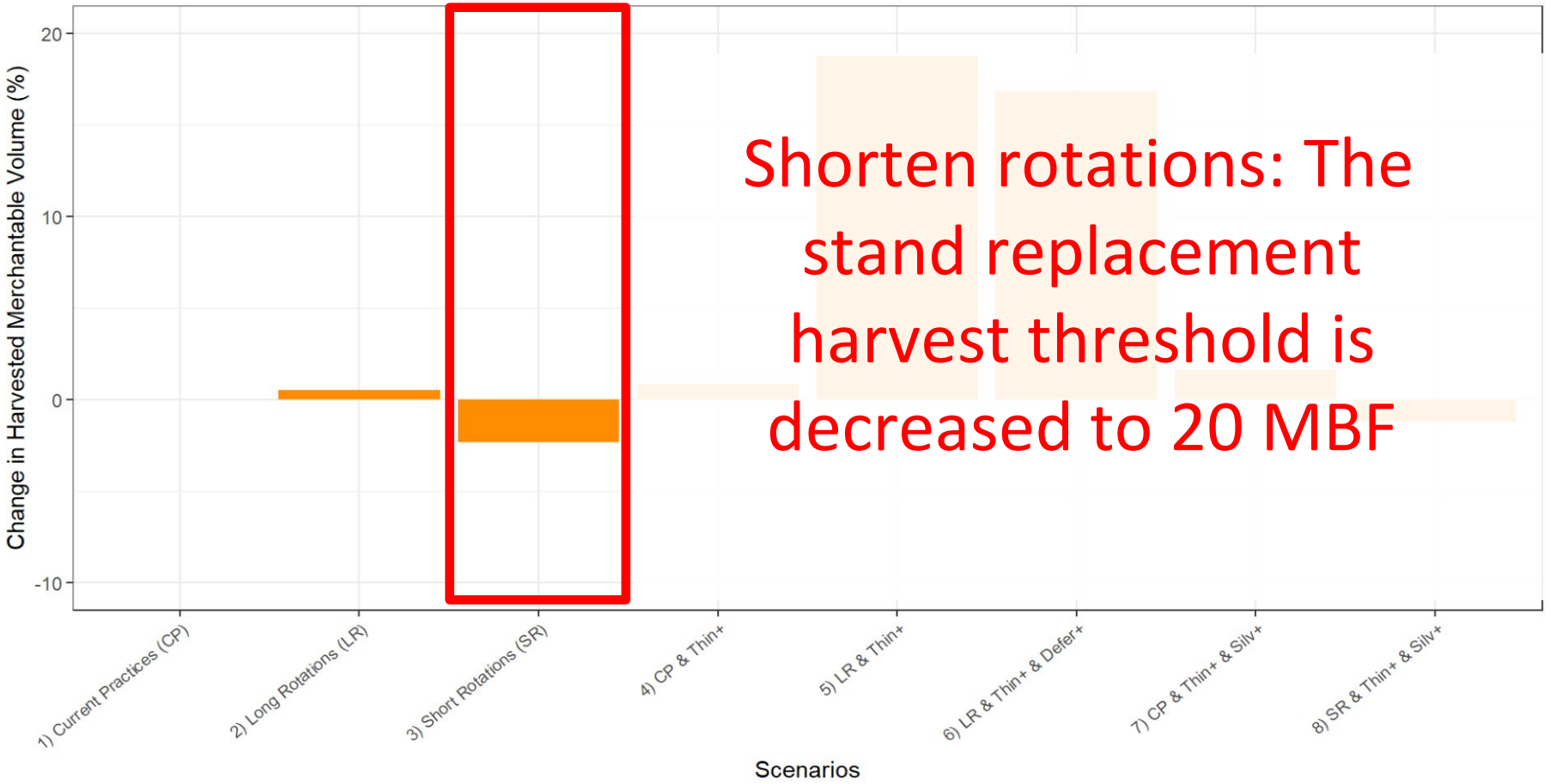
Simulated Timber Yield



Lengthen harvest rotations: The stand replacement harvest threshold is increased to 50 MBF

Scenario Results - Landscape Level

Simulated Timber Yield



Shorten rotations: The stand replacement harvest threshold is decreased to 20 MBF

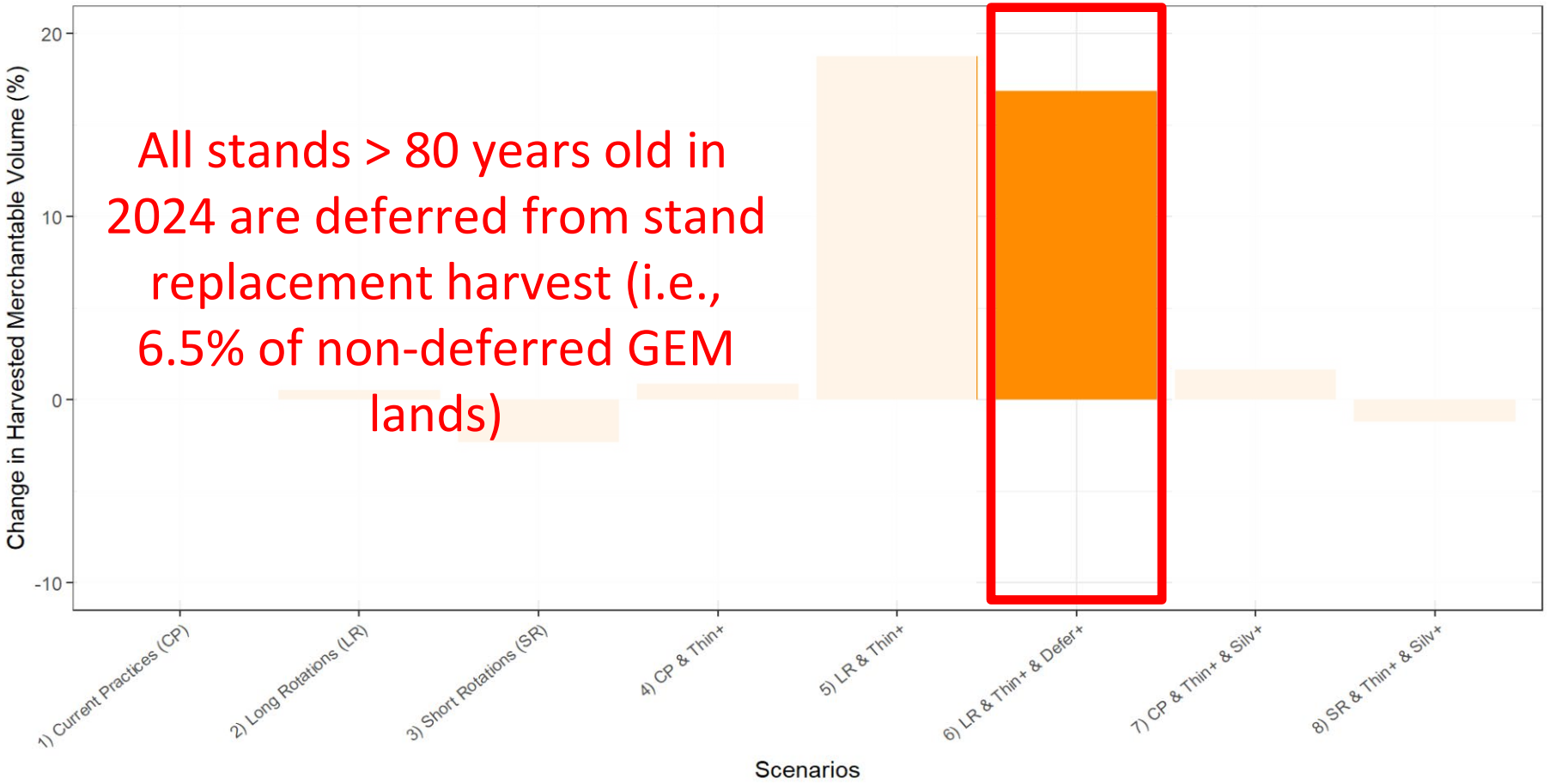
Scenario Results - Landscape Level

Simulated Timber Yield

‘Significantly increase thinning’ requires a commercial thinning every rotation and increases pre-commercial thinning from 75-100%

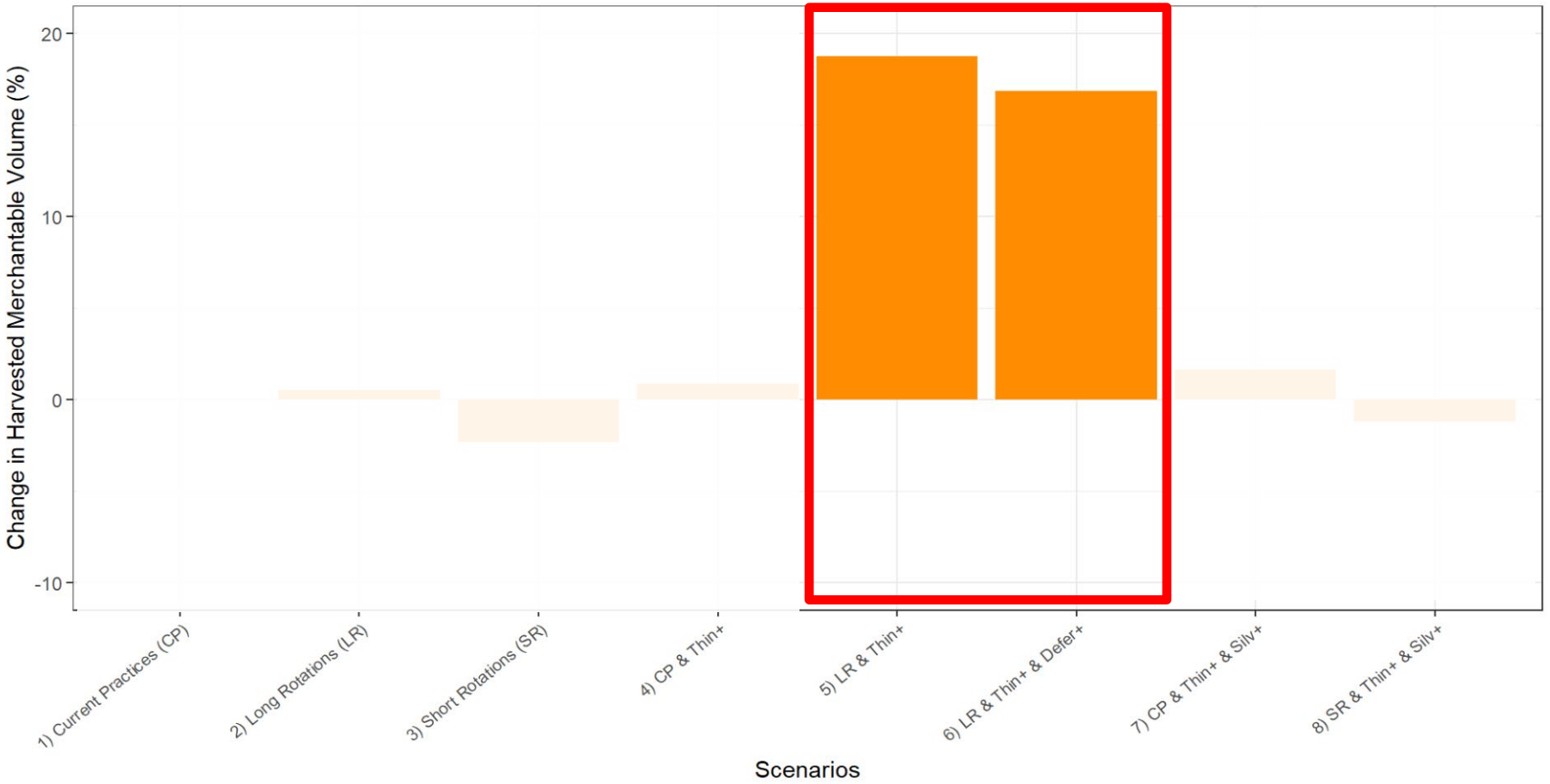
Scenario Results - Landscape Level

Simulated Timber Yield



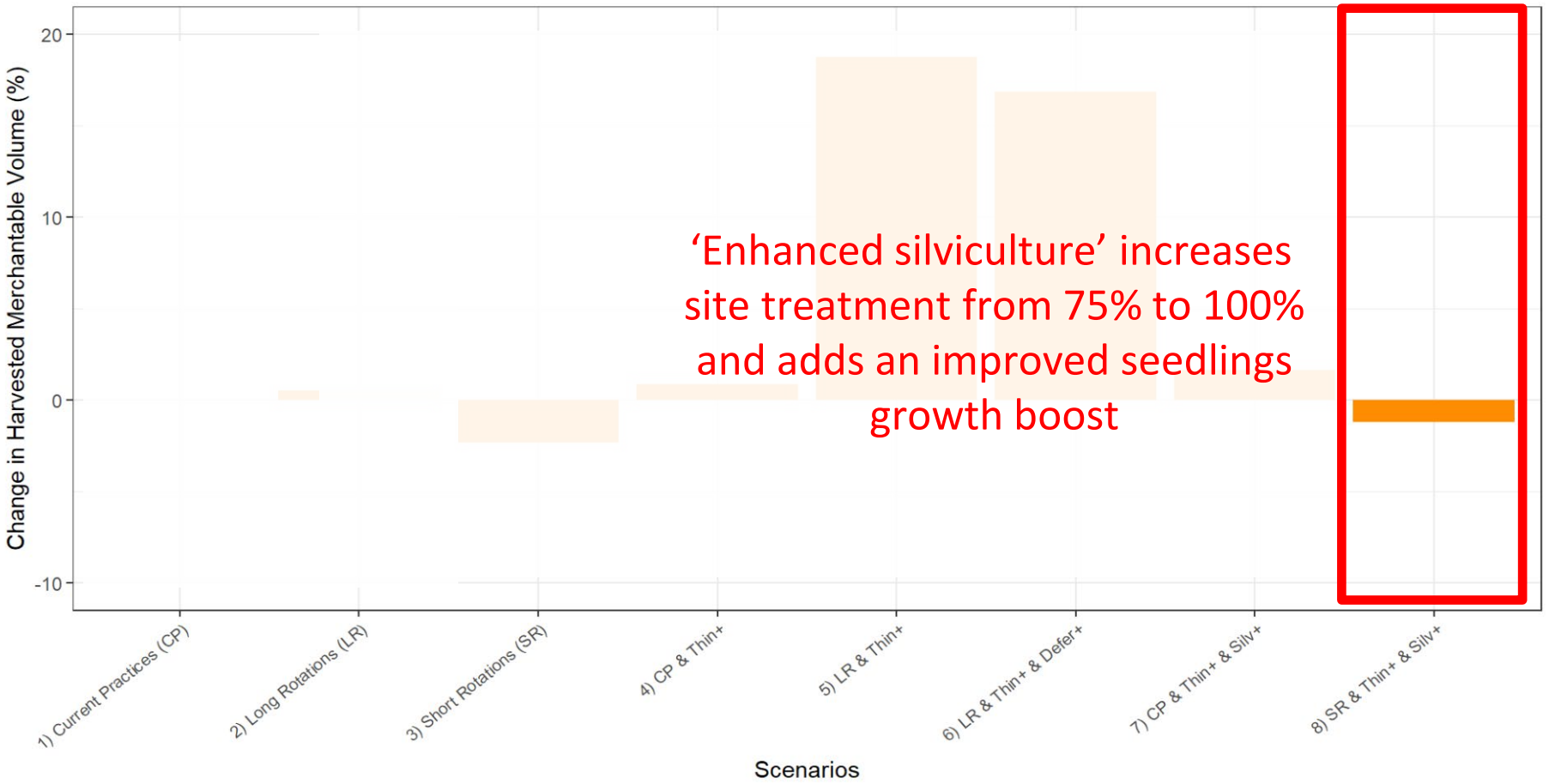
Scenario Results - Landscape Level

Simulated Timber Yield



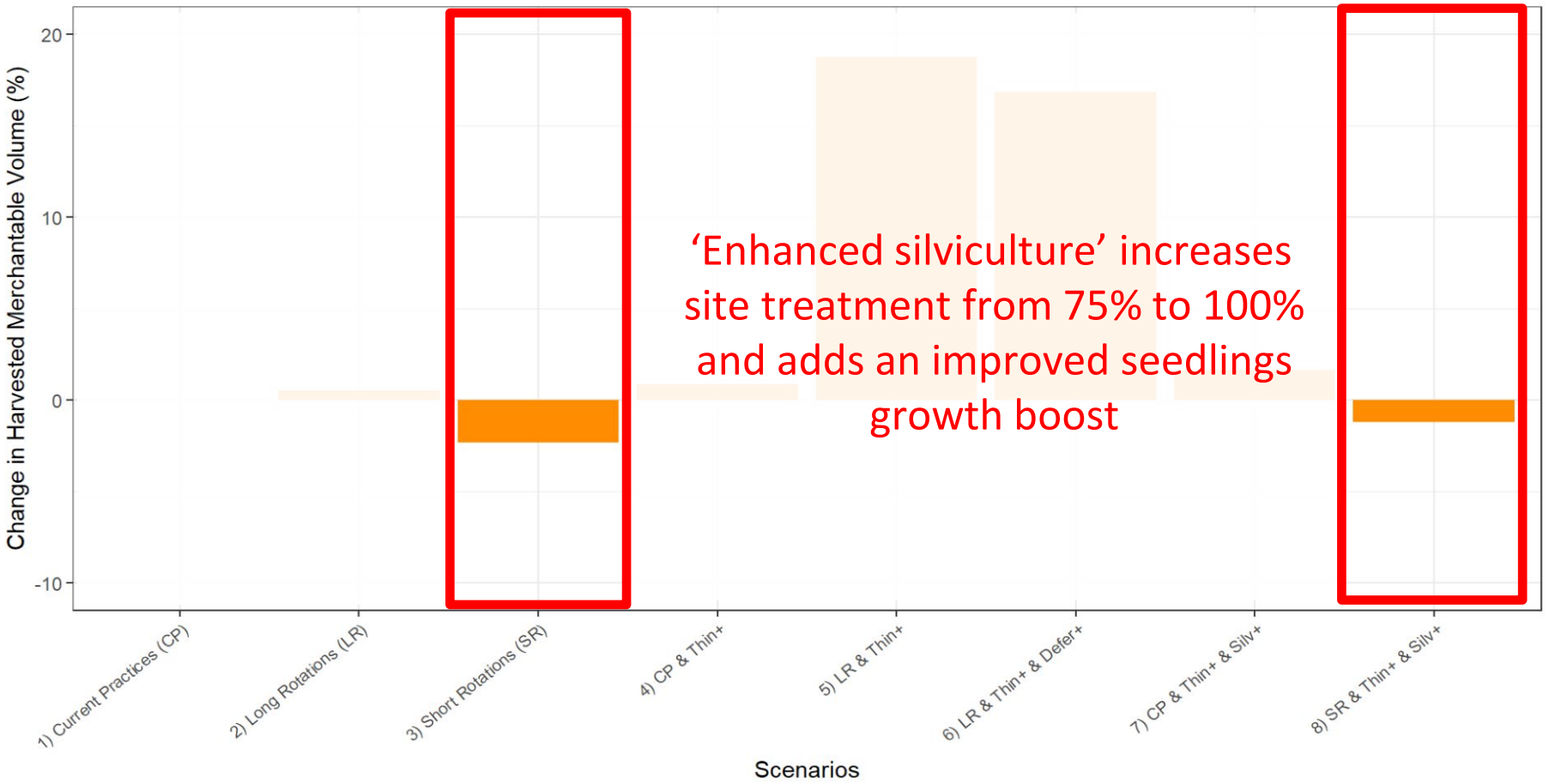
Scenario Results - Landscape Level

Simulated Timber Yield



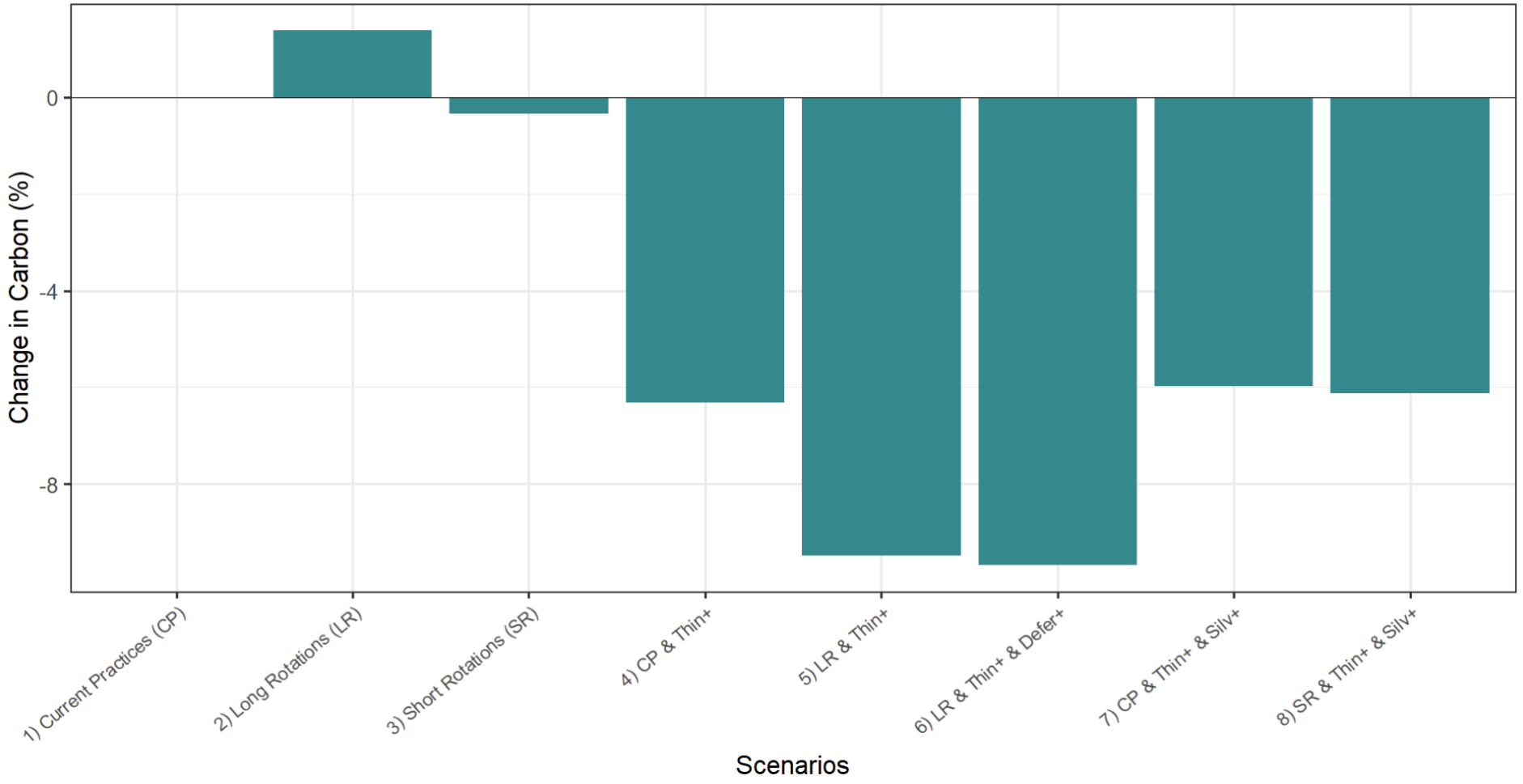
Scenario Results - Landscape Level

Simulated Timber Yield

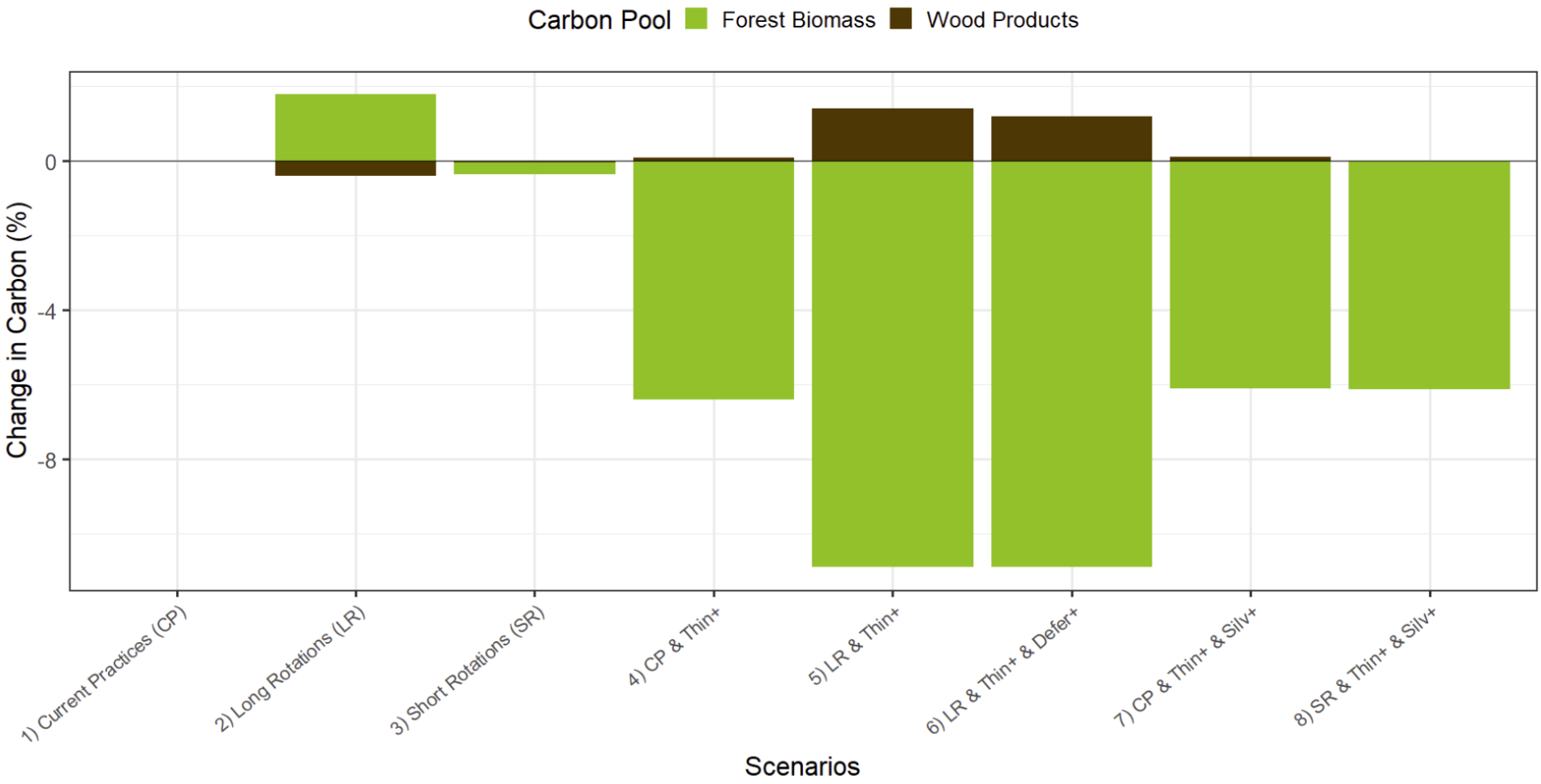


'Enhanced silviculture' increases site treatment from 75% to 100% and adds an improved seedlings growth boost

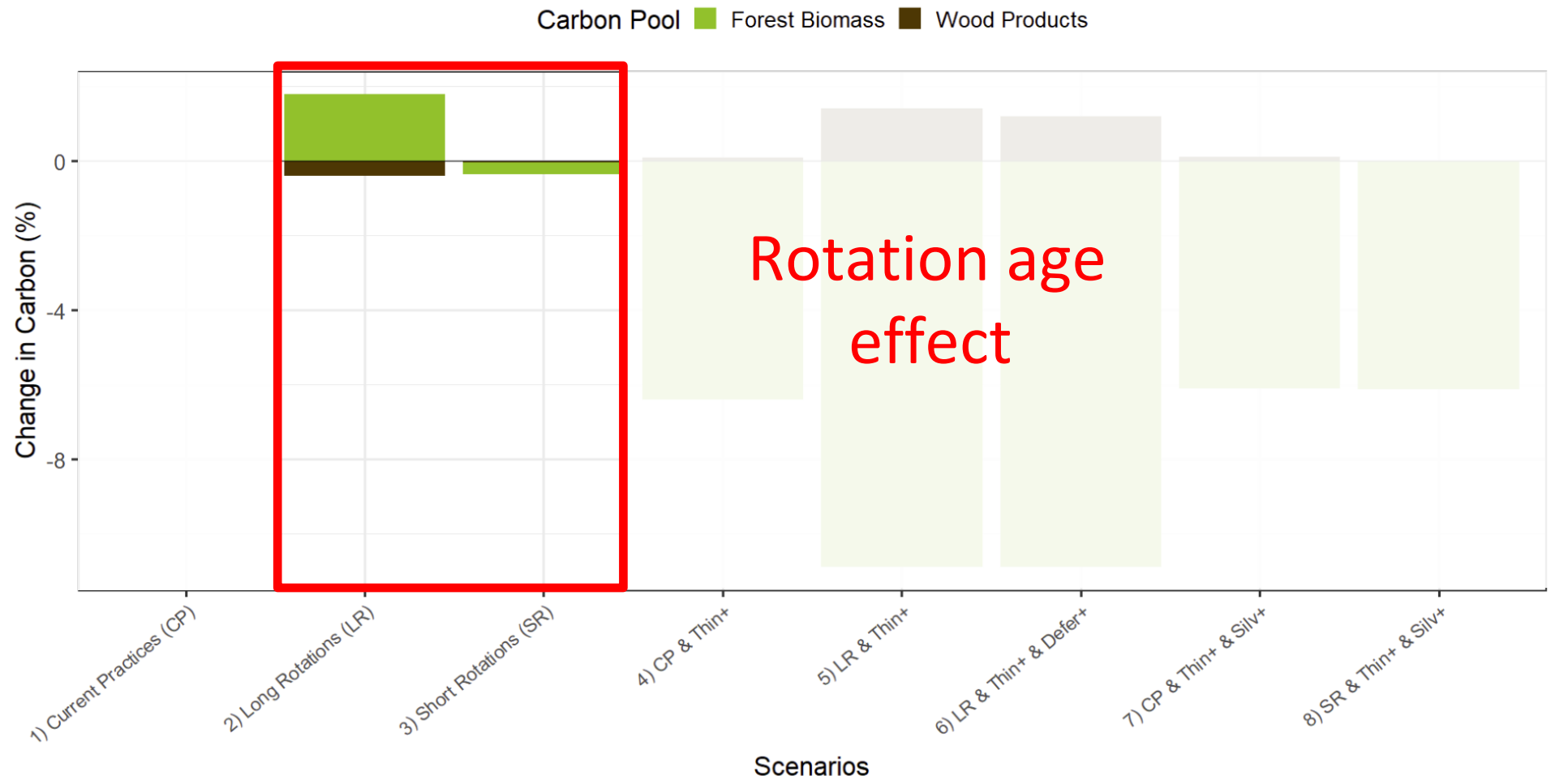
Scenario Results - Landscape-Level



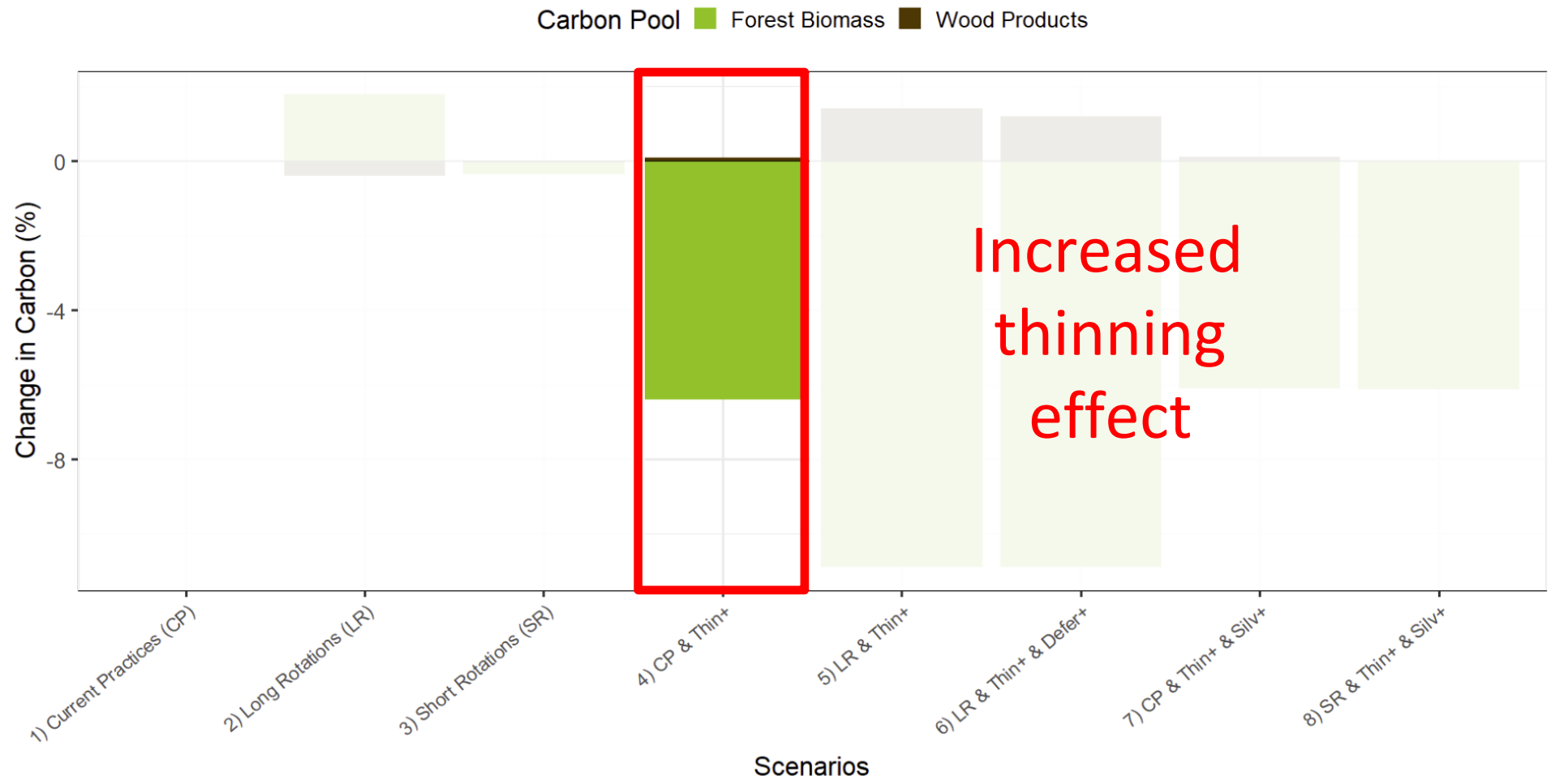
Scenario Results - Landscape-Level



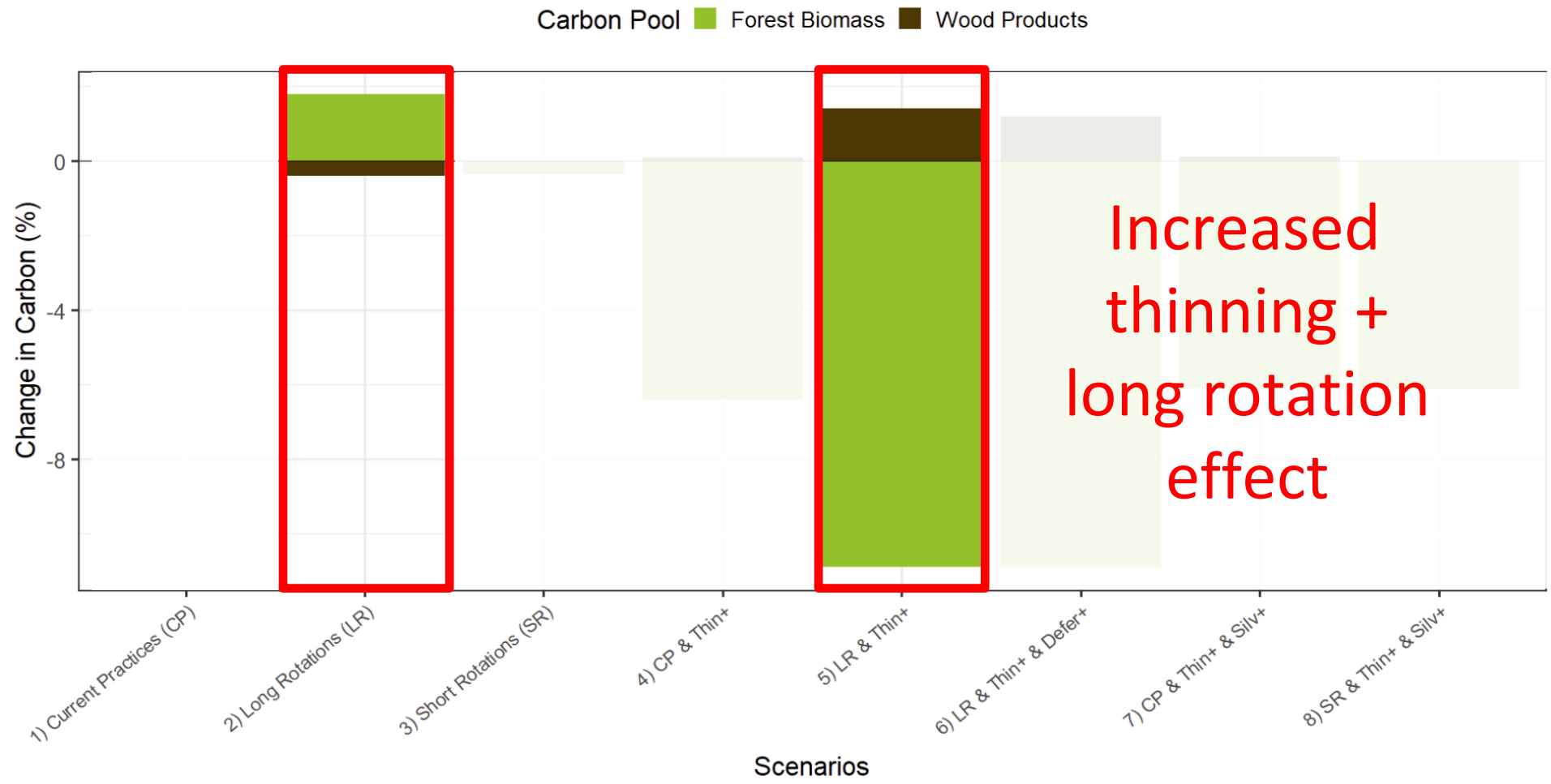
Scenario Results - Landscape-Level



Scenario Results - Landscape-Level

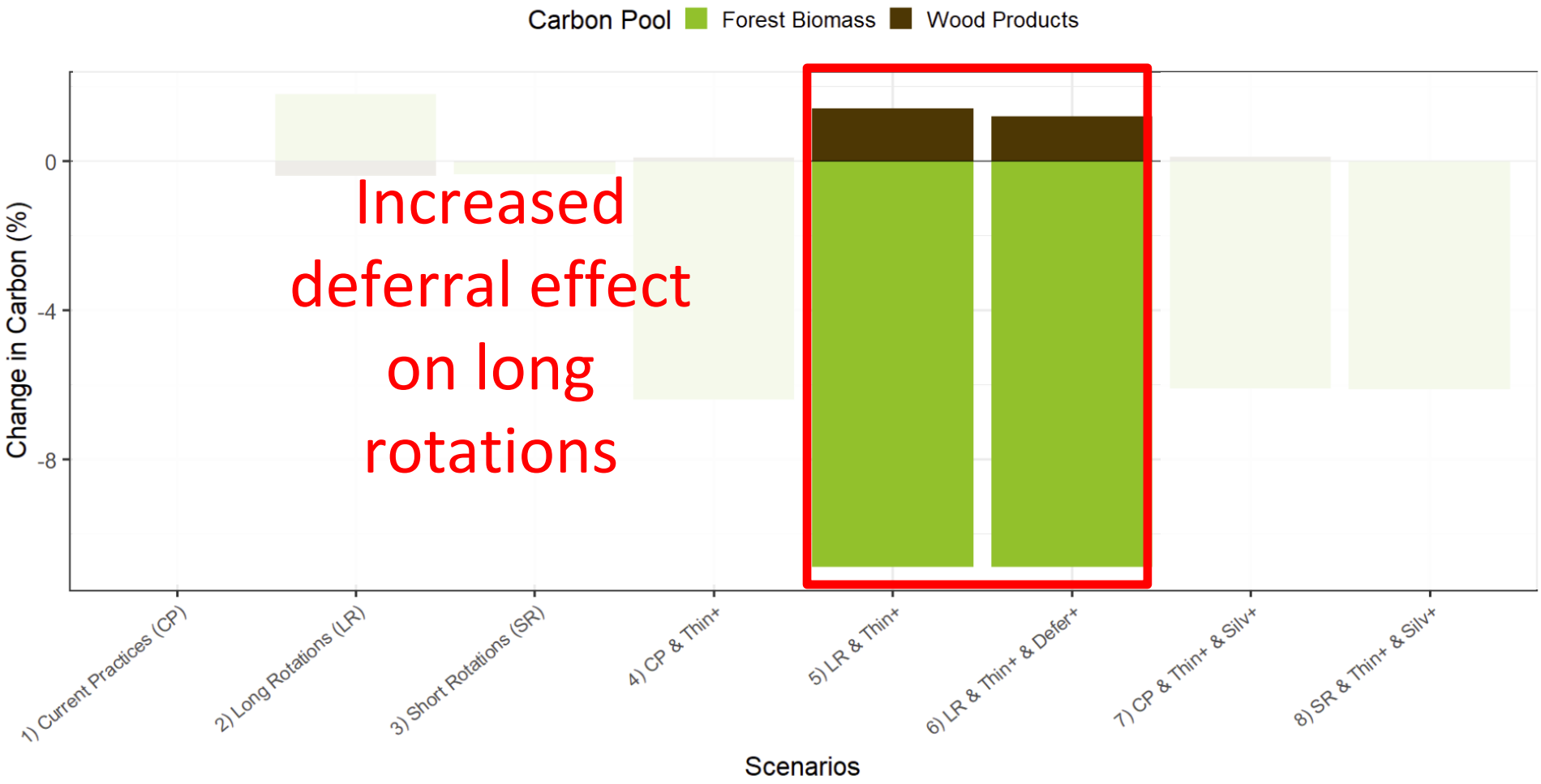


Scenario Results - Landscape-Level

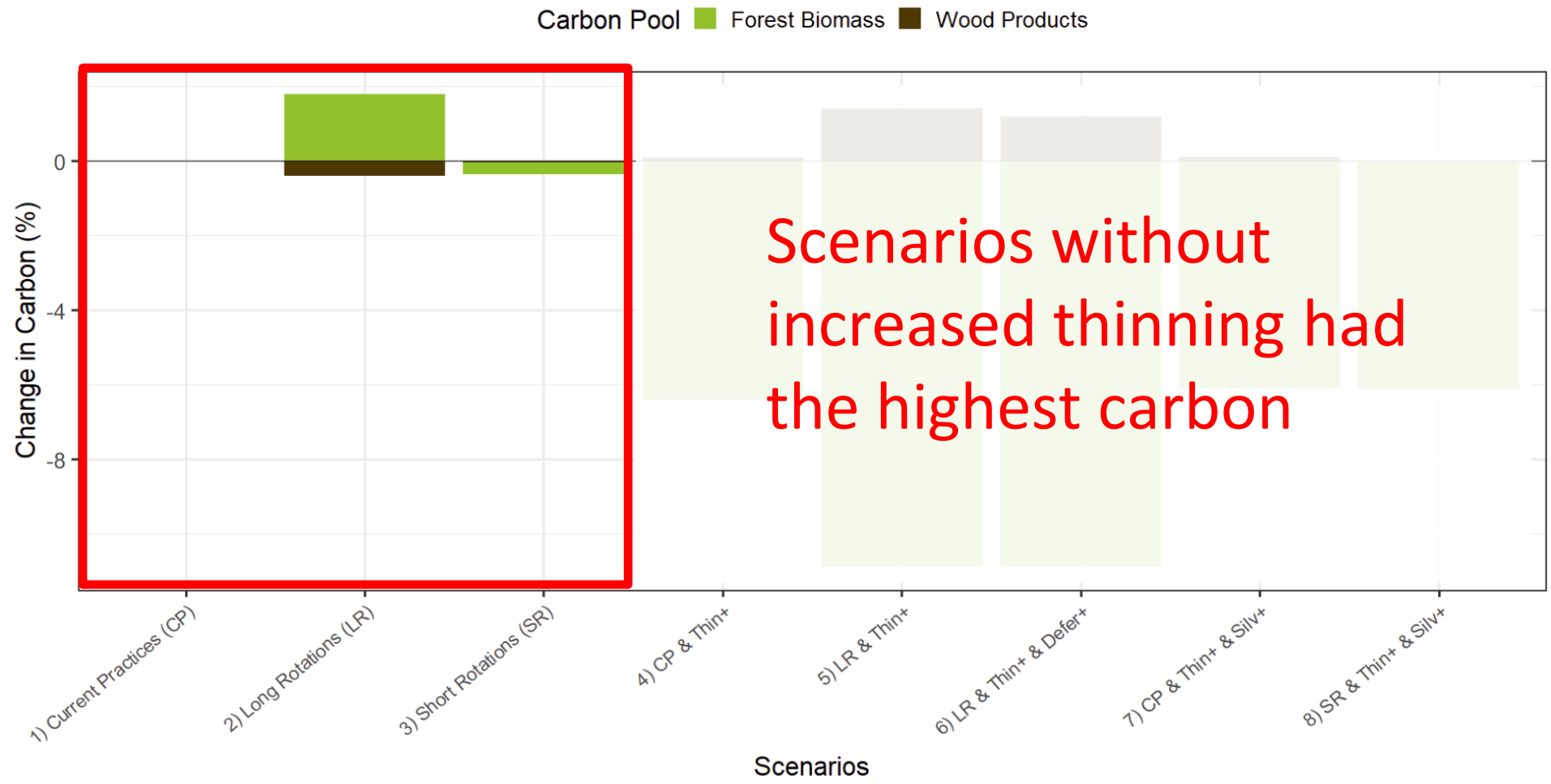


Scenario Results - Landscape-Level

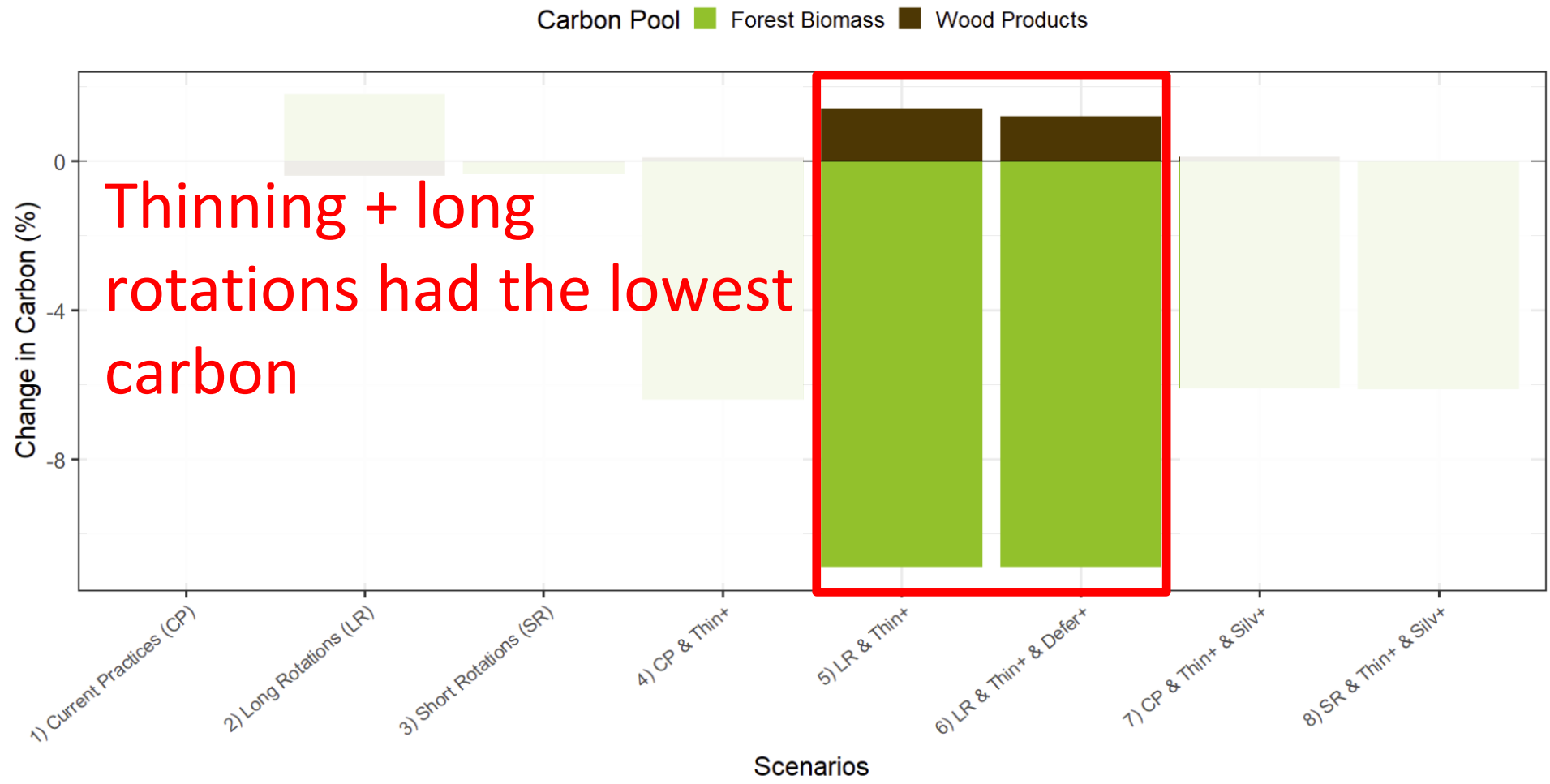
Scenario Results - Landscape-Level



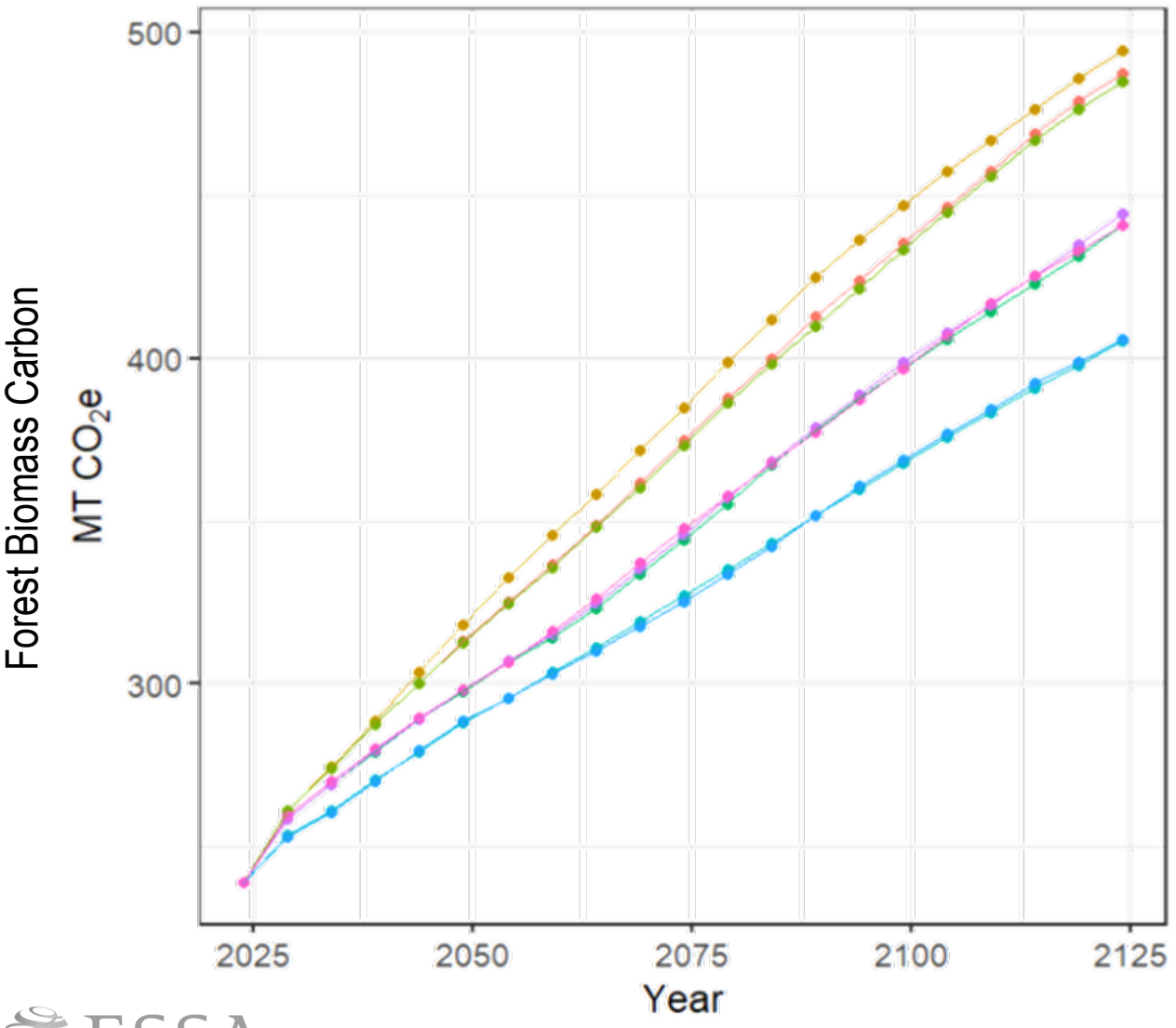
Scenario Results - Landscape-Level



Scenario Results - Landscape-Level



Scenario Results - Landscape Level

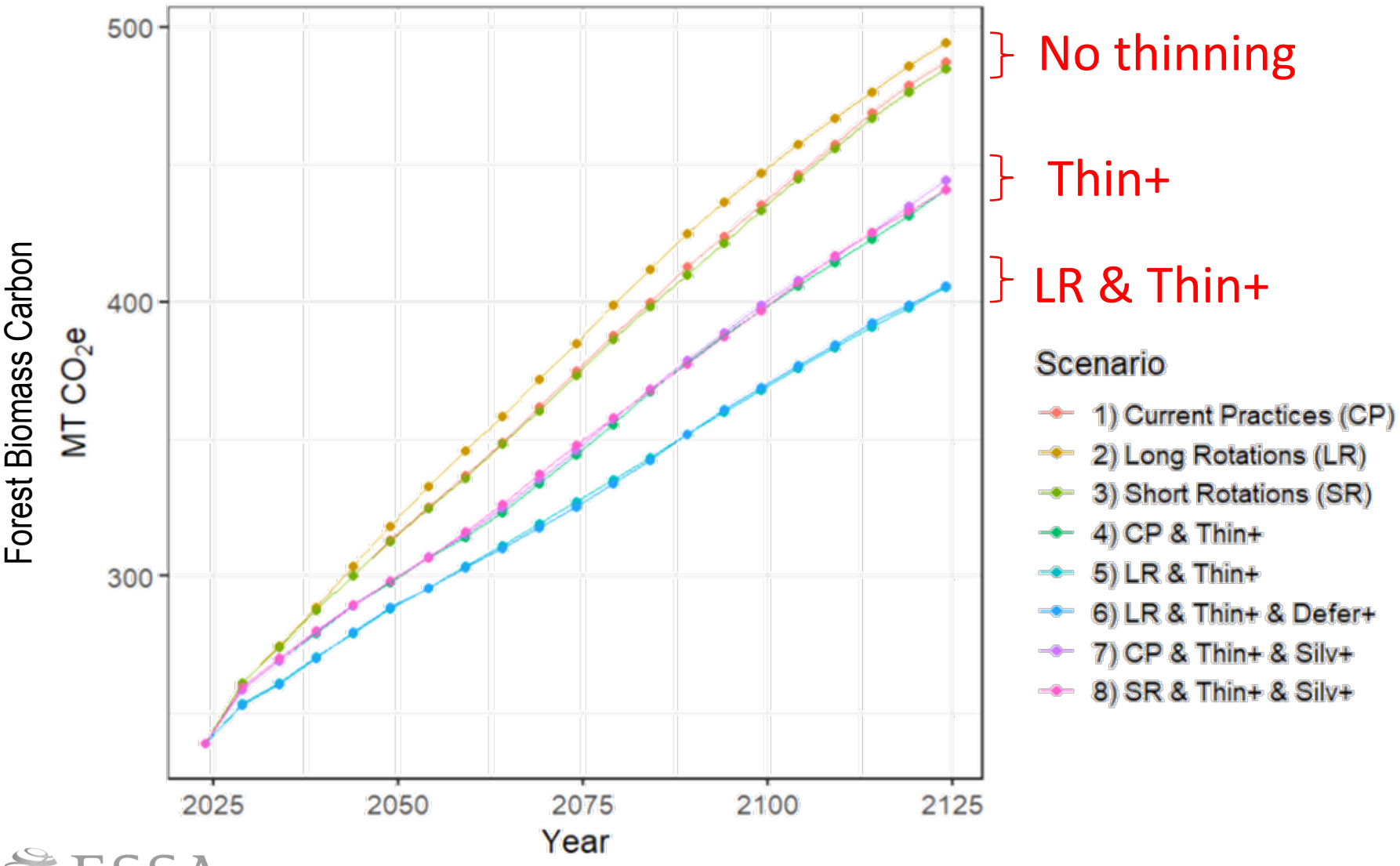


Forest Biomass Carbon 2024 - 2124

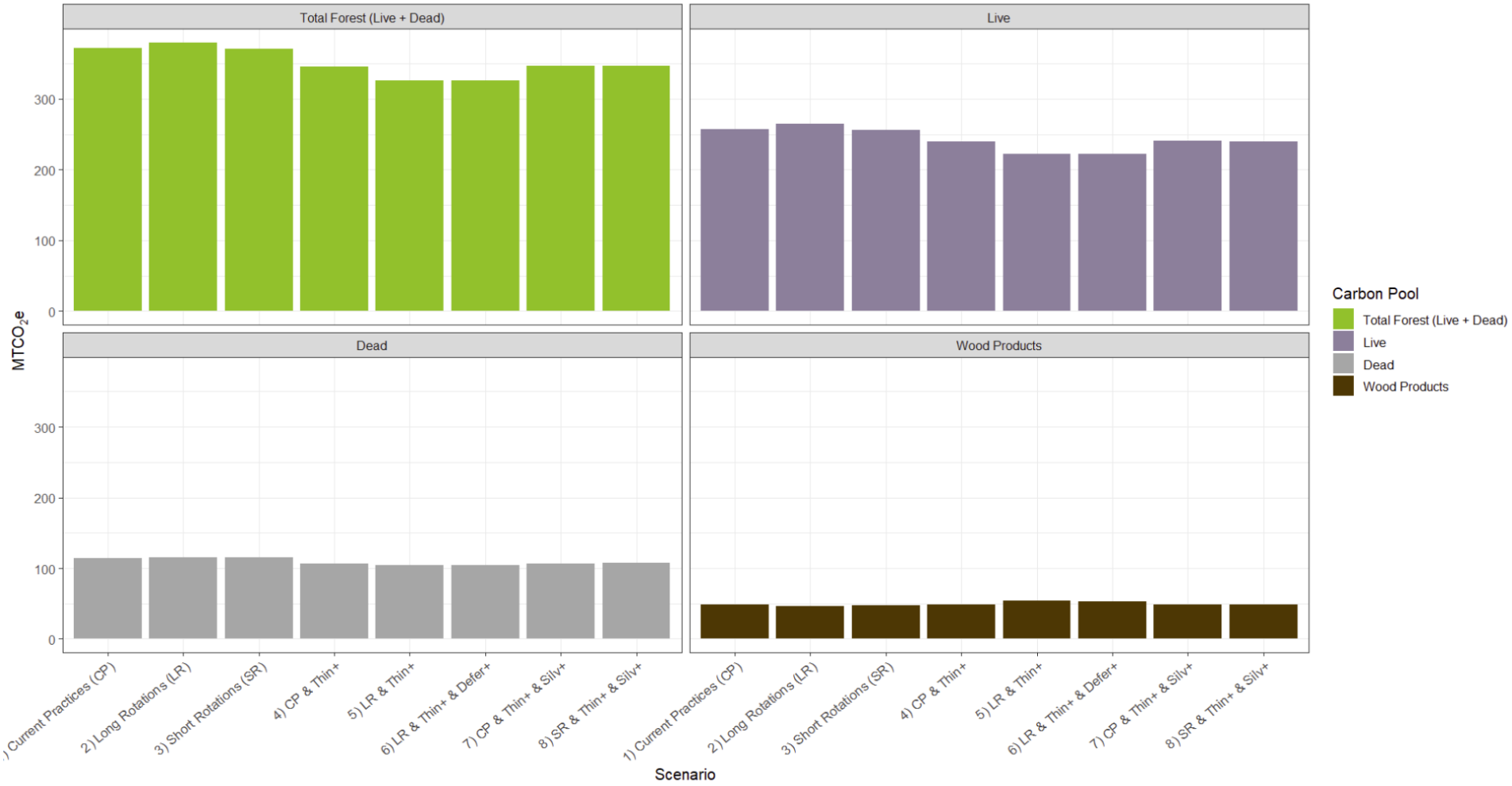
Scenario
- 1) Current Practices (CP)
- 2) Long Rotations (LR)
- 3) Short Rotations (SR)
- 4) CP & Thin+
- 5) LR & Thin+
- 6) LR & Thin+ & Defer+
- 7) CP & Thin+ & Silv+
- 8) SR & Thin+ & Silv+

ESSA

Scenario Results - Landscape Level



Scenario Results - Landscape Level



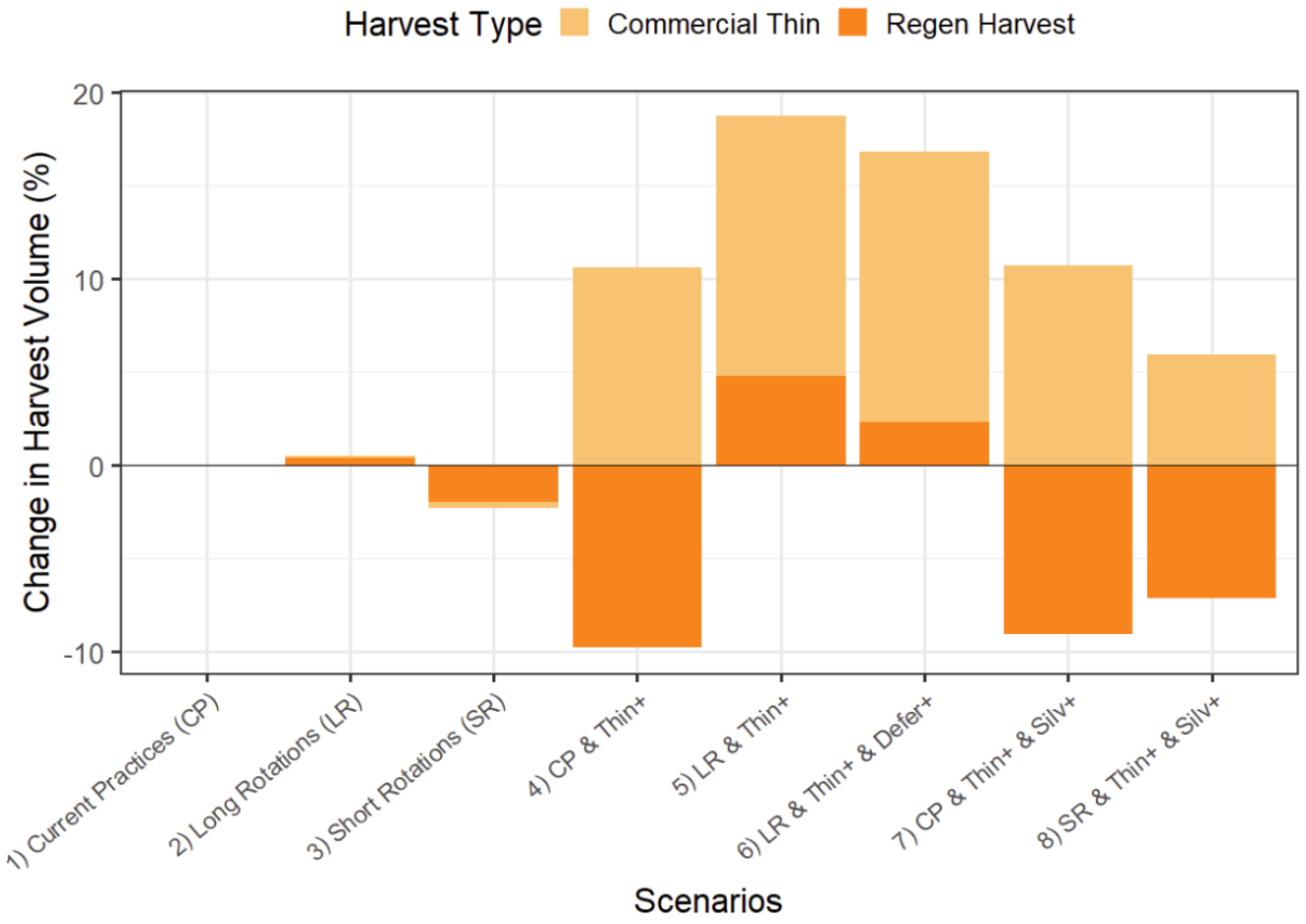
Scenario Results - Landscape Level

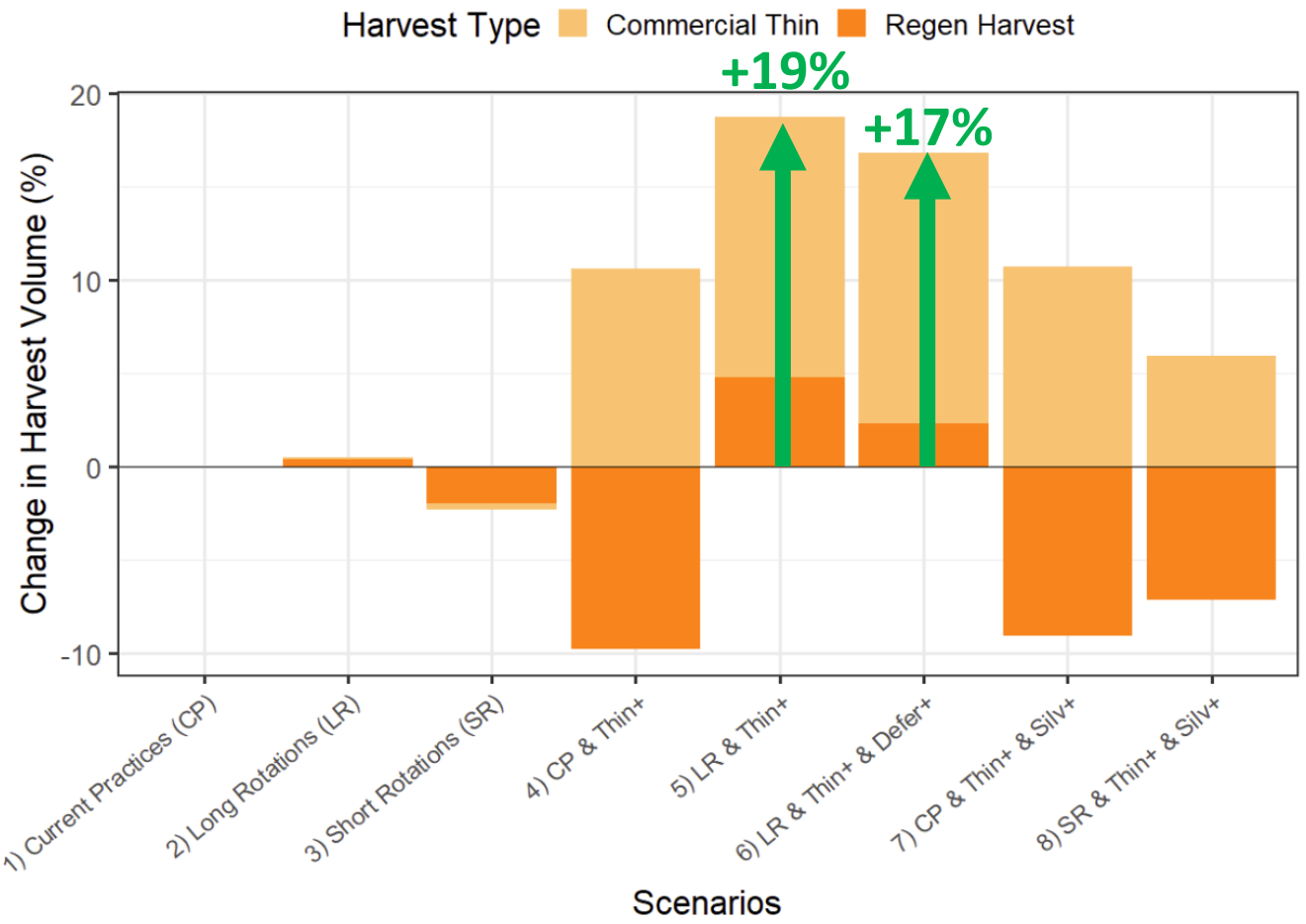
Scenario	Total stored carbon (mean annual MTCO2e 2024-2124)	Total stored carbon (MTCo2e in 2124)	Merchantable timber yield (mean annual MBF 2024-2124)	Merchantable timber yield (MBF in 2124)
1) Current Practices	420	574	365,232	355,756
2) Long Rotations	426	582	367,092	368,910
3) Short Rotations	419	571	356,839	312,968
4) CP & Thin+	394	528	368,476	337,244
5) LR & Thin+	381	505	433,661	439,366
6) LR & Thin+ & Defer+	380	504	426,793	439,366
7) CP & Thin+ & Silv+	396	531	371,292	364,637
8) SR & Thin+ & Silv+	395	526	360,890	334,834

Scenario Results - Landscape Level

Scenario	**Change in total stored carbon** (% difference from CP)	**Change in merchantable timber yield** (% difference from CP)
1) Current Practices (CP)	420 Mt CO2e	48,235 MBF
2) Long Rotations (LR)	+1.4	0.5
3) Short Rotations (SR)	-0.3	-2.3
4) CP & Thin+	-6.4	0.9
5) LR & Thin+	-9.4	18.7
6) LR & Thin+ & Defer+	-9.6	16.9
7) CP & Thin+ & Silv+	-6.09	1.7
8) SR & Thin+ & Silv+	-6.1	-1.2

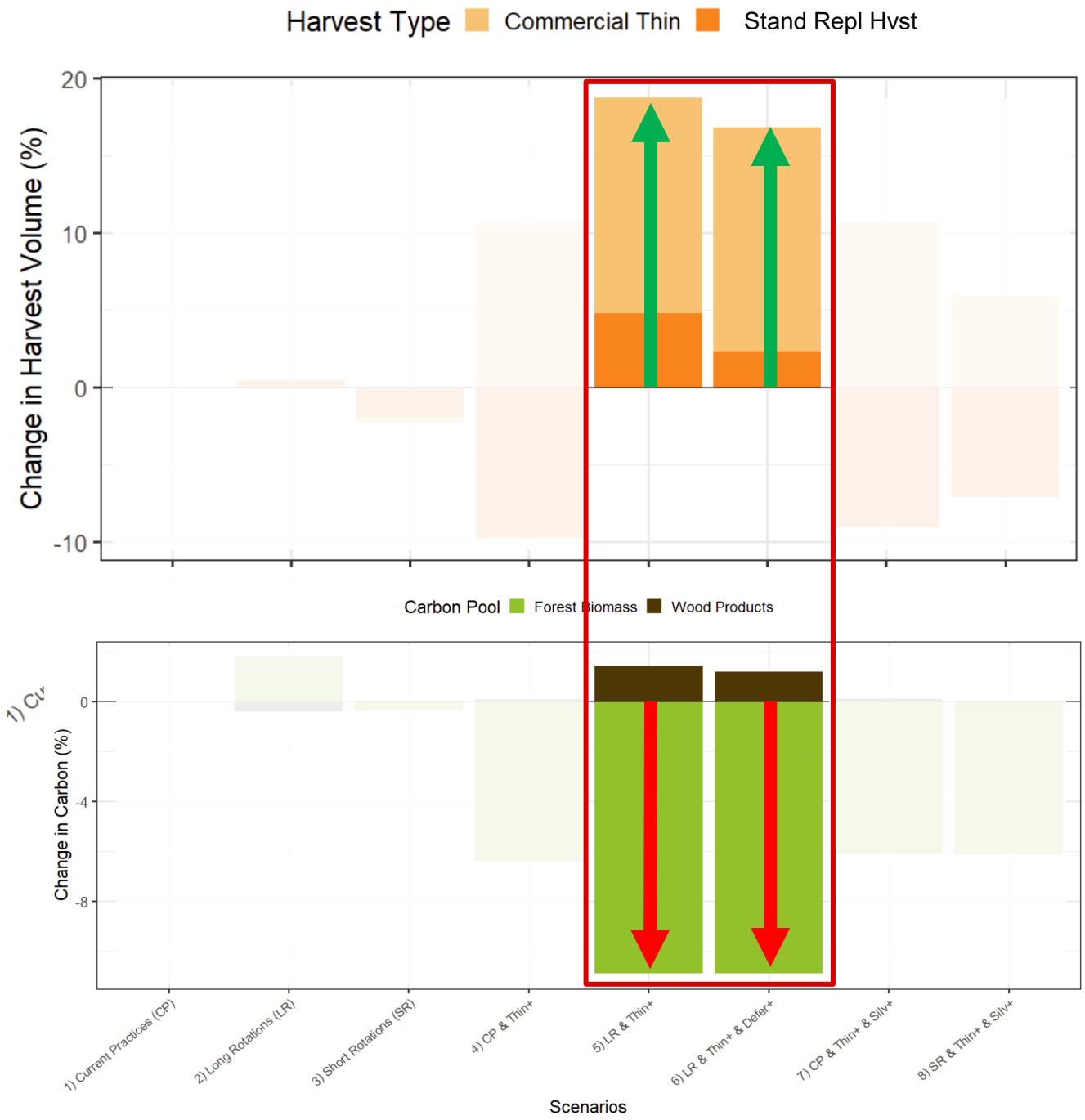
Why does carbon decrease in the significantly increased thinning scenarios?


Harvest Type
Commercial Thin
Regen Harvest
Change in Harvest Volume (%)
20
10
0
-10
1) Current Practices (CP)
2) Long Rotations (LR)
3) Short Rotations (SR)
4) CP & Thin+
5) LR & Thin+
6) LR & Thin+ & Defer+
7) CP & Thin+ & Silv+
8) SR & Thin+ & Silv+
Scenarios

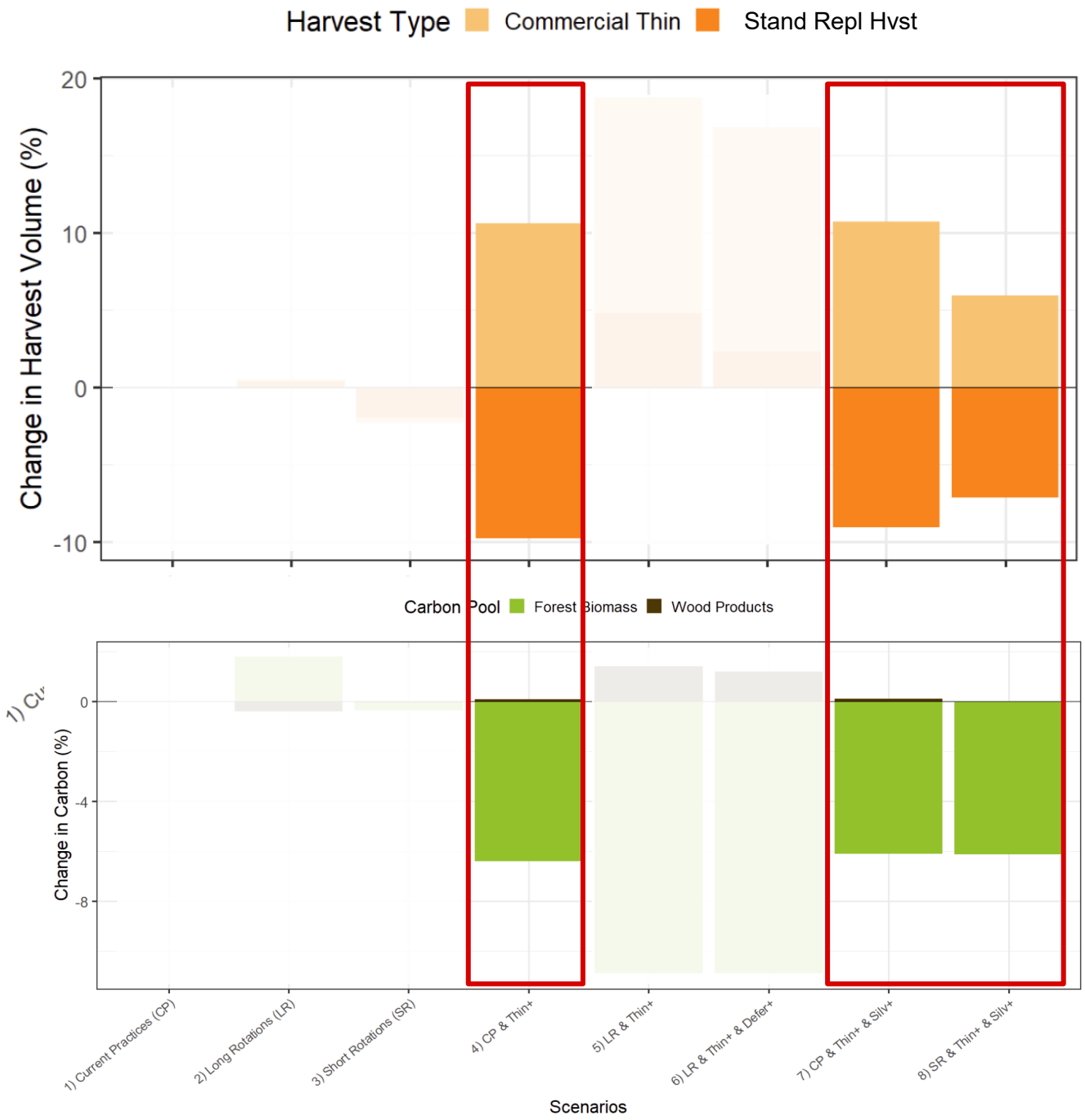

Harvest Type
Commercial Thin
Regen Harvest
+19%
+17%
20
10
0
-10
Change in Harvest Volume (%)
1) Current Practices (CP)
2) Long Rotations (LR)
3) Short Rotations (SR)
4) CP & Thin+
5) LR & Thin+
6) LR & Thin+ & Defer+
7) CP & Thin+ & Silv+
8) SR & Thin+ & Silv+
Scenarios

Reason 1)

Increased harvest = less forest biomass carbon

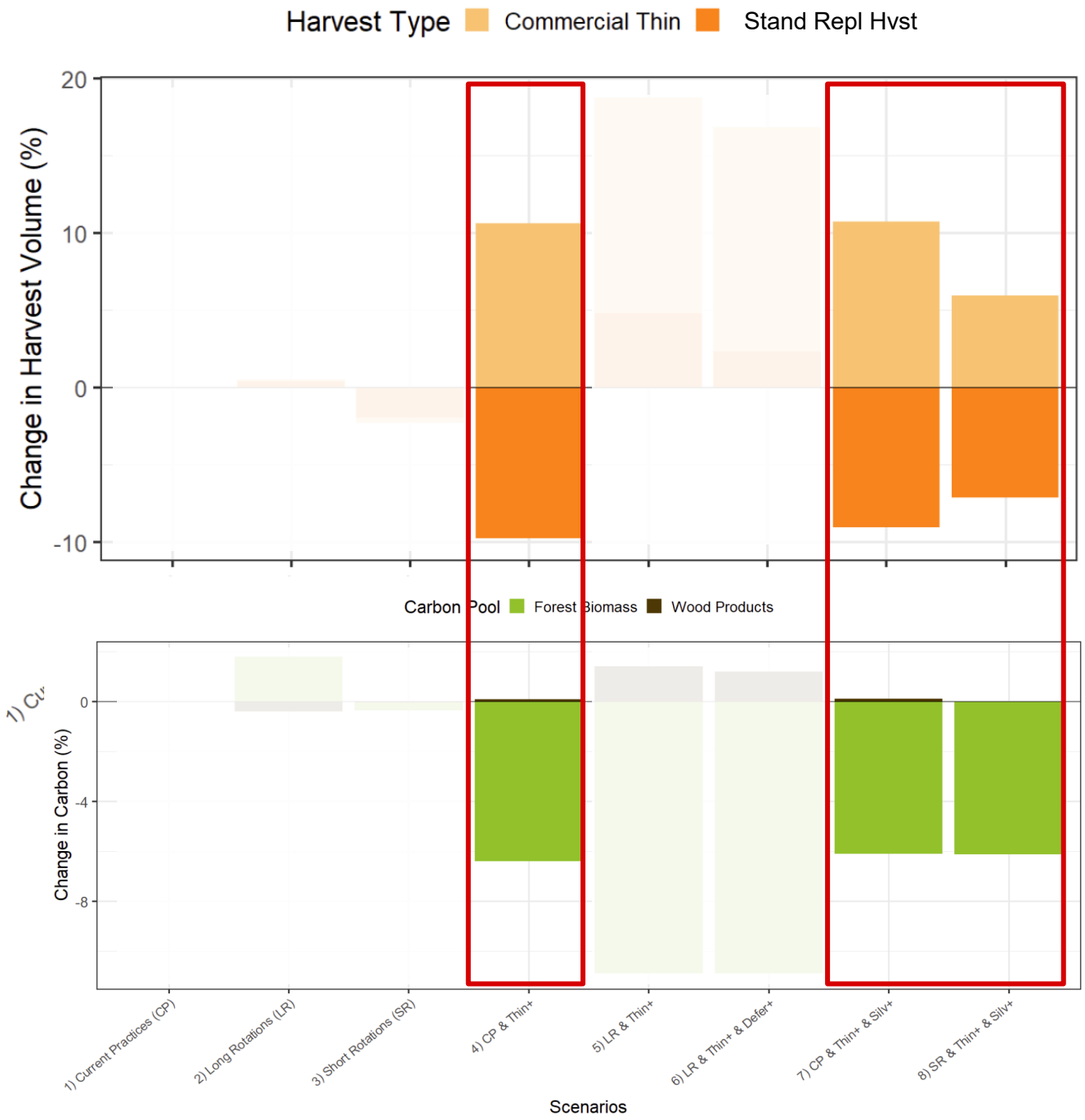


ESSA


Harvest Type
Commercial Thin
Stand Repl Hvst
Change in Harvest Volume (%)
20
10
0
-10
Carbon Pool
Forest Biomass
Wood Products
Change in Carbon (%)
0
-4
-8
1) Current Practices (CP)
2) Long Rotations (LR)
3) Short Rotations (SR)
4) CP & Thin+
5) LR & Thin+
6) LR & Thin+ & Defer+
7) CP & Thin+ & Silv+
8) SR & Thin+ & Silv+
Scenarios

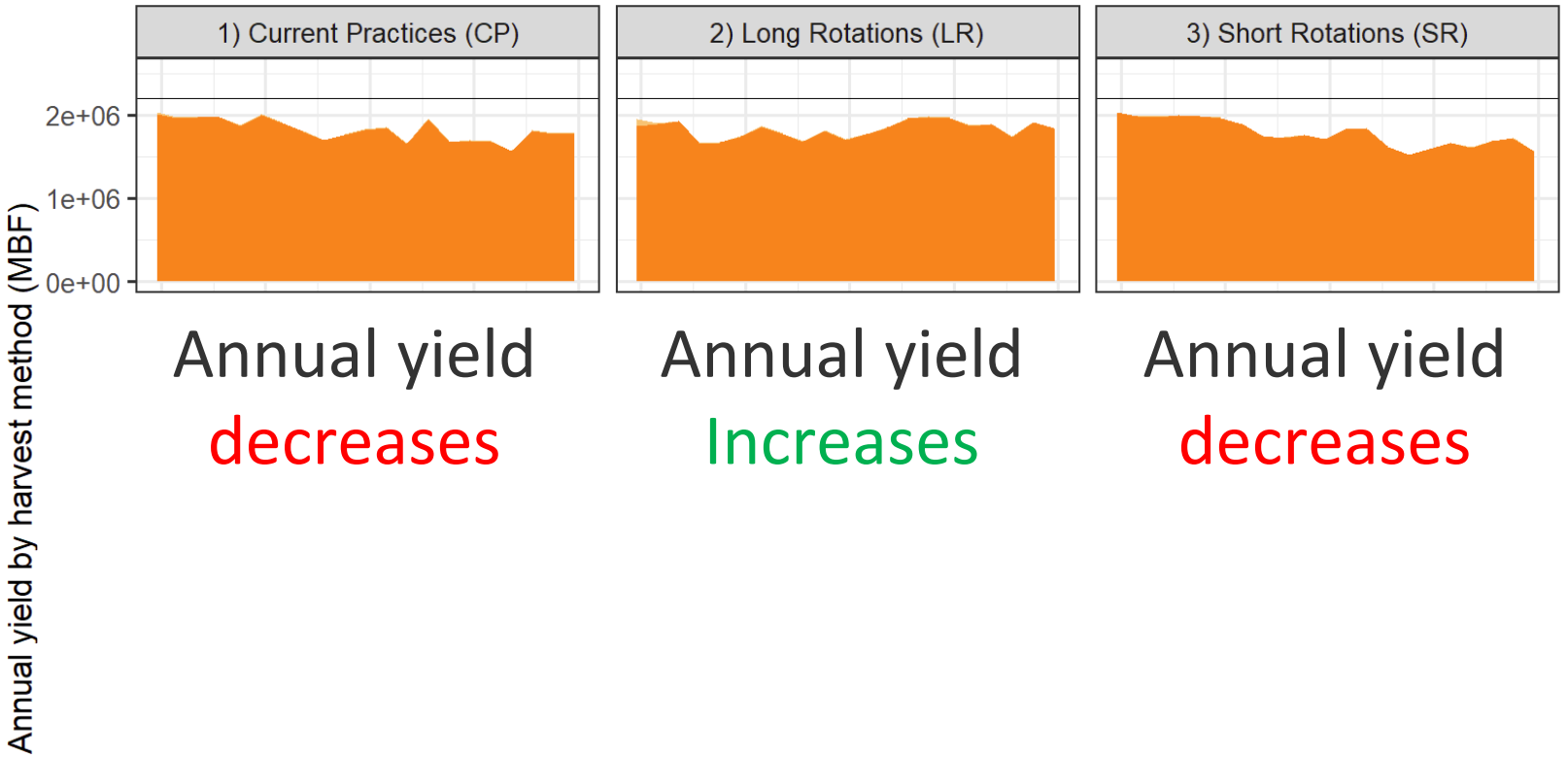
Reason 2)

Extensive thinning decreases average carbon per acre



Scenario Results - Landscape Level

Simulated Timber Yield 2024-2124



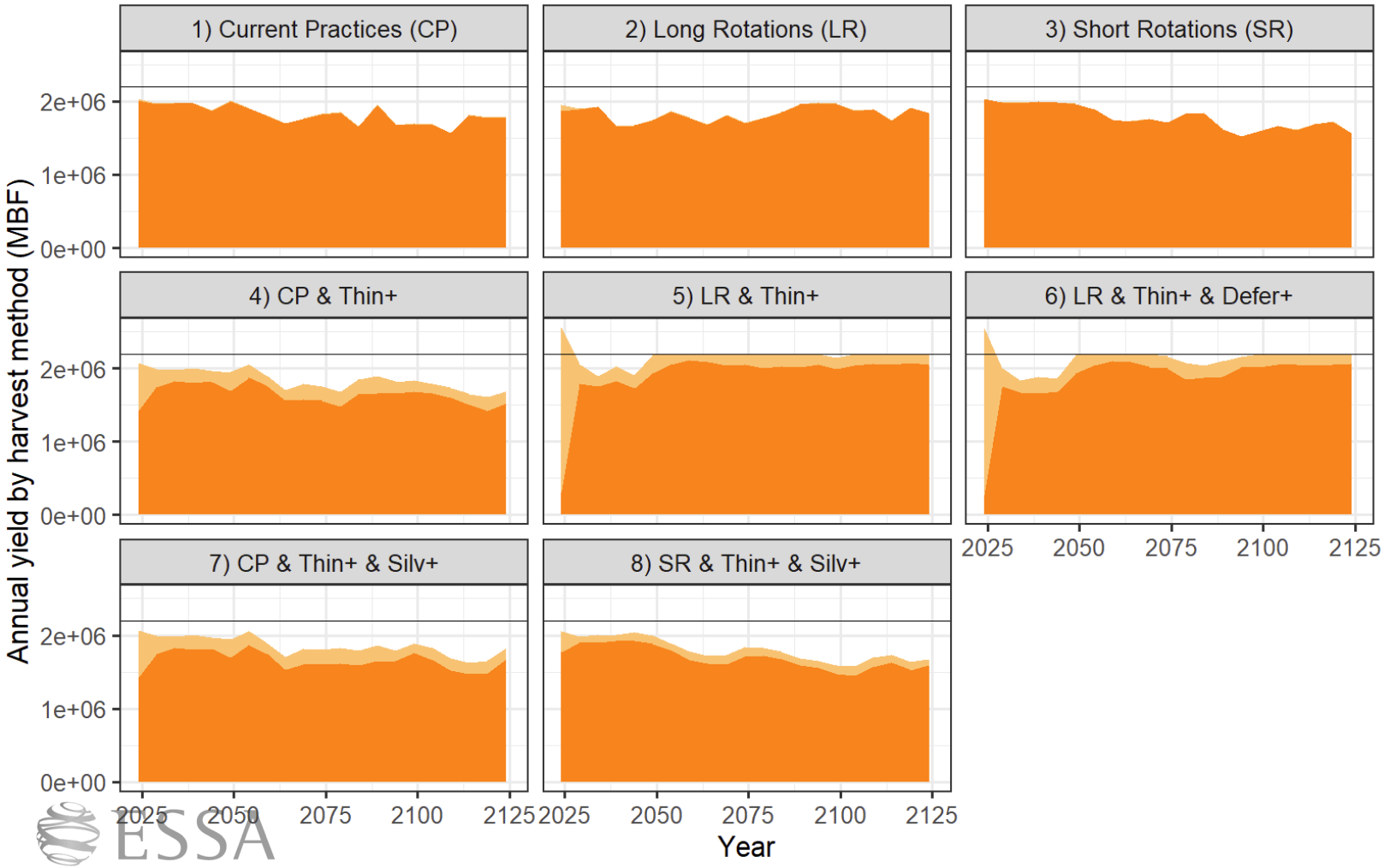
Annual yield decreases

Annual yield Increases

Annual yield decreases

Scenario Results - Landscape Level

Simulated Timber Yield 2024-2124



Summary of Results

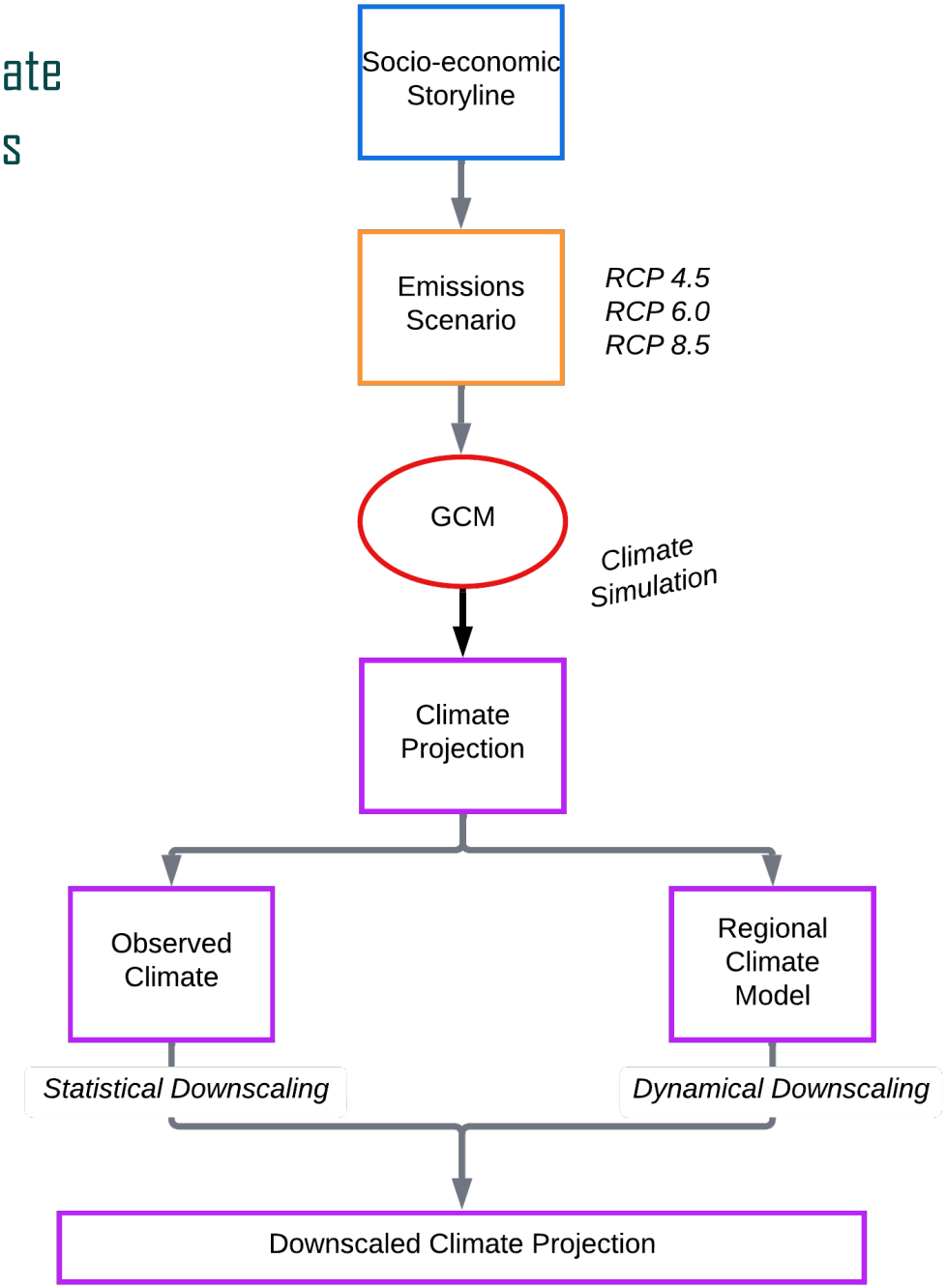
1. Lower yields in all scenarios relative to 2013-2023, related to county-level harvest limits.
2. Significantly increased commercial thinning (CT) = higher timber yields but reduced carbon. CT is the dial with the largest overall effect. This is because yield and area thinned were higher relative to other scenarios.
3. Longer rotations (Scenario 2) = only scenario to increase both timber yield and carbon over current practices.
4. Shortened rotations (Scenario 3) = only scenario to decrease both.
5. Scenarios with the highest timber yields also had the lowest carbon benefits

Your Turn!
Questions

Lunch Break (60min)

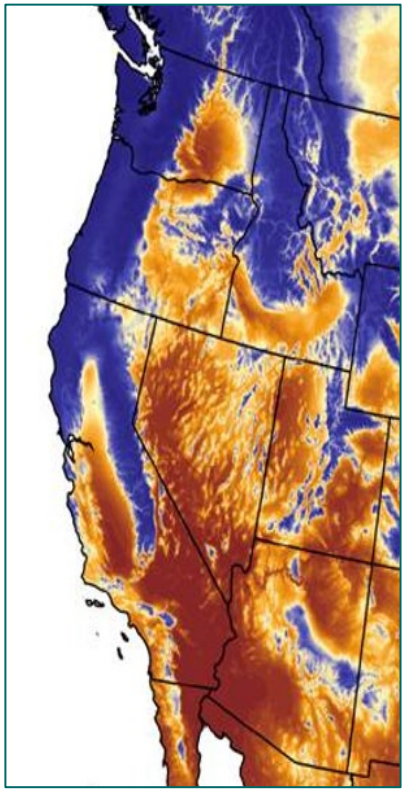
Part 2: Climate Change Results

Refresher: Climate Change Methods

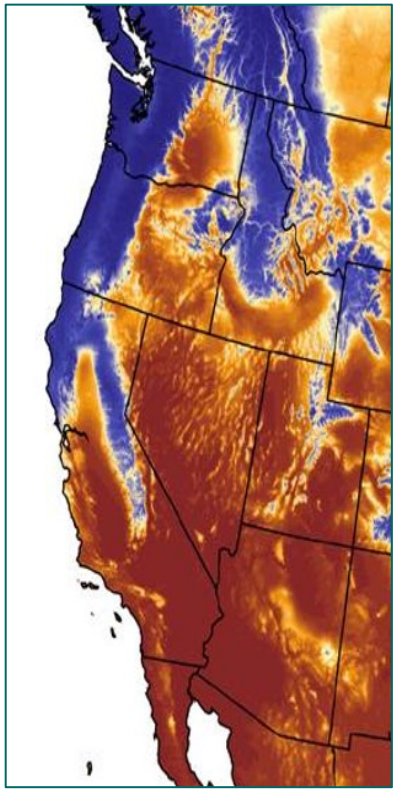


Refresher: Climate Change Methods

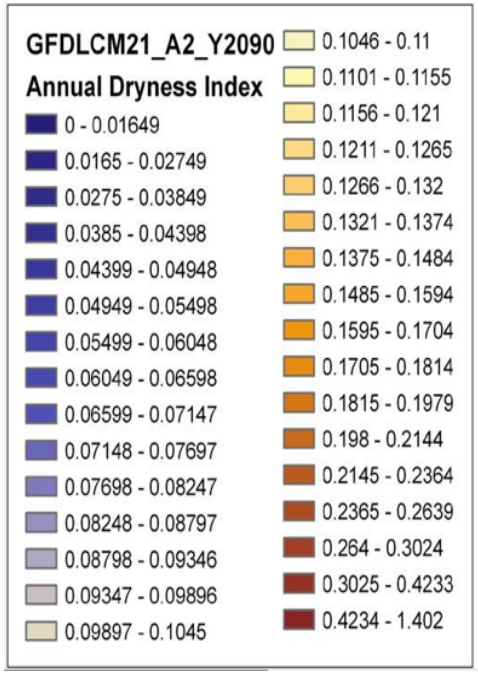
Current



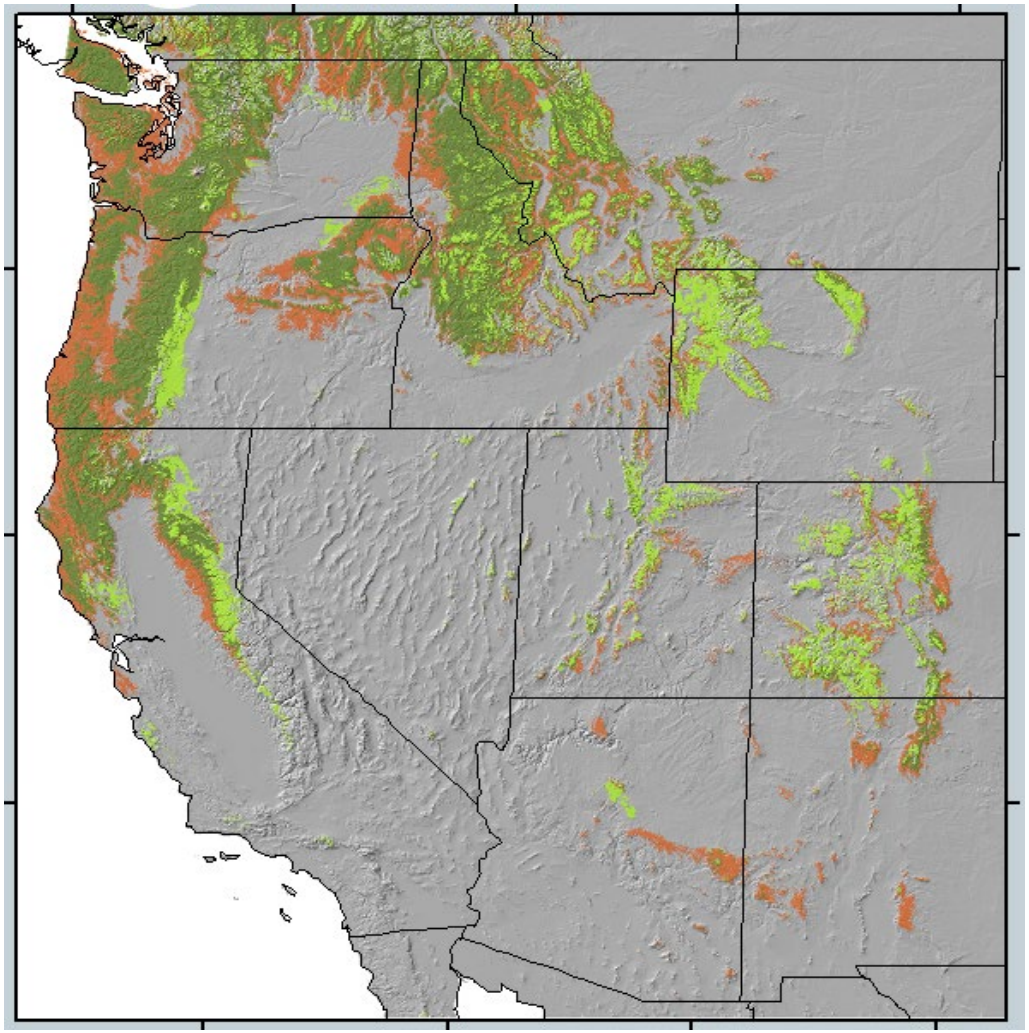
2090



Predictions of **dryness** with one GCM and one RCP

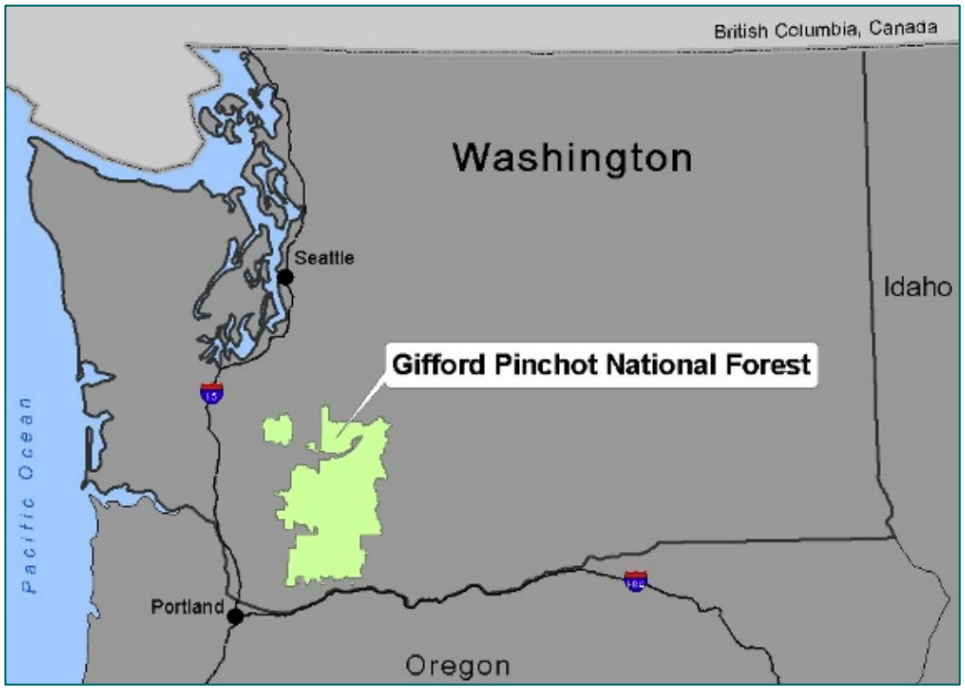


Refresher: Climate Chage Methods



Douglas-fir
current vs 2060
GFDLCM21 B1

Refresher: Climate Change Methods



Viability Scores

	DF	WH	PP
1990	0.973	0.960	0.376
2030	0.960	0.656	0.290
2060	0.857	0.236	0.546
2090	0.877	0.131	0.596

*Over time **less** suitable for DF & WH*
*Over time **more** suitable for PP*

What Does Climate-FVS Change?

Using the Viability Score, these will all change on a species or tree basis:

- **Stand carrying capacity**
- **Tree mortality**
- **Tree growth**
- **Species regeneration**

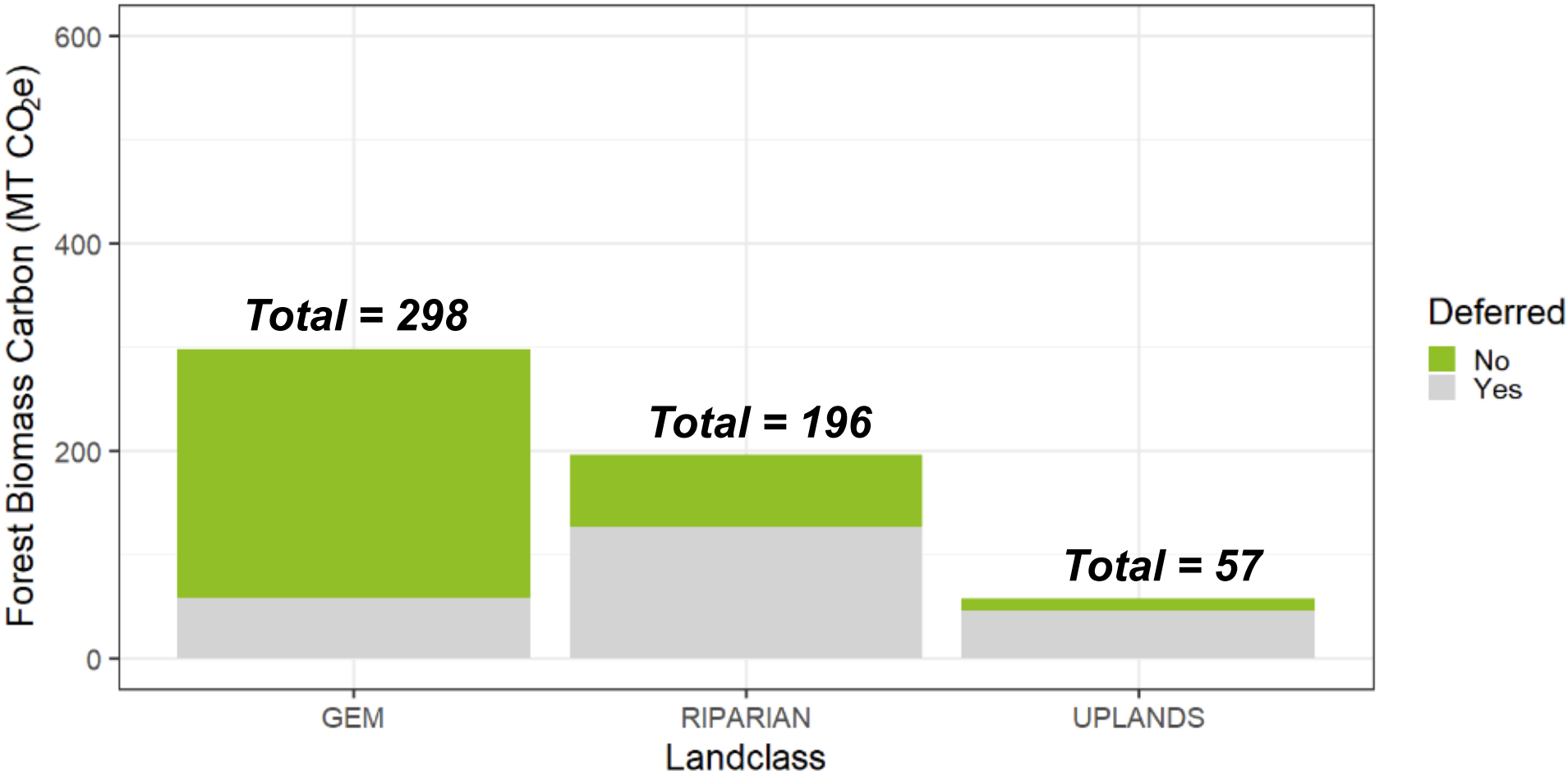
What Is Left Out?

Climate-FVS does not currently simulate changes to these processes

- **Fire dynamics**, which depend on fuel moisture, temperature and wind speed.
- **Decay** rate of down wood
- **Snag** dynamics
- **Elevation sensitivity** (dClim rule) has been disabled

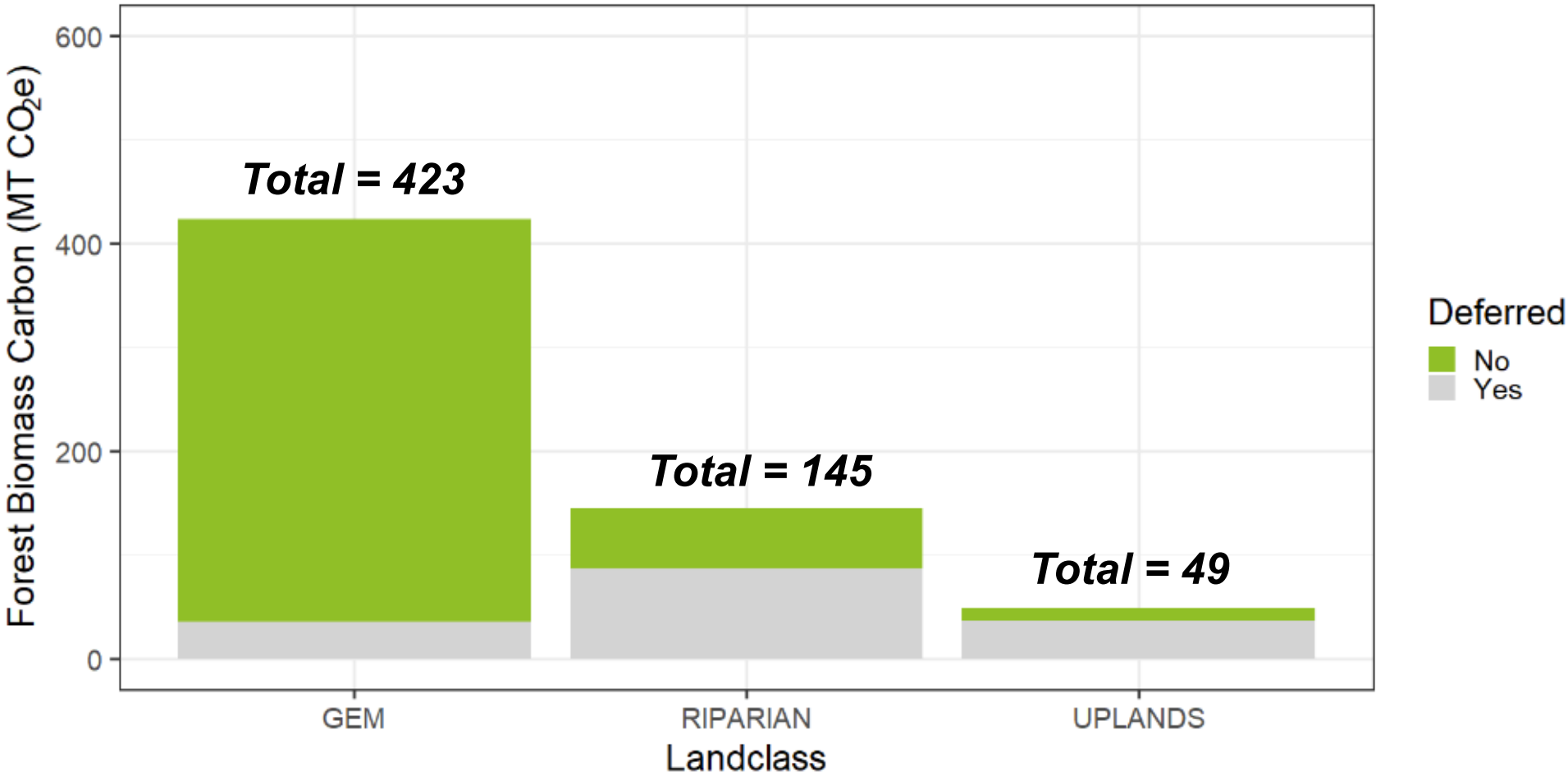
Baseline for Comparison: Scenario 1 Current Practices (Climate Change)

550 Mt CO2e in 2024

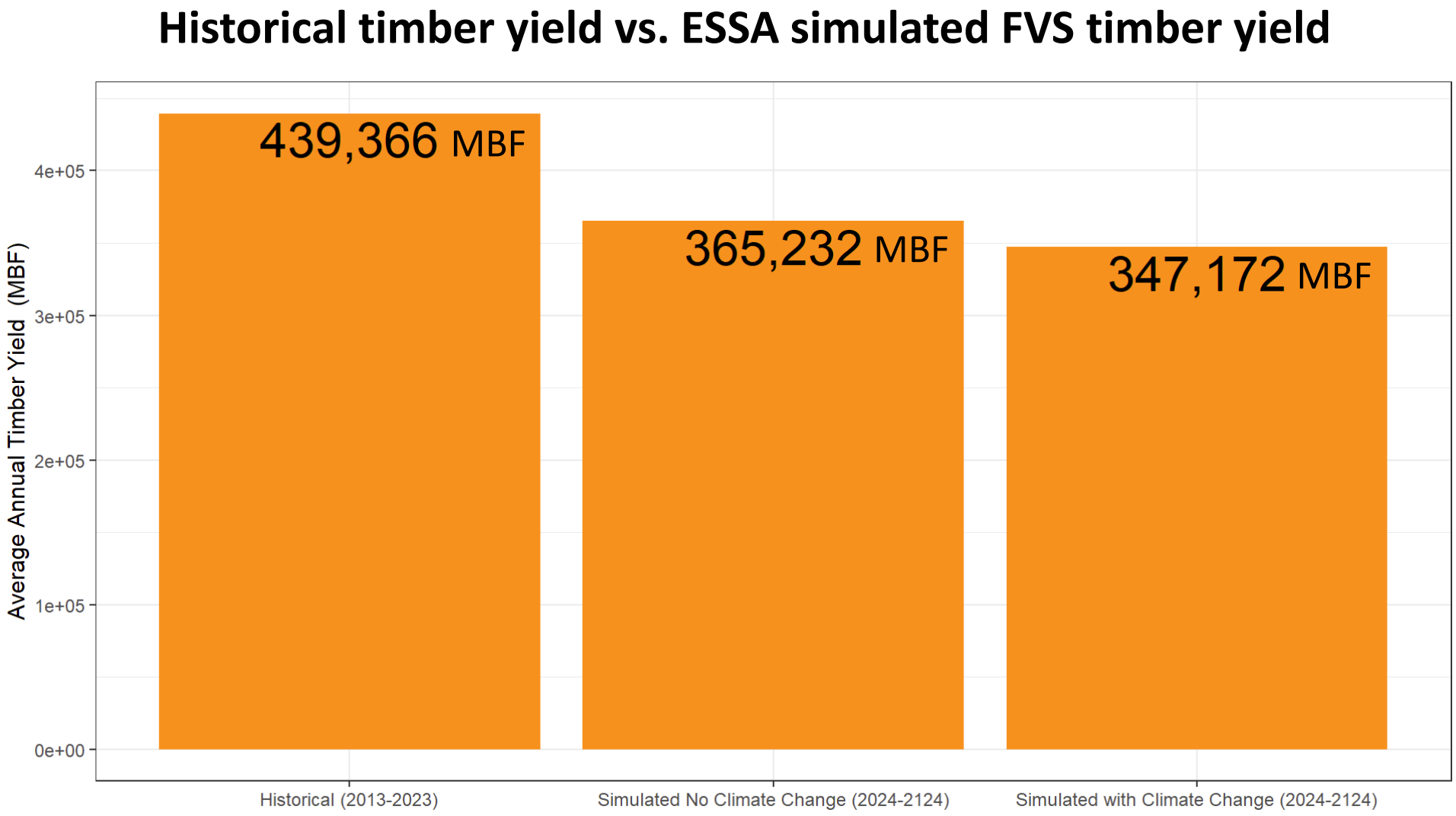


Baseline for Comparison: Scenario 1 Current Practices (Climate Change)

617 Mt CO2e in 2124

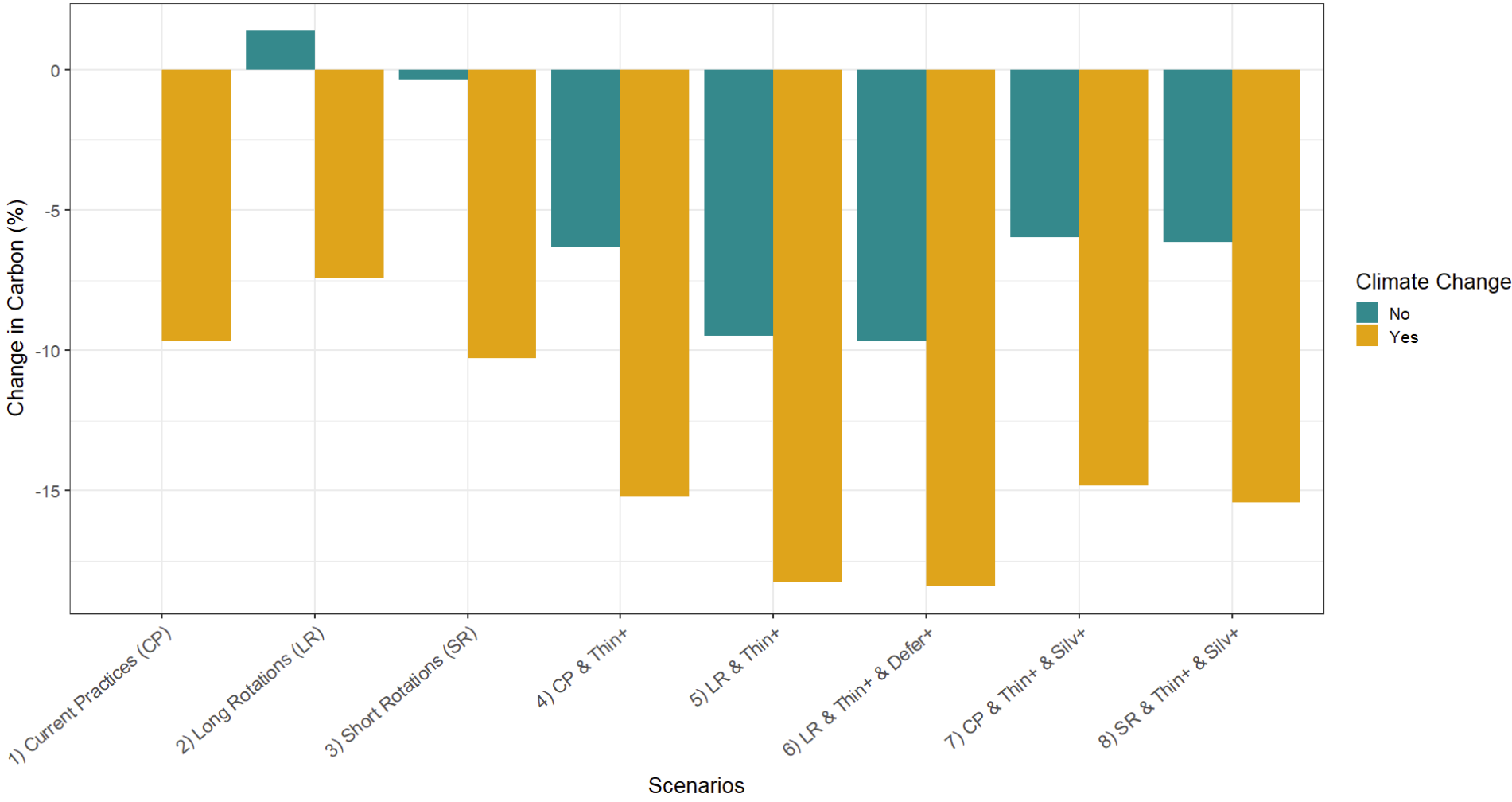


Baseline for Comparison: Scenario 1 Current Practices (with Climate Change)

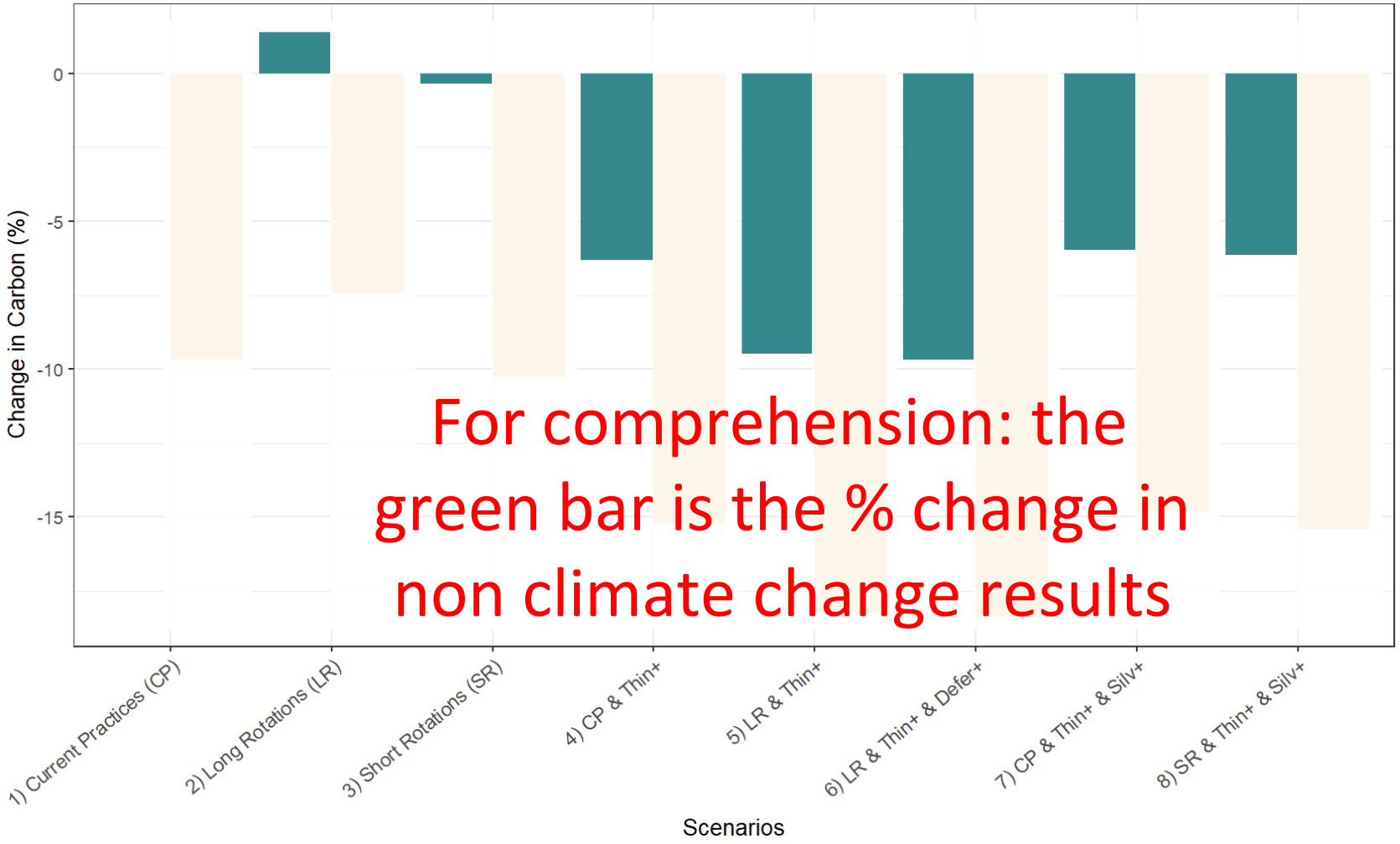


ESSA

Landscape-Level Results with Climate Change

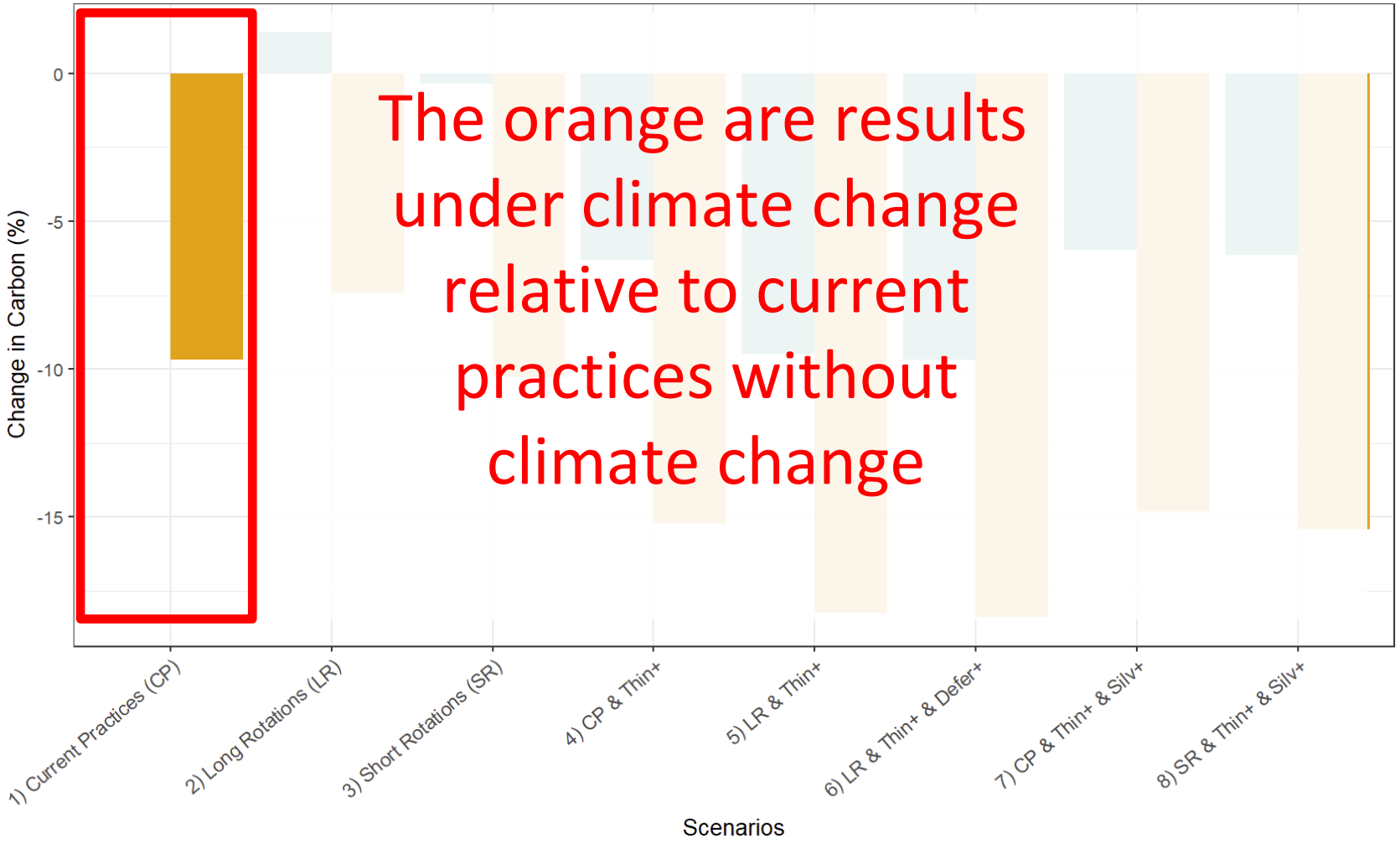


Landscape-Level Results with Climate Change



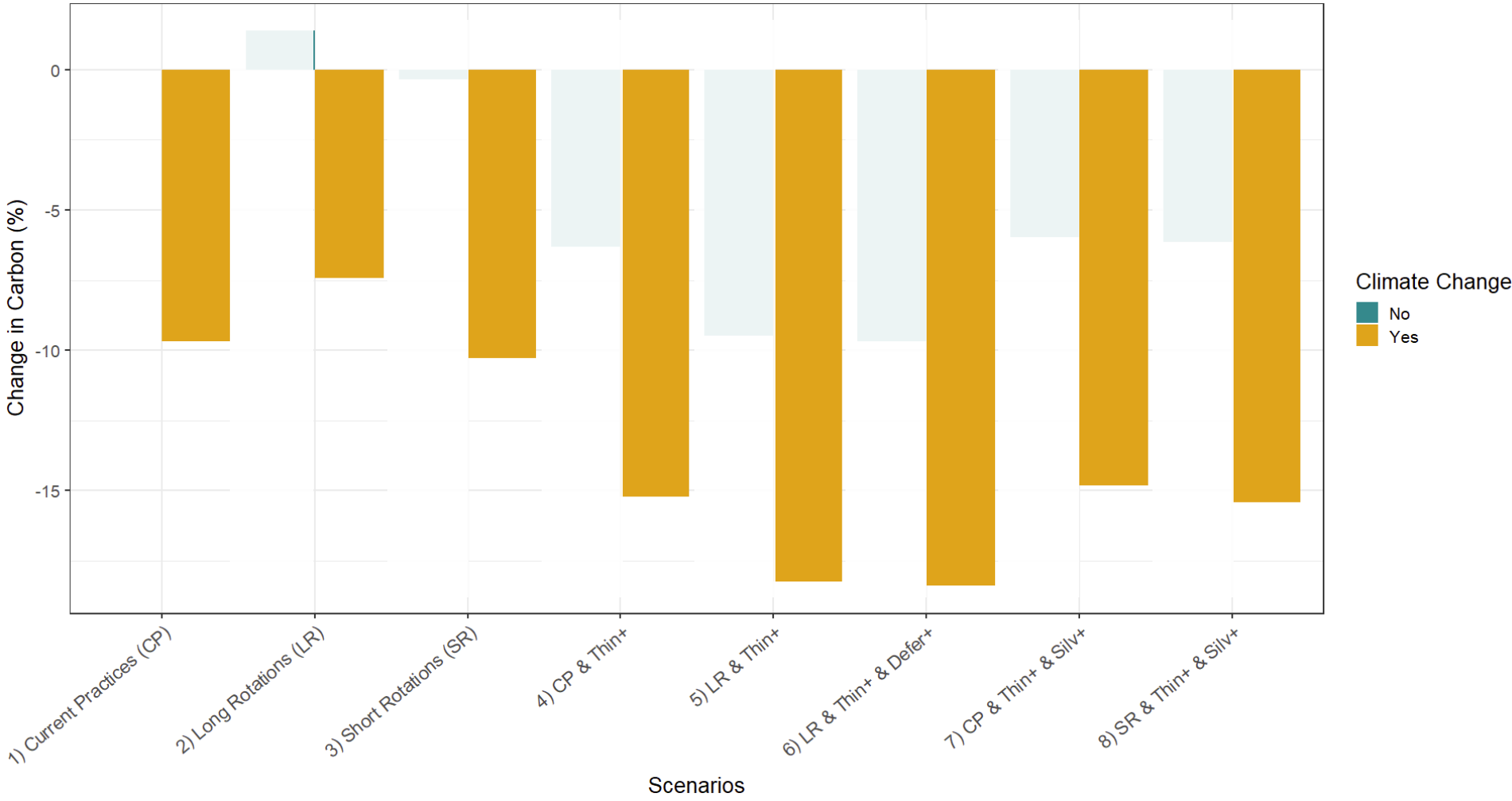
For comprehension: the green bar is the % change in non climate change results

Landscape-Level Results with Climate Change

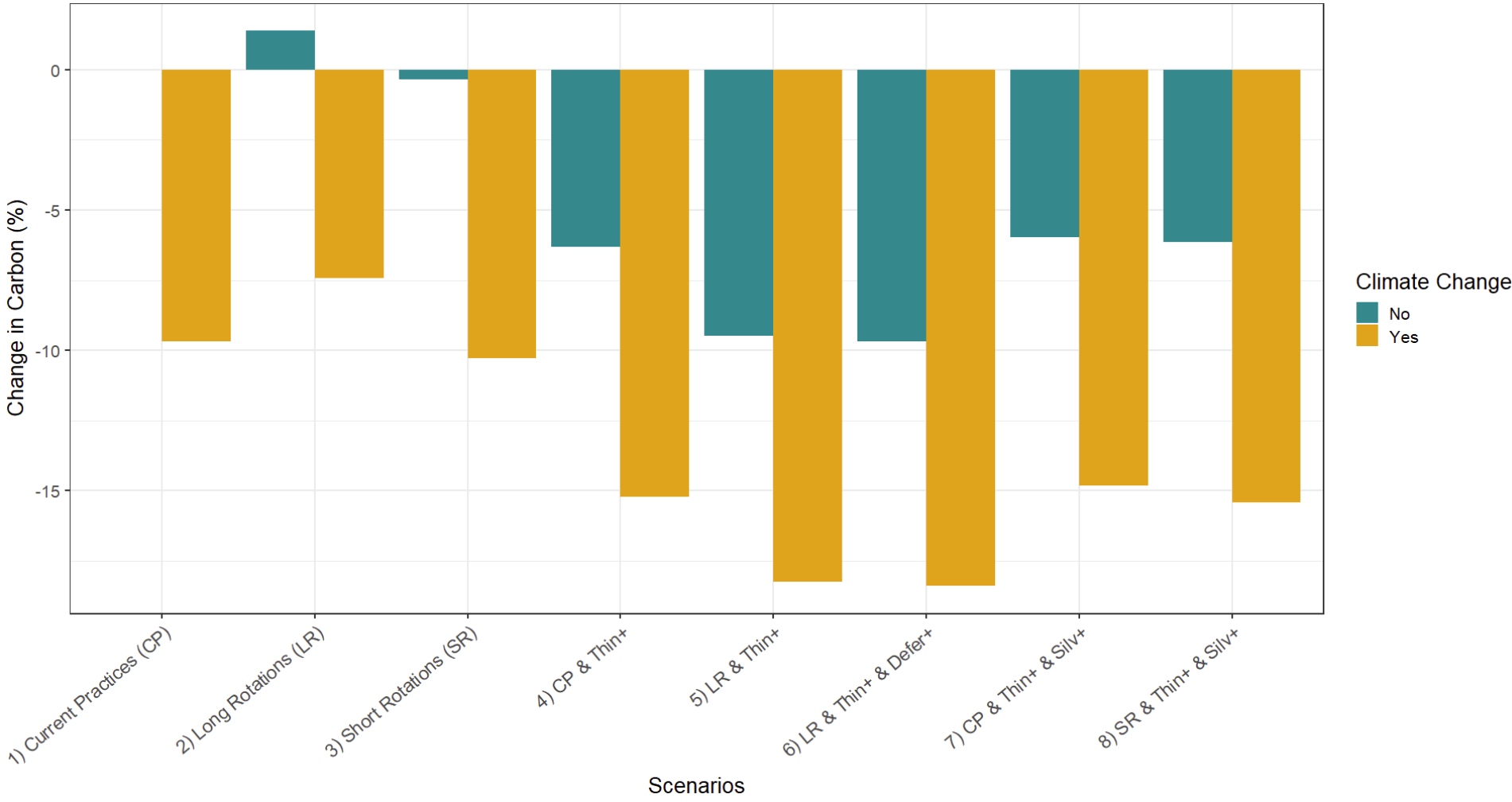


The orange are results under climate change relative to current practices without climate change

Landscape-Level Results with Climate Change



Landscape-Level Results with Climate Change



The pattern across scenarios holds for noCC vs. CC

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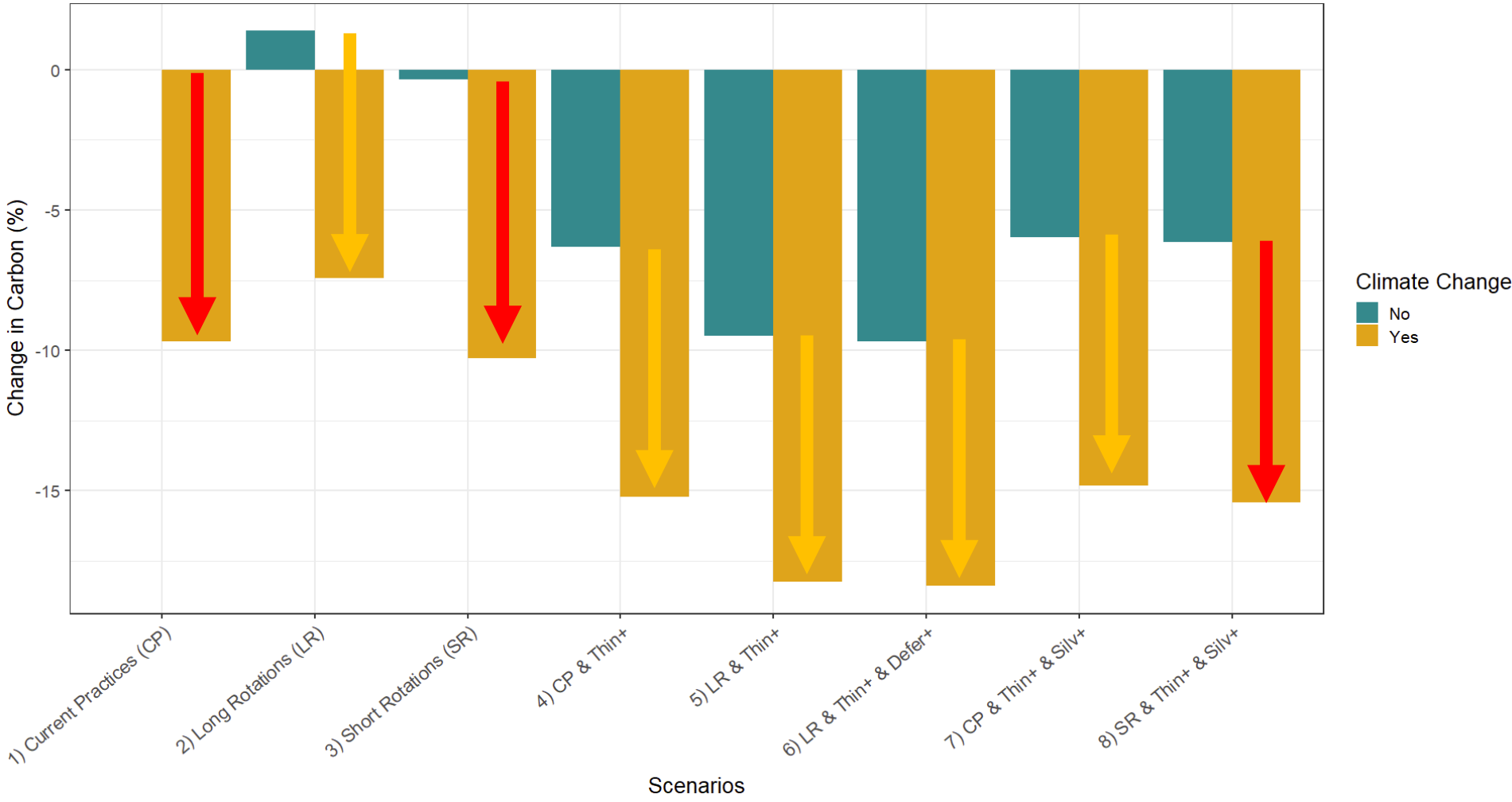
Landscape-Level Results with Climate Change



But with a 8% - 10% drop in carbon

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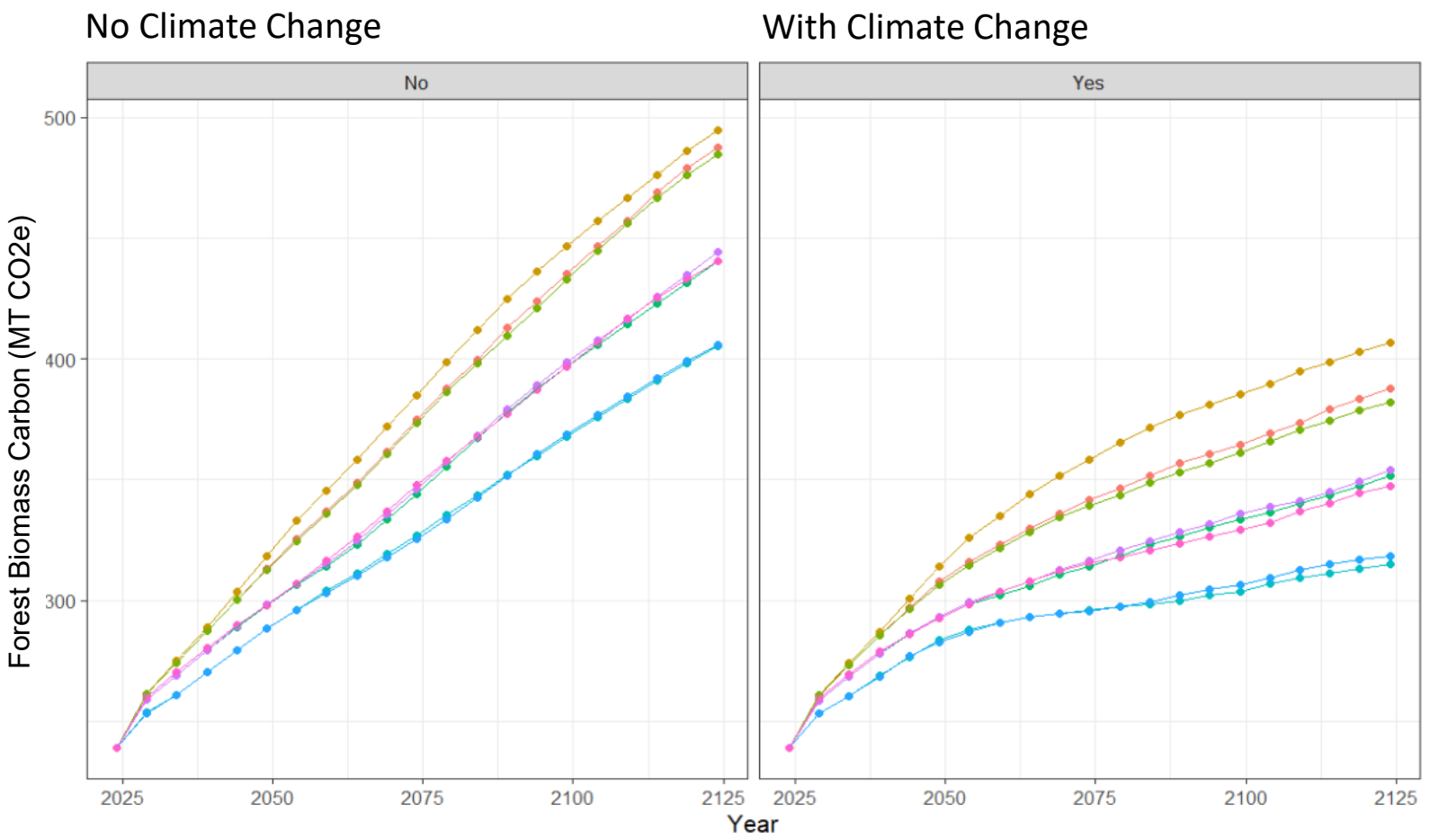
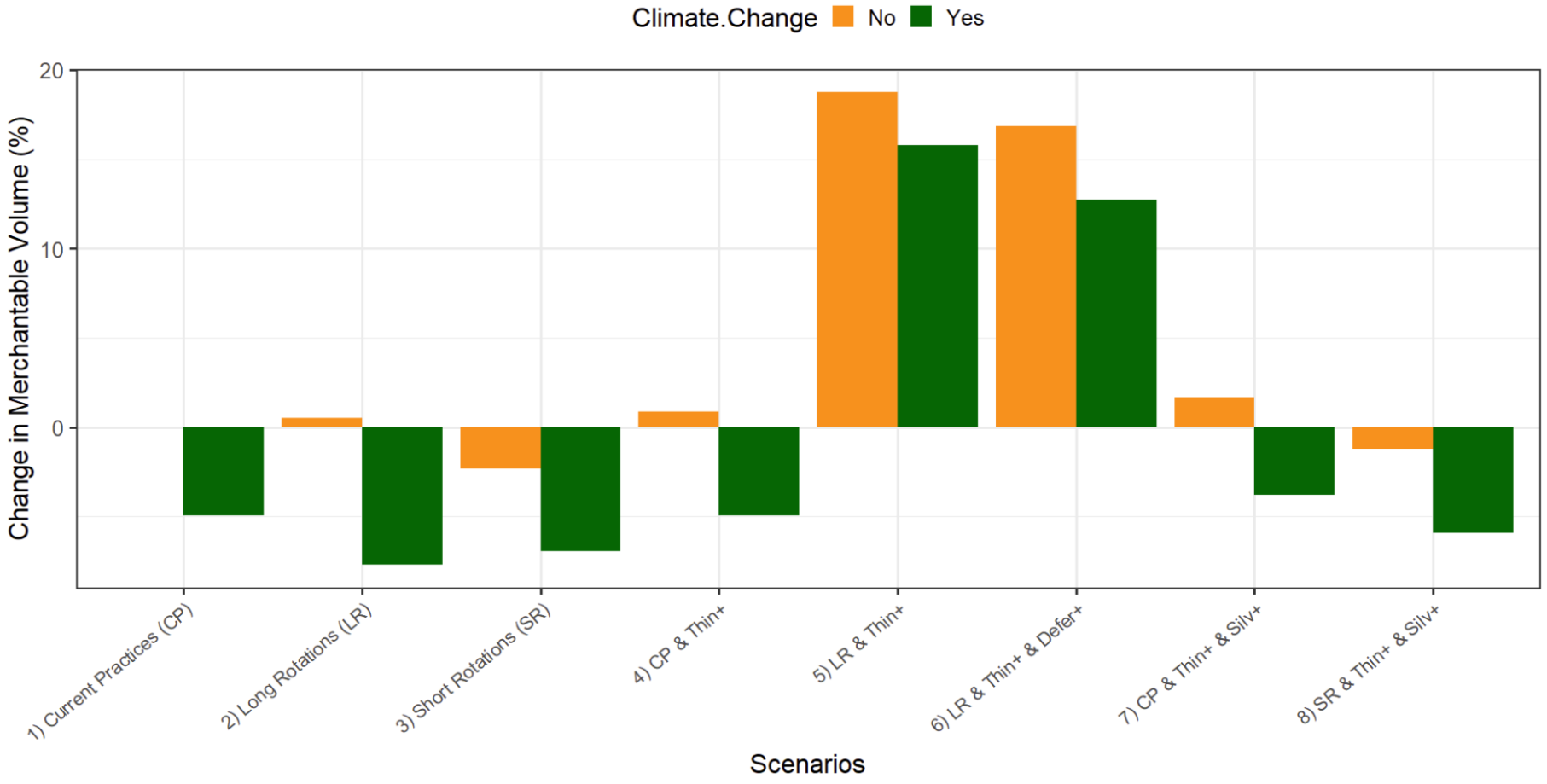
Landscape-Level Results with Climate Change

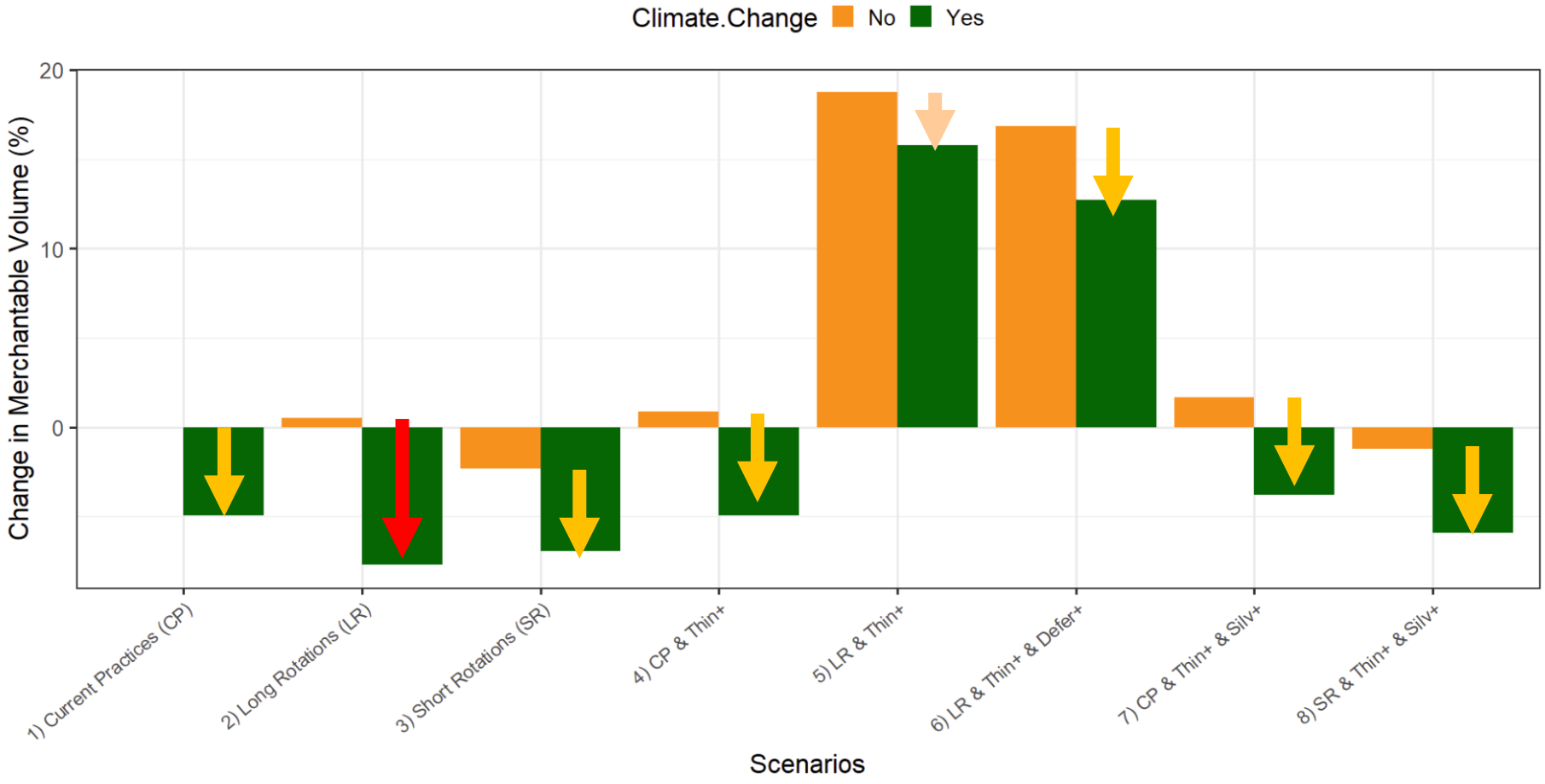


Landscape-Level Results with Climate Change



The pattern across scenarios holds for noCC vs. CC

Landscape-Level Results with Climate Change



But with a 4% - 8% drop in yield

Reference – absolute values across scenarios (climate change)

Scenario	**Total stored carbon** (mean annual Mt CO2e 2024-2124)	**Total stored carbon** (Mt Co2e in 2124)	**Merchantable timber yield** (mean annual MBF 2024-2124)	**Merchantable timber yield** (MBF in 2124)
1) Current Practices	380	473	347,172	298,479
2) Long Rotations	389	488	337,200	342,122
3) Short Rotations	377	465	339,943	276,228
4) CP & Thin+	357	434	347,250	298,735
5) LR & Thin+	344	413	422,904	439,366
6) LR & Thin+ & Defer+	343	414	411,661	438,402
7) CP & Thin+ & Silv+	358	437	351,474	333,807
8) SR & Thin+ & Silv+	356	429	343,650	309,418

Landscape-Level Results with Climate Change

scenario	**Change in total stored carbon** (% from CP no climate change)	**Change in merchantable timber harvested** (% from CP no climate change)
1) Current Practices (no climate change)	420 Mt CO2e	365 MBF
1) Current Practices (CP)	-9.7	-4.9
2) Long Rotations (LR)	-7.4	-7.7
3) Short Rotations (SR)	-10.3	-6.9
4) CP & Thin+	-15.2	-4.9
5) LR & Thin+	-18.2	15.8
6) LR & Thin+ & Defer+	-18.4	12.7
7) CP & Thin+ & Silv+	-15	-3.9
8) SR & Thin+ & Silv+	-15.4	-5.9

Landscape-Level Results with Climate Change

scenario	**Change in total stored carbon** (% from CP no climate change)	**Change in merchantable timber harvested** (% from CP no climate change)
1) Current Practices (with climate change)	380 Mt CO2e	347,172 MBF
2) Long Rotations (LR)	2.5	-2.9
3) Short Rotations (SR)	-0.7	-2.1
4) CP & Thin+	-6.1	0.0
5) LR & Thin+	-9.5	21.8
6) LR & Thin+ & Defer+	-9.7	18.6
7) CP & Thin+ & Silv+	-5.7	1.2
8) SR & Thin+ & Silv+	-6.4	-1.0

Summary of Results

1. Scenario effects + or – hold under climate change.
2. In managed lands (GEM, non-deferred) carbon increased or stable with climate change; riparian & uplands carbon decreases.
3. Climate change impacts arise around the year ~2045

Your Turn!
Questions

Break (10min)

Next Up: Scenario Modification Discussion (DNR)

Questions for Discussion of Possible Revisions

- Q1. Are there any "dials" the working group feels we should adjust up or down (e.g., reduce/increase commercial thinning in some scenarios)?
- Q2. Are there any ways we implemented the "dials" we should change?
- Q3. Should we vary species plantings over time under climate change?
- Q4. Should we vary the default planting density under climate change?

Supplementary Slides

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Stand-replacement harvest board feet requirement (MBF/ac)	30	50	20	30	50, 80 years (site class 3), 90 years (site class 4)	50, 80 years (site class 3), 90 years (site class 4)	30	20
Commercial thinning board feet requirement (MBF/ac)	18	18	18	18	18	18	18	10
Precommercial thinning stand age requirement	Between 8-12 years old							
Precommercial thinning (trees/ac remaining) – High Elevation zone	330	280	330	429	429	429	29	429
Precommercial thinning (trees/ac remaining) – Coastal Low Elevation zone	300	250	300	390	390	390	390	390
Precommercial thinning (trees/ac remaining) – Near to Coast Low Elevation zone	300	250	300	390	390	390	390	390
Precommercial thinning (trees/ac remaining) – Not Near to Coast Low Elevation zone	250	211	250	325	325	325	325	325

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Precommercial thinning (trees/ac remaining) – Mixed Species zone	250	211	250	325	325	325	325	325
Precommercial thinning (trees/ac trigger) – High Elevation zone	660+							
Precommercial thinning (trees/ac trigger) – Coastal Low Elevation zone	600+							
Precommercial thinning (trees/ac trigger) – Near to Coast Low Elevation zone	600+							
Precommercial thinning (trees/ac trigger) – Not Near to Coast Low Elevation zone	500+							
Precommercial thinning (trees/ac trigger) – Mixed Species zone	500+							
Stand-replacement harvest (leave trees/ac)	8 (2 leave trees in the largest diameter class, 6 leave trees in the intermediate diameter class, remove all trees 10 inches DBH or smaller in the intermediate diameter class and smaller classes. Leave trees, on average, account for approximately 10% of stand volume, leaving 90% of volume available for harvest under current practices.)							

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Commercial thinning (% stand basal area harvested)	30							
Annual stand-replacement harvest target (BF, full study area)	2,196,831,000							
Commercial thinning harvest target (% of stands or area)	8%	8%	8%	100%				
Precommercial thinning harvest target (% of stands receiving PCT in GEM areas)	50%	50%	50%	75%	75%	75%	75%	75%
Stand-replacement harvest type	Thin from above to a trees per acre target (8 leave trees).							
Commercial thinning harvest type	First, thin across all diameters to 90% of original basal area remaining, then Thin from below to a basal area target (70% of original basal area remaining).							
New harvest deferrals	None	None	None	None	None	Defer all stands ≥ 80 years at start of simulation	None	None
Stand regeneration lag	2 years							
Natural regeneration density (seedlings/acre) – High Elevation zone (Mountain Hemlock and Silver Fir)	20 MH, 20 SF							

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Natural regeneration density (seedlings/acre) – Coastal Low Elevation zone (Western Hemlock, Red Alder, Douglas Fir, Western Redcedar)	34 WH, 2 RA, 2 DF, 2 RC							
Natural regeneration density (seedlings/acre) – Near to Coast Low Elevation zone (Western Hemlock, Red Alder, Douglas Fir, Western Redcedar)	34 WH, 2 RA, 2 DF, 2 RC							
Natural regeneration density (seedlings/acre) – Not Near to Coast Low Elevation zone (Western Hemlock, Red Alder, Douglas Fir, Western Redcedar)	17 WH, 1 RA, 1 DF, 1 RC							
Natural regeneration density (seedlings/acre) – Mixed Species zone (Western Hemlock, Red Alder, Douglas Fir, Western Redcedar)	17 WH, 1 RA, 1 DF, 1 RC							

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Planting density (seedlings/acre) – High Elevation zone (Noble Fir)	440	375	440	572	572	572	572	572
Planting density (seedlings/acre) – Coastal Low Elevation zone (Western Hemlock)	400	340	400	520	520	520	520	520
Planting density (seedlings/acre) – Near to Coast Low Elevation zone (Douglas-fir, Western Hemlock)	200 DF, 200WH	170 DF, 170 WH	200 DF, 200WH	260 DF, 260 WH	260 DF, 260 WH	260 DF, 260 WH	260 DF, 260 WH	260 DF, 260 WH
Planting density (seedlings/acre) – Not Near to Coast Low Elevation zone (Douglas Fir, Western Hemlock, Red-cedar)	275 DF, 50 WH	242 DF, 21 WH, 12RC	275 DF, 50 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH
Planting density (seedlings/acre) – Mixed Species zone (Douglas Fir, Western Hemlock, Red-cedar)	295 DF, 25 HW 15 RC	242 DF, 21 WH, 12RC	275 DF, 50 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH	357 DF, 65 WH
Increased growth due to improved genetic stock (% increase in diameter and height growth)	0	0	0	0	0	0	2	2

Model Parameter Settings by Scenario

Configuration Settings (GEM)	Scenario #1: Current DNR Management Practice	Scenario #2: Lengthen Harvest Rotation	Scenario #3: Shorten Harvest Rotation	Scenario #4: Significantly Increase Thinning	Scenario #5: Lengthen Harvest Rotation and Significantly Increase Thinning	Scenario #6: Lengthen Harvest Rotation, Significantly Increase Thinning, Increase Deferrals	Scenario #7: Significantly Increase Thinning and Increased Emphasis on Silviculture	Scenario #8: Shorten Harvest Rotation, Significantly Increase Thinning, Increased Emphasis on Silviculture
Increased growth due to site preparation and release treatments (% increase in diameter and height growth of small trees after 10 years)	84							
Extent of site preparation and release treatments (% of plots)	75	75	75	100	100	100	100	100
Fire rate (% basal area affected annually, by county)	Island = 0.0058% Clallam = 0.0117% Mason = 0.0124% San-Juan = 0.0126% Pierce = 0.0141% Wahkiakum = 0.0155% Jefferson = 0.0179% Pacific = 0.0186019% Lewis = 0.019% Kitsap = 0.0216% Grays-Harbor = 0.0249% Thurston = 0.0255% Clark = 0.0316% Cowlitz = 0.0378% Skamania = 0.0436% King = 0.0892% Snohomish = 0.1310% Skagit = 0.2072% Whatcom = 0.4698%							

Model Parameter Settings by Scenario

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Insect mortality rate (% basal area affected annually)	0.0061%							
Blowdown rate (% basal area affected annually)	0.05676%							
Drought rate (% basal area affected annually)	0.0040%							
Disease rate (% basal area affected annually)	0.0806%							
Temporal parameters	100-year time horizon, 5-year time steps, length of first cycle differs to accommodate differing inventory years							
Climate change	1 run without climate change, 1 run with 17 GCM ensemble and RCP4.5 implemented in Climate-FVS							