Forest Carbon Modelling Results

December 11, 2024

ESSA

Outline

Last time (Nov. 13)…

- Introduction
- **Part 1**: Methods Refresher

This time…

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

Part 1: Methods Refresher

SEE April 10 and November 13 Meeting Recordings:

https://www.dnr.wa.gov/about/boards-and-commissions/carbon-and-forest-management-work-group

Output Units

Total stored carbon

Live/dead forest biomass

MtCO2e

Harvested wood products

MtCO2e

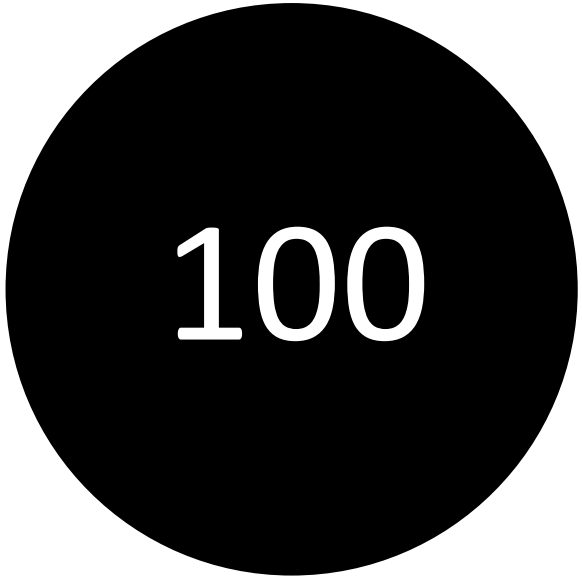
Harvested merchantable timber volume

MBF

Temporal Units

Time Steps (years)

Time Horizon (years)



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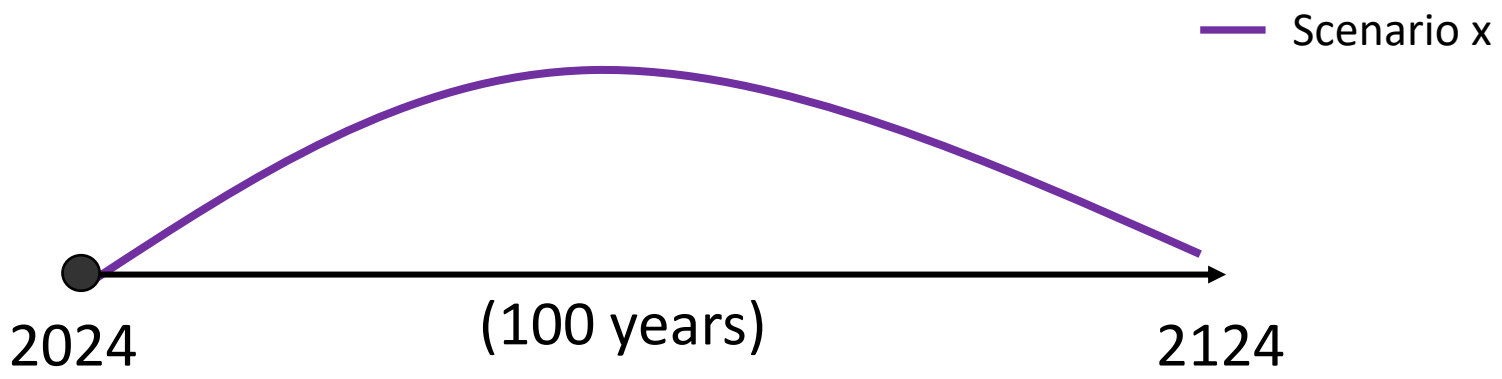
Performance Metric

Scenario performance metric:

Mean of total $MtCO_2e$ across simulation time steps



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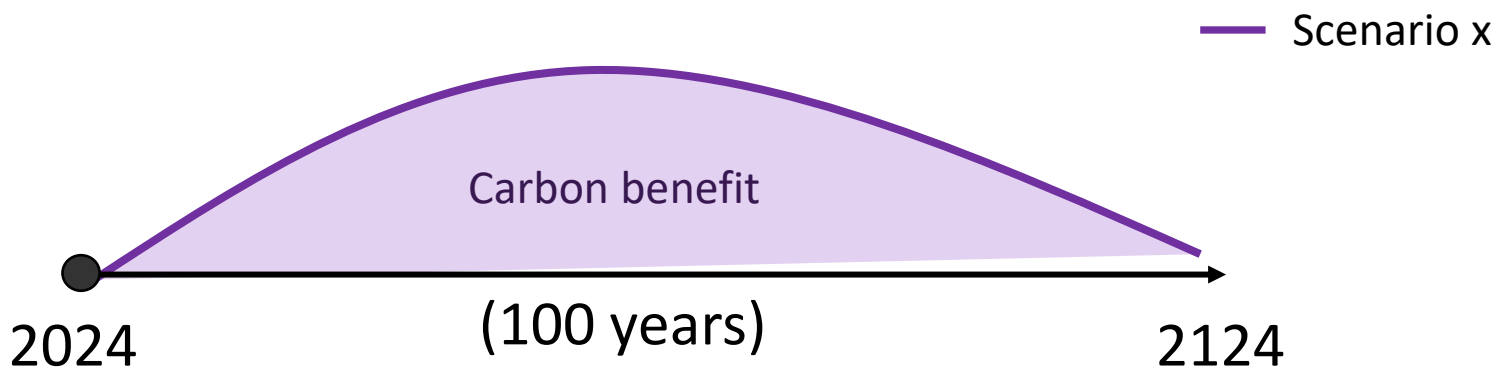

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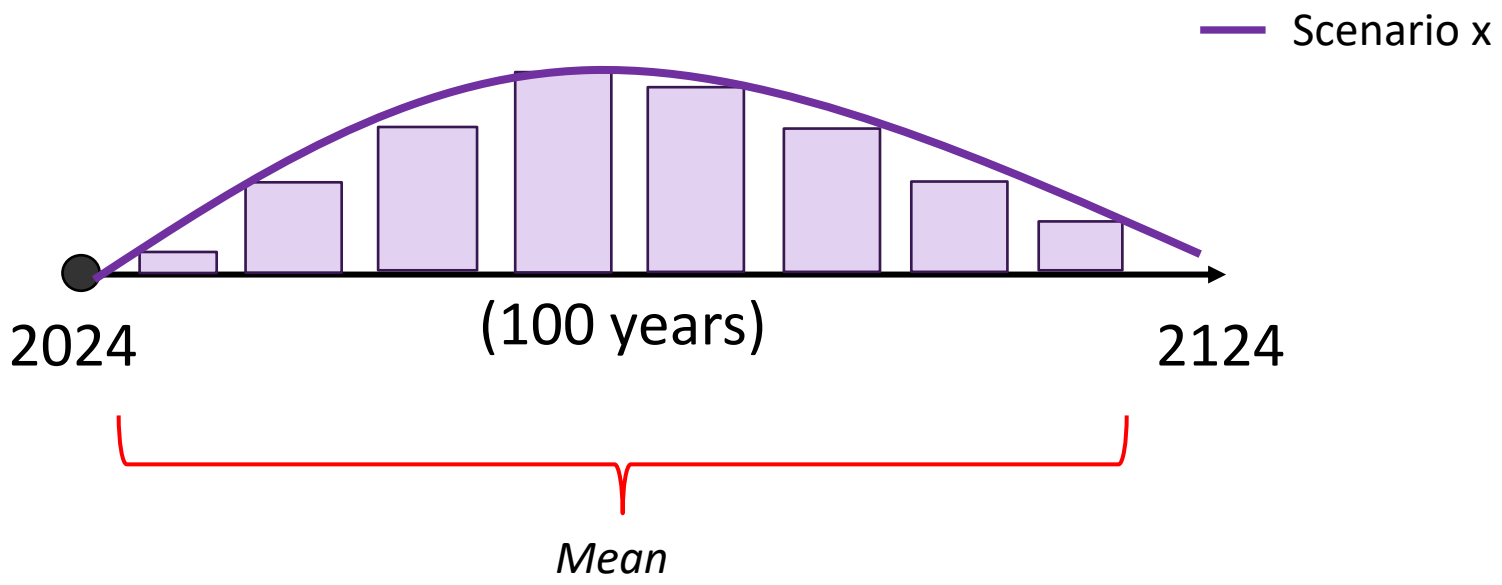
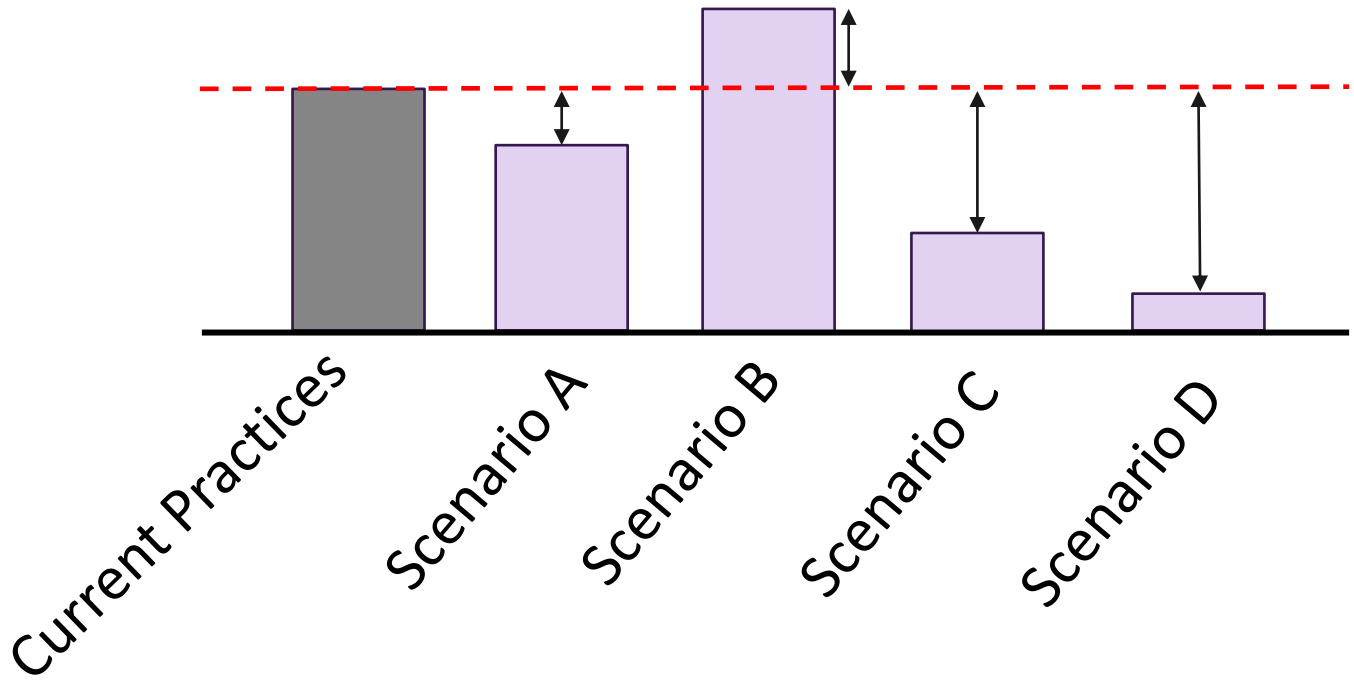


Performance Metric

Scenario performance metric:

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



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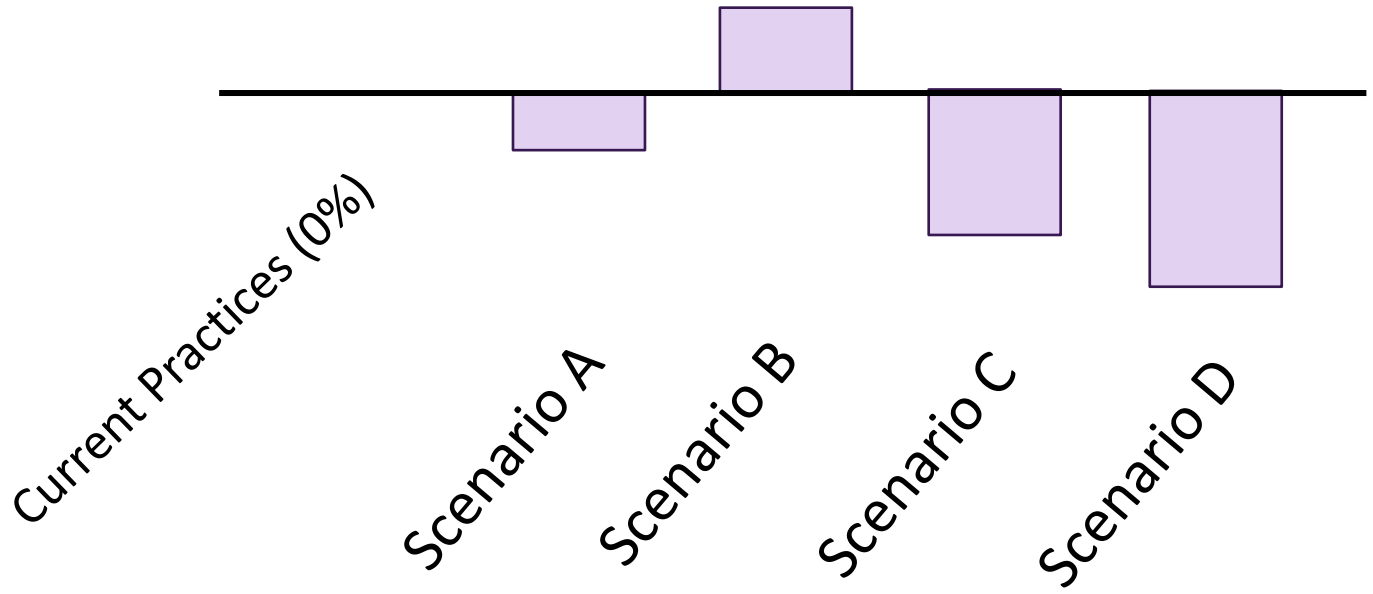


New Methods Since Last Time...

Summary of complex harvest methods (new)

- If habitat thresholds in **Northern Spotted Owl Management Units** are not currently met (i.e., 50% SOMU area deferred in non-OESF, 40% area deferred in OESF), limited harvest will be allowed as long as it does not interfere with stands that will eventually grow into suitable habitat to meet SOMU thresholds

- **66% of** the area in **rain-on-snow zones** must be **hydrologically mature** before harvest is permitted in these zones

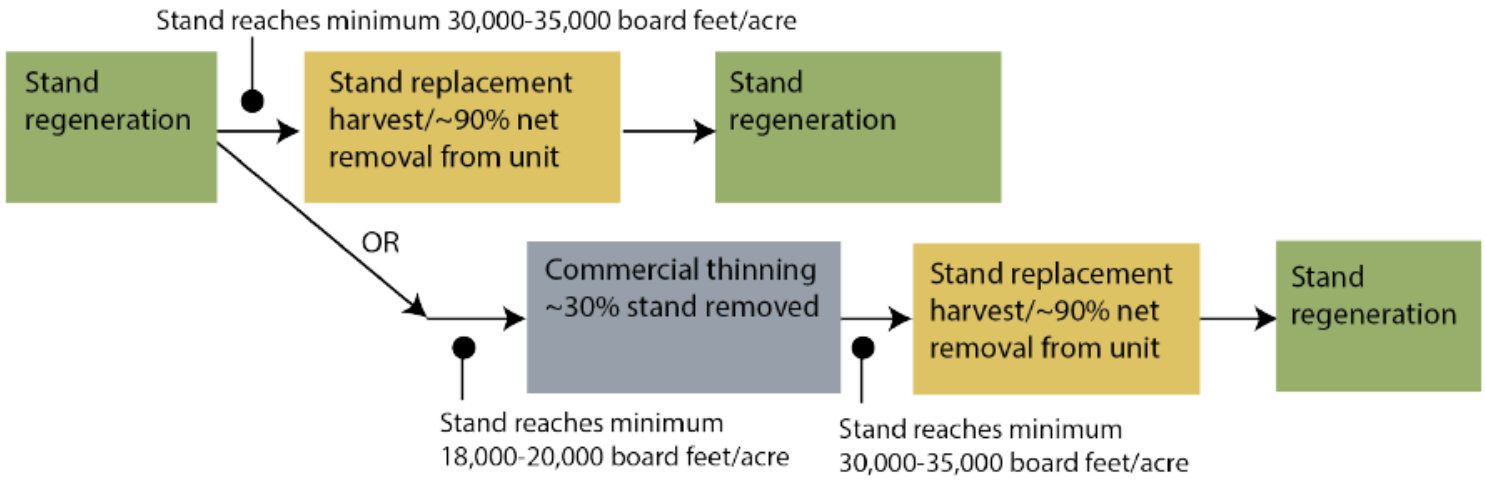
OESF = Olympic Experimental State Forest

Part 1: Landscape-level Results

Baseline for Comparison

Scenario 1: Current Practices

GEM Areas



Riparian Areas

Commercial thinning (~30% of stand removed) after stand reaches 18,000-20,000 board feet/acre*

*Roughly 83 acres of riparian forest thinned per year in western Washington. Per the RFRS, riparian forests can be thinned only once.

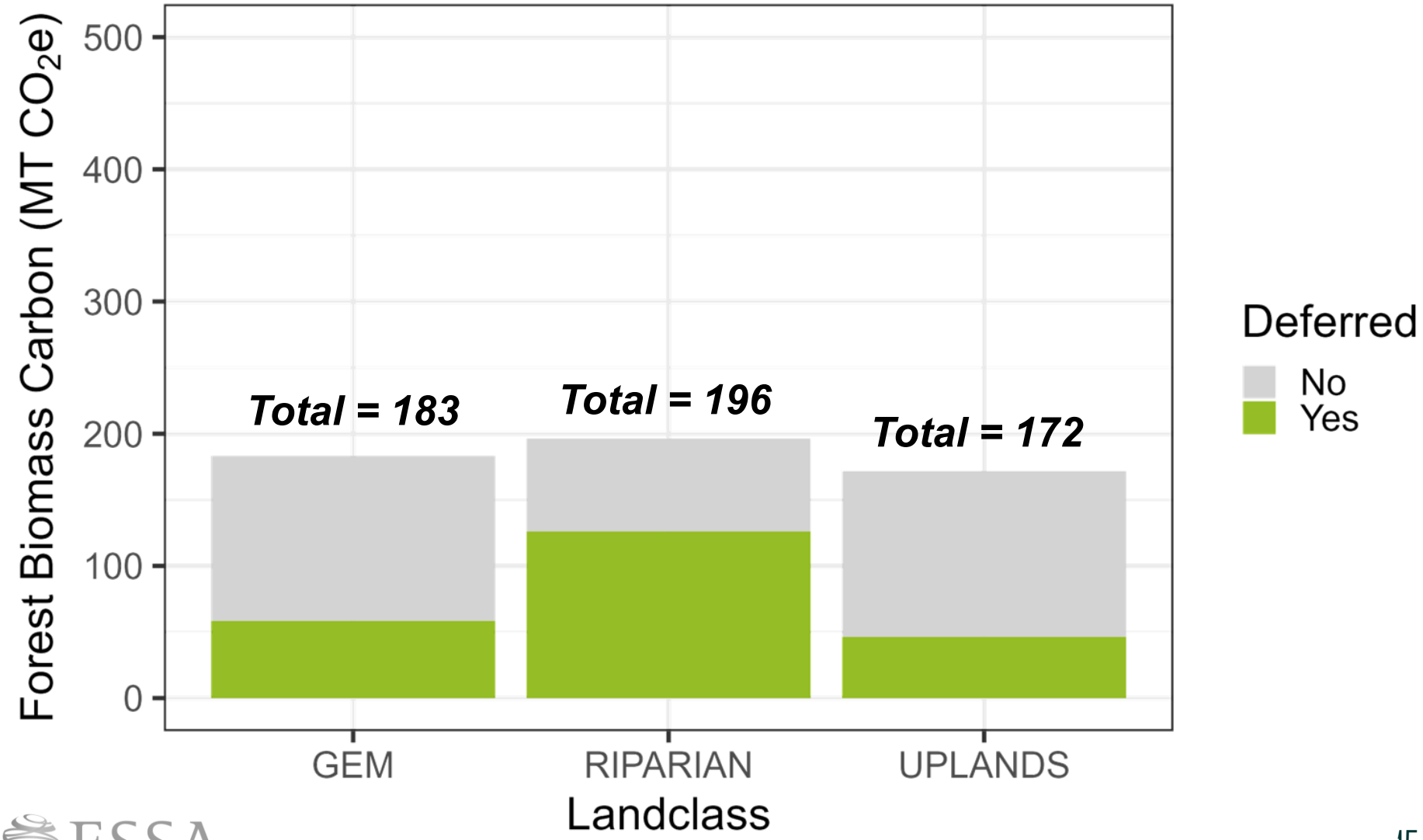
Upland Areas

Commercial thinning (~30% of stand removed) after stand reaches 18,000-20,000 board feet/acre**

**Only one thinning entry will be modeled in upland areas to better align with HCP requirements.

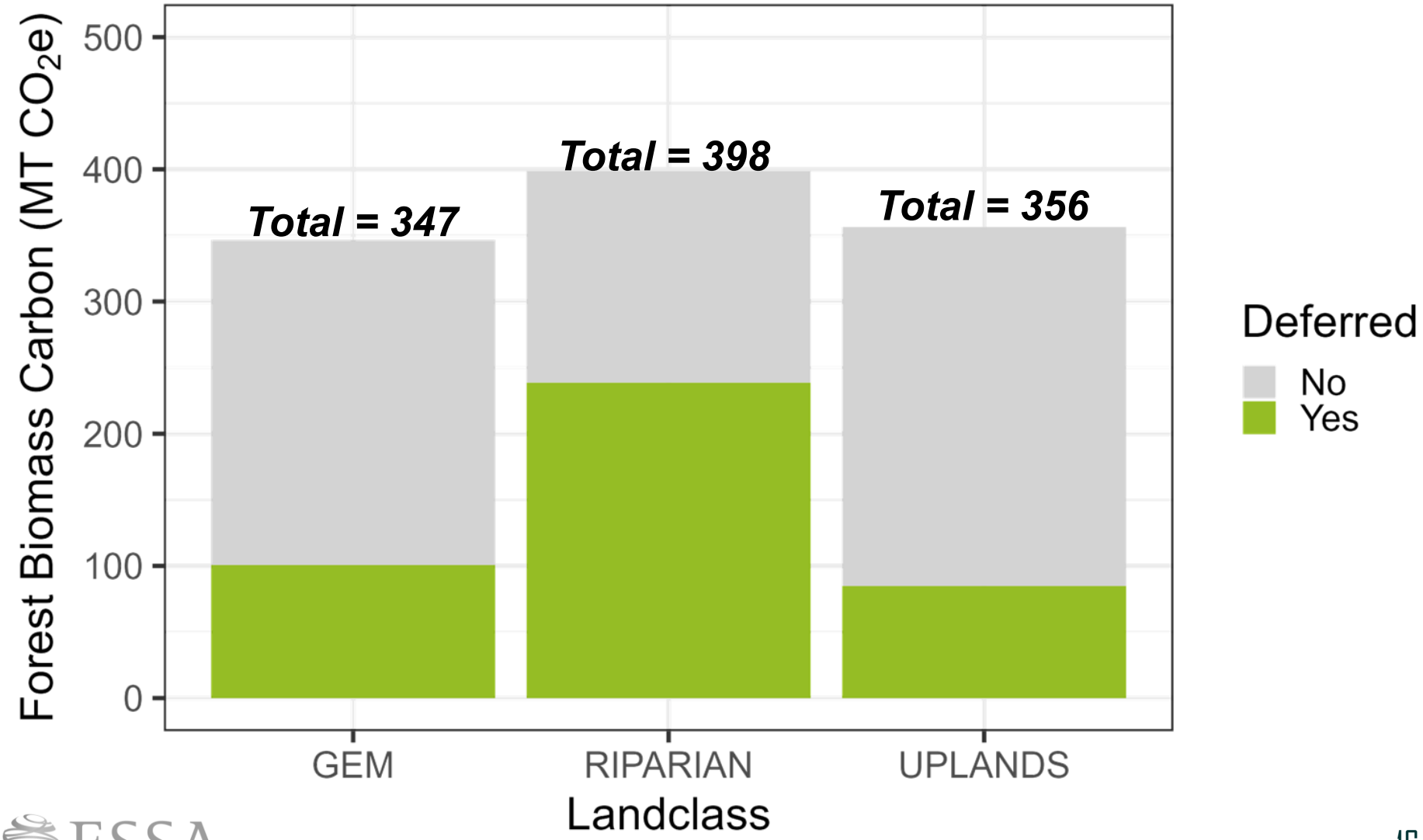
Baseline for Comparison: Scenario 1 Current Practices

551 Mt CO2e in 2024



Baseline for Comparison: Scenario 1 Current Practices

1,101 Mt CO2e in 2124



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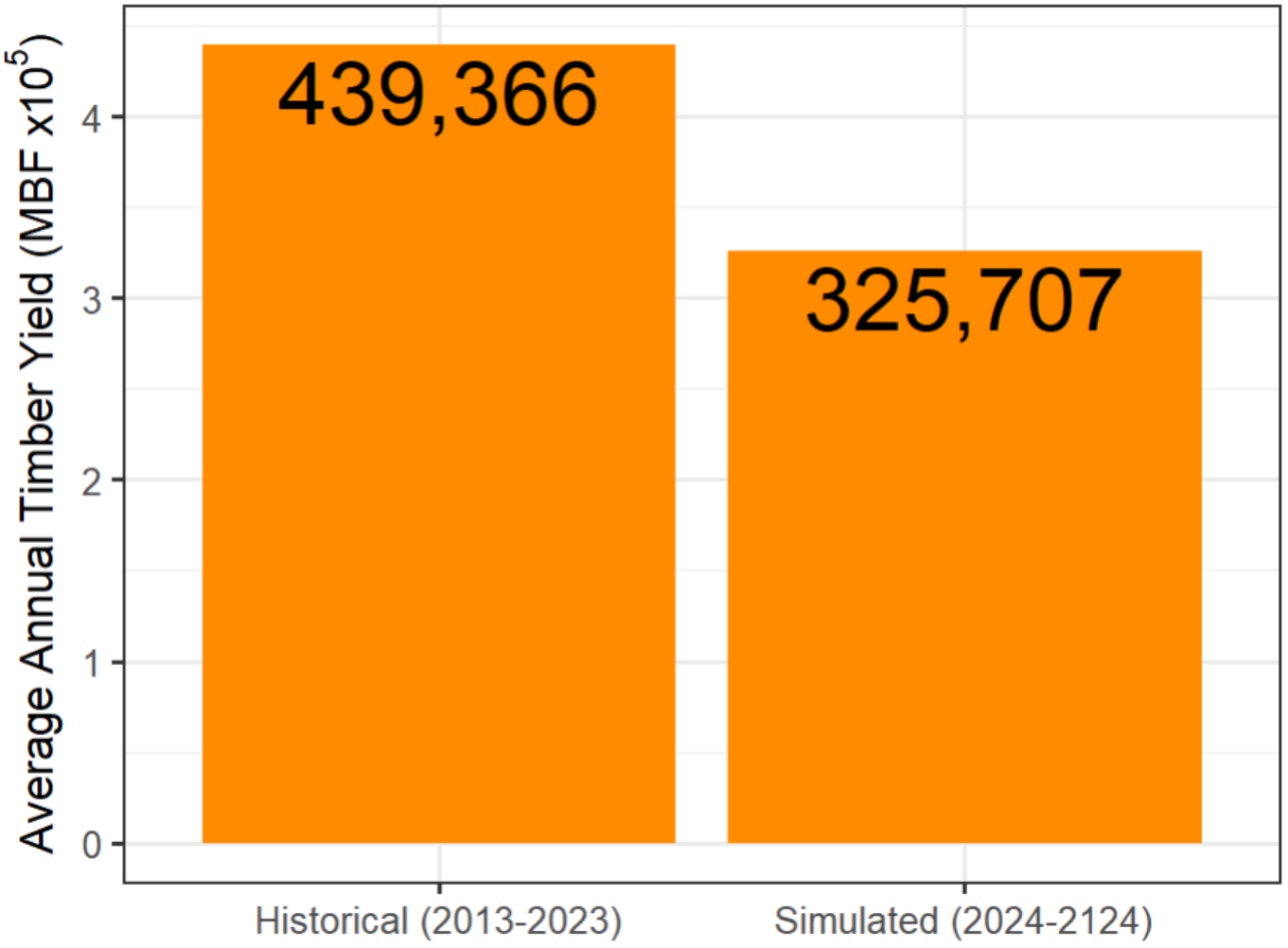
Baseline for Comparison: Scenario 1 Current Practices

Historical yield vs. ESSA Simulated FVS Timber Yield



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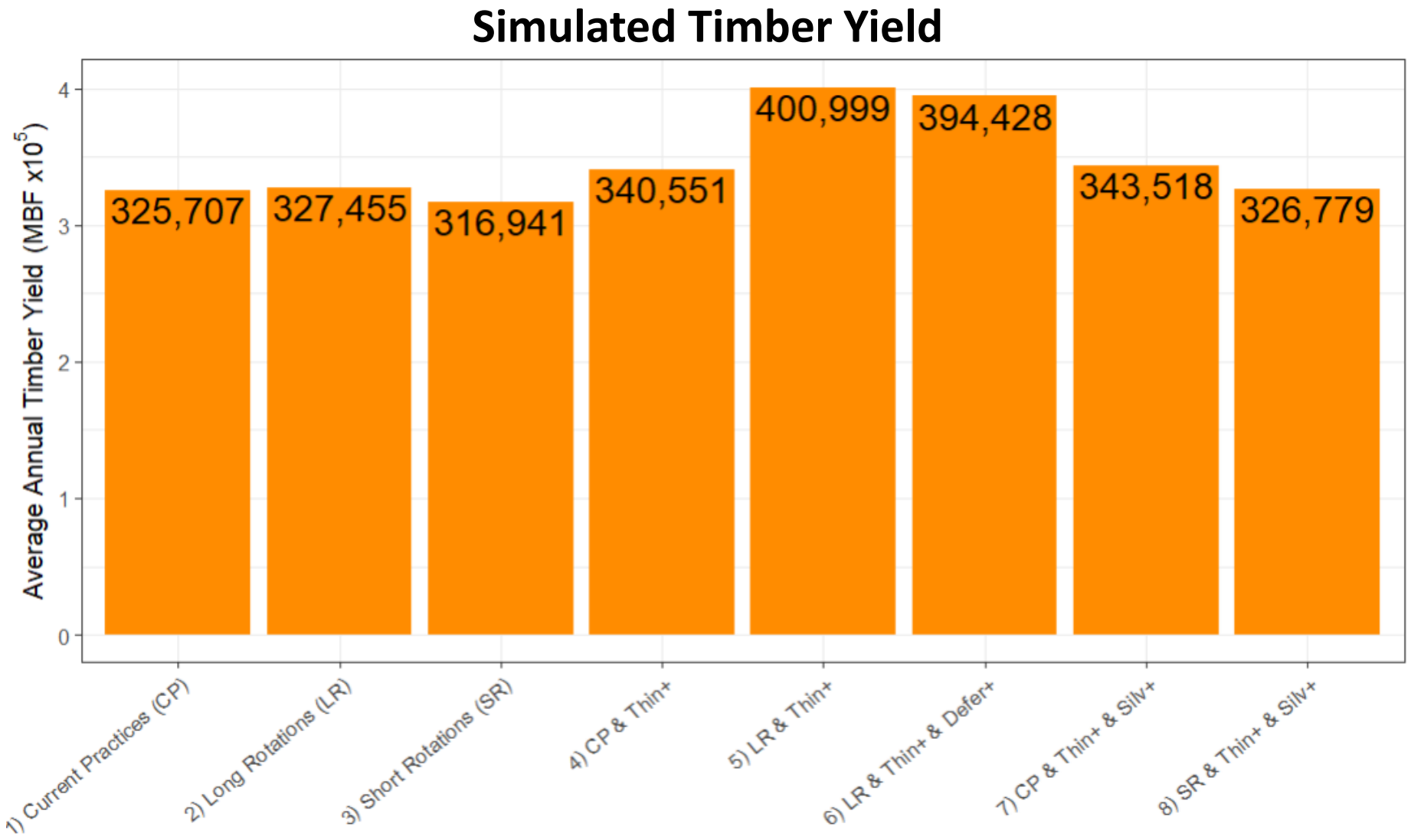
Scenario Results - Landscape Level



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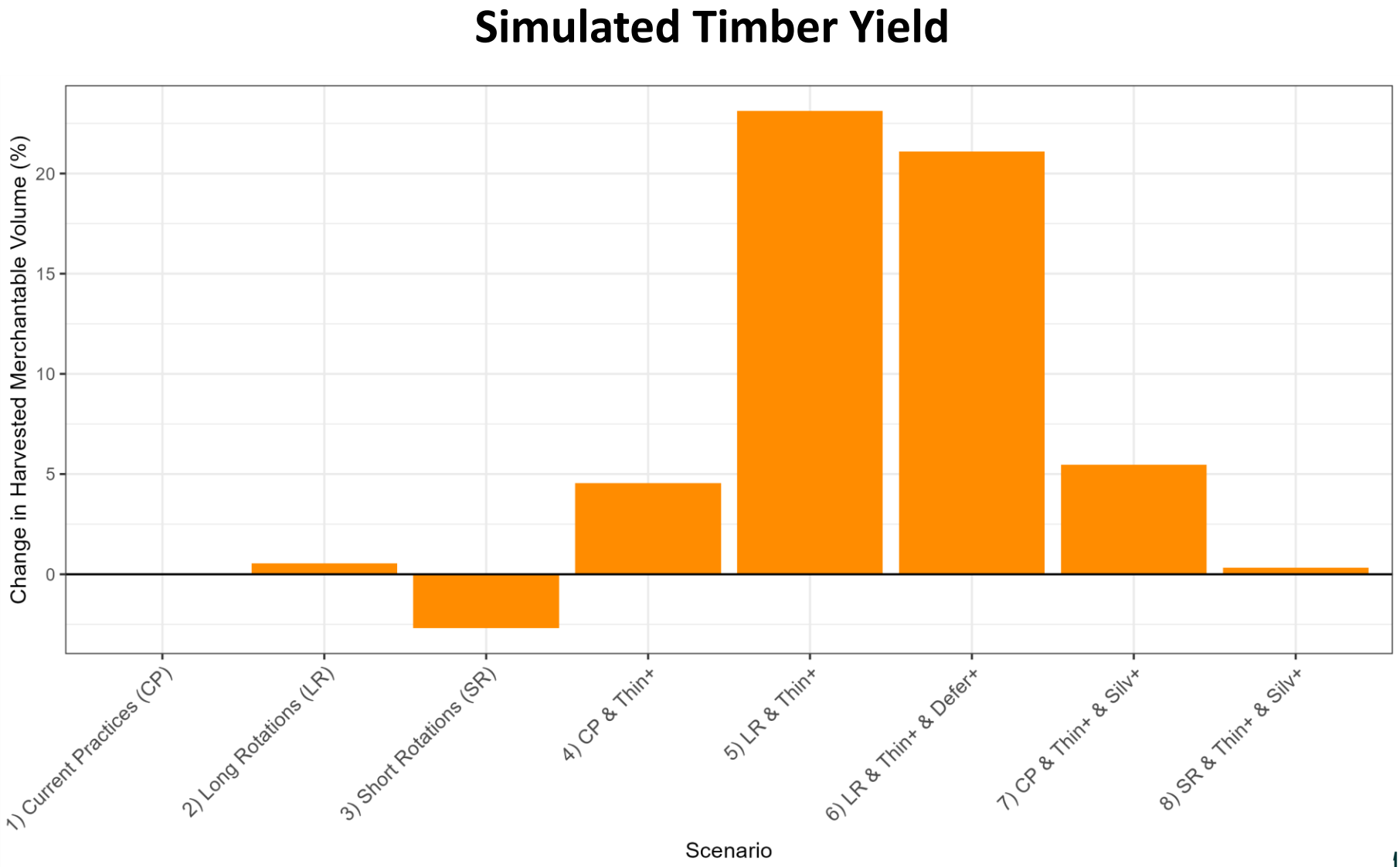

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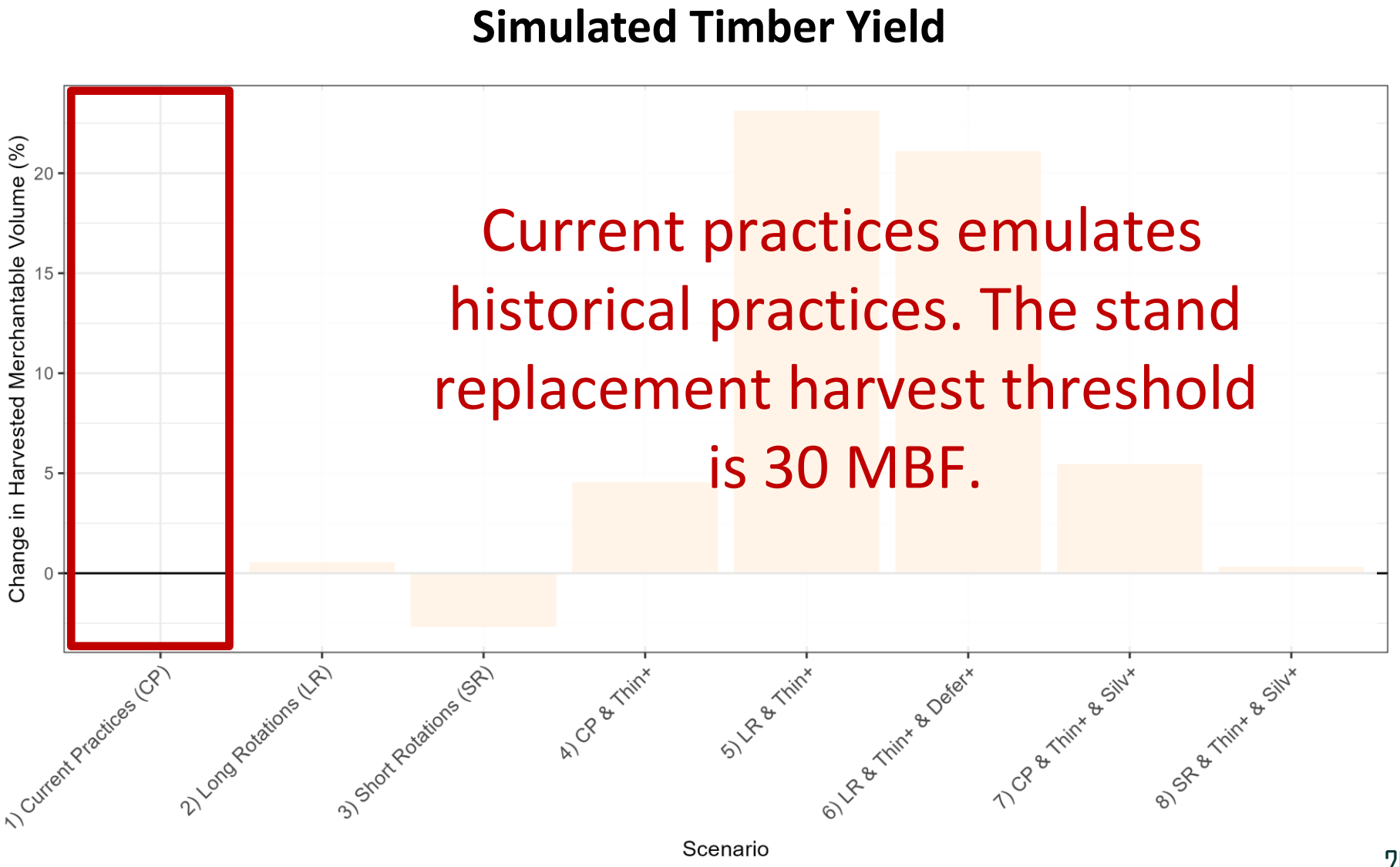

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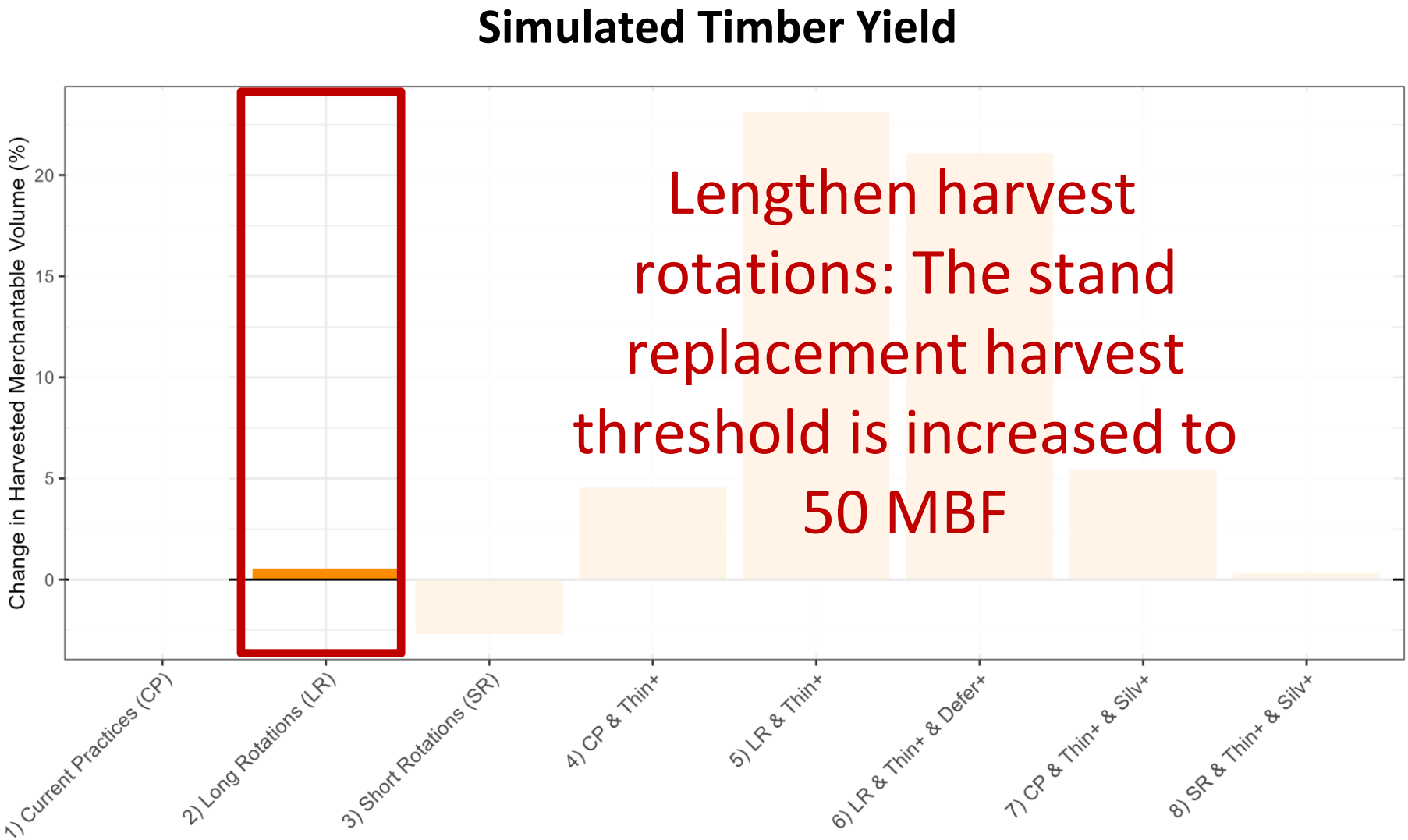

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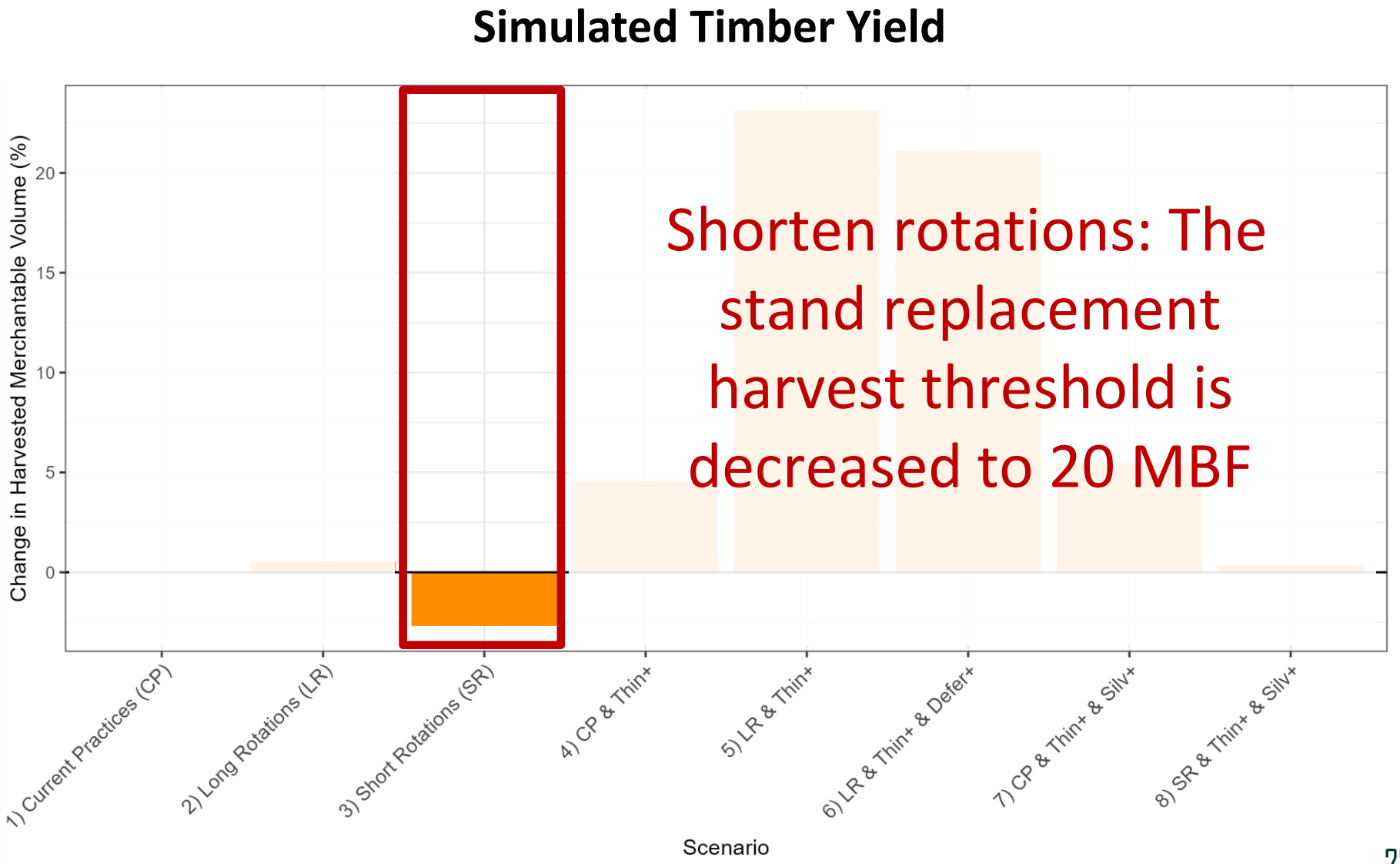
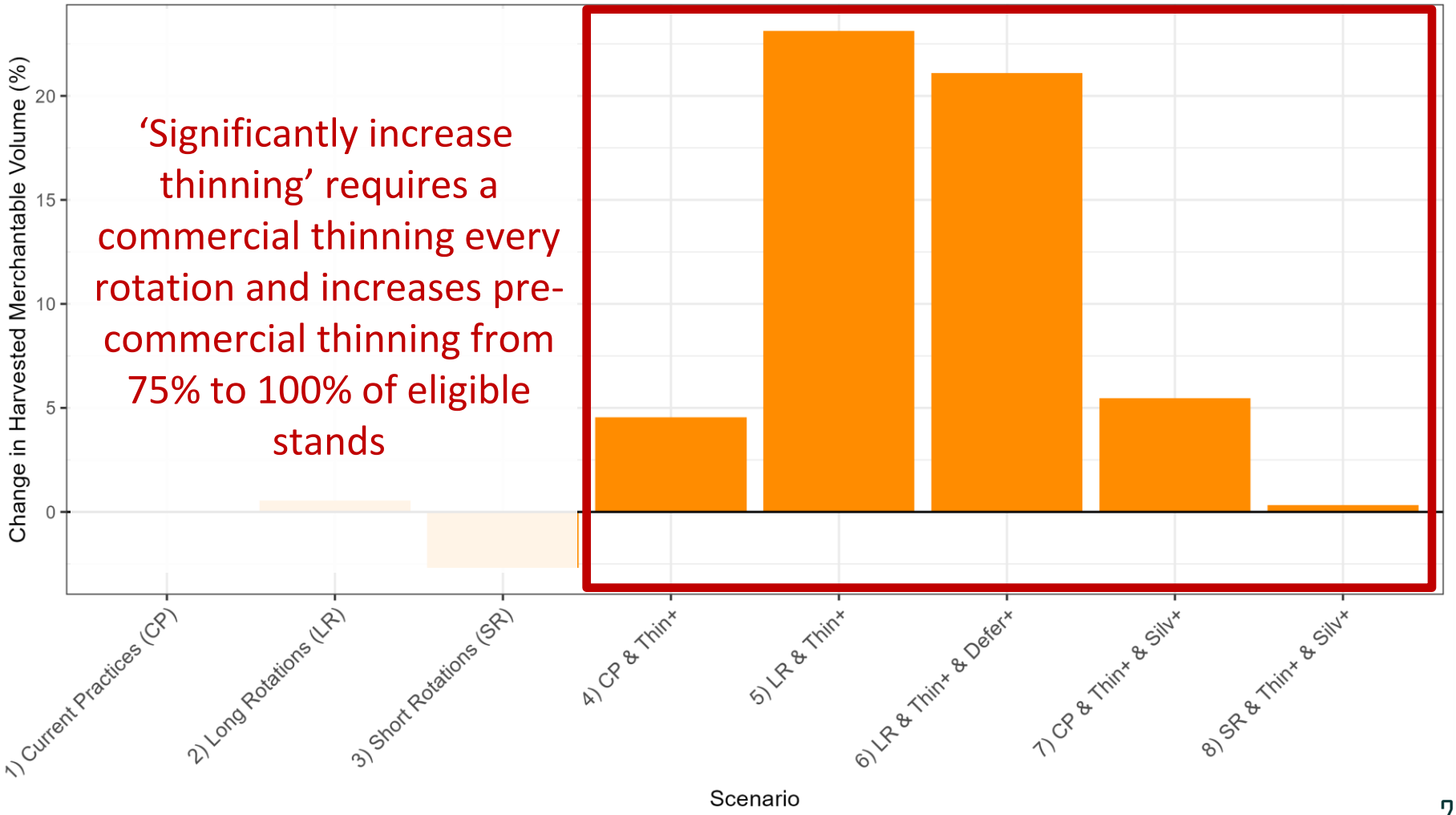


Scenario Results - Landscape Level

Simulated Timber Yield

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



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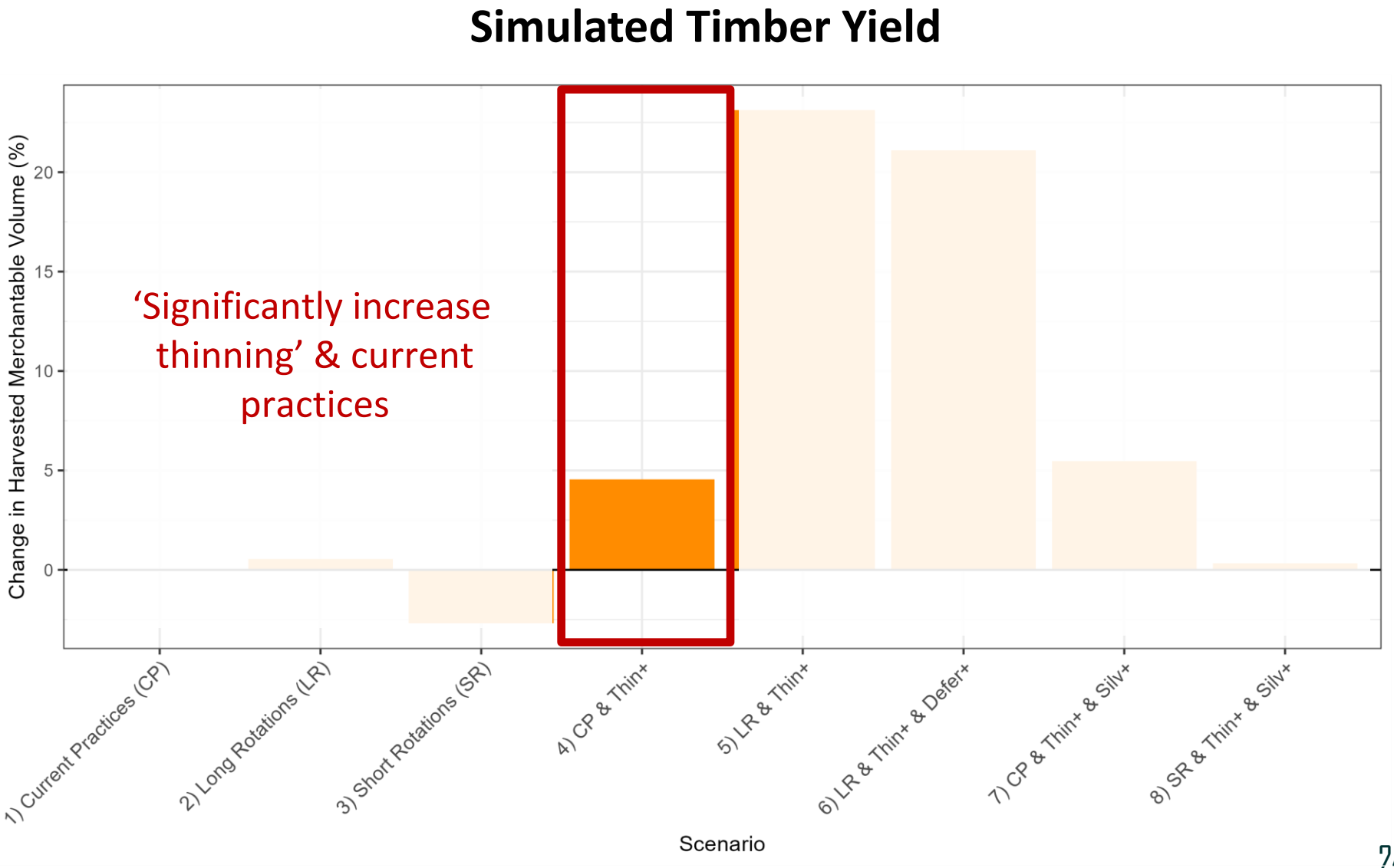

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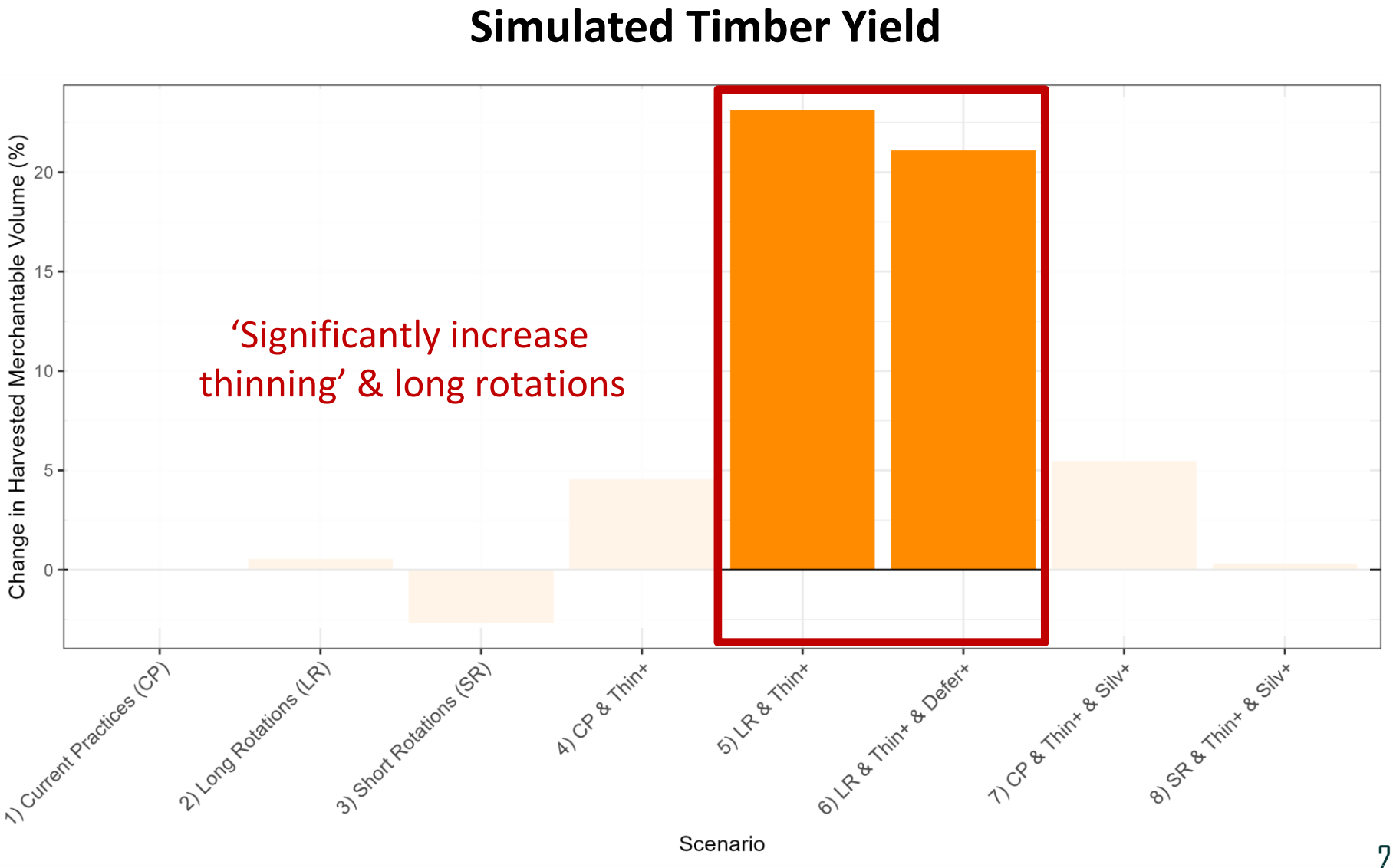

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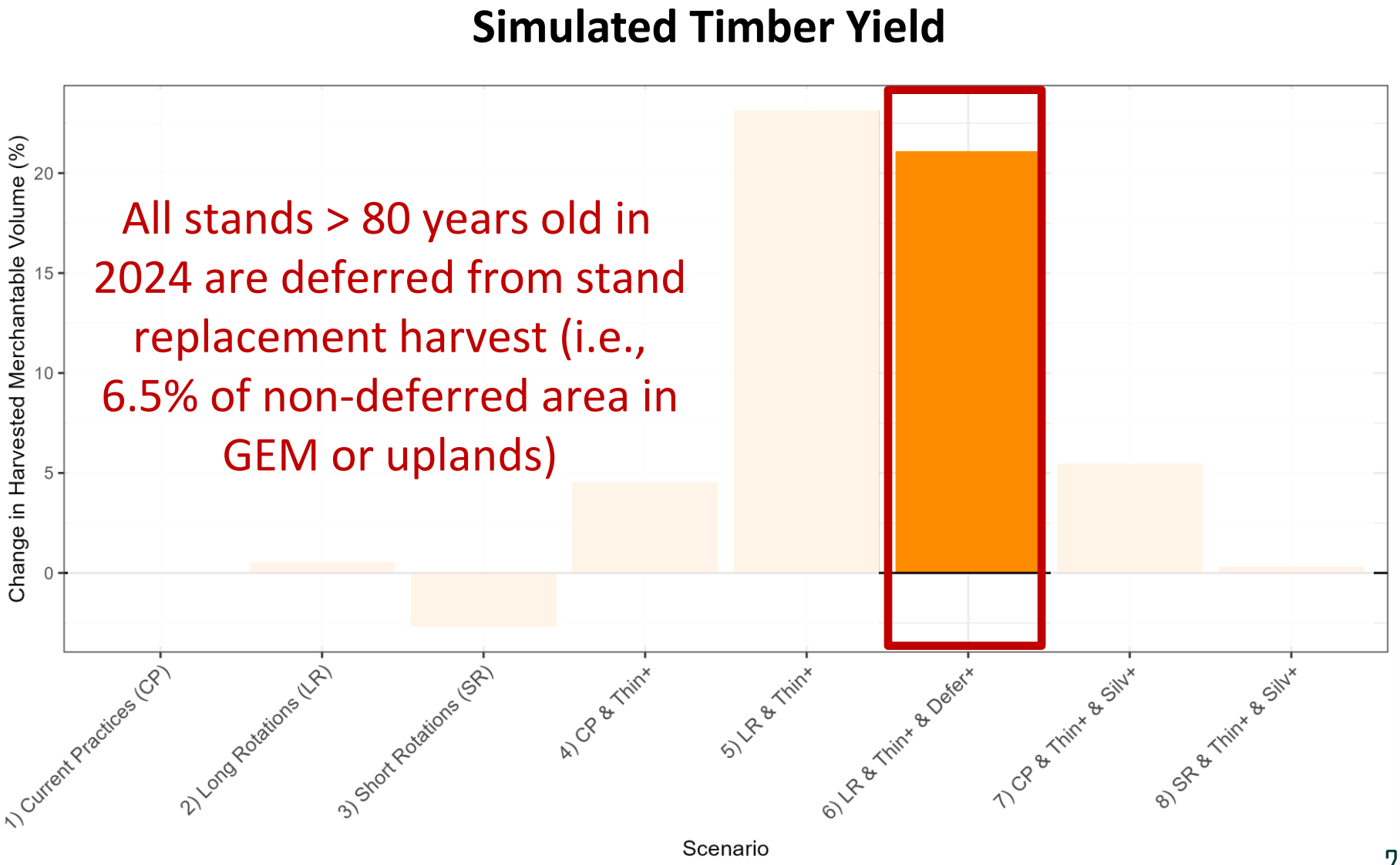

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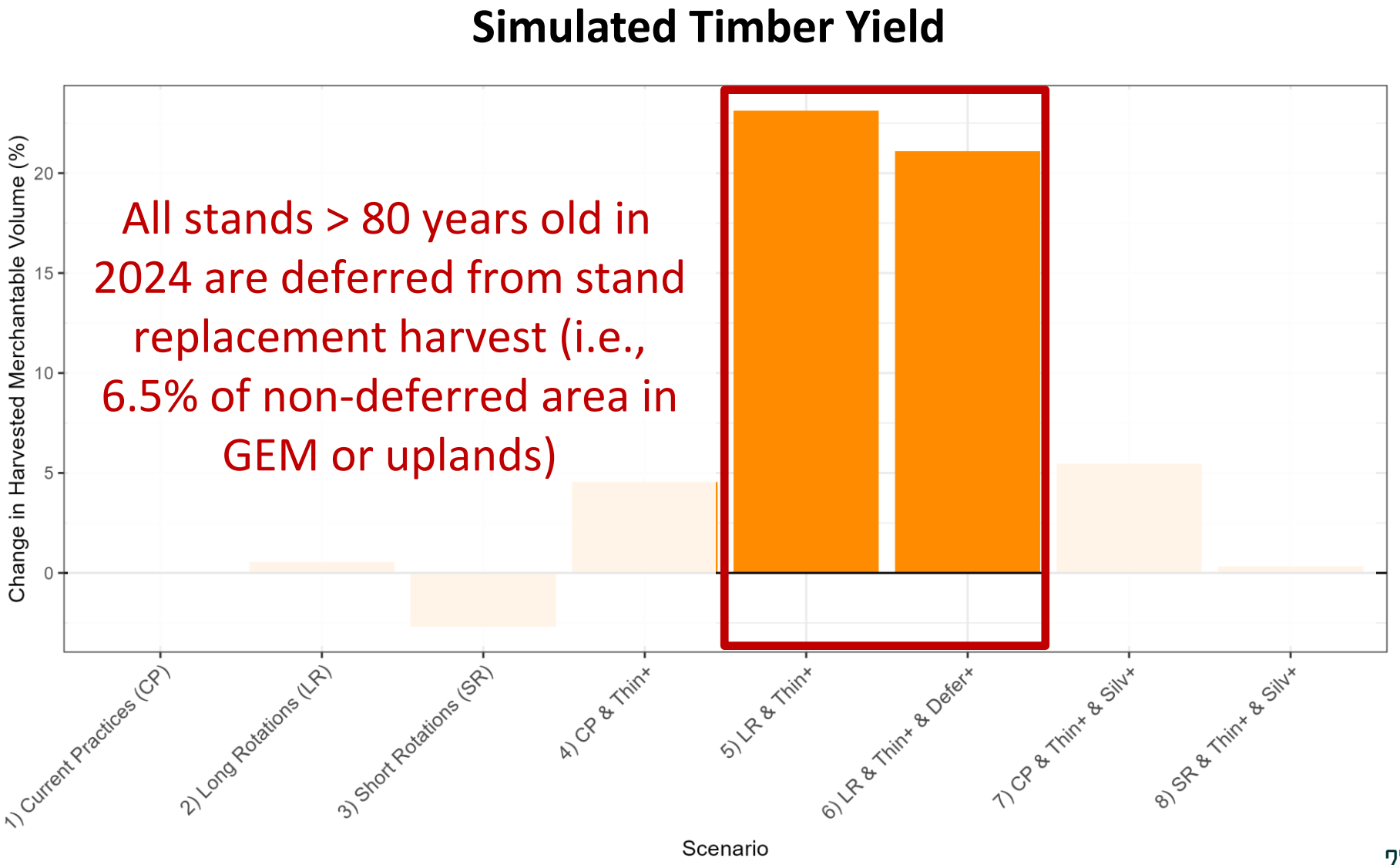

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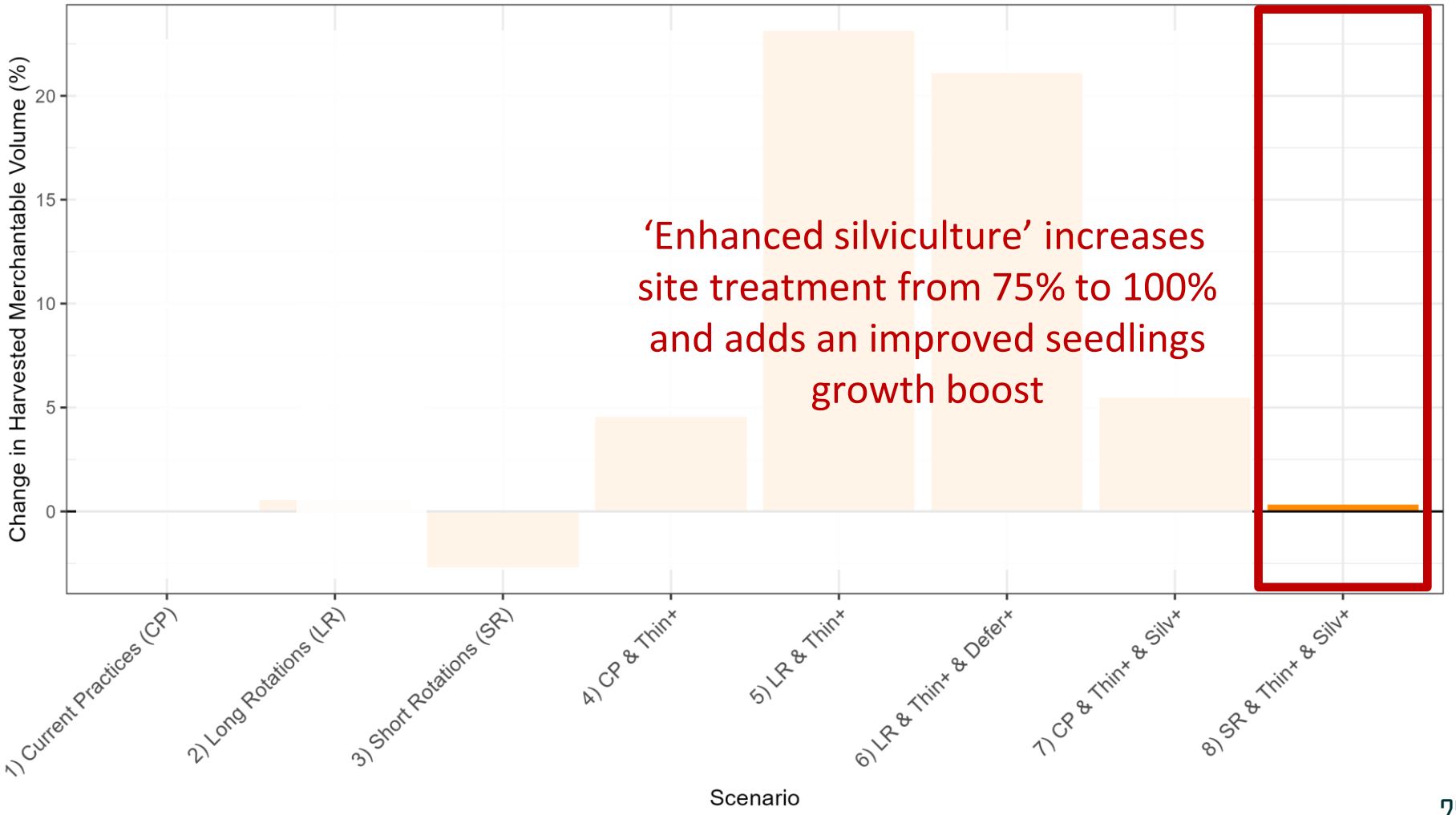

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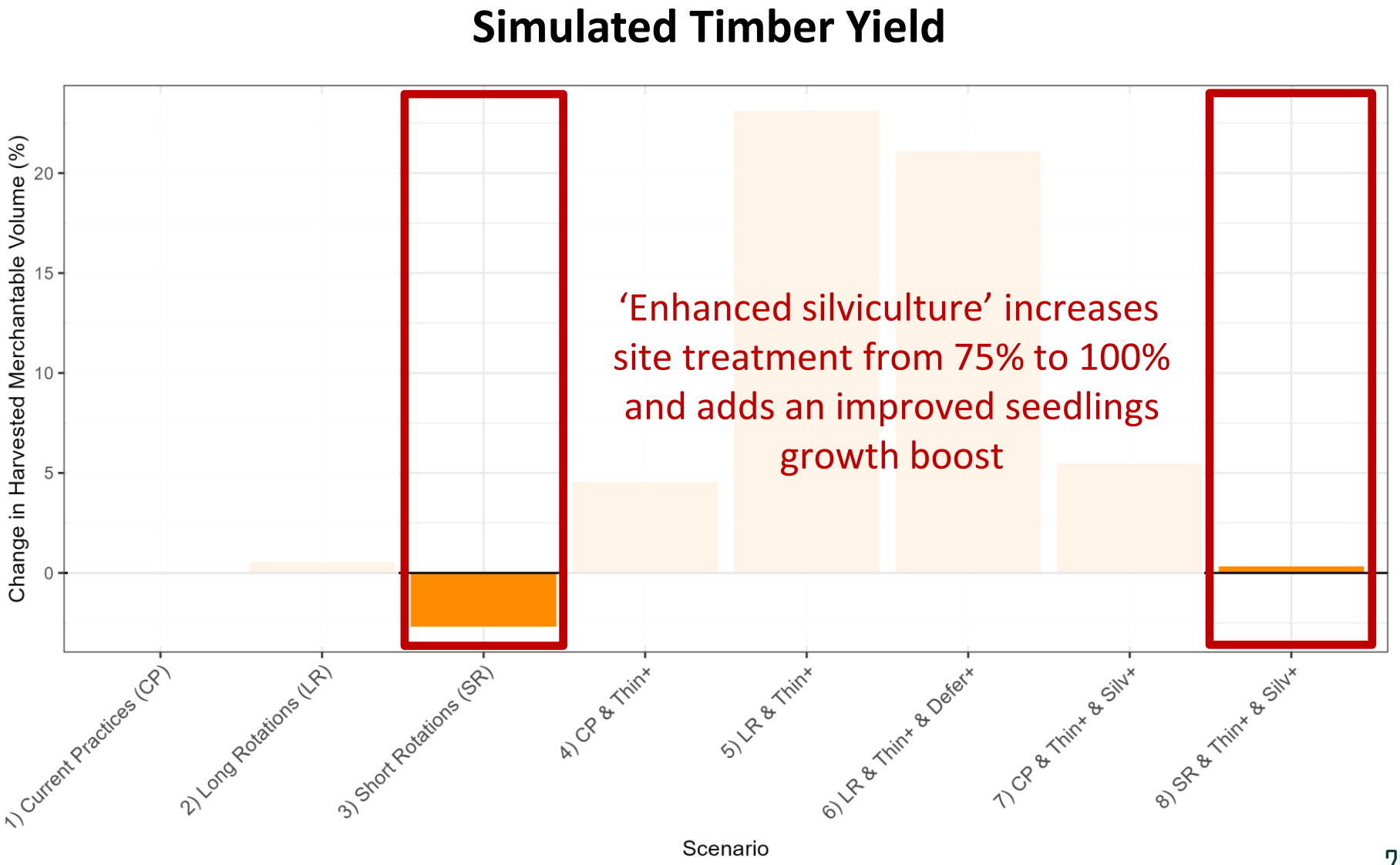
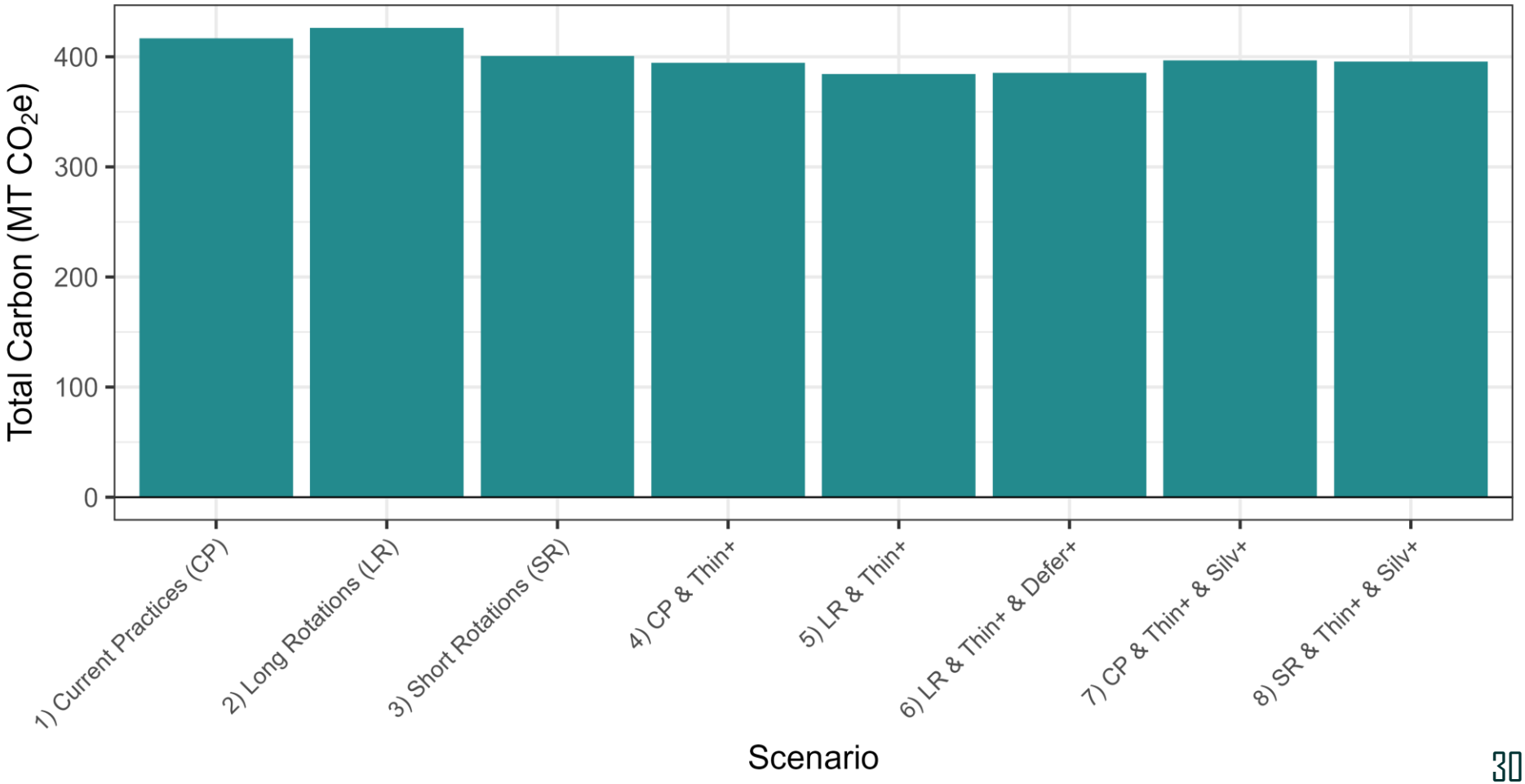


Scenario Results - Landscape-Level: Carbon



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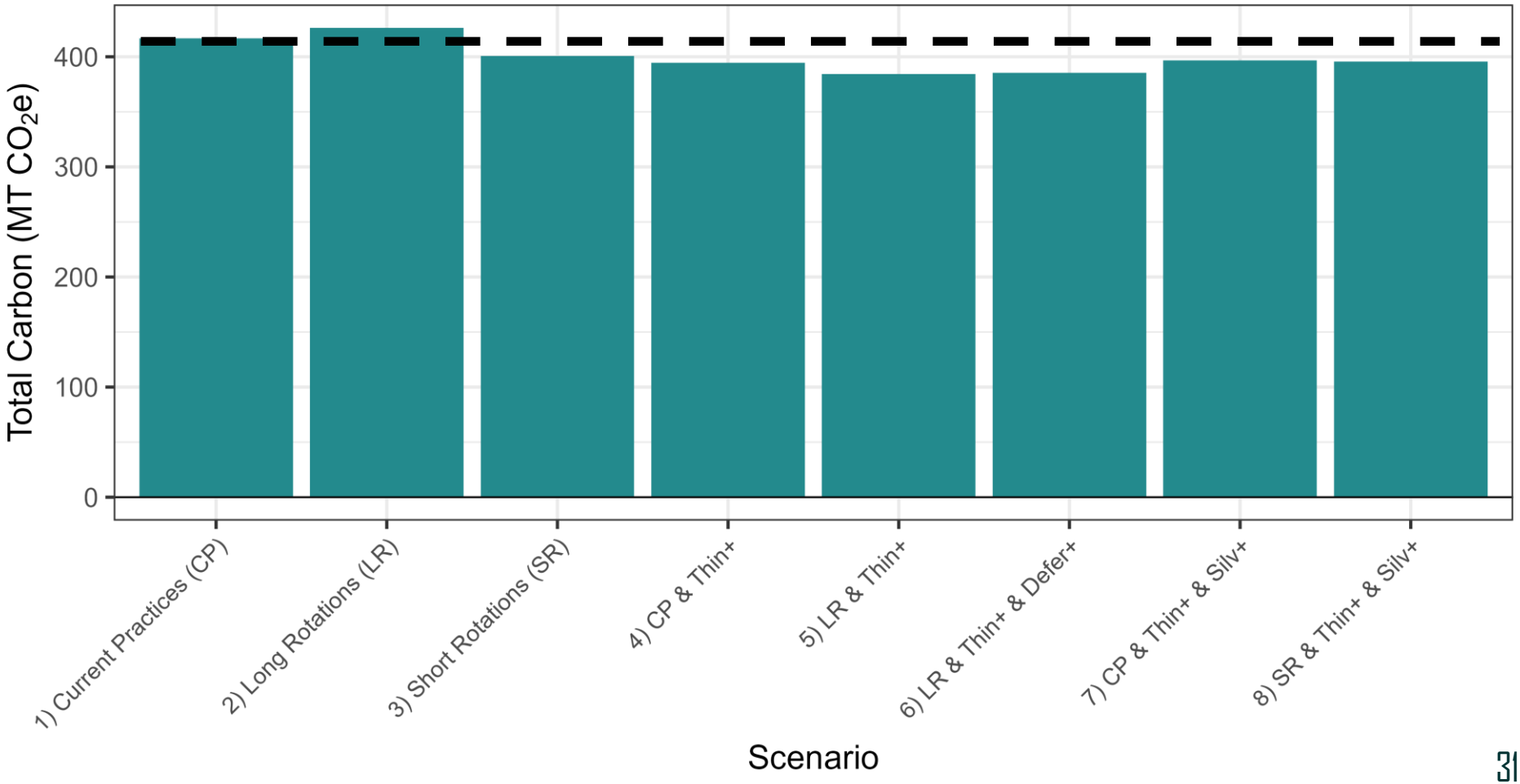

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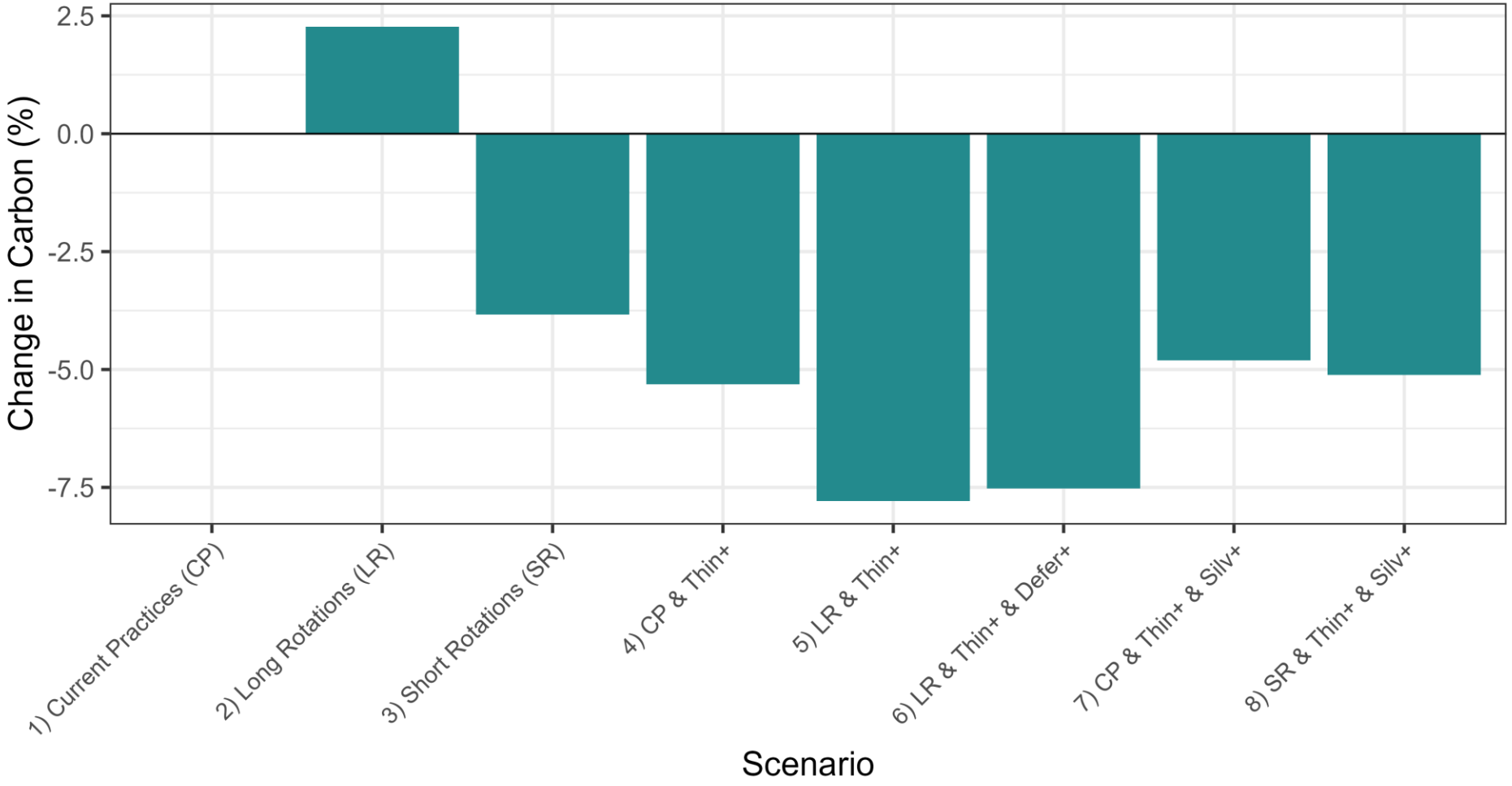

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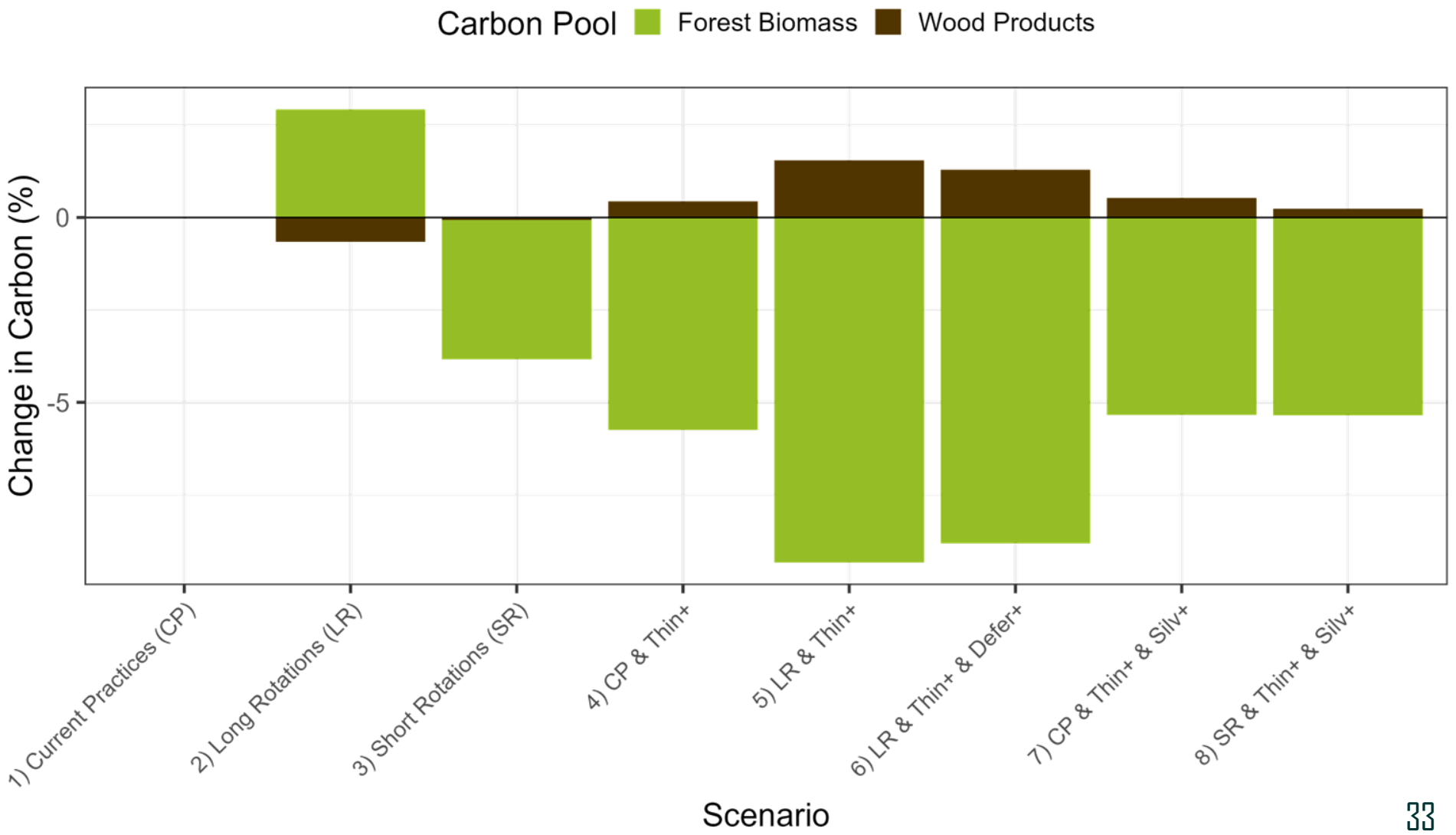

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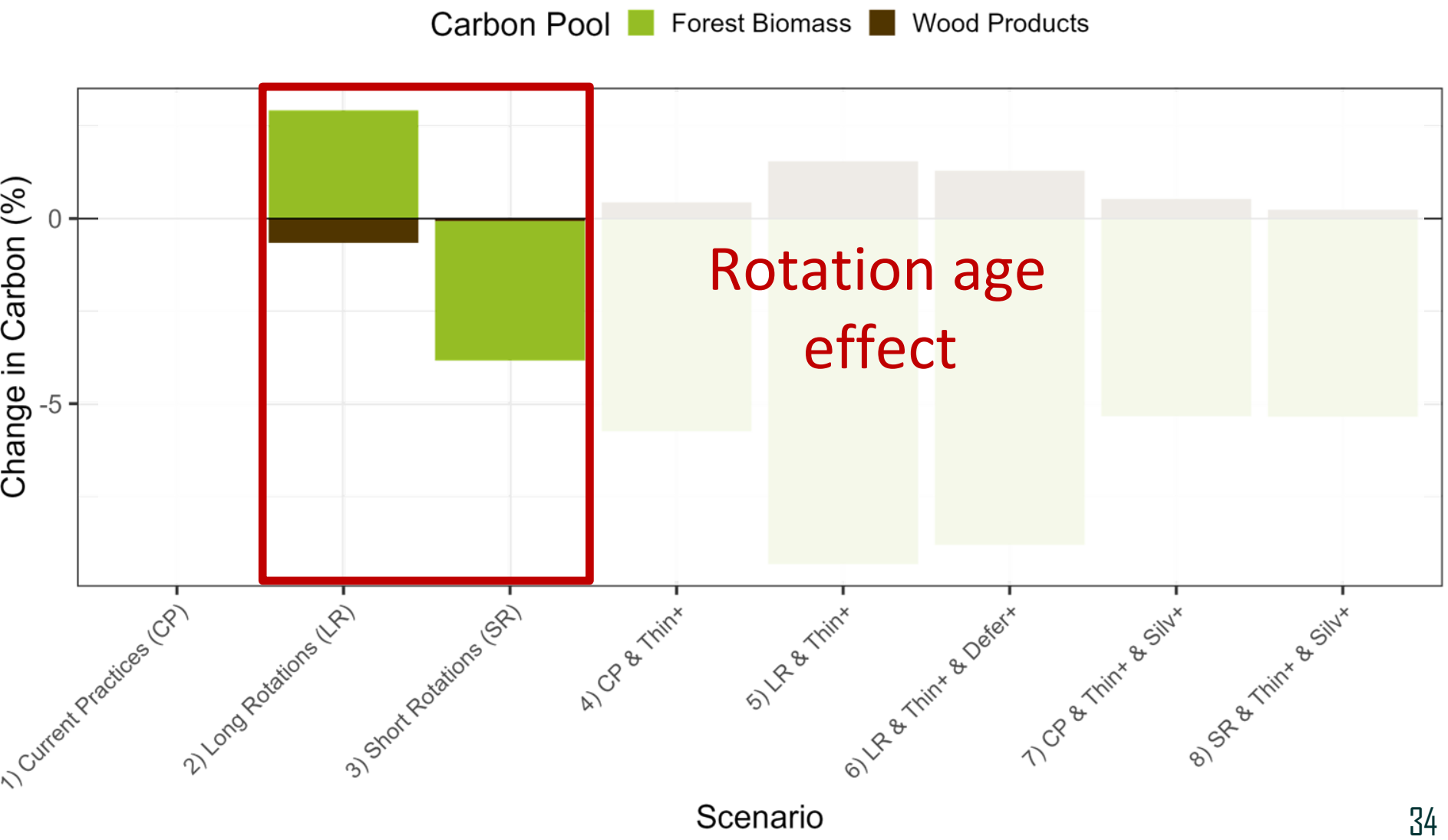

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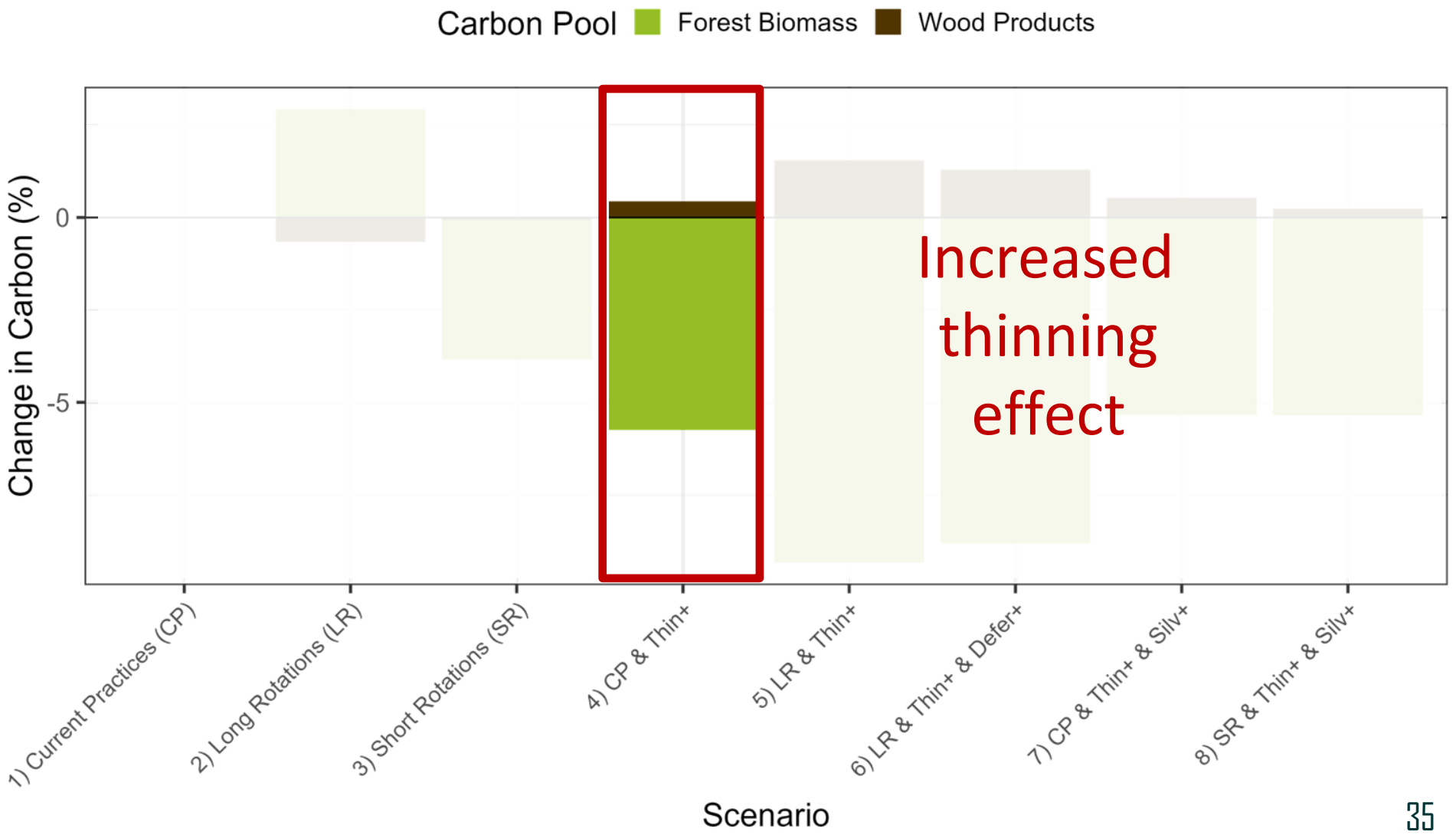

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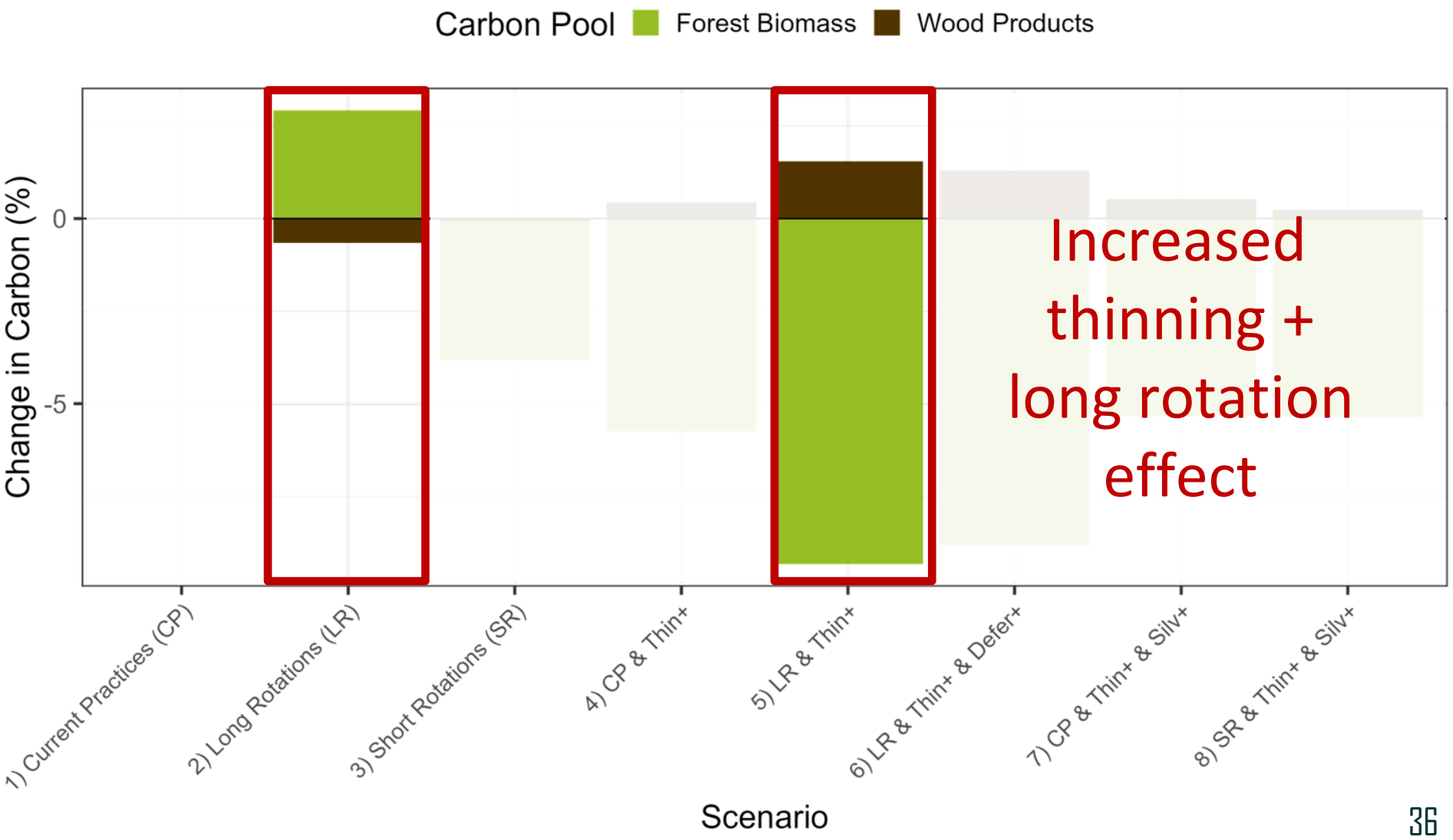

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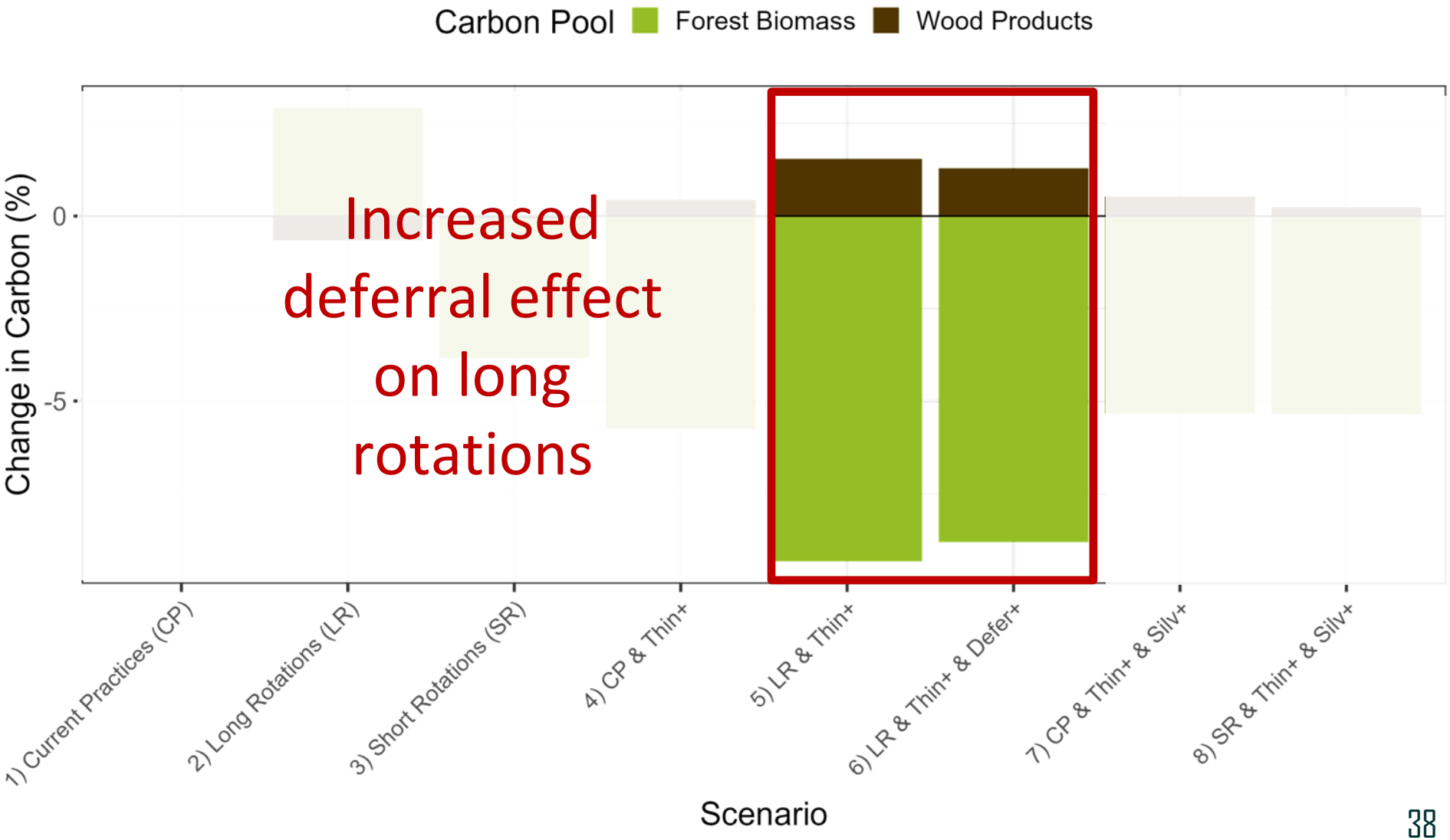

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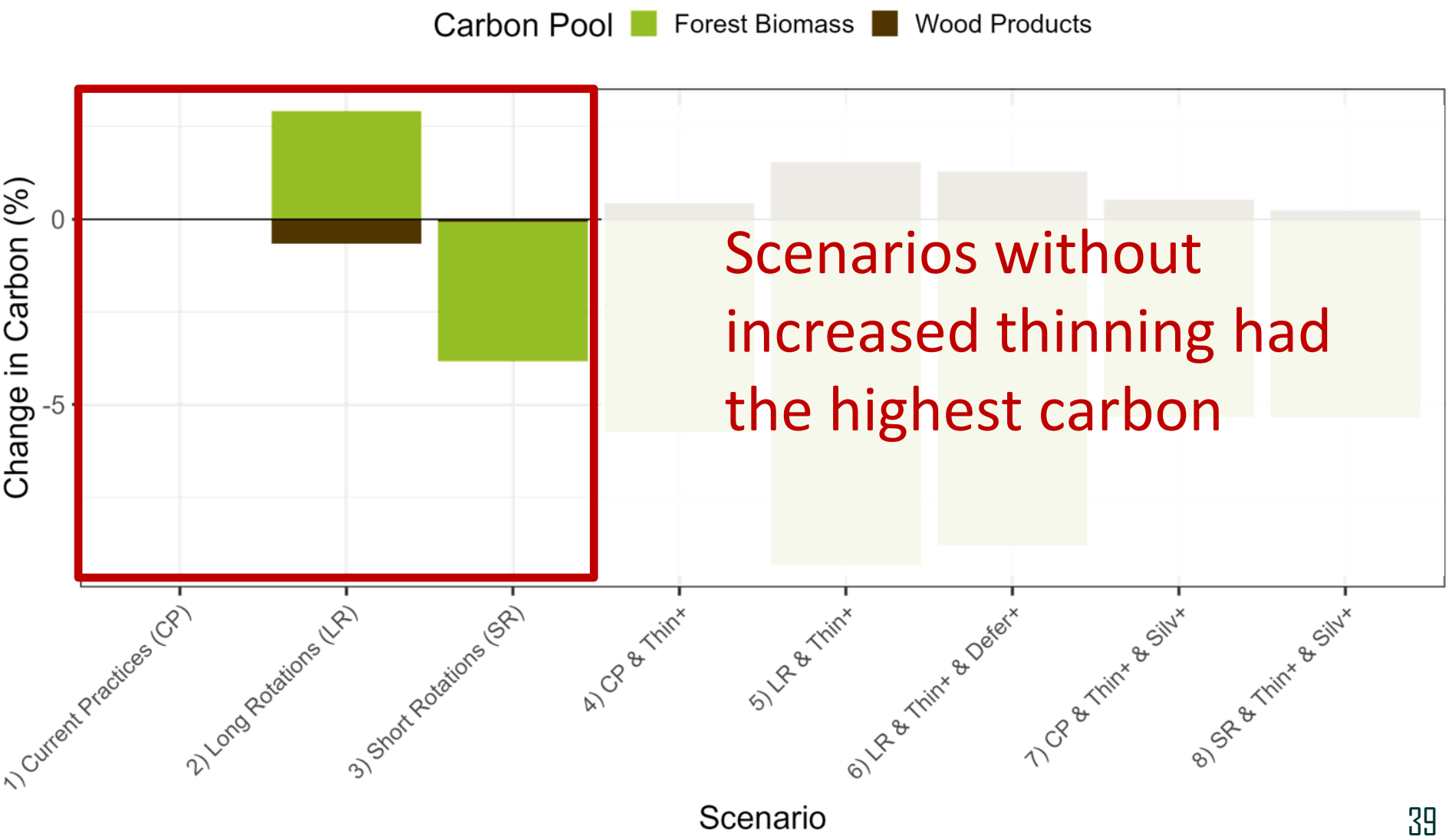
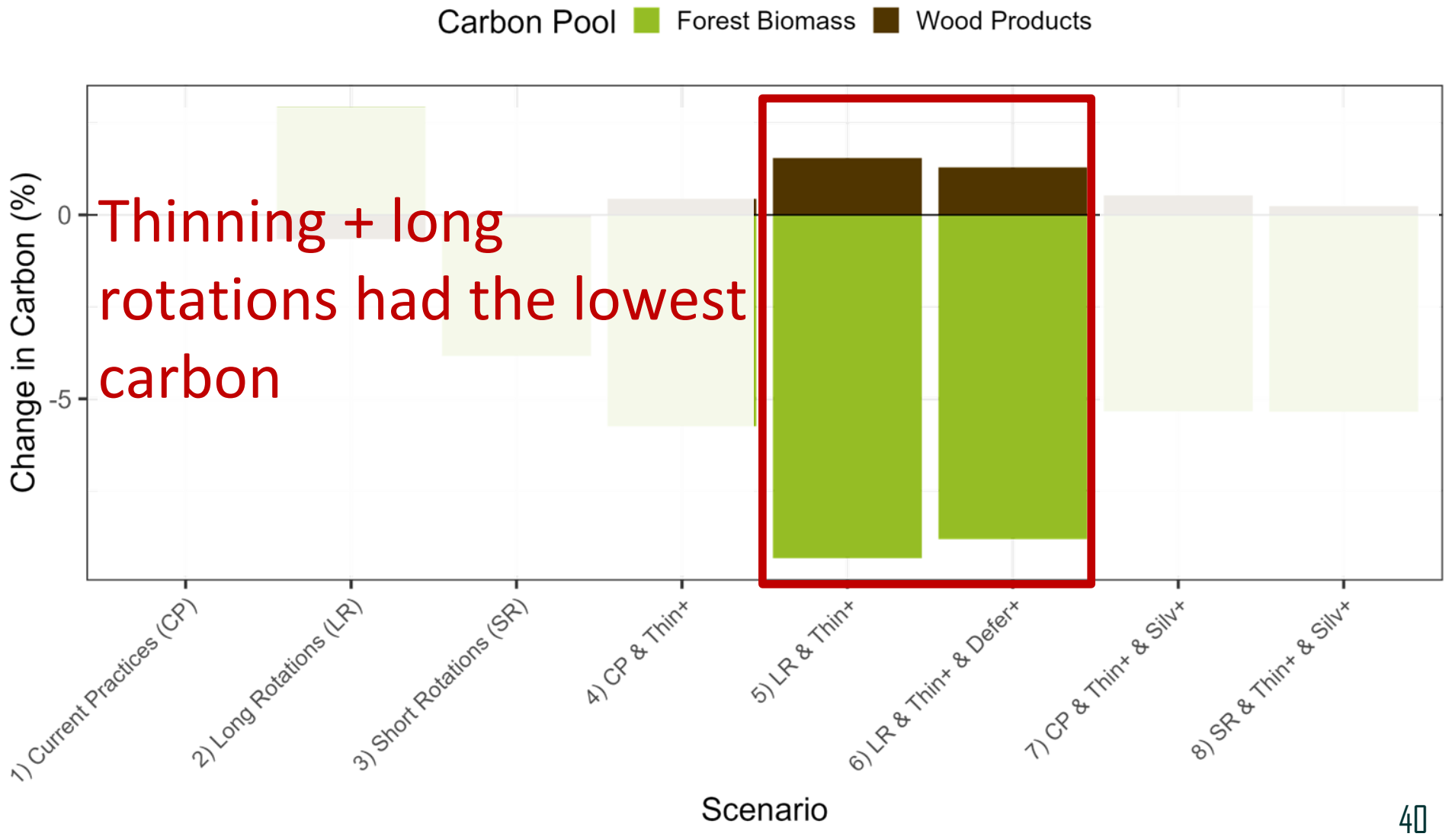


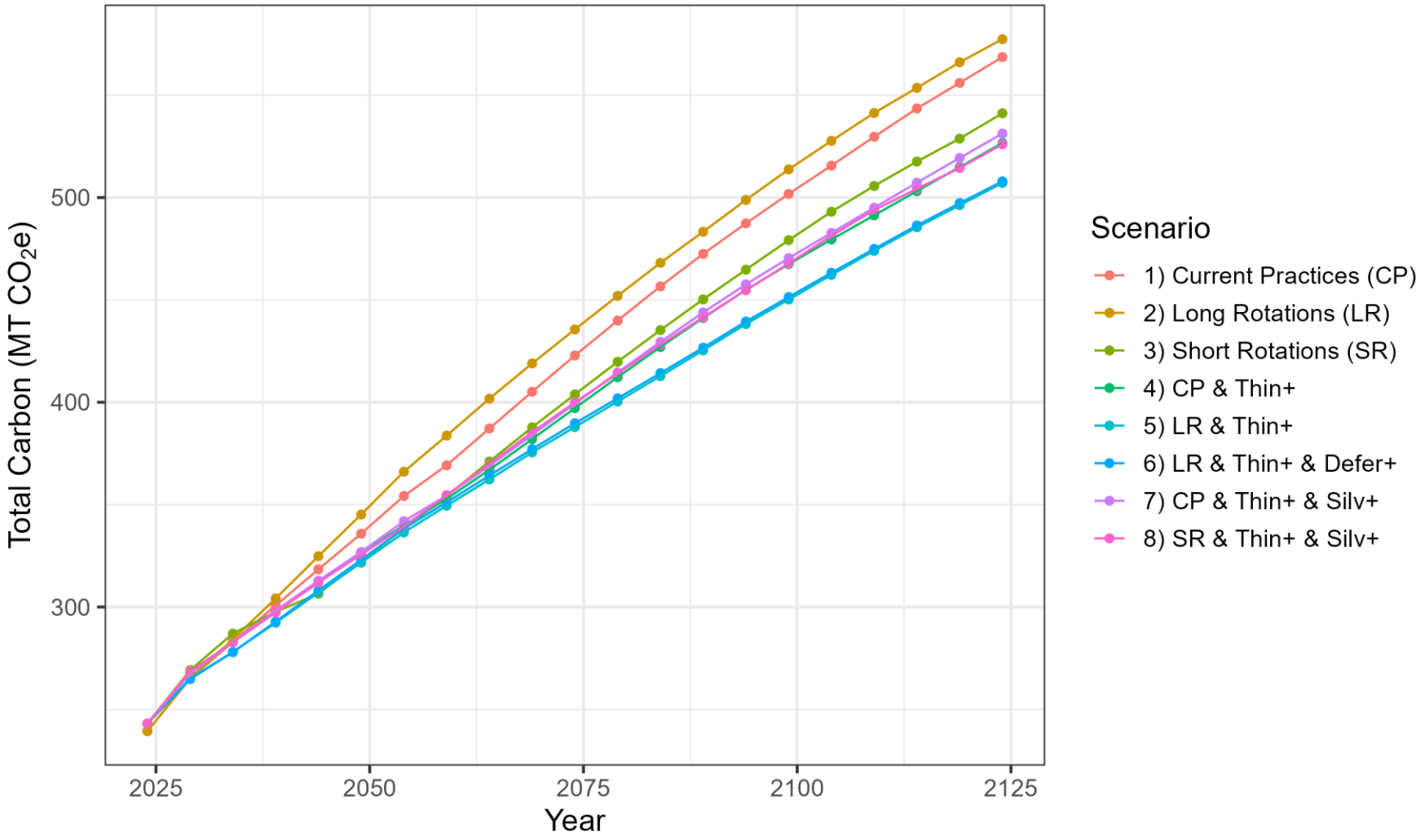
Scenarios without increased thinning had the highest carbon

Scenario Results - Landscape-Level: Carbon



Scenario Results - Landscape Level

Total Carbon
2024 - 2124



Scenario Results - Landscape Level

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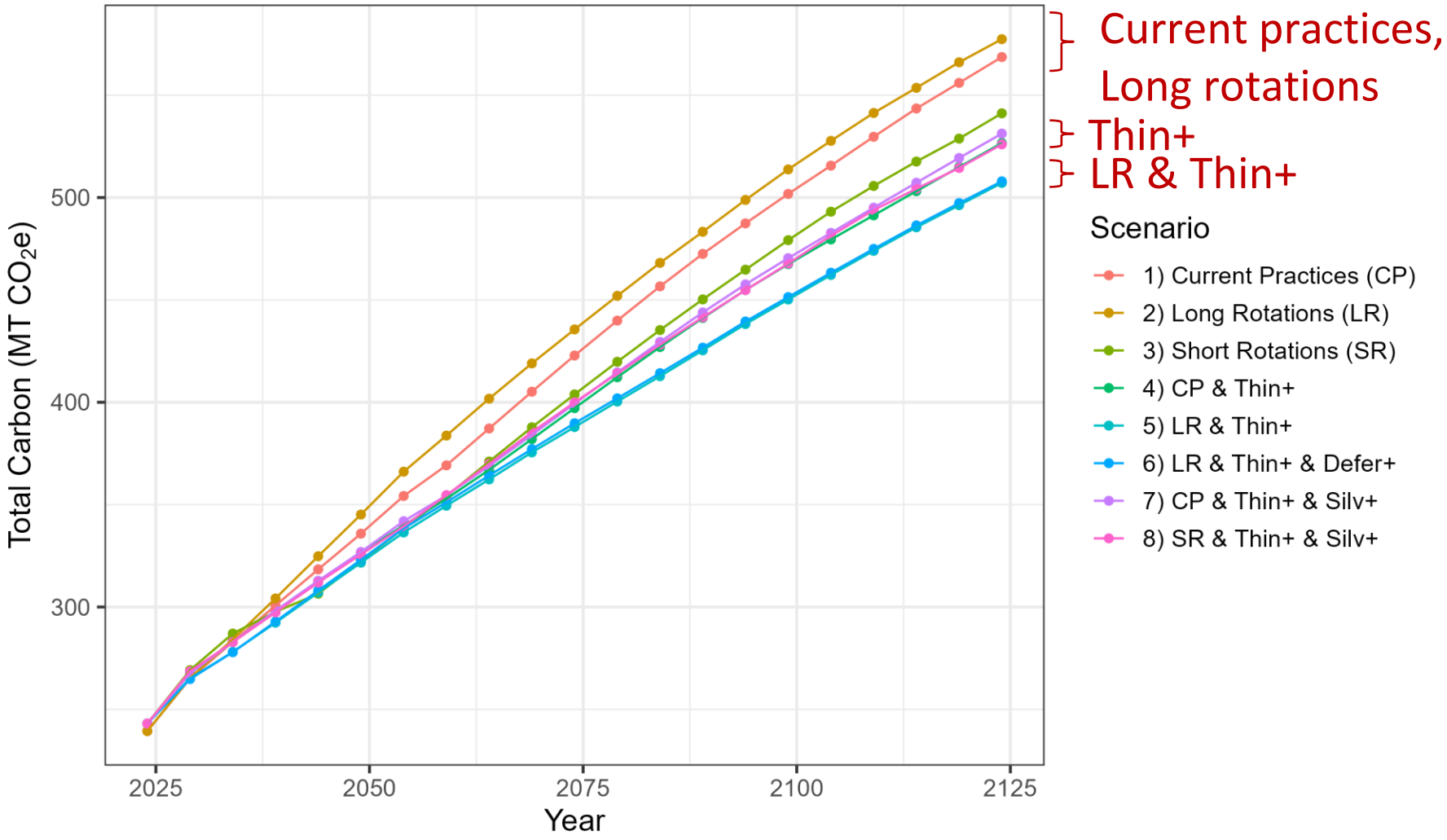

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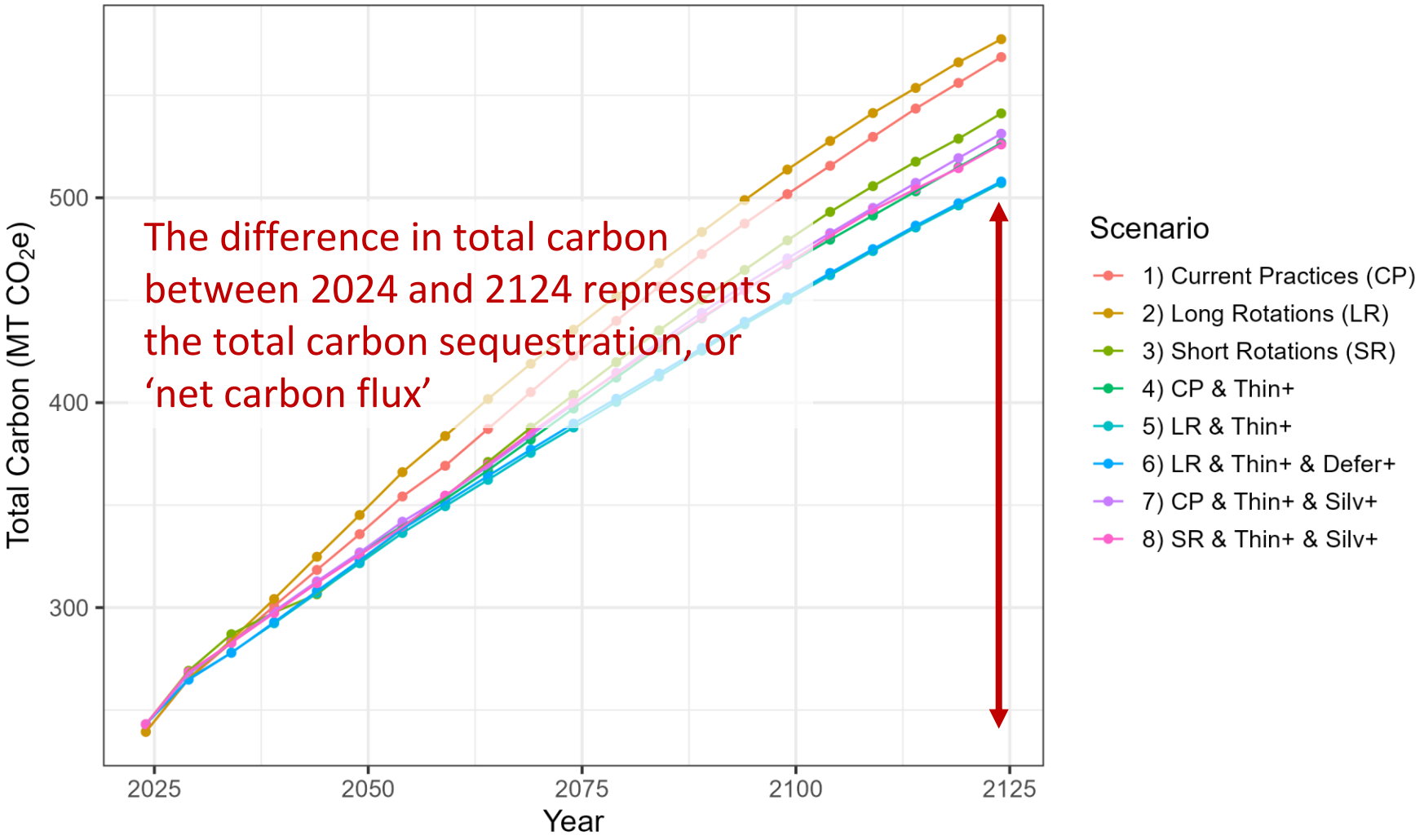
Scenario Results - Landscape Level

Total Carbon 2024 - 2124



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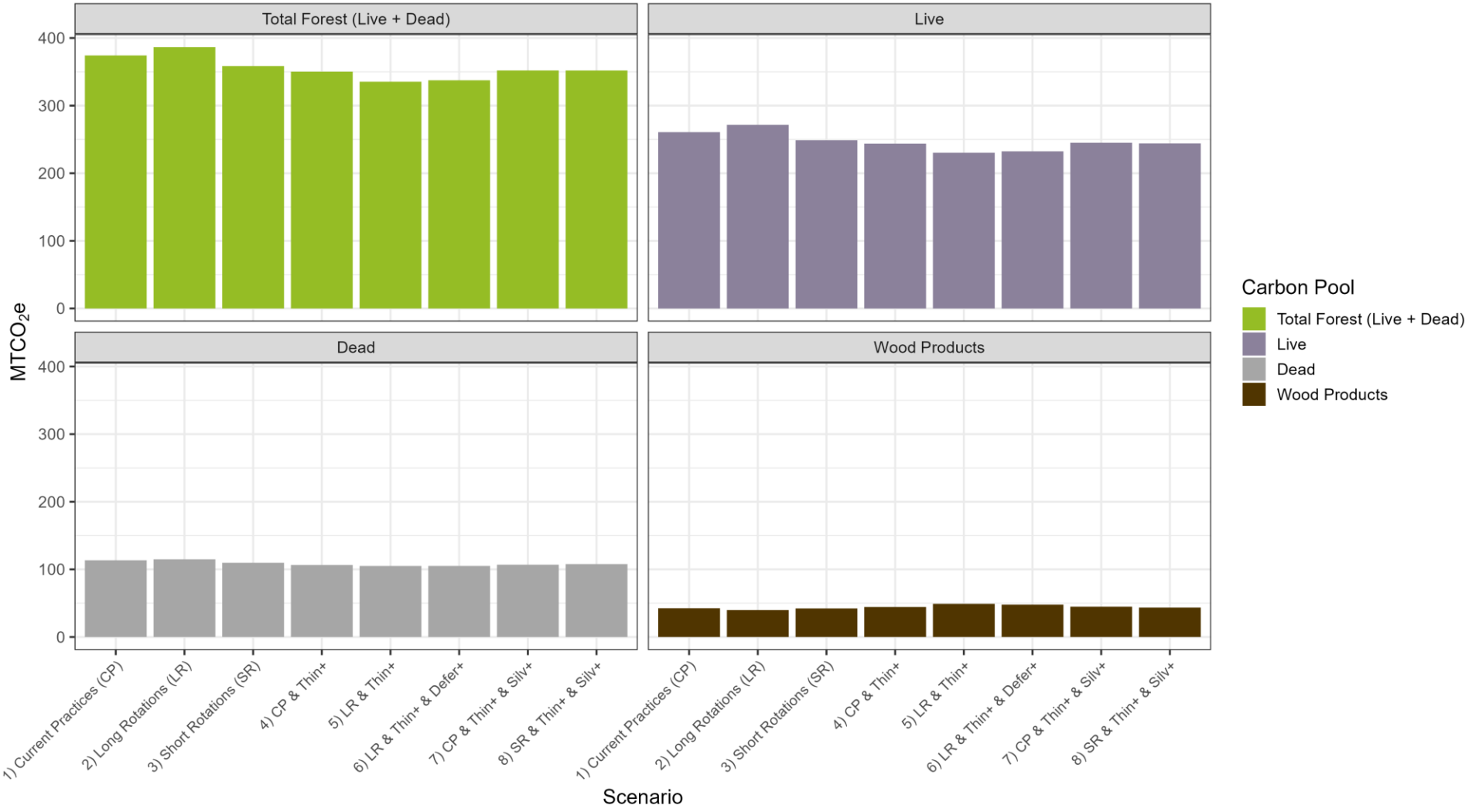
Scenario Results - Landscape Level: Carbon Sequestration

Net Carbon Flux (forest + Harvested wood)

Scenario	Initial Total Carbon in 2024 (Mt CO2e)	Final Total Carbon in 2124 (Mt CO2e)	Net Carbon Flux Over 100 Year Simulation (Mt CO2e)	Change in Net Carbon Flux Relative to Current Practices (%)
1) Current Practices (CP)	239.4	568.6	329.2	0
2) Long Rotations (LR)	239.4	577.4	338.0	+2.7
3) Short Rotations (SR)	243.1	541.1	298.1	-9.4
4) CP & Thin+	243.1	526.6	283.5	-13.9
5) LR & Thin+	243.1	507.1	264.1	-19.8
6) LR & Thin+ & Defer+	243.1	507.9	264.8	-19.6
7) CP & Thin+ & Silv+	243.1	531.2	288.2	-12.5
8) SR & Thin+ & Silv+	243.1	526	282.9	-14.1

Scenario Results - Landscape Level: Carbon



Scenario Results - Landscape Level Summary

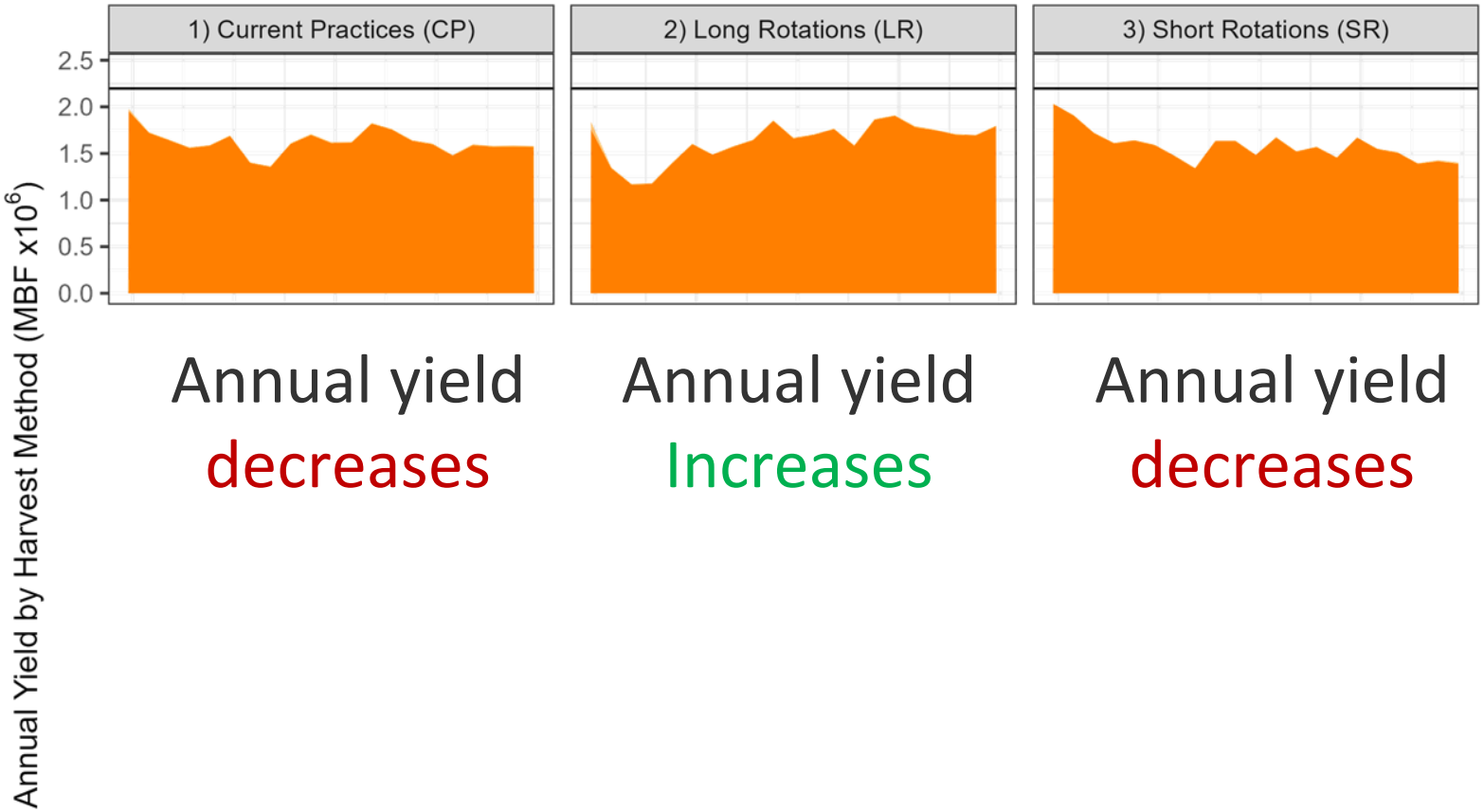
Scenario	**Total stored carbon** (mean annual MTCO2e 2024-2124)	**Total stored carbon** (MTCo2e in 2124)	**Merchantable timber yield** (mean annual MBF 2024-2124)	**Merchantable timber yield** (MBF in 2124)
1) Current Practices	417	569	1,628,538	1,579,479
2) Long Rotations	426	577	1,637,275	1,798,388
3) Short Rotations	401	541	1,584,710	1,402,470
4) CP & Thin+	395	526	1,702,757	1,587,758
5) LR & Thin+	384	507	2,004,998	2,072,989
6) LR & Thin+ & Defer+	385	508	1,972,142	2,066,351
7) CP & Thin+ & Silv+	397	531	1,717,592	1,653,921
8) SR & Thin+ & Silv+	395	526	1,633,899	1,460,960

Scenario Results - Landscape Level Summary

Scenario	**Change in total stored carbon** (% difference from CP)	**Change in merchantable timber yield** (% difference from CP)
1) Current Practices (CP)	417 Mt CO2e	1,628,538 MBF
2) Long Rotations (LR)	+2.3	0.5
3) Short Rotations (SR)	-3.8	-2.7
4) CP & Thin+	-5.3	4.5
5) LR & Thin+	-7.8	23.1
6) LR & Thin+ & Defer+	-7.5	21.1
7) CP & Thin+ & Silv+	-4.8	5.5
8) SR & Thin+ & Silv+	-5.1	0.3

Scenario Results - Landscape Level

Simulated Timber Yield 2024-2124



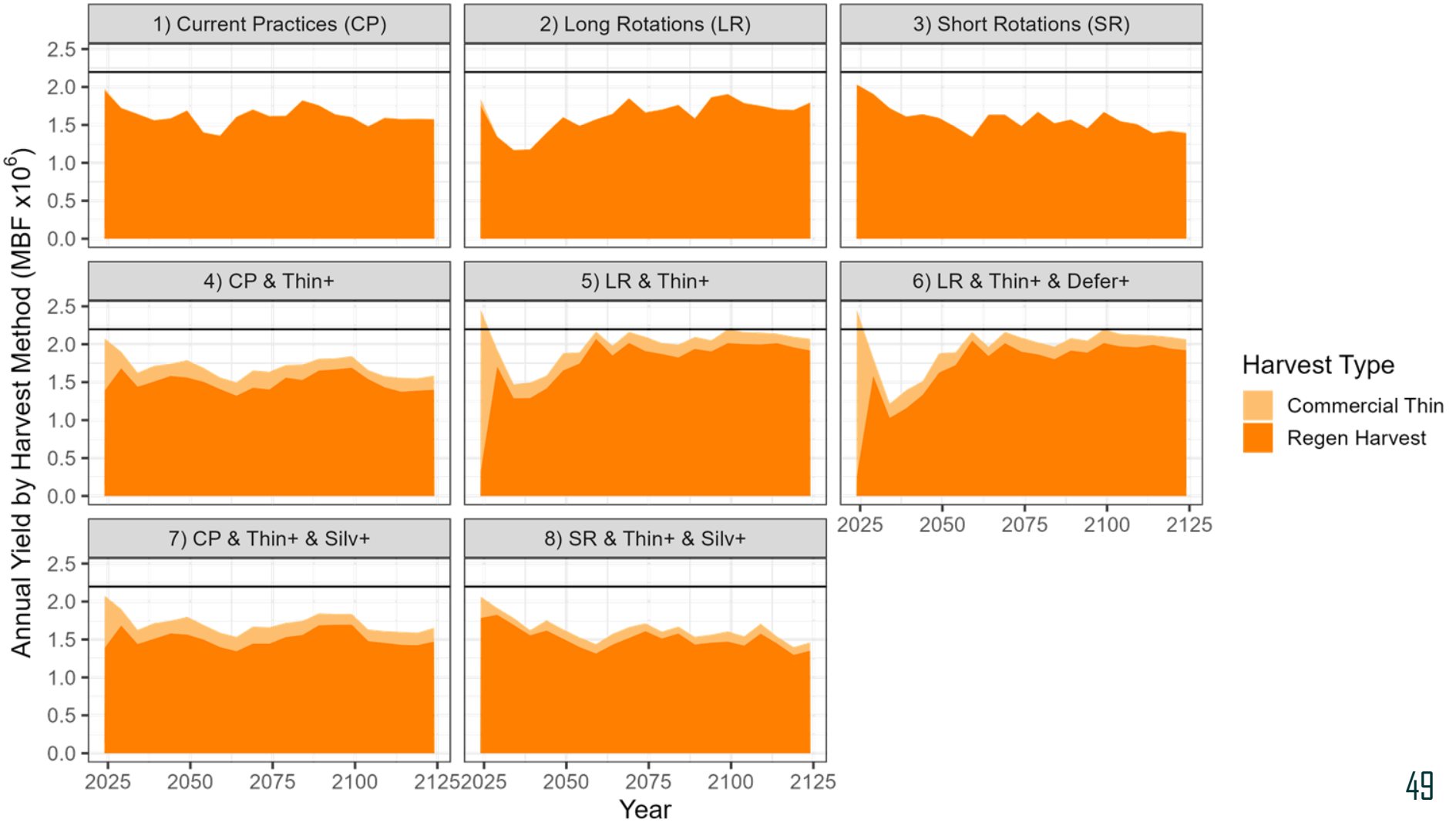
Annual yield decreases

Annual yield Increases

Annual yield decreases

Scenario Results - Landscape Level

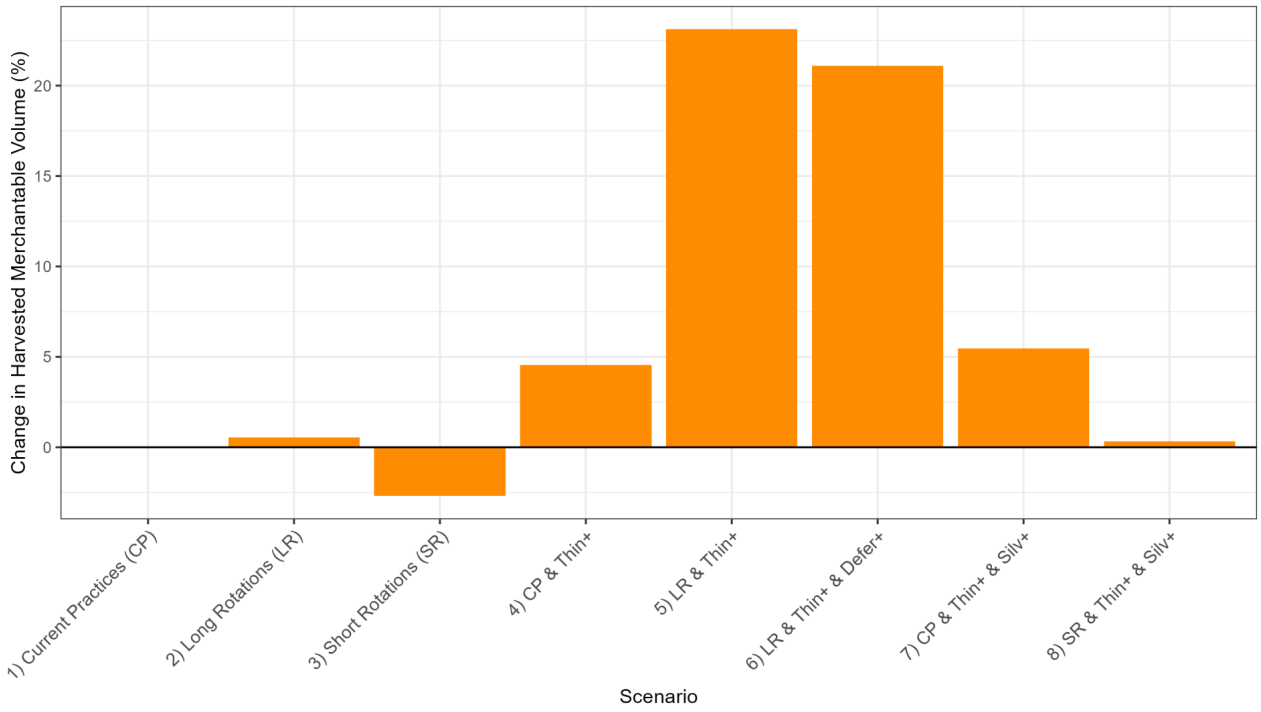
Simulated Timber Yield 2024-2124



Special Focus on Commercial Thinning

Why does carbon decrease in the significantly increased thinning scenarios?

Special Focus on Commercial Thinning



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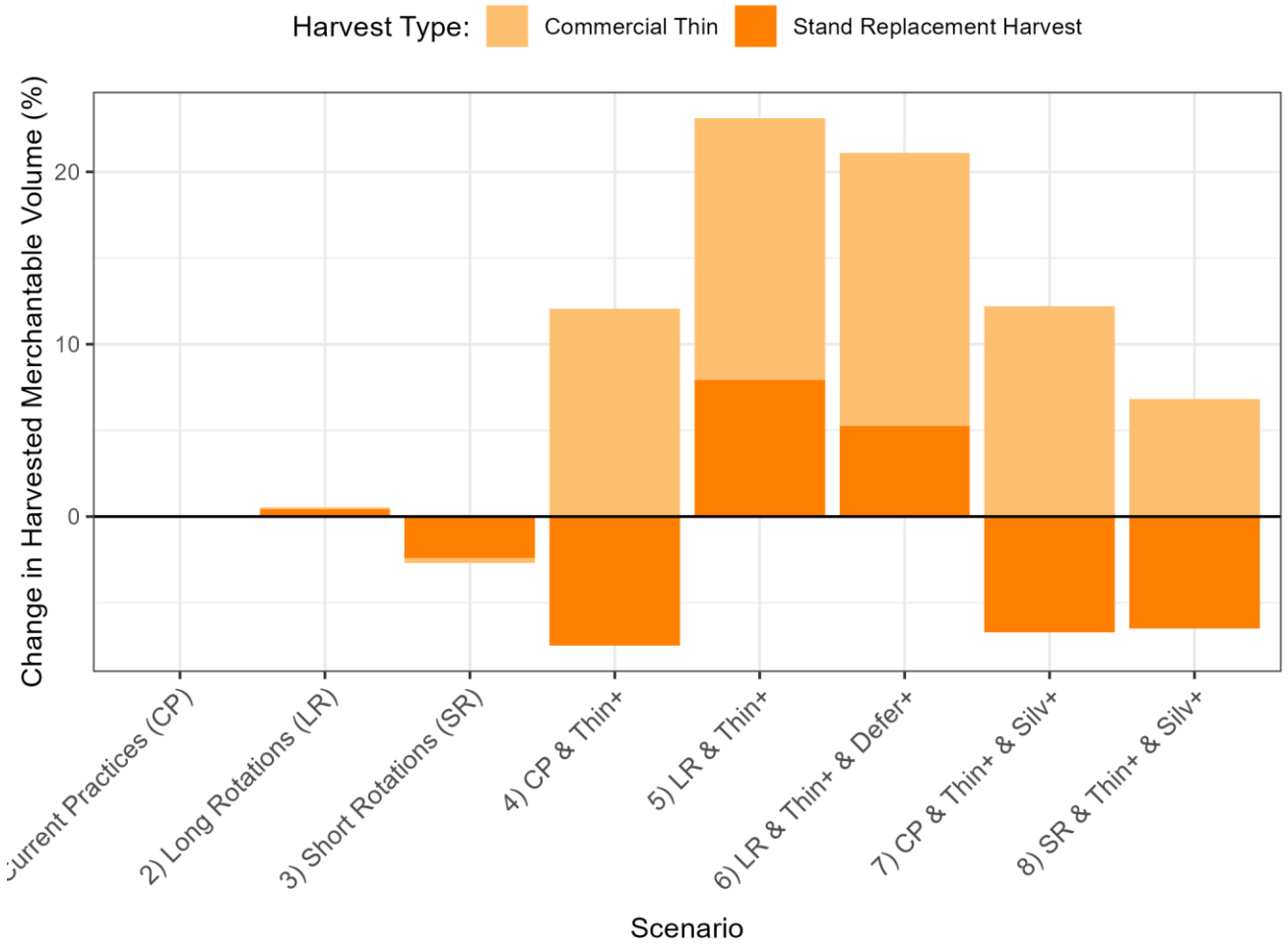

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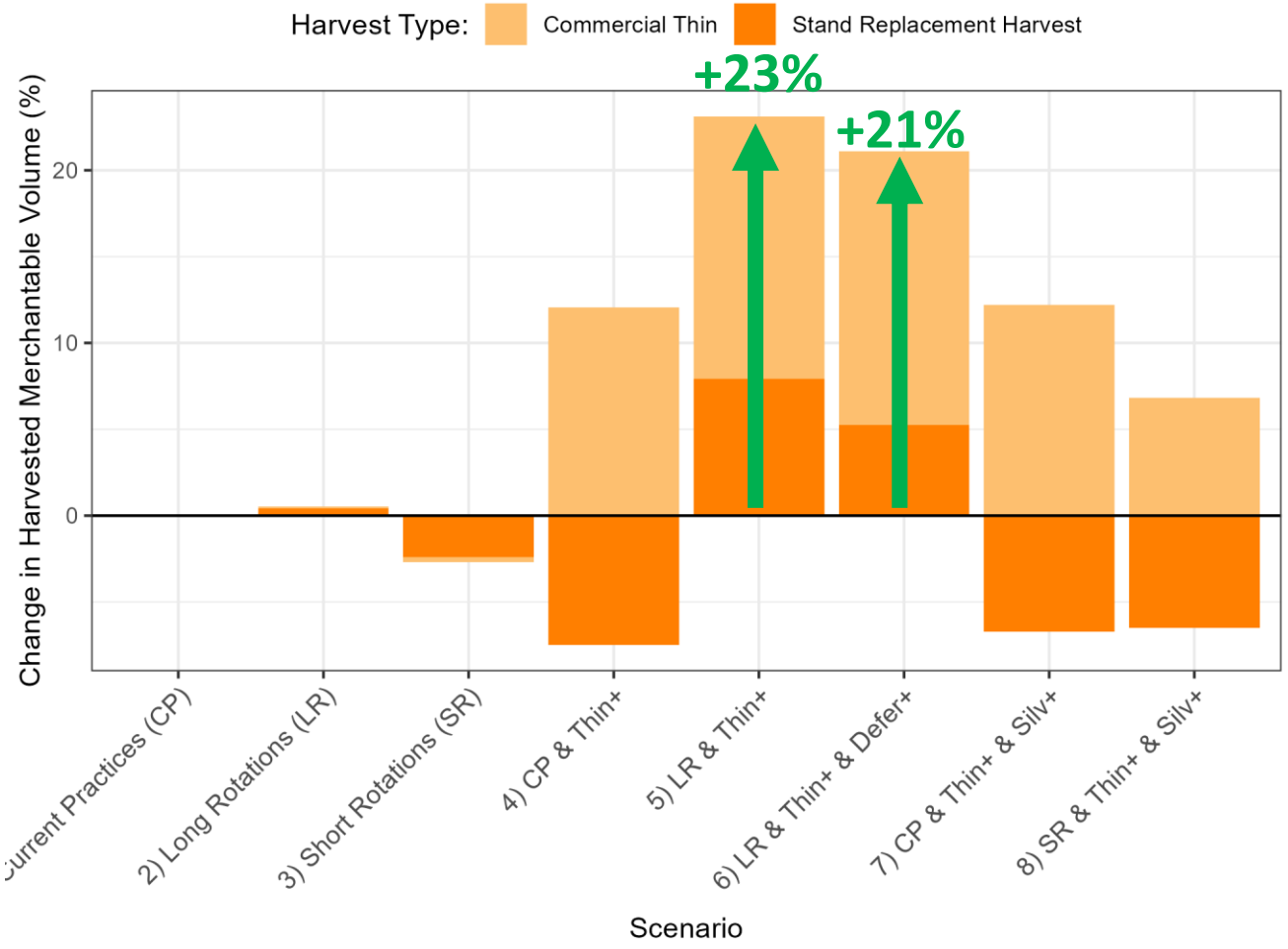
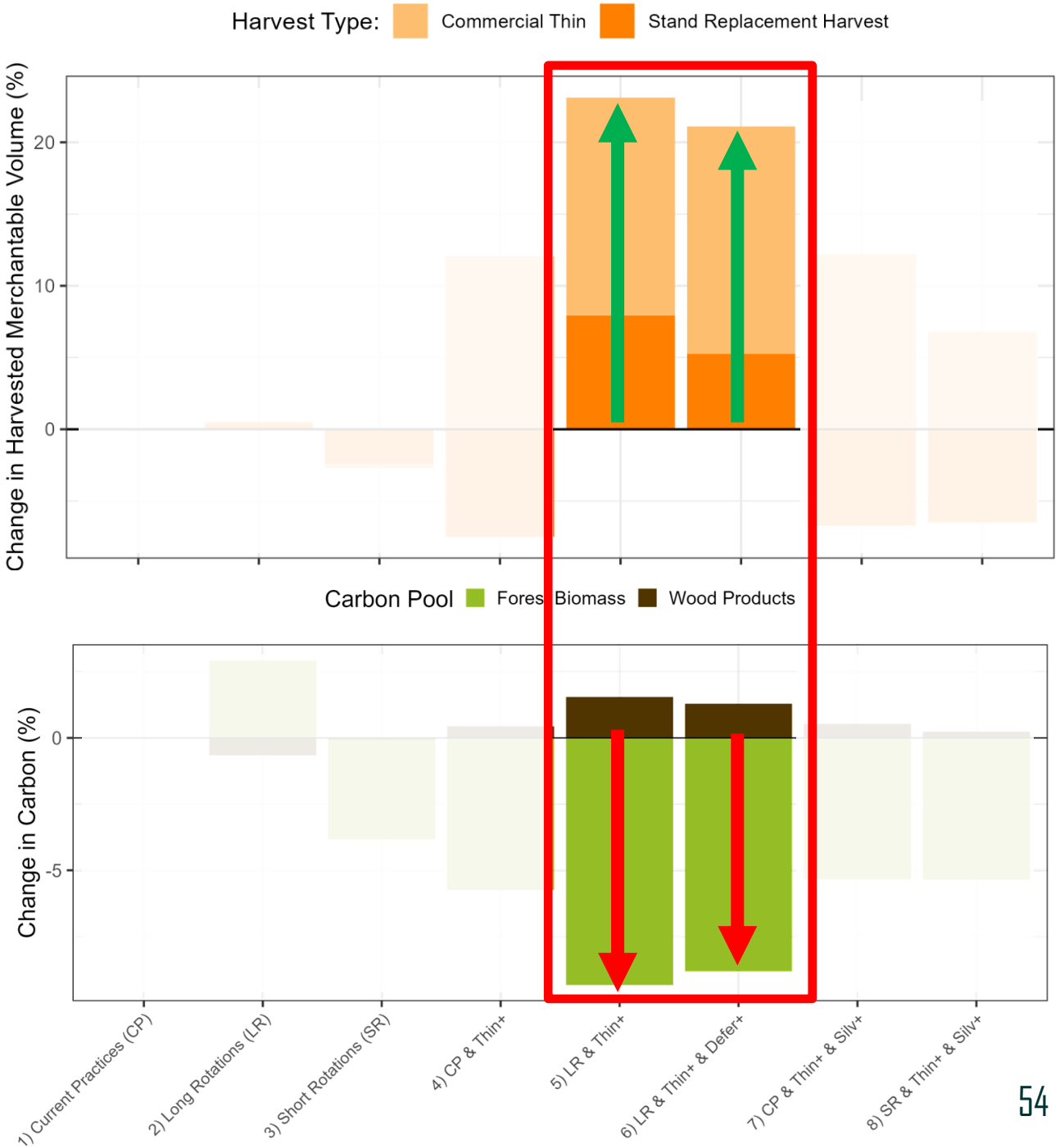


Special Focus on Commercial Thinning

Reason 1)

Increased harvest = less forest biomass carbon



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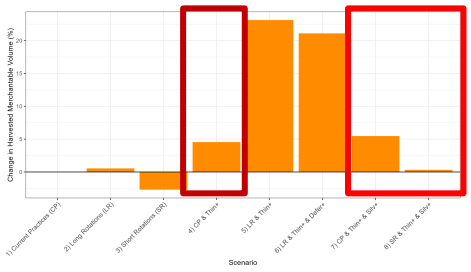
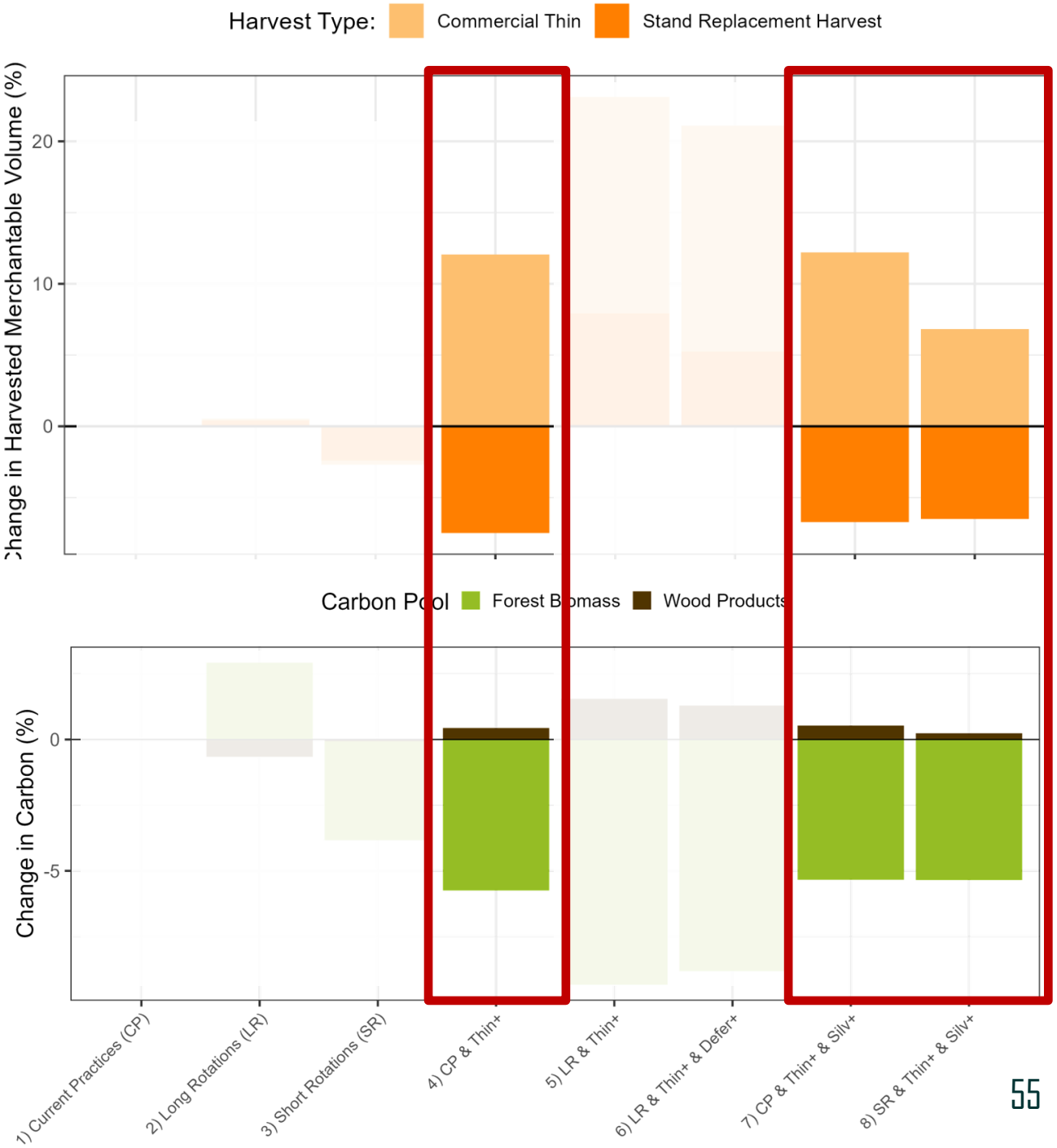
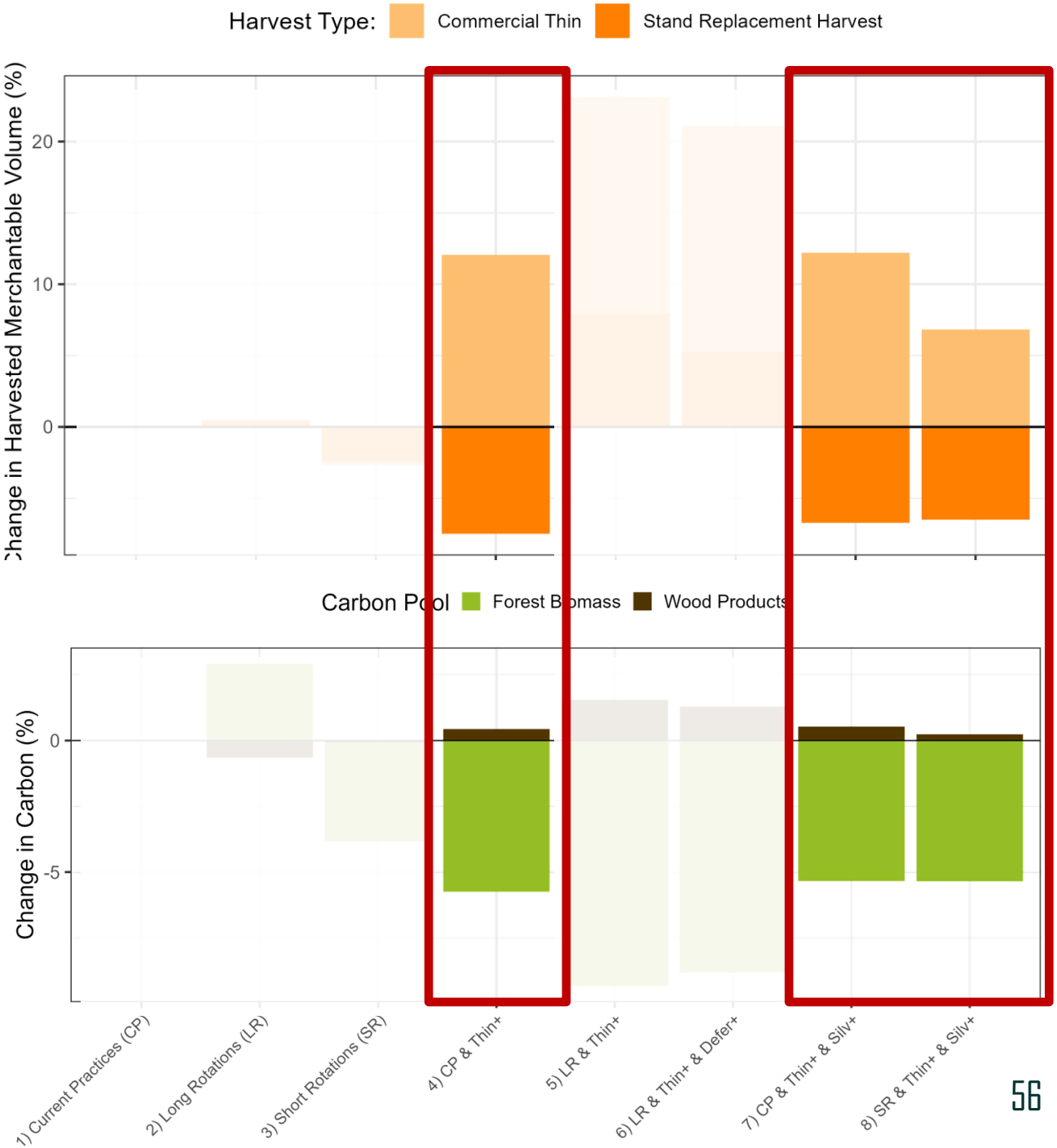




Special Focus on Commercial Thinning

Reason 2)

Extensive thinning decreases average carbon per acre



Summary of Results

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2. Significantly increased commercial thinning (CT) = higher timber yields but reduced carbon. It is the dial with the largest overall effect.
3. Longer rotations (Scenario 2) = only scenario to increase both timber yield and carbon over current practices.

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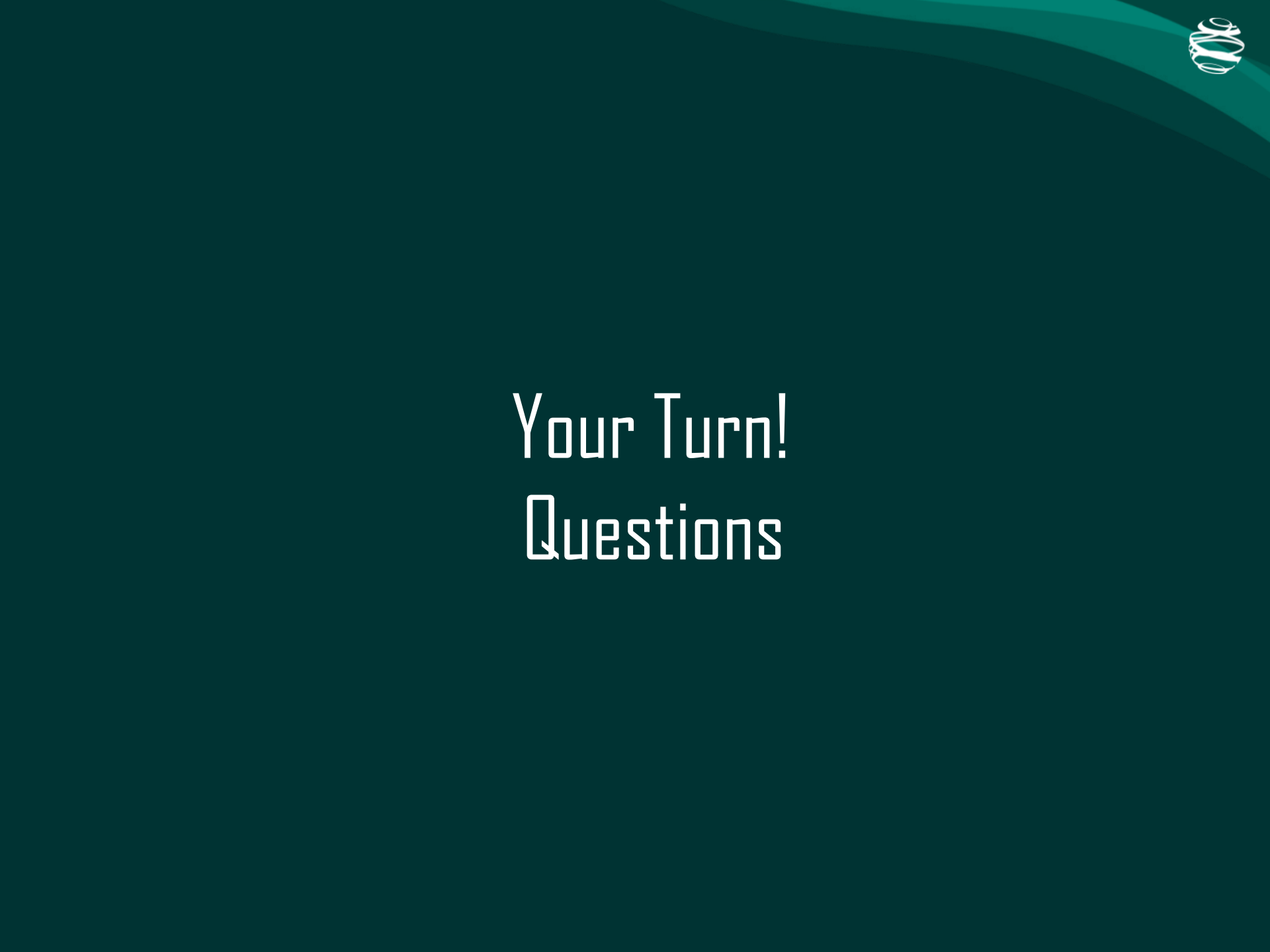
1. Lower yields in all scenarios relative to 2013-2023, related to county-level harvest limits.
2. Significantly increased commercial thinning (CT) = higher timber yields but reduced carbon. It is the dial with the largest overall effect.
3. Longer rotations (Scenario 2) = only scenario to increase both timber yield and carbon over current practices.
4. Shortened rotations (Scenario 3) = only scenario to decrease both.

Summary of Results

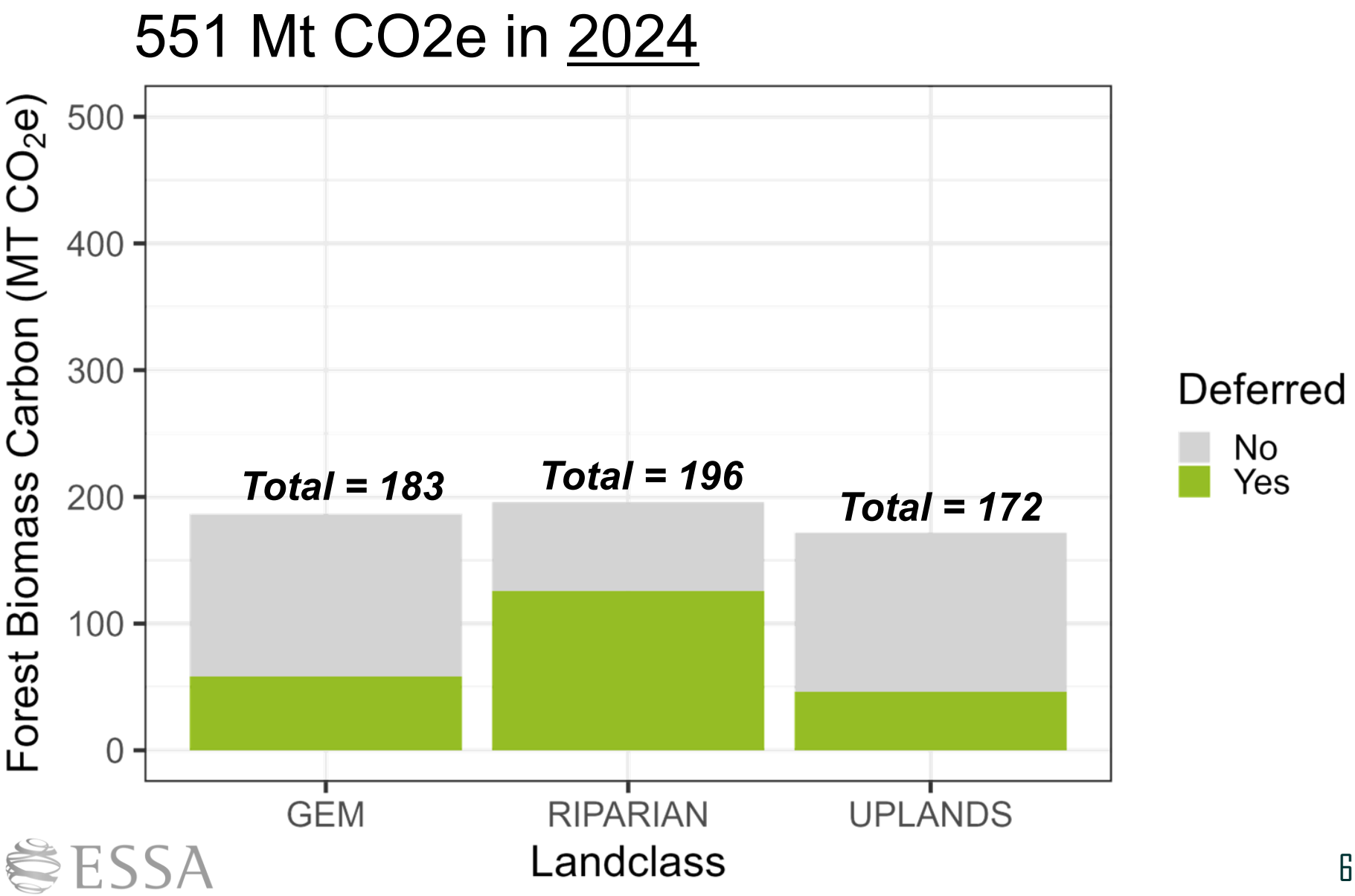
1. Lower yields in all scenarios relative to 2013-2023, related to county-level harvest limits.
2. Significantly increased commercial thinning (CT) = higher timber yields but reduced carbon. It is the dial with the largest overall effect.
3. Longer rotations (Scenario 2) = only scenario to increase both 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


Break (10min)

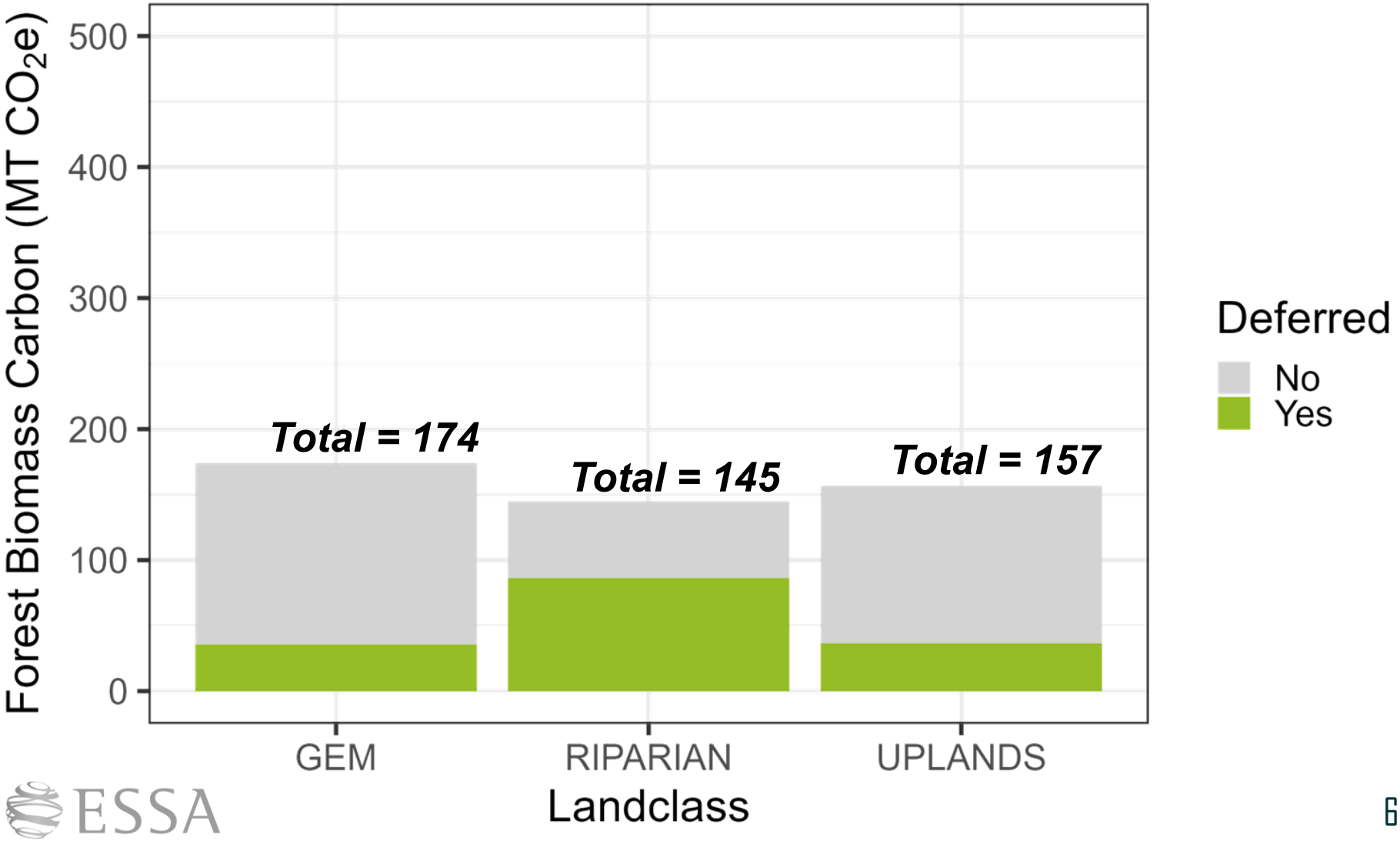
Part 2: Climate Change Results

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



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

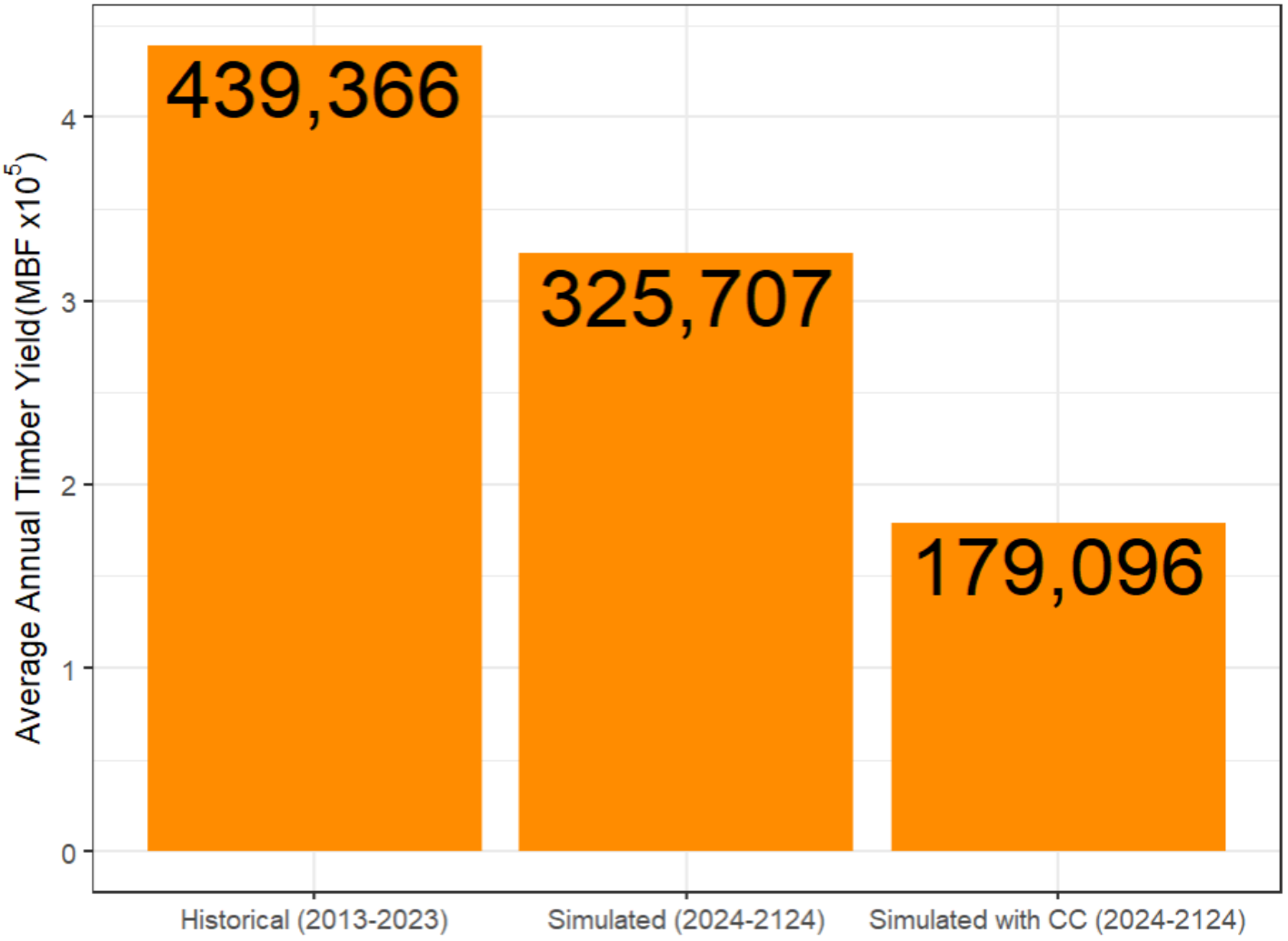
476 Mt CO2e in 2124



ESSA

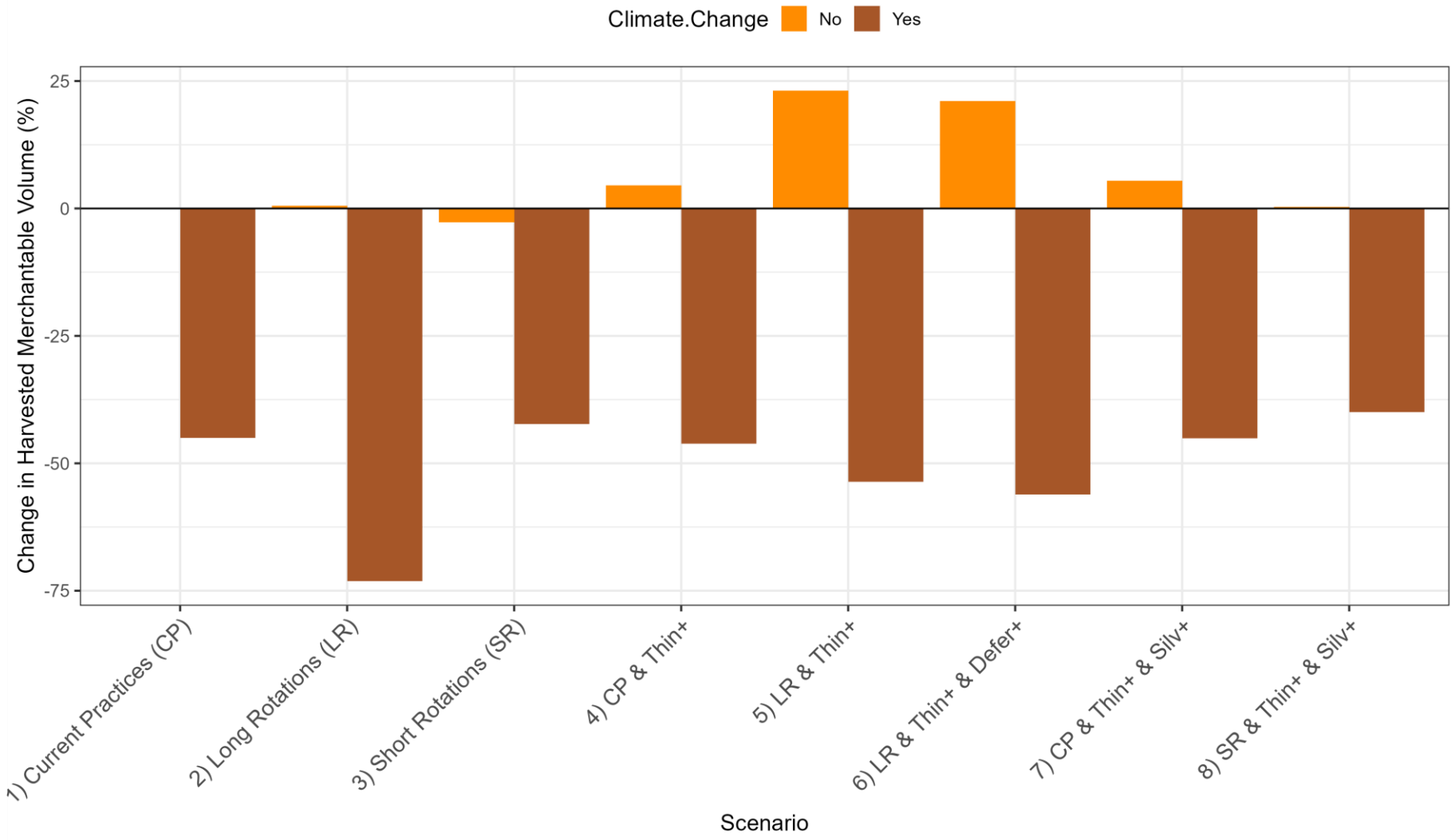
Baseline for Comparison: Scenario 1 Current Practices (Climate Change)

Historical timber yield vs. ESSA simulated FVS timber yield

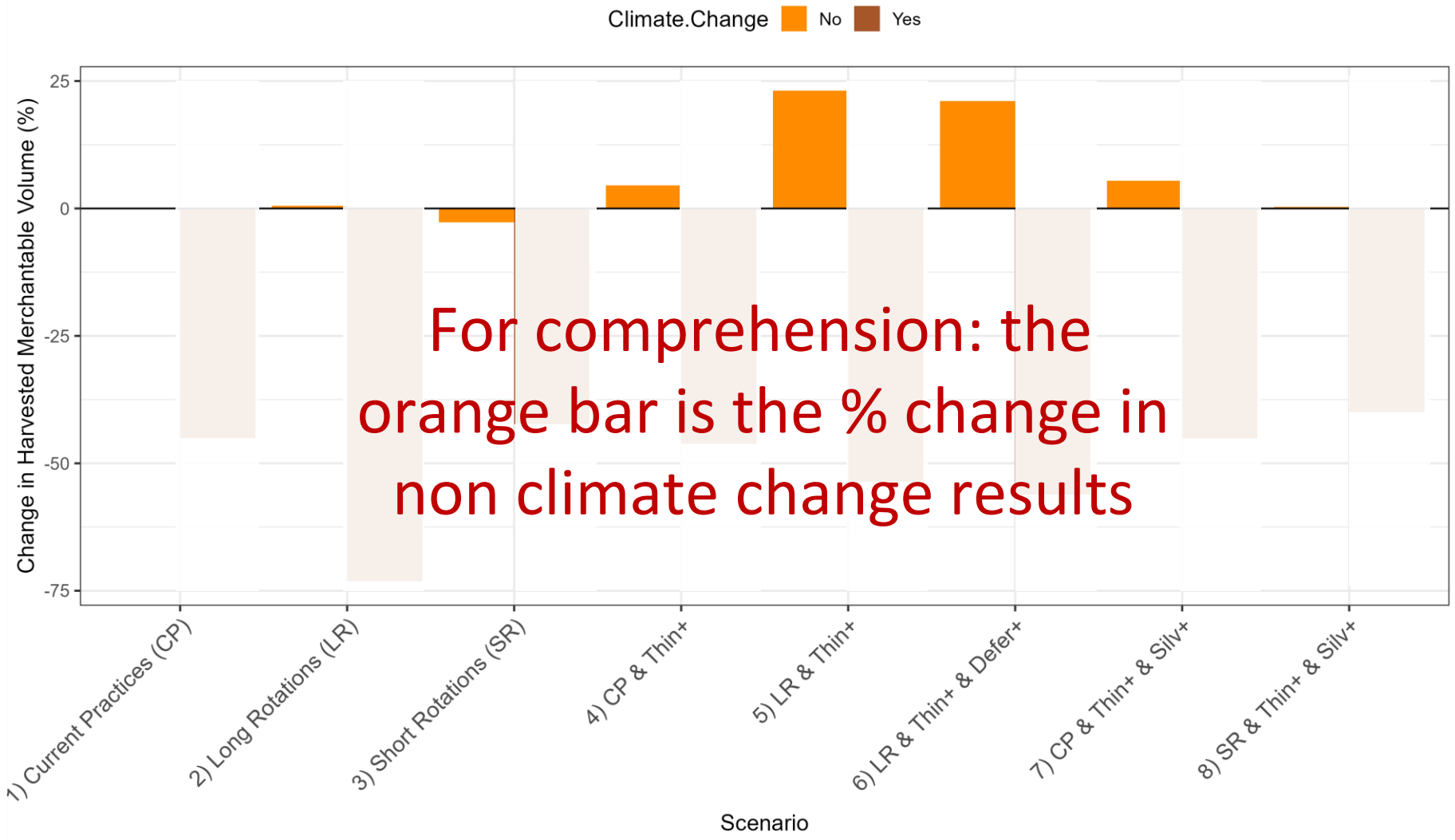


ESSA

Landscape-Level Results with Climate Change: Simulated Timber Yield

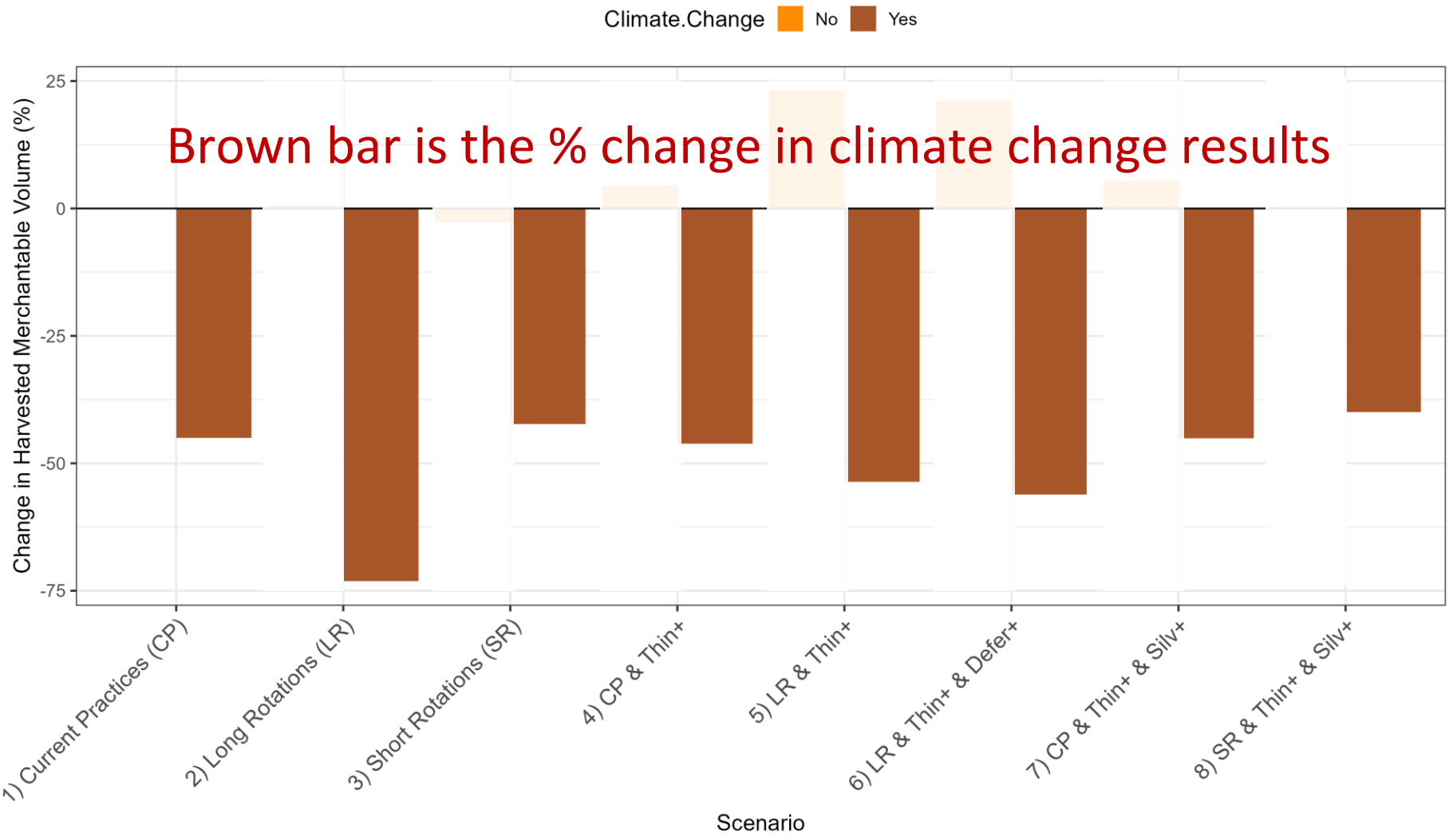


Landscape-Level Results with Climate Change: Simulated Timber Yield

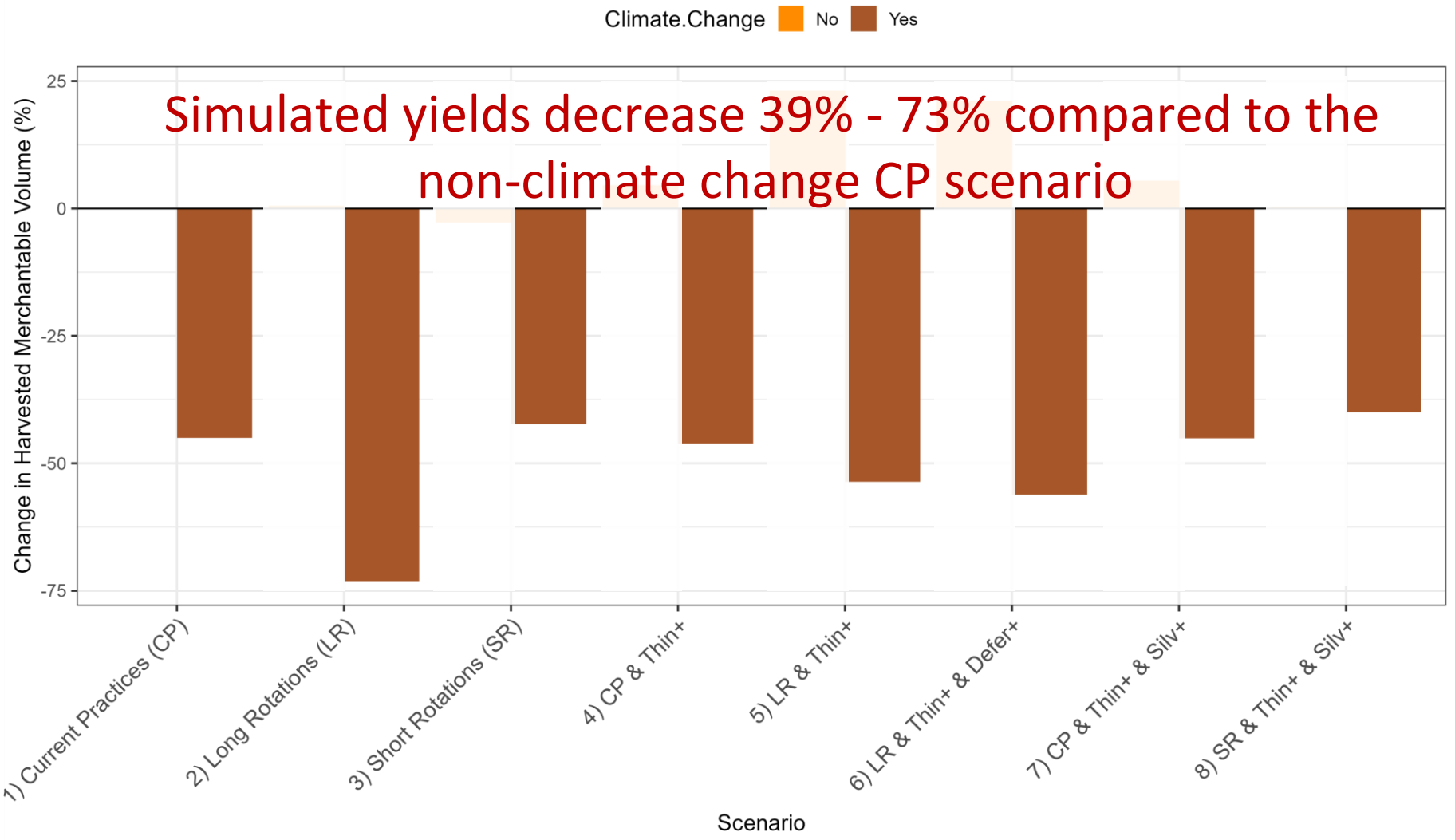


For comprehension: the orange bar is the % change in non climate change results

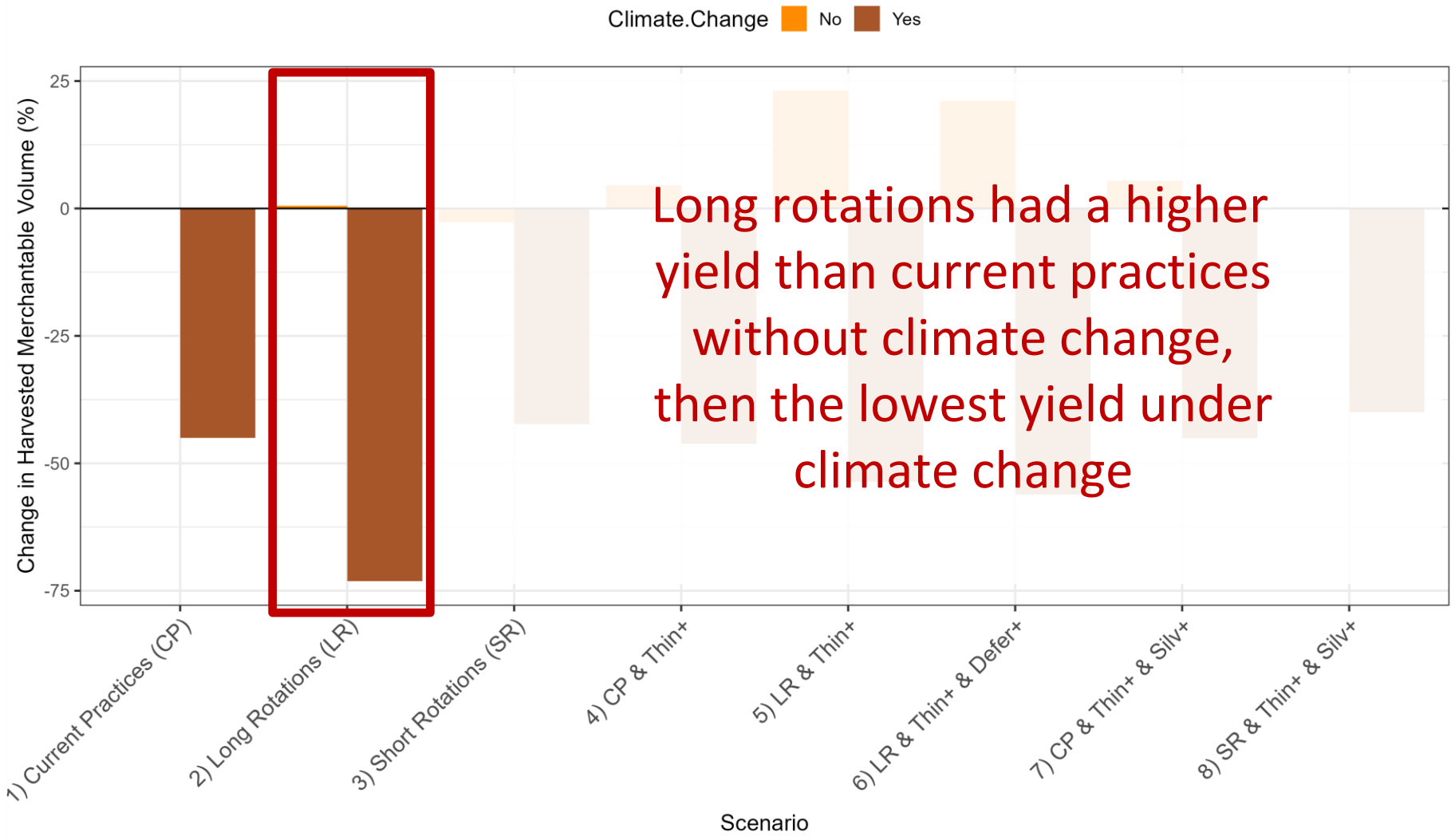
Landscape-Level Results with Climate Change: Simulated Timber Yield



Landscape-Level Results with Climate Change: Simulated Timber Yield

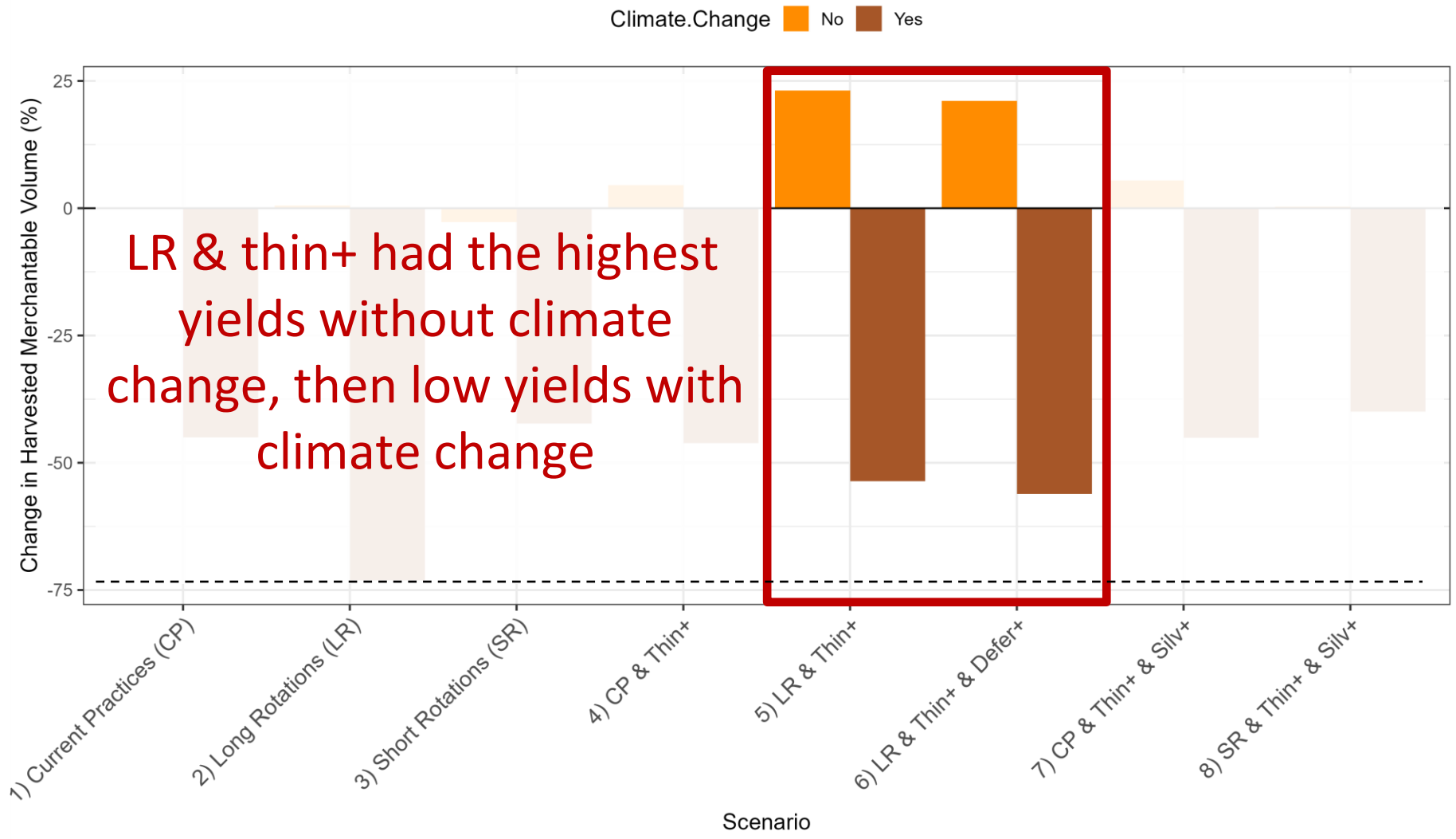


Landscape-Level Results with Climate Change: Simulated Timber Yield

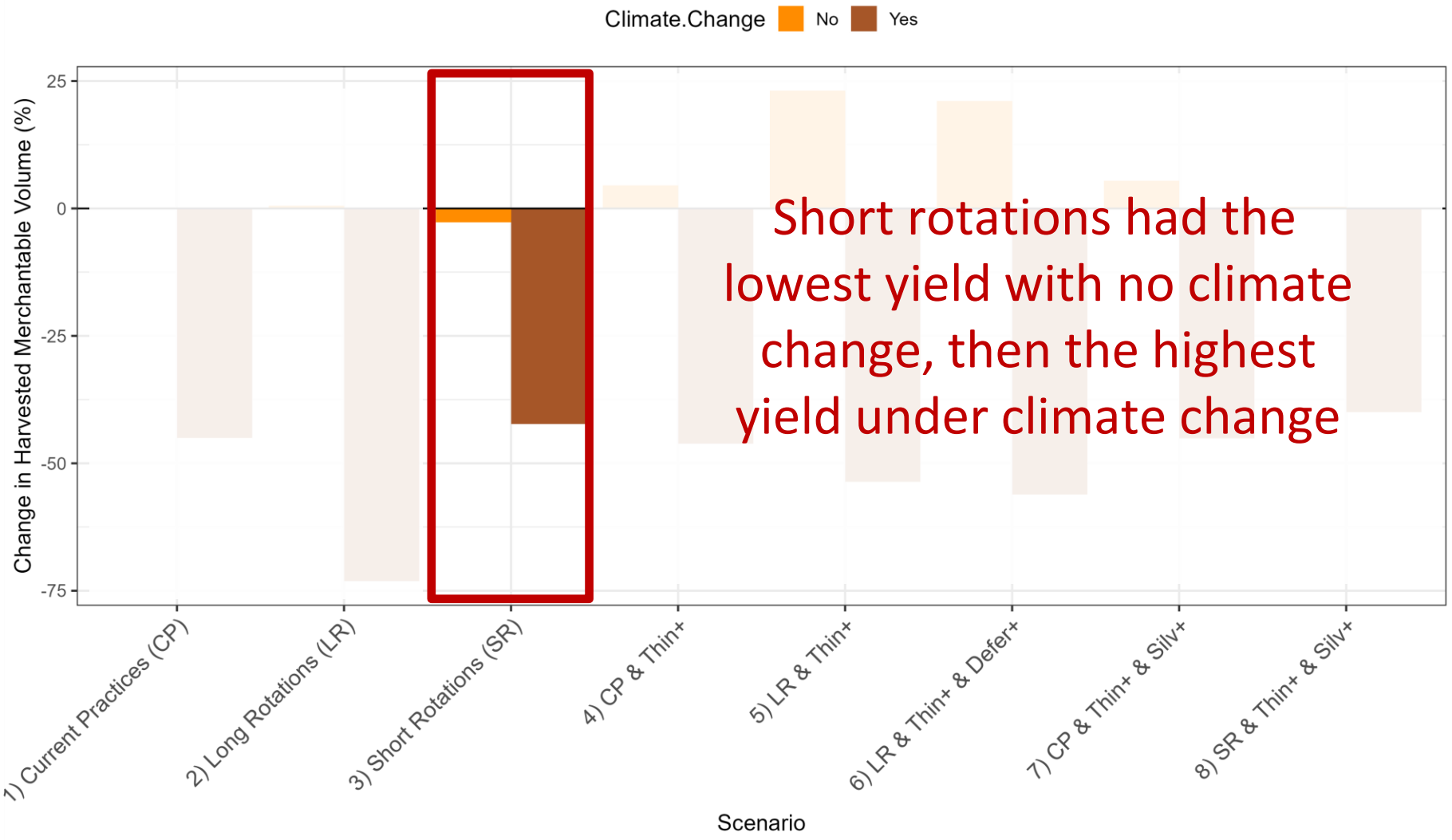


Long rotations had a higher yield than current practices without climate change, then the lowest yield under climate change

Landscape-Level Results with Climate Change: Simulated Timber Yield



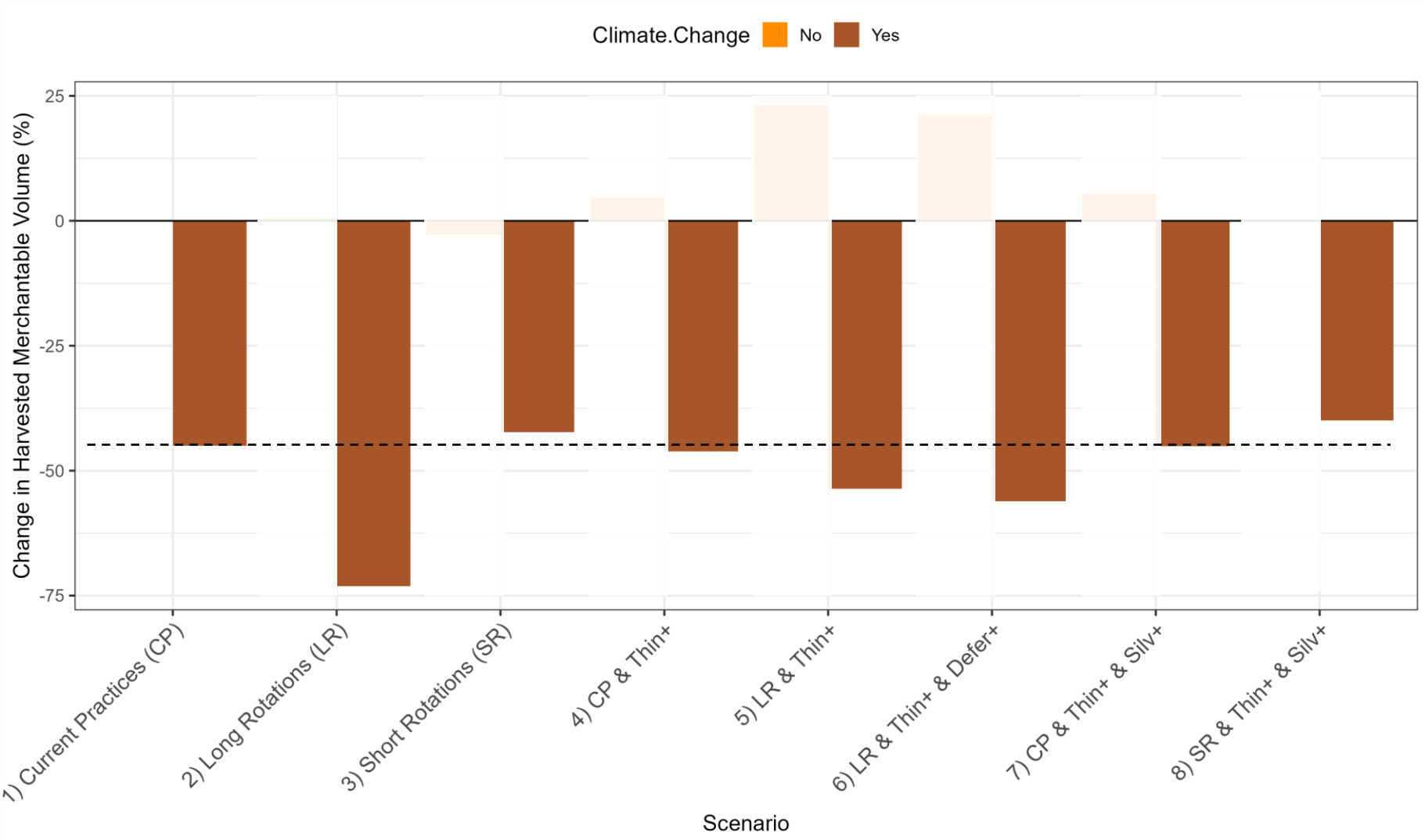
Landscape-Level Results with Climate Change: Simulated Timber Yield



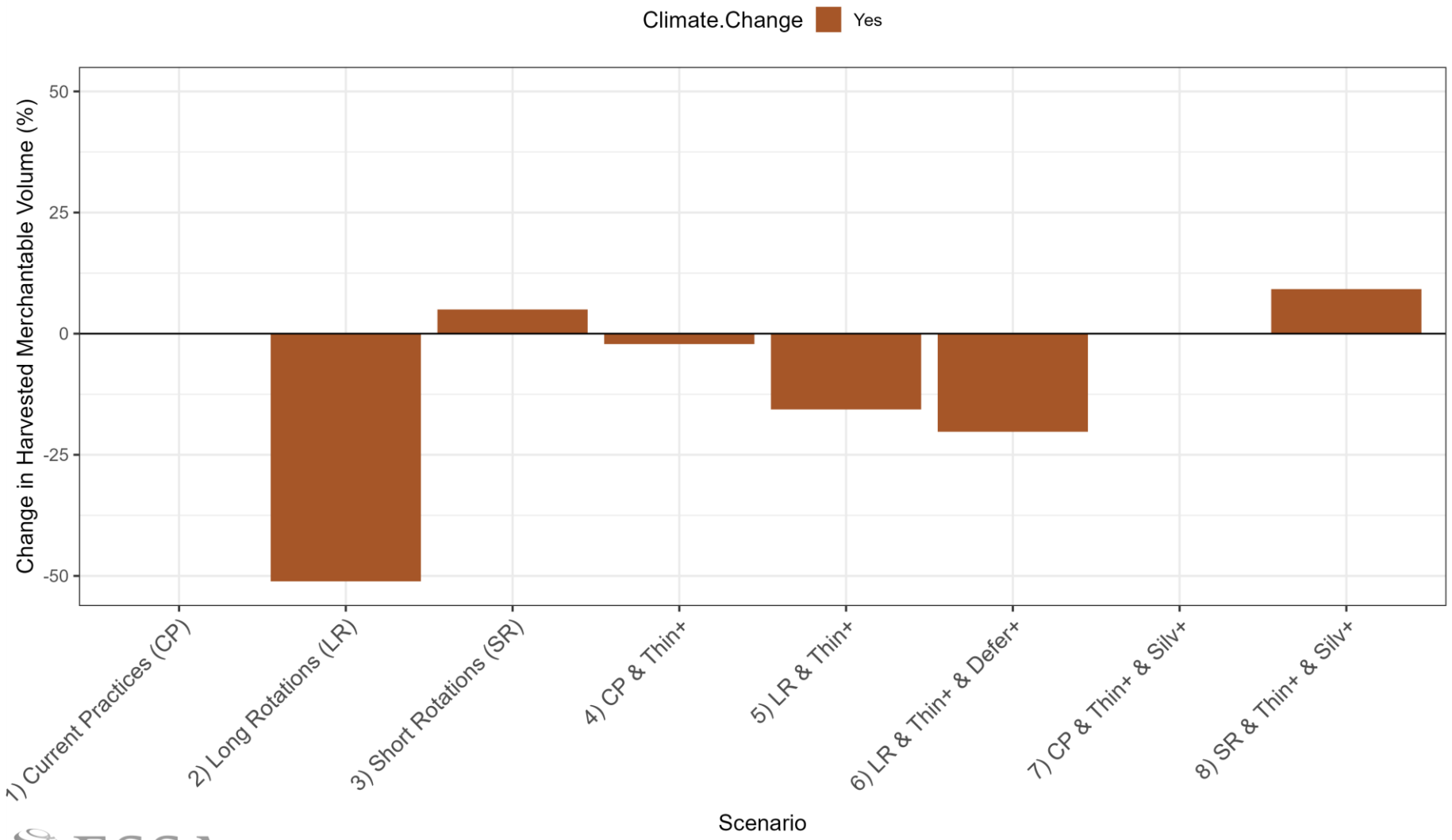
Short rotations had the lowest yield with no climate change, then the highest yield under climate change

ESSA

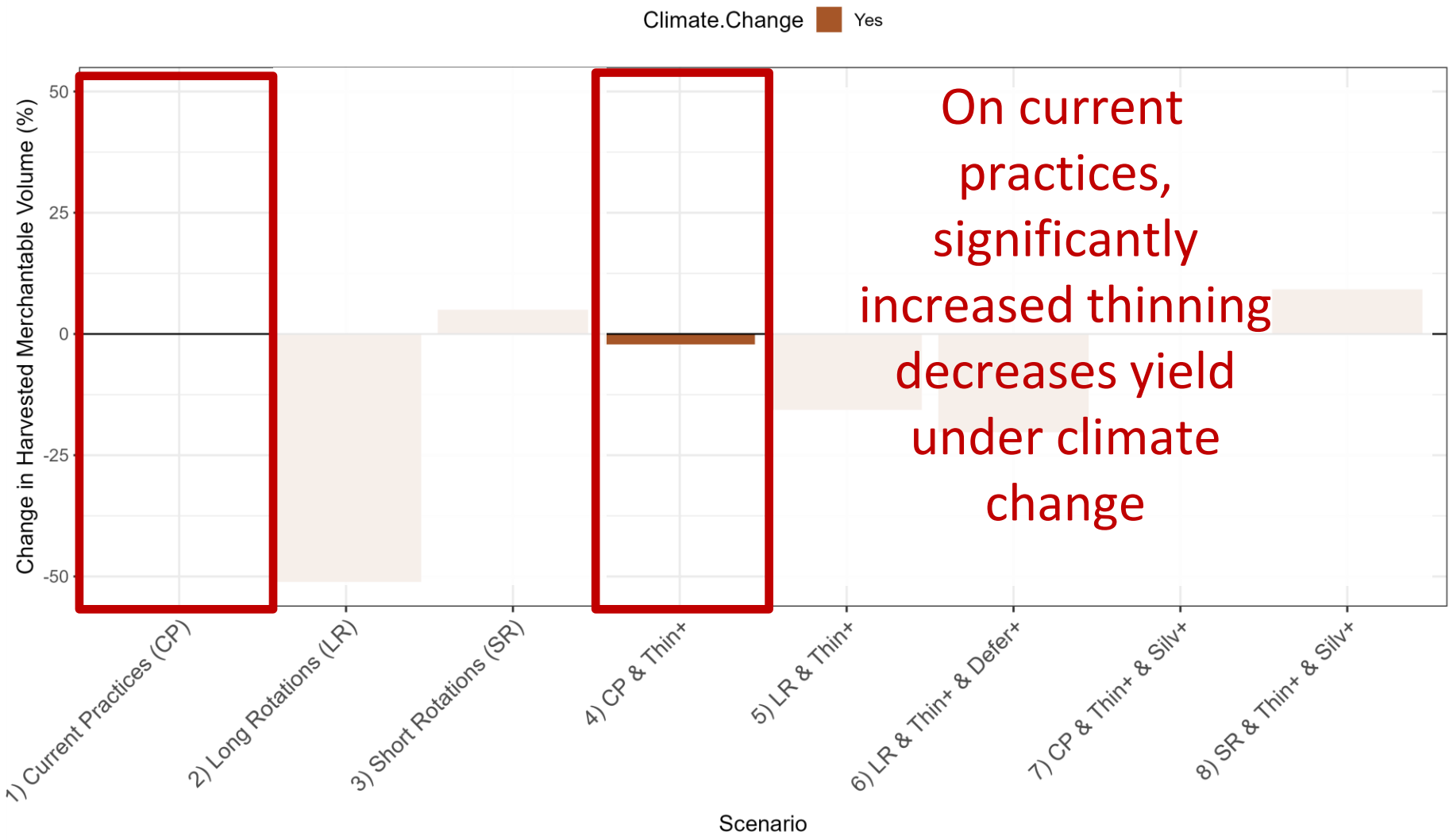
Landscape-Level Results with Climate Change: Simulated Timber Yield



Landscape-Level Results with Climate Change: Simulated Timber Yield

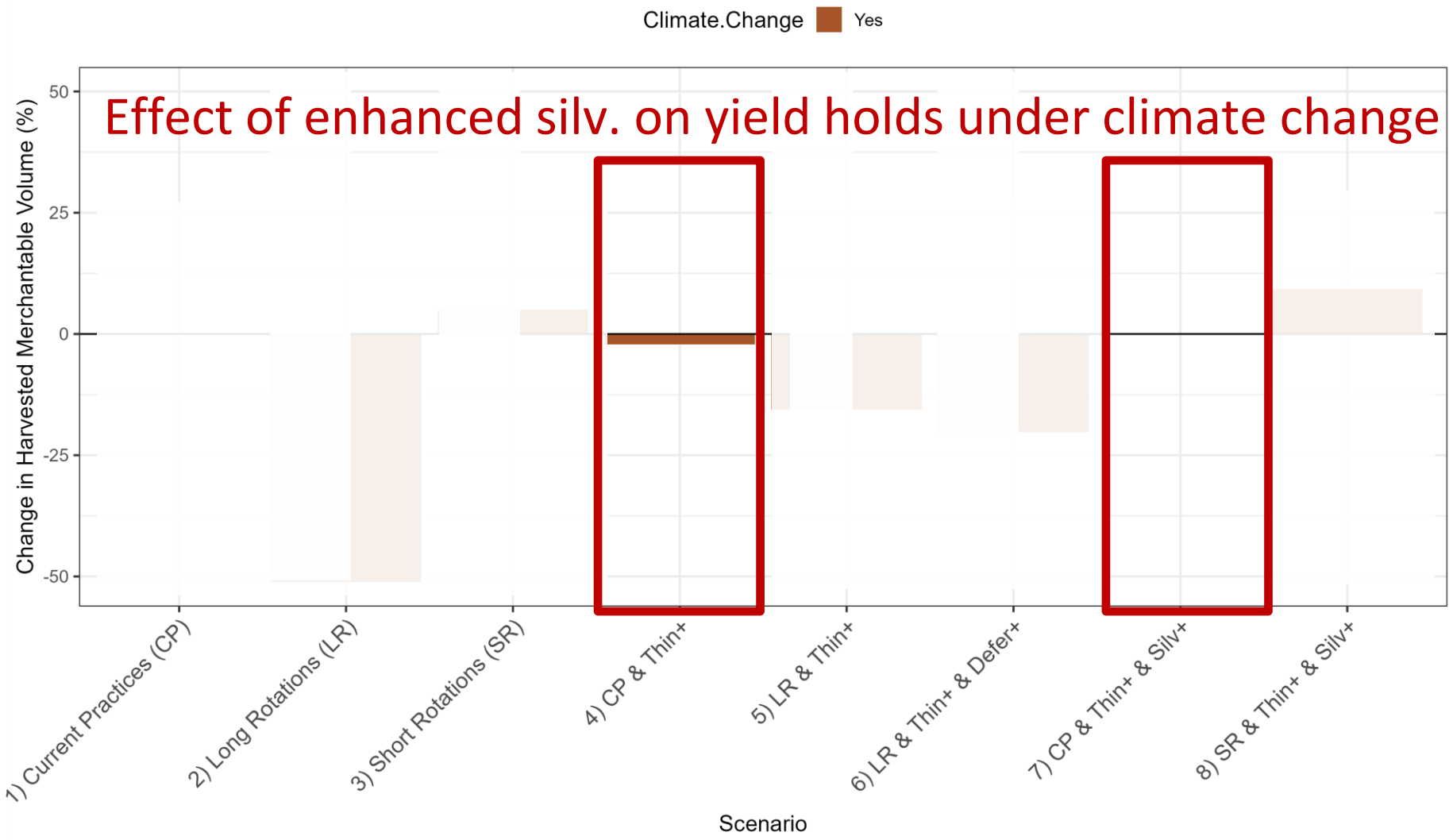


Landscape-Level Results with Climate Change: Simulated Timber Yield

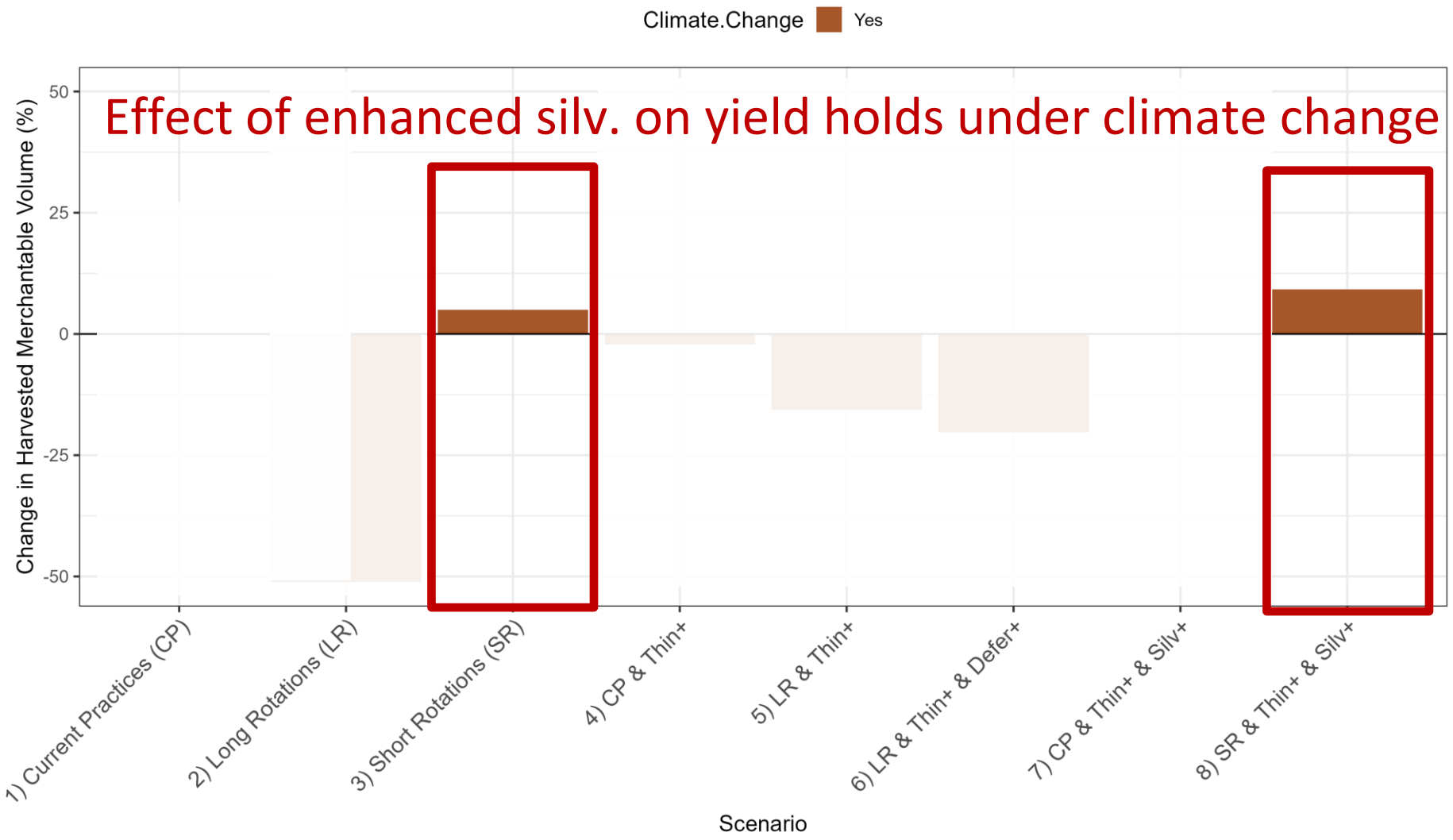


On current practices, significantly increased thinning decreases yield under climate change

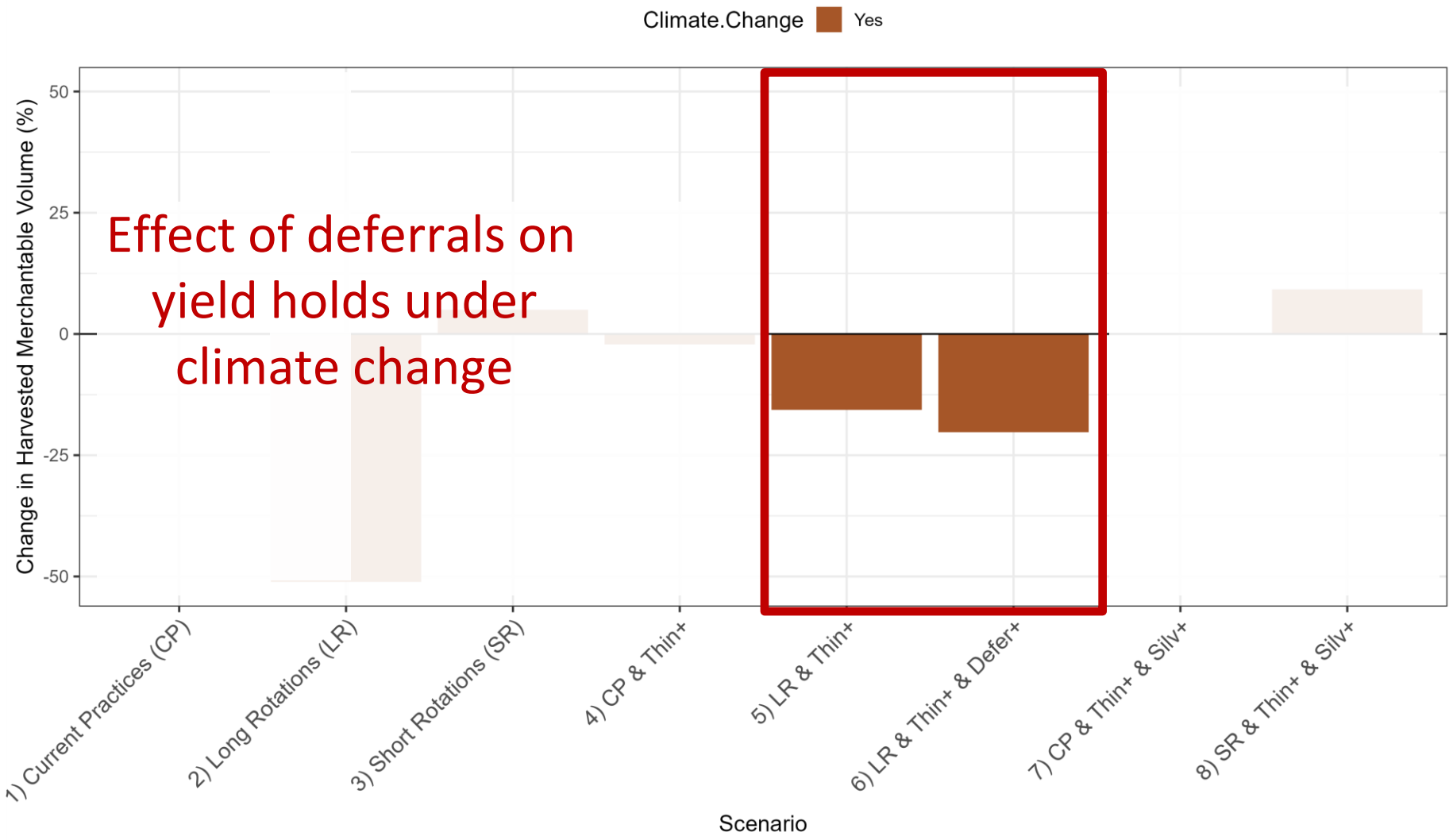
Landscape-Level Results with Climate Change: Simulated Timber Yield



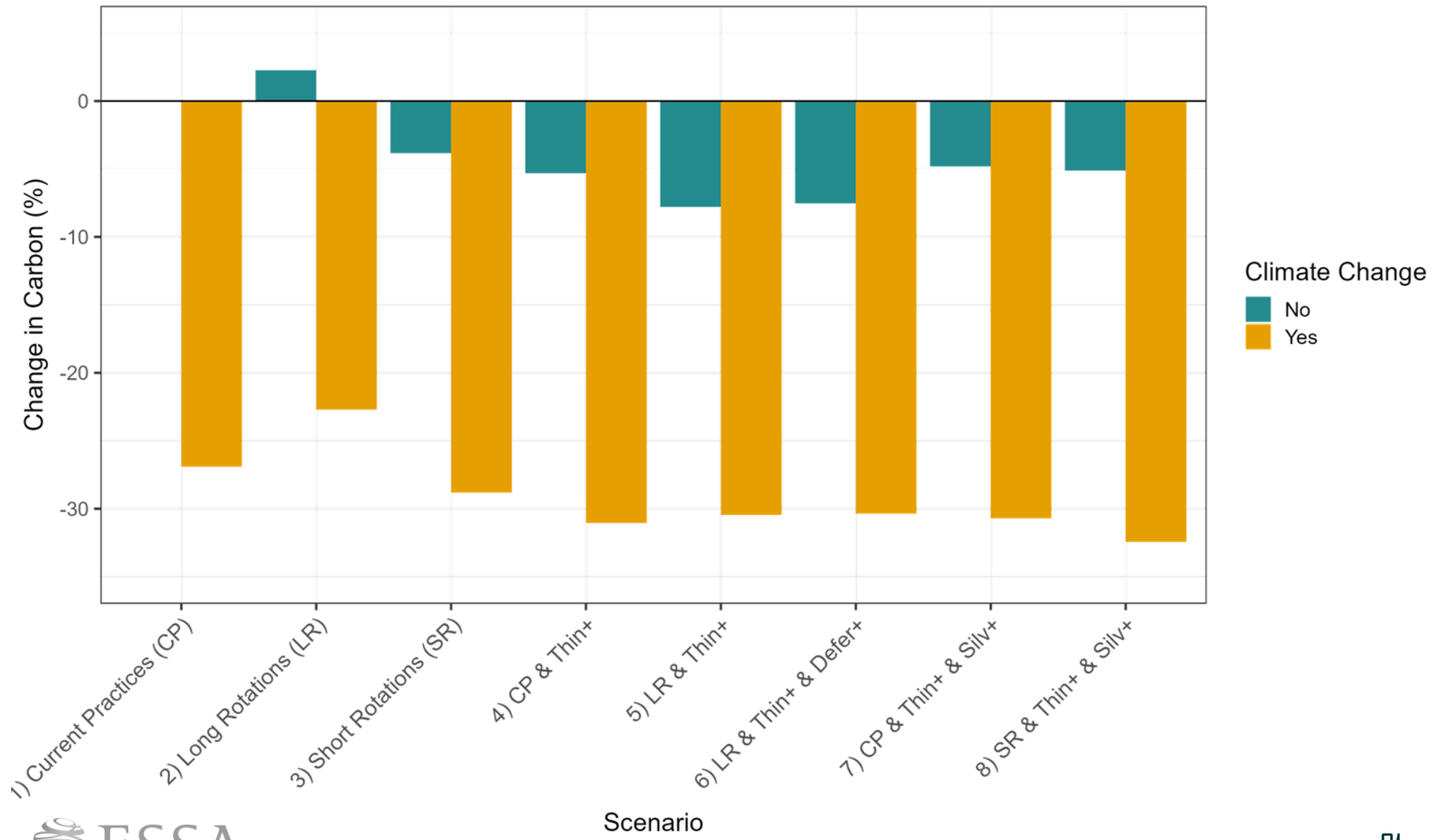
Landscape-Level Results with Climate Change: Simulated Timber Yield



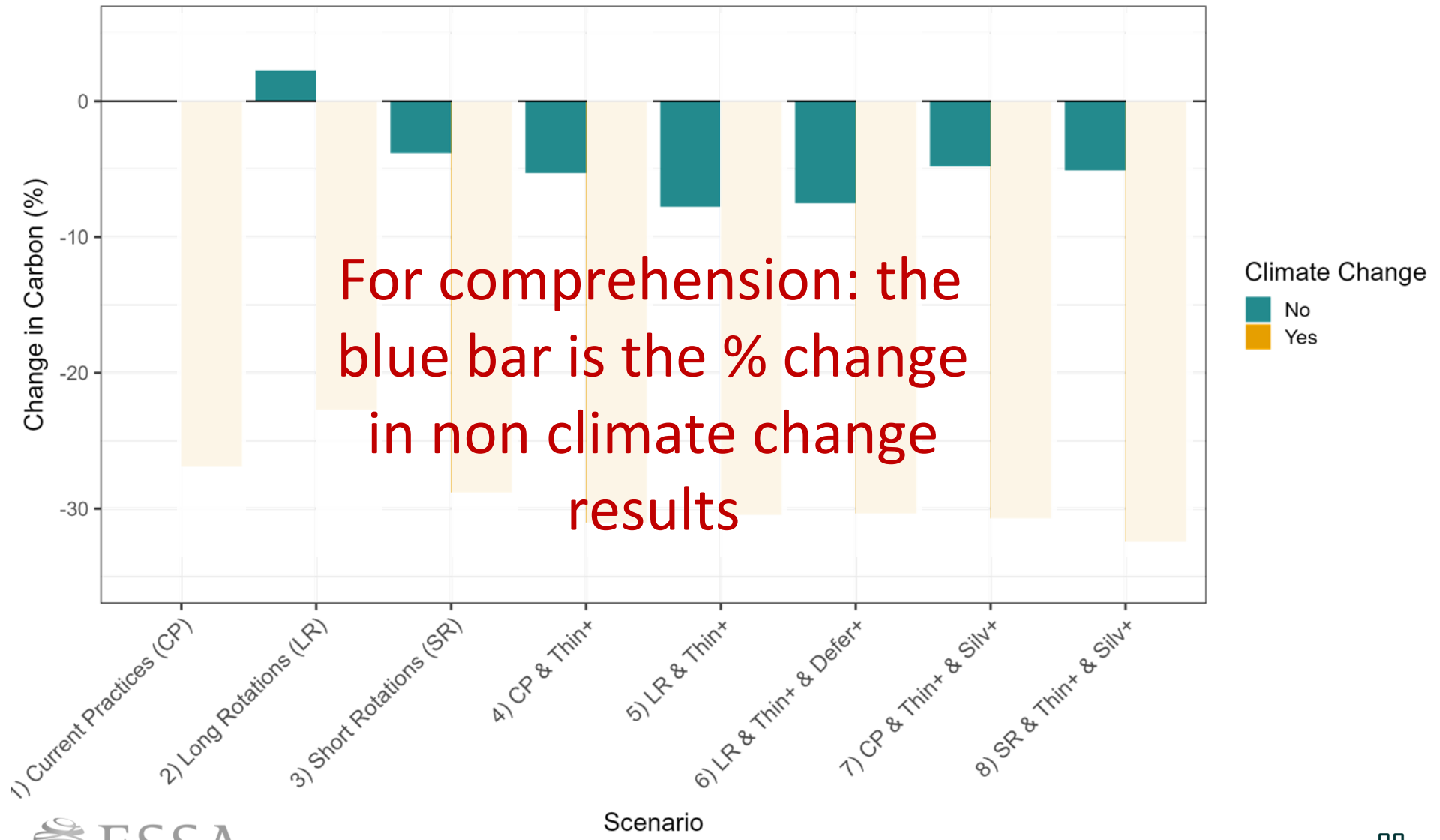
Landscape-Level Results with Climate Change: Simulated Timber Yield



Landscape-Level Results with Climate Change: Carbon



Landscape-Level Results with Climate Change: Carbon



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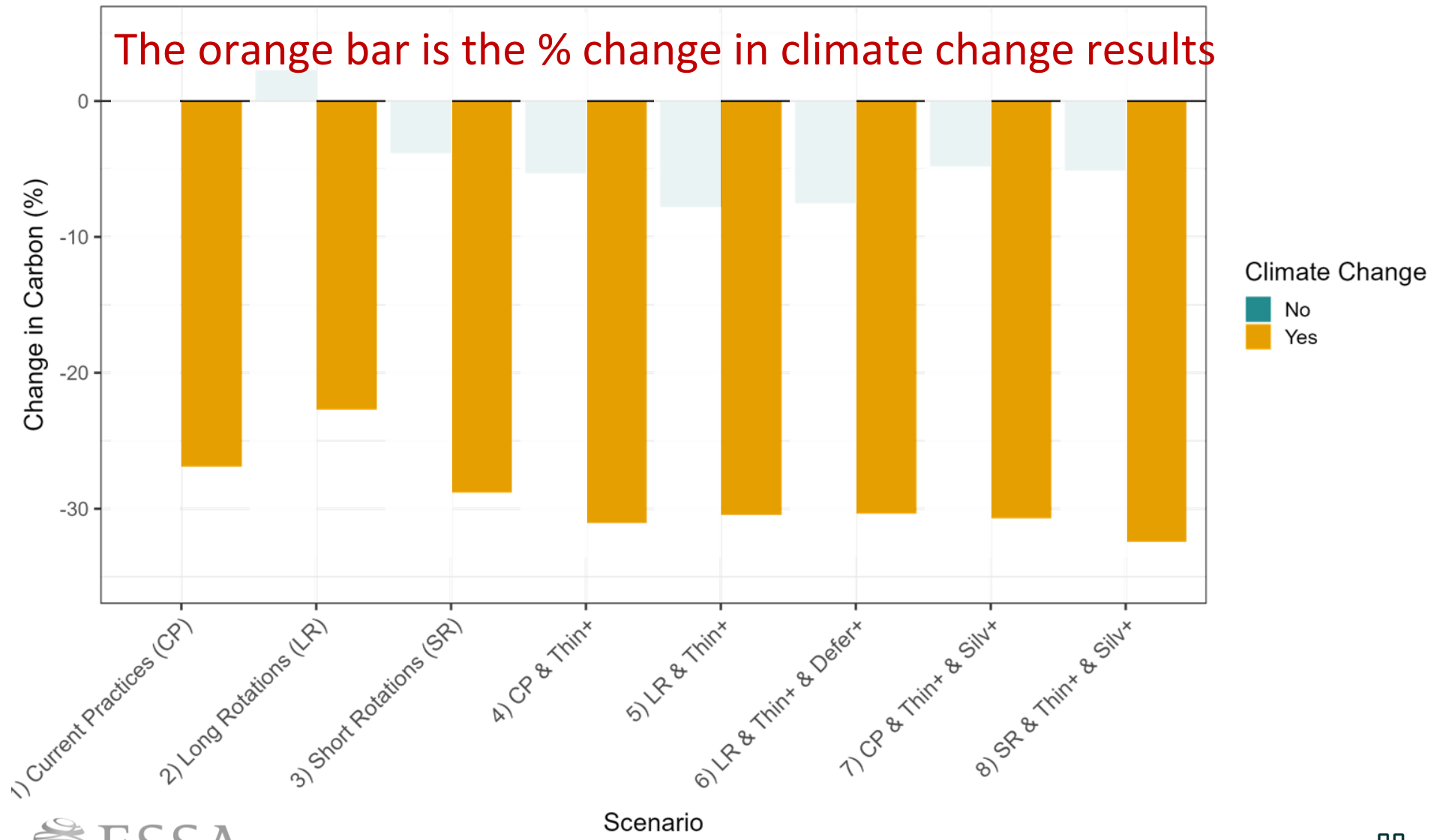
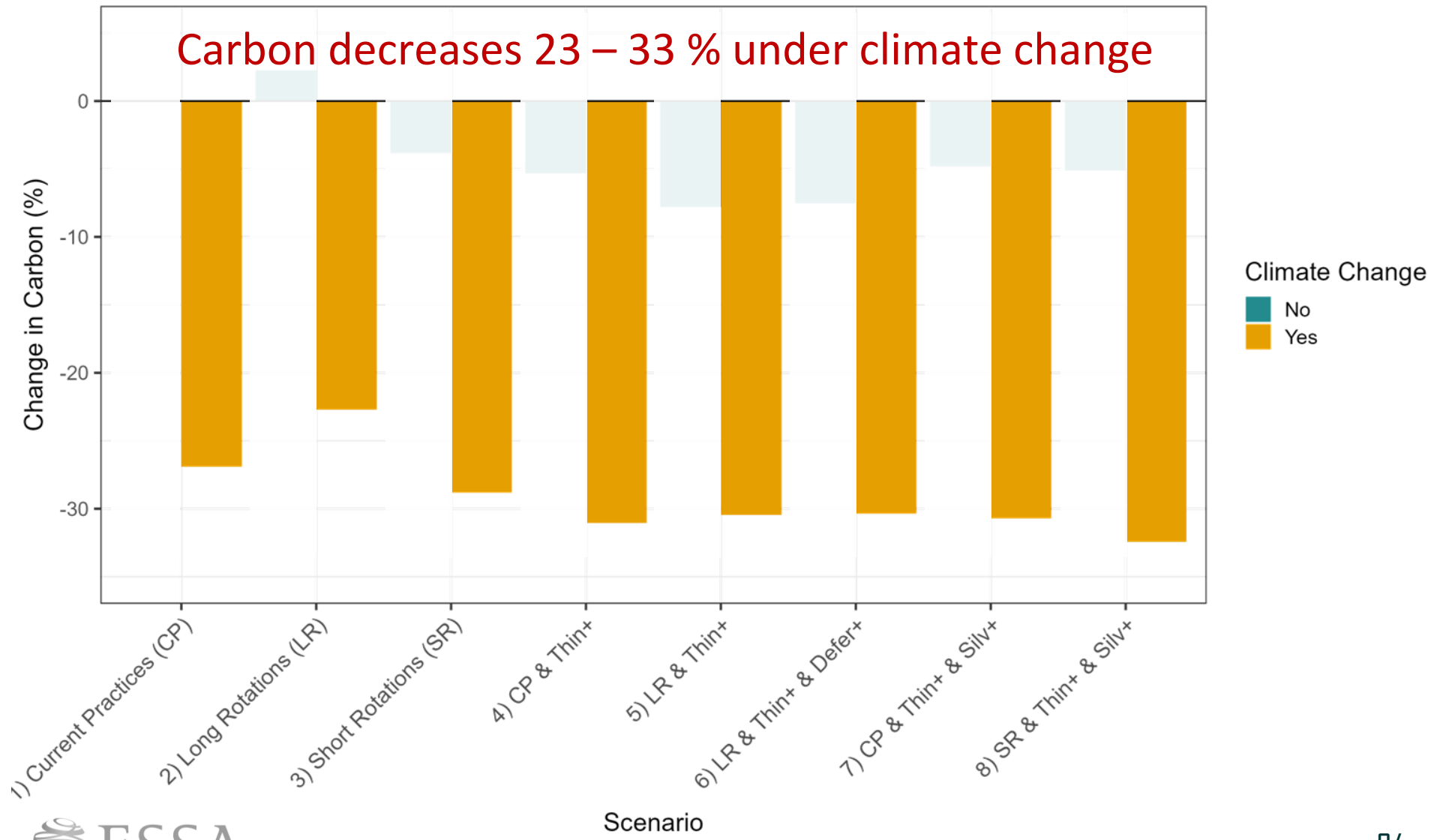
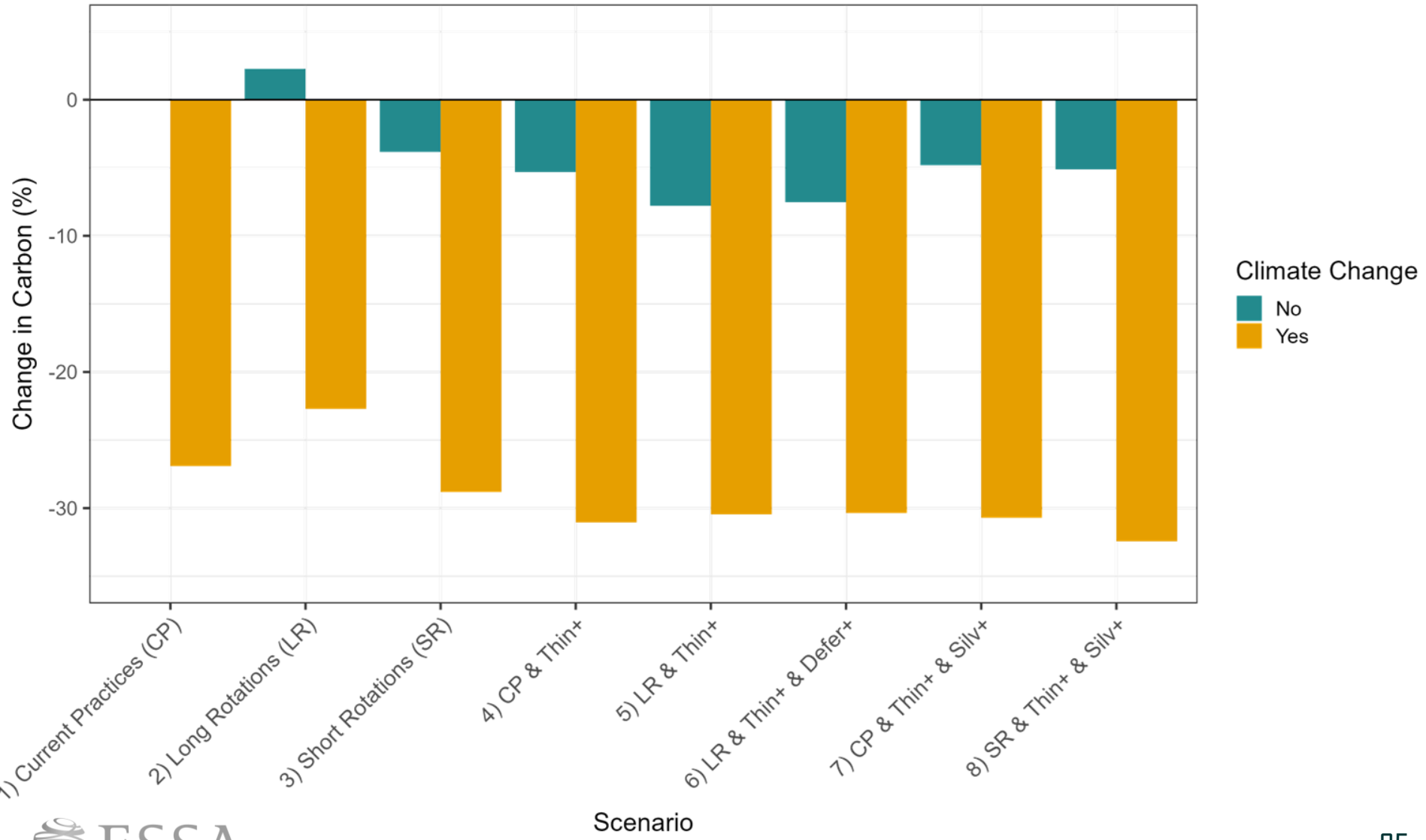
Landscape-Level Results with Climate Change: Carbon



Landscape-Level Results with Climate Change: Carbon



Landscape-Level Results with Climate Change: Carbon



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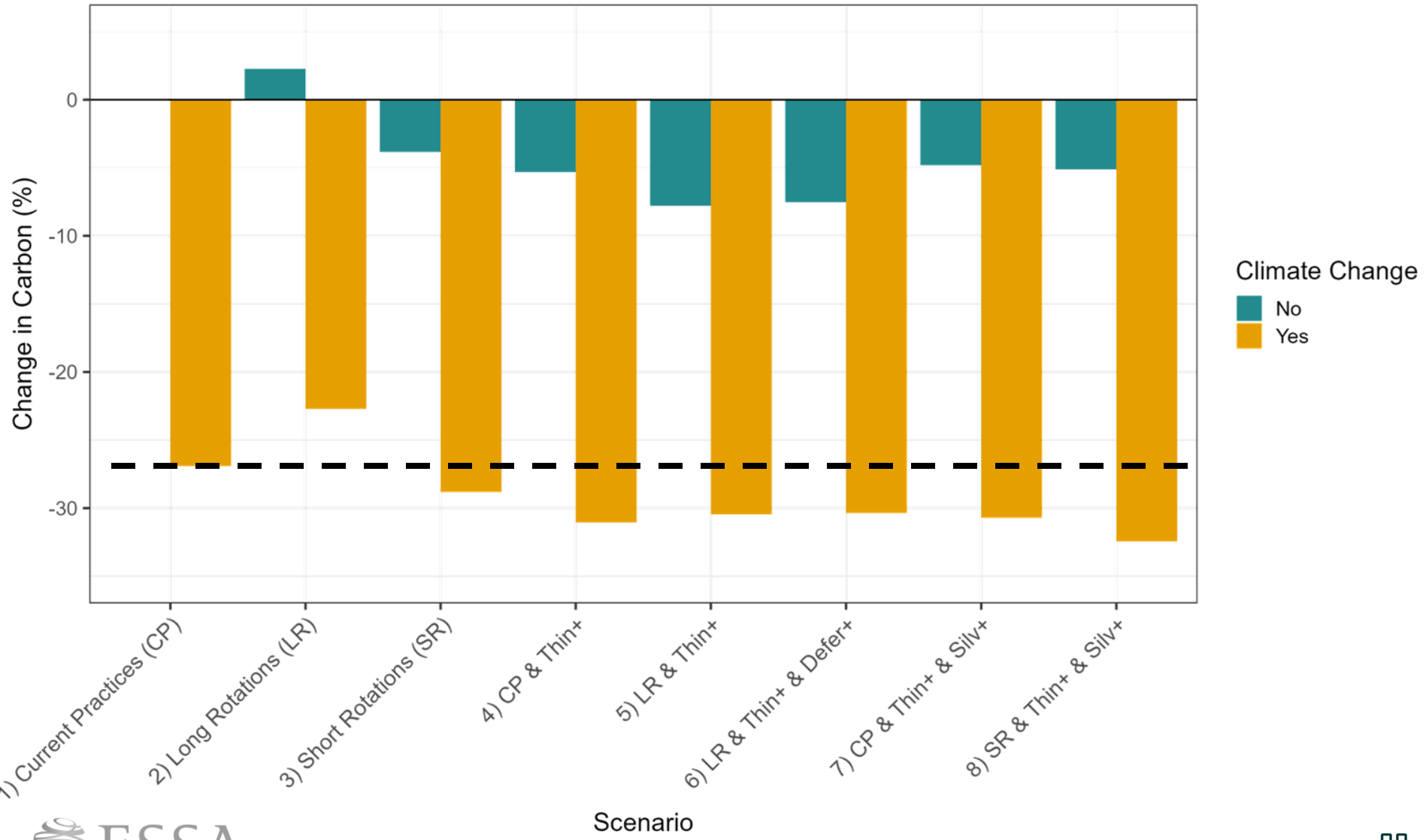
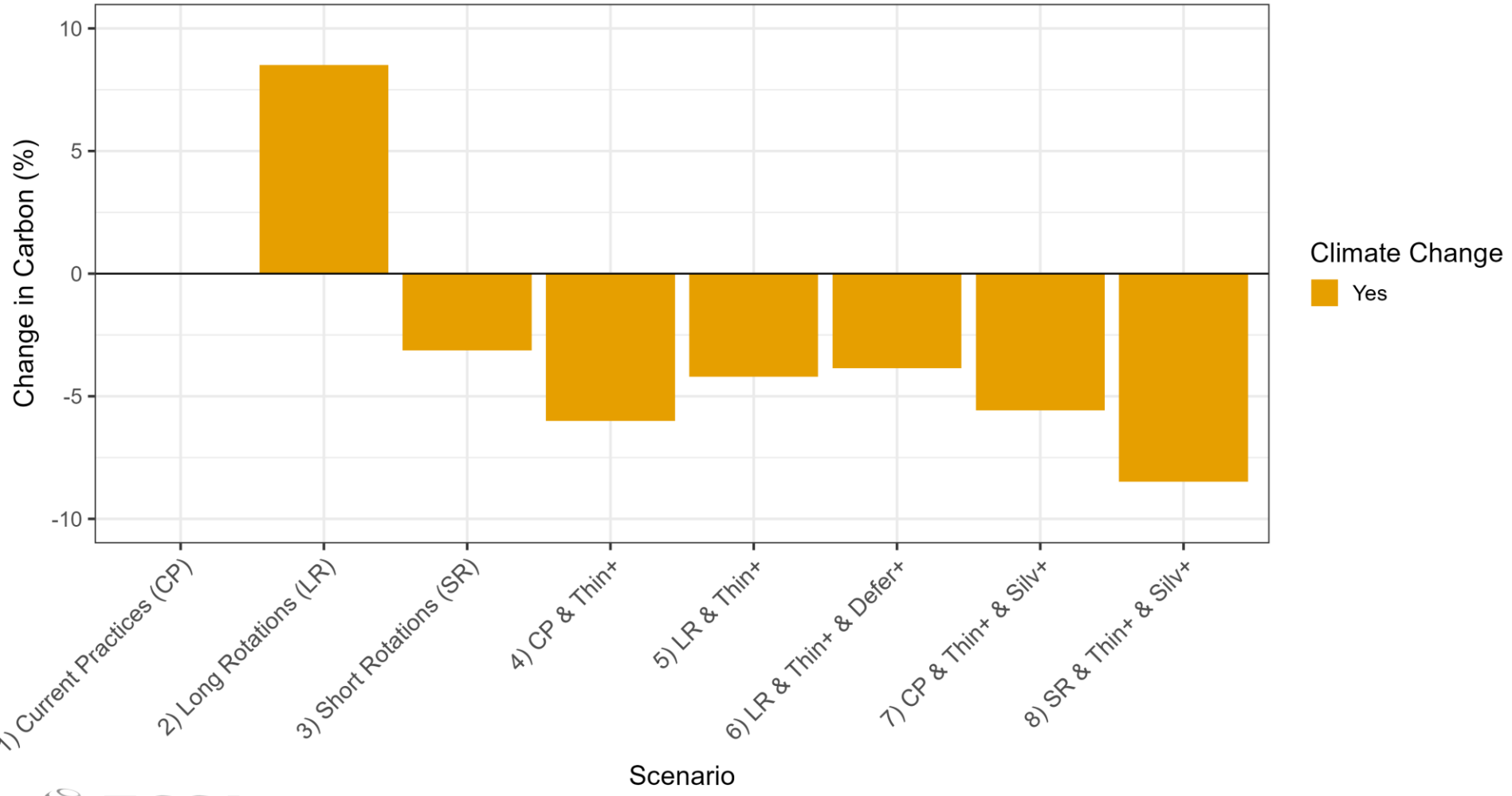
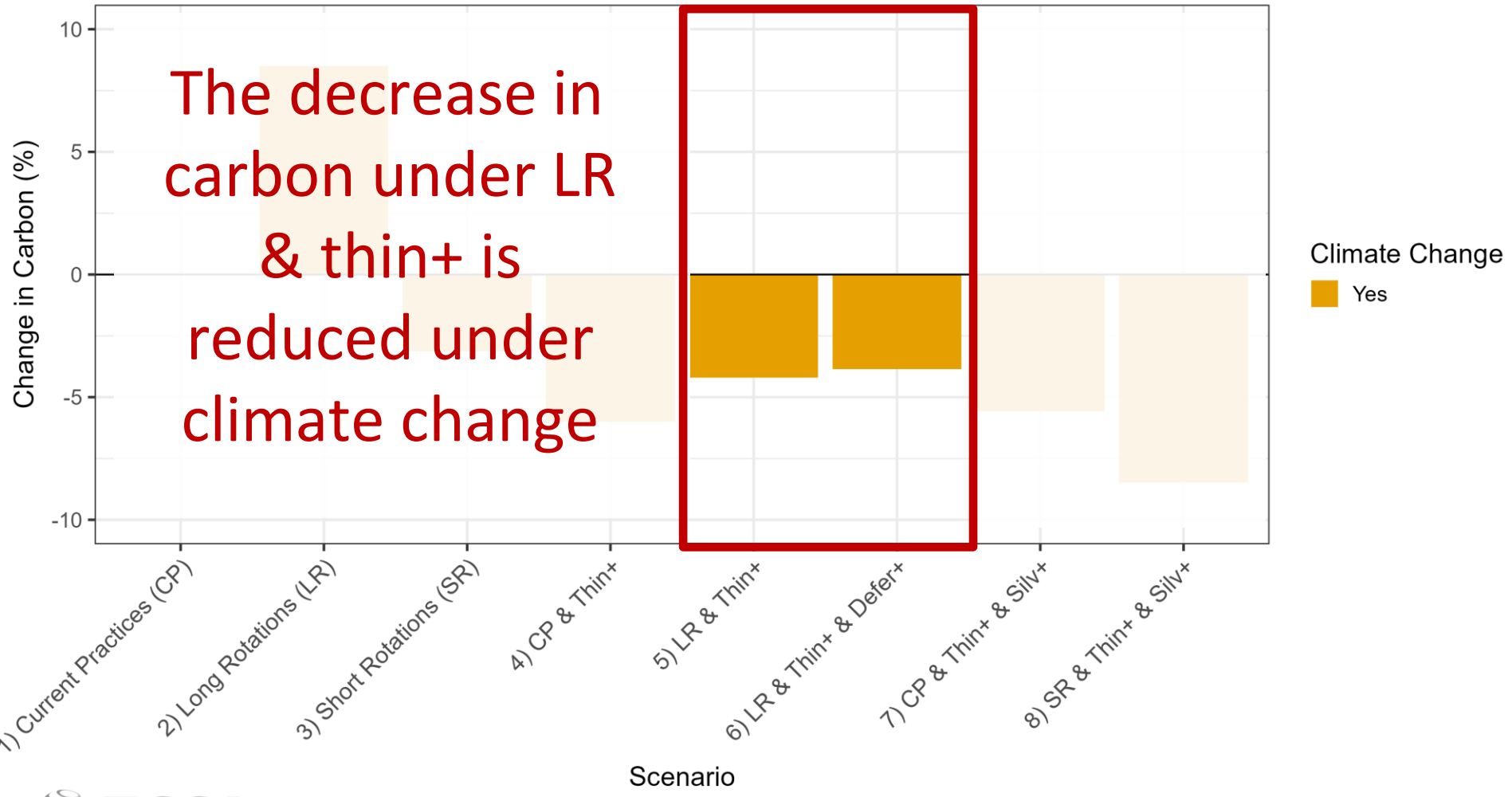


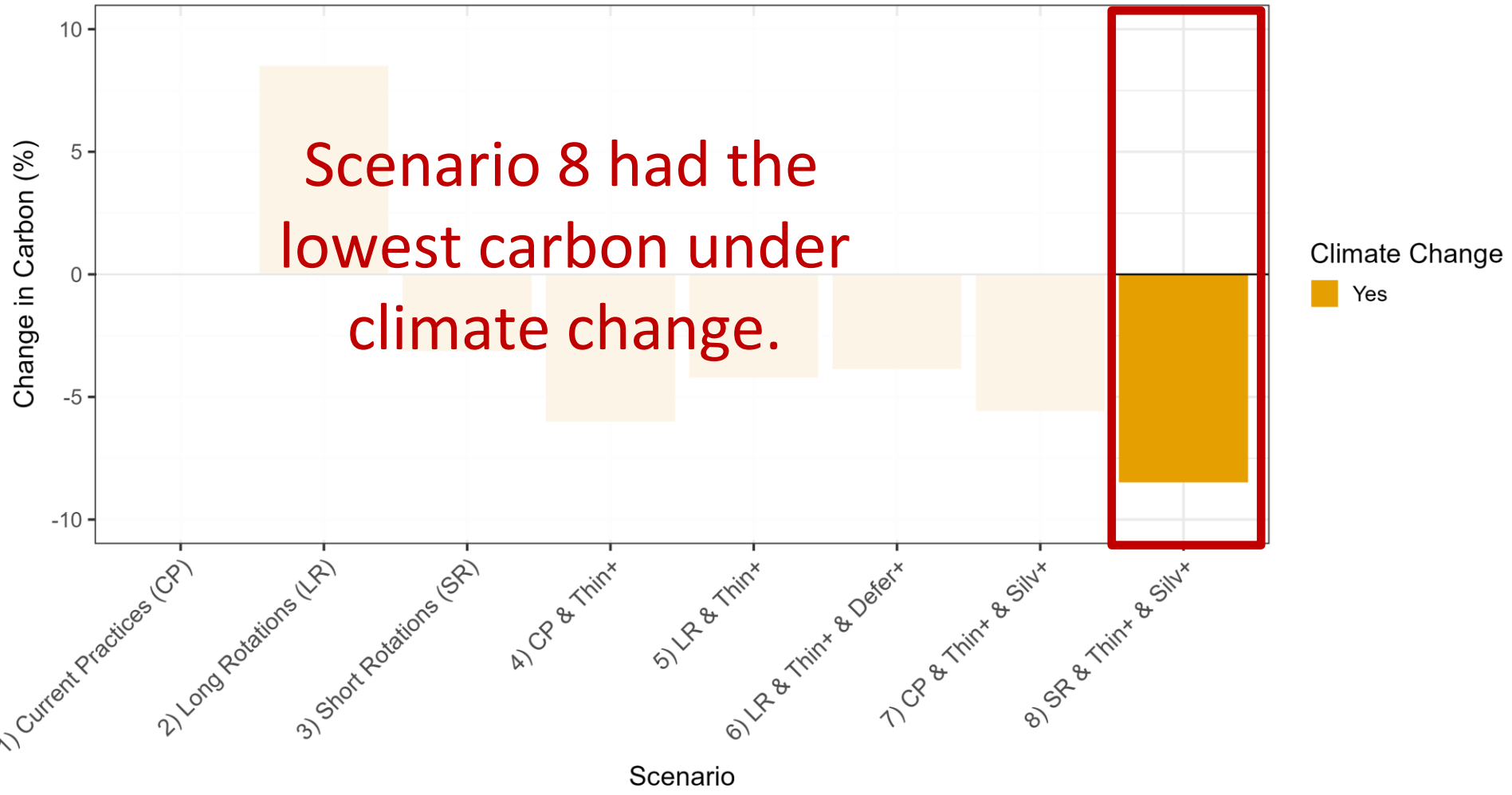
Landscape-Level Results with Climate Change: Carbon



Landscape-Level Results with Climate Change: Carbon

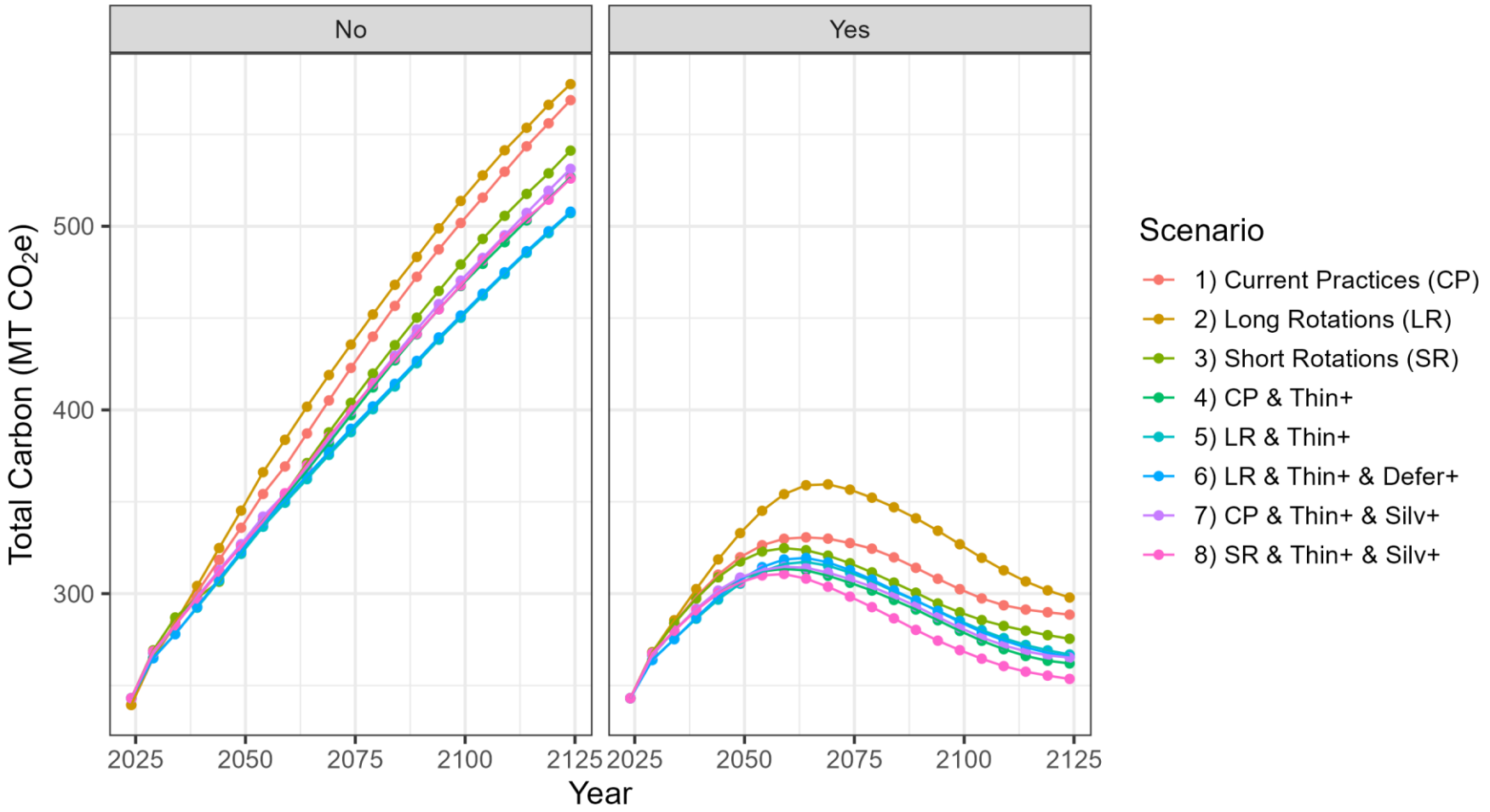


Landscape-Level Results with Climate Change: Carbon

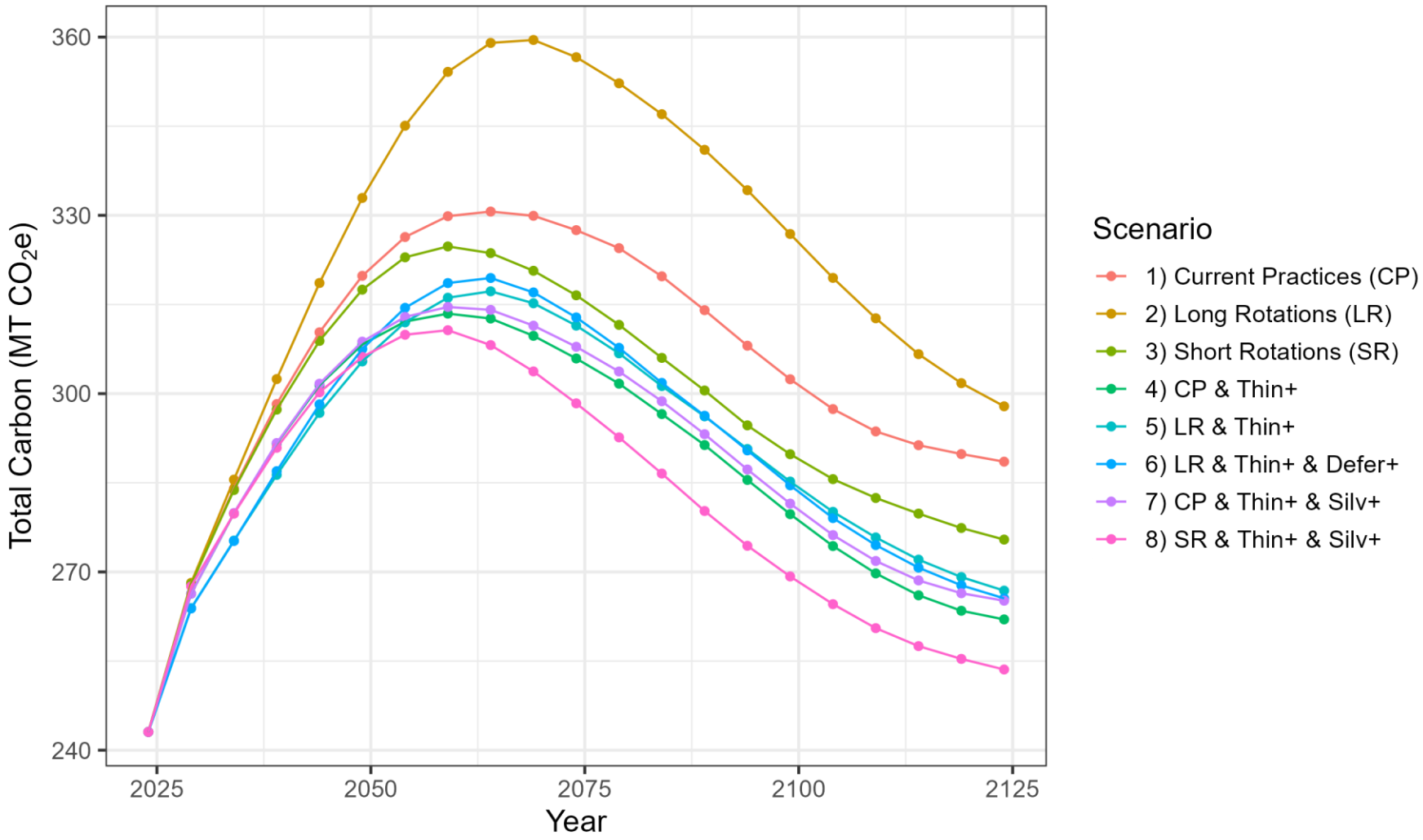


Landscape-Level Results with Climate Change: Carbon

Total Carbon
2024 - 2124



Landscape-Level Results with Climate Change: Carbon



Scenario Results - Landscape Level Summary

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	305	288	895,482	697,855
2) Long Rotations	322	298	437,373	243,992
3) Short Rotations	297	275	940,223	557,775
4) CP & Thin+	287	262	874,472	361,476
5) LR & Thin+	290	267	755,675	394,651
6) LR & Thin+ & Defer+	290	266	714,059	403,011
7) CP & Thin+ & Silv+	289	265	894,541	445,787
8) SR & Thin+ & Silv+	282	254	977,764	527,734

Scenario Results - Landscape Level Summary

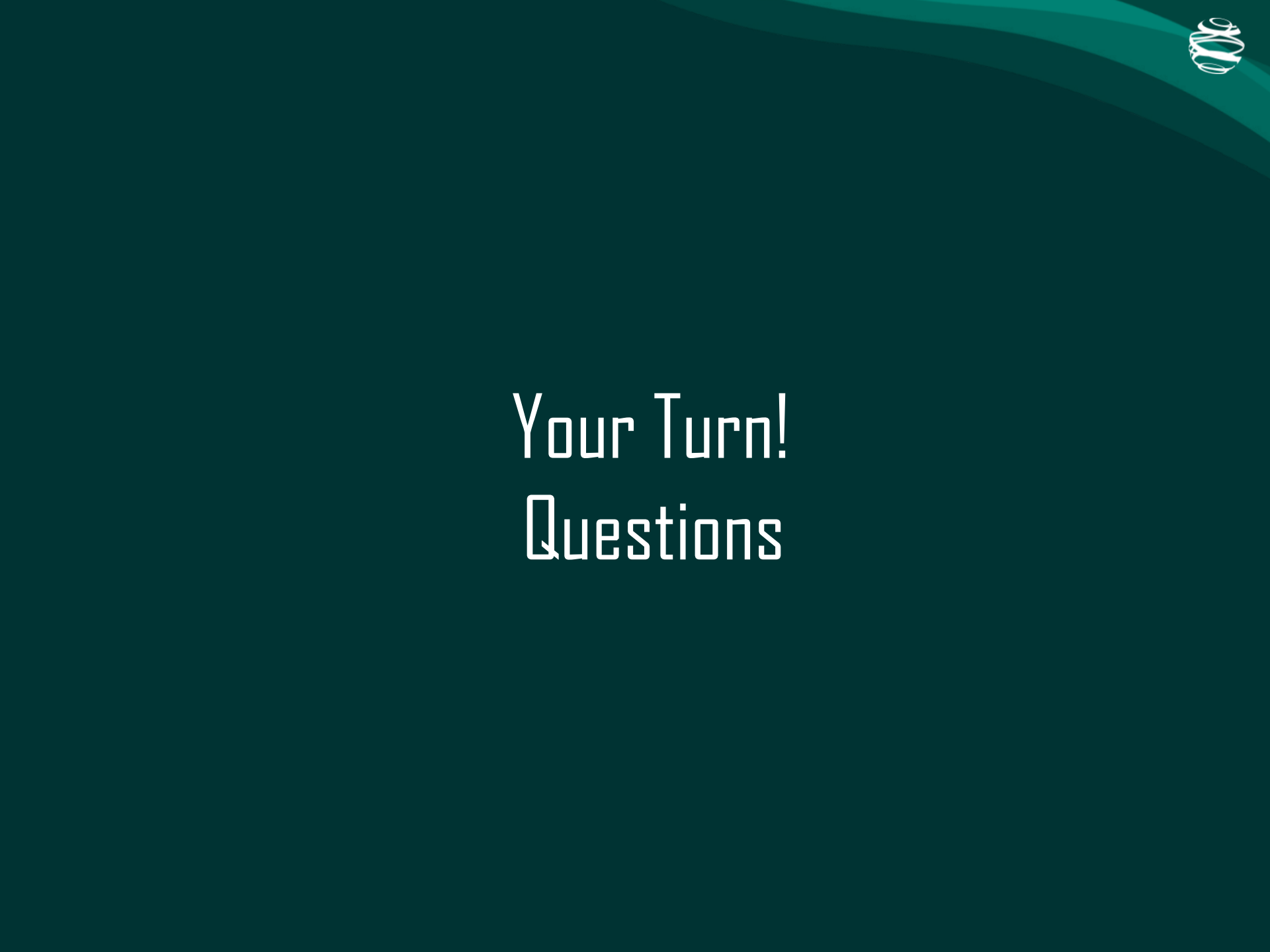
scenario	Change in total stored carbon (% from CP no climate change)	Change in merchantable timber harvested (% from CP no climate change)
1) Current Practices (no climate change)	417 Mt CO2e	1,628,538 MBF
1) Current Practices (CP)	-26.9	-45
2) Long Rotations (LR)	-22.7	-73
3) Short Rotations (SR)	-28.8	-42
4) CP & Thin+	-31.0	-46
5) LR & Thin+	-30.5	-53
6) LR & Thin+ & Defer+	-30.3	-56
7) CP & Thin+ & Silv+	-30.7	-45
8) SR & Thin+ & Silv+	-32.4	-39

Scenario Results - Landscape Level Summary

scenario	**Change in total stored carbon** (% from CP climate change)	**Change in merchantable timber harvested** (% from CP climate change)
1) Current Practices (climate change)	305 Mt CO2e	895,482 MBF
2) Long Rotations (LR)	5.74	-51
3) Short Rotations (SR)	-2.6	4.9
4) CP & Thin+	-5.7	-2.1
5) LR & Thin+	-4.9	-15.6
6) LR & Thin+ & Defer+	-4.7	-20.3
7) CP & Thin+ & Silv+	-5.2	-0.1
8) SR & Thin+ & Silv+	-7.6	9.1

Climate Change Summary

1. Carbon declines 23% – 33% and simulated yield declines 39%-73% underclimate change compared to a non-climate change current practices baseline. [Remember: this is without simulation of climate change adaptation - e.g., planting with climate adapted species]
2. Carbon increasesinitially (i.e., first 2-3 decades), then flattens out, before declining toward the end of simulation.
3. Climate change causes the pattern across scenarios relative to current practices to shift for timber yield in some cases.
4. Under climate change, the direction of change in scenarios relative to current practices holds, but the magnitude varies.


Your Turn!
Questions

Lunch Break (45min)

Next Up: Scenario Modification Discussion (DNR)

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

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
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							