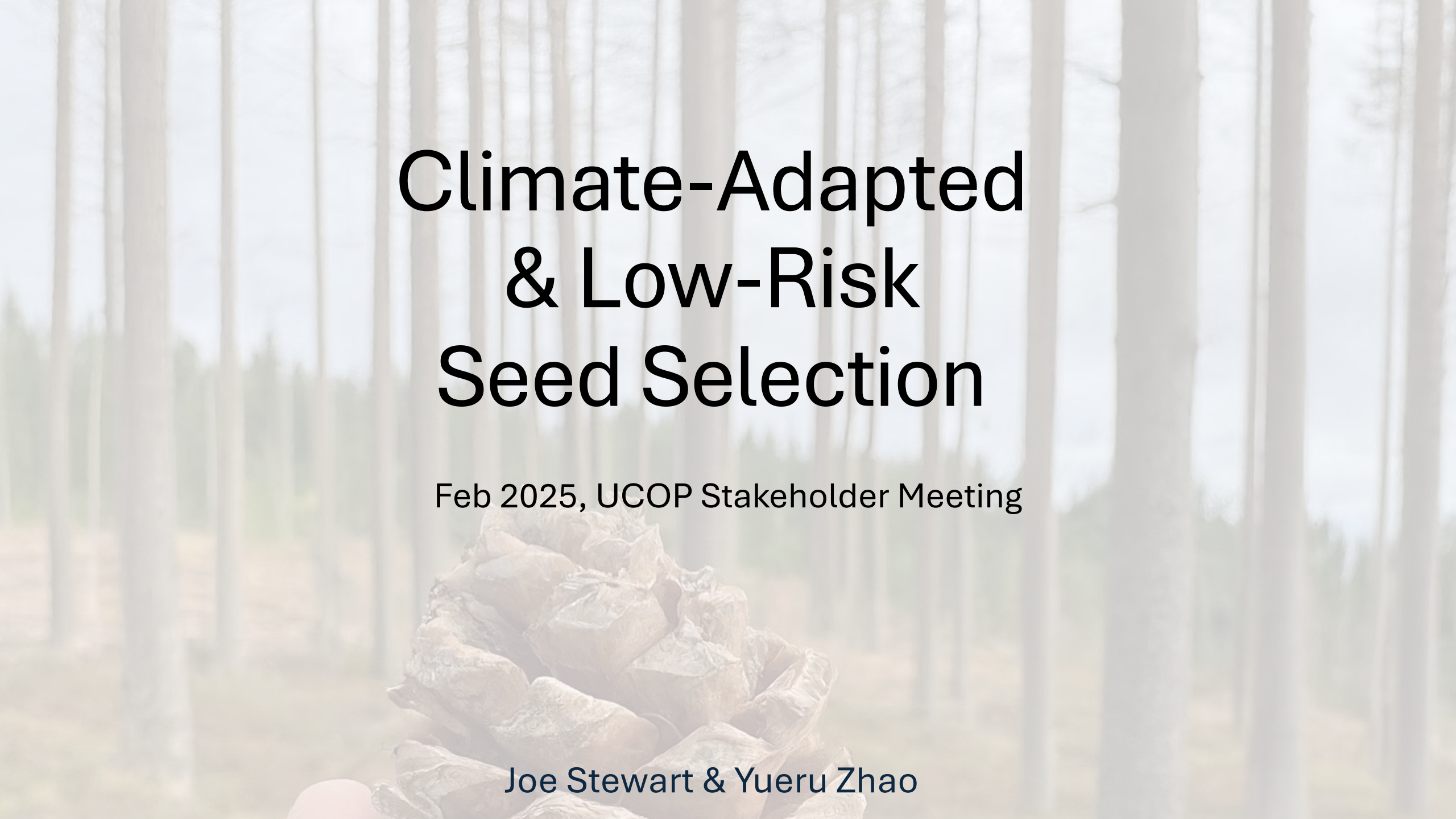
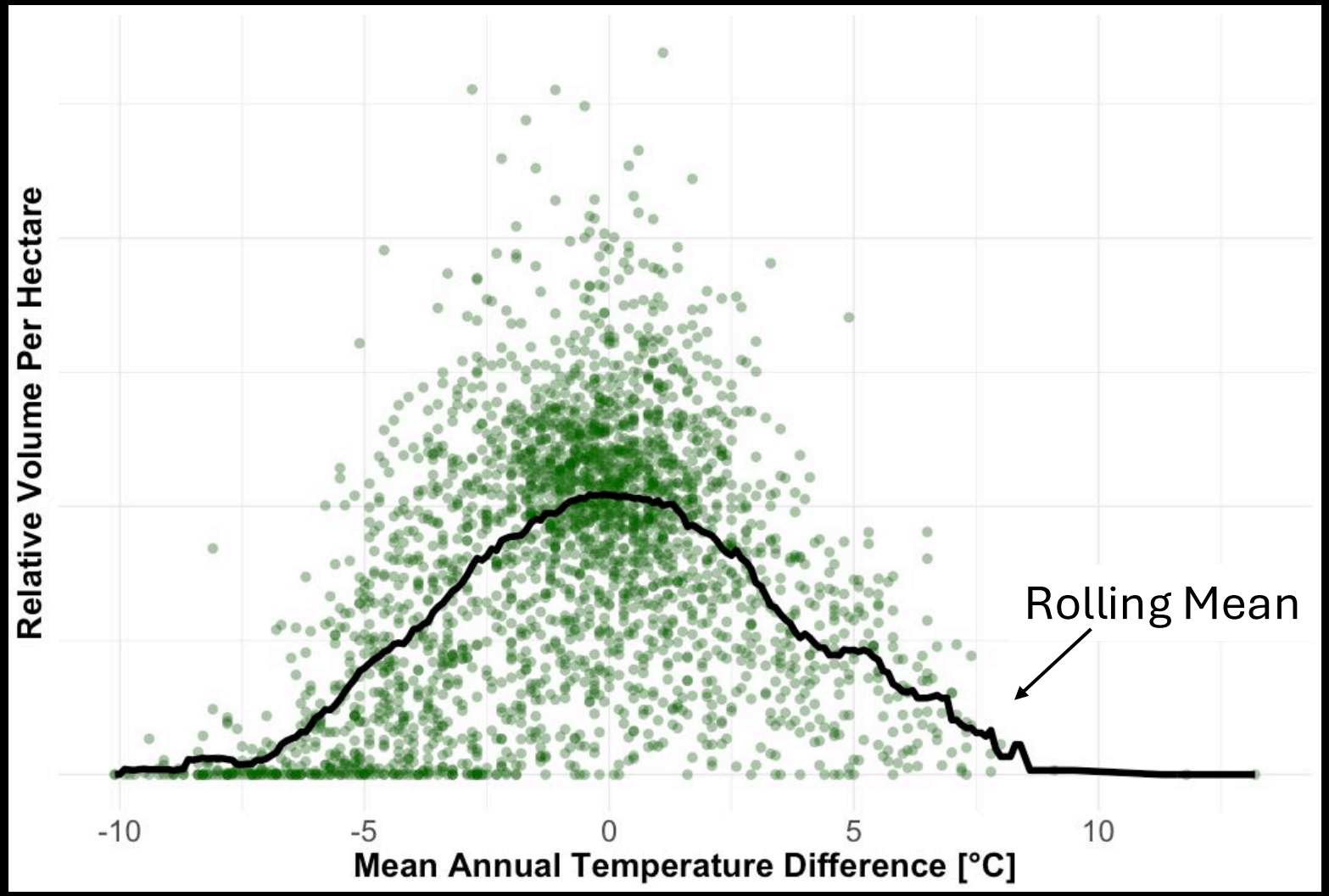
Climate-Adapted & Low-Risk Seed Selection

Feb 2025, UCOP Stakeholder Meeting



Joe Stewart & Yueru Zhao

Tree Populations are Adapted to Historical Climate



Growing in colder climate than seed origin

Growing in warmer climate than seed origin

Age 32 lodgepole pine data

- 44 sites
- 182 Provenances
- ~50,000 trees

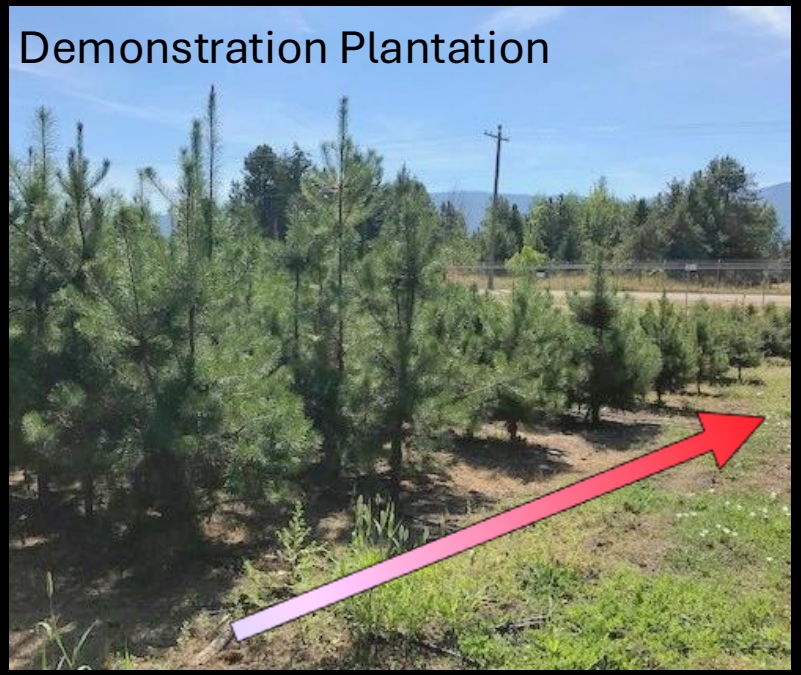
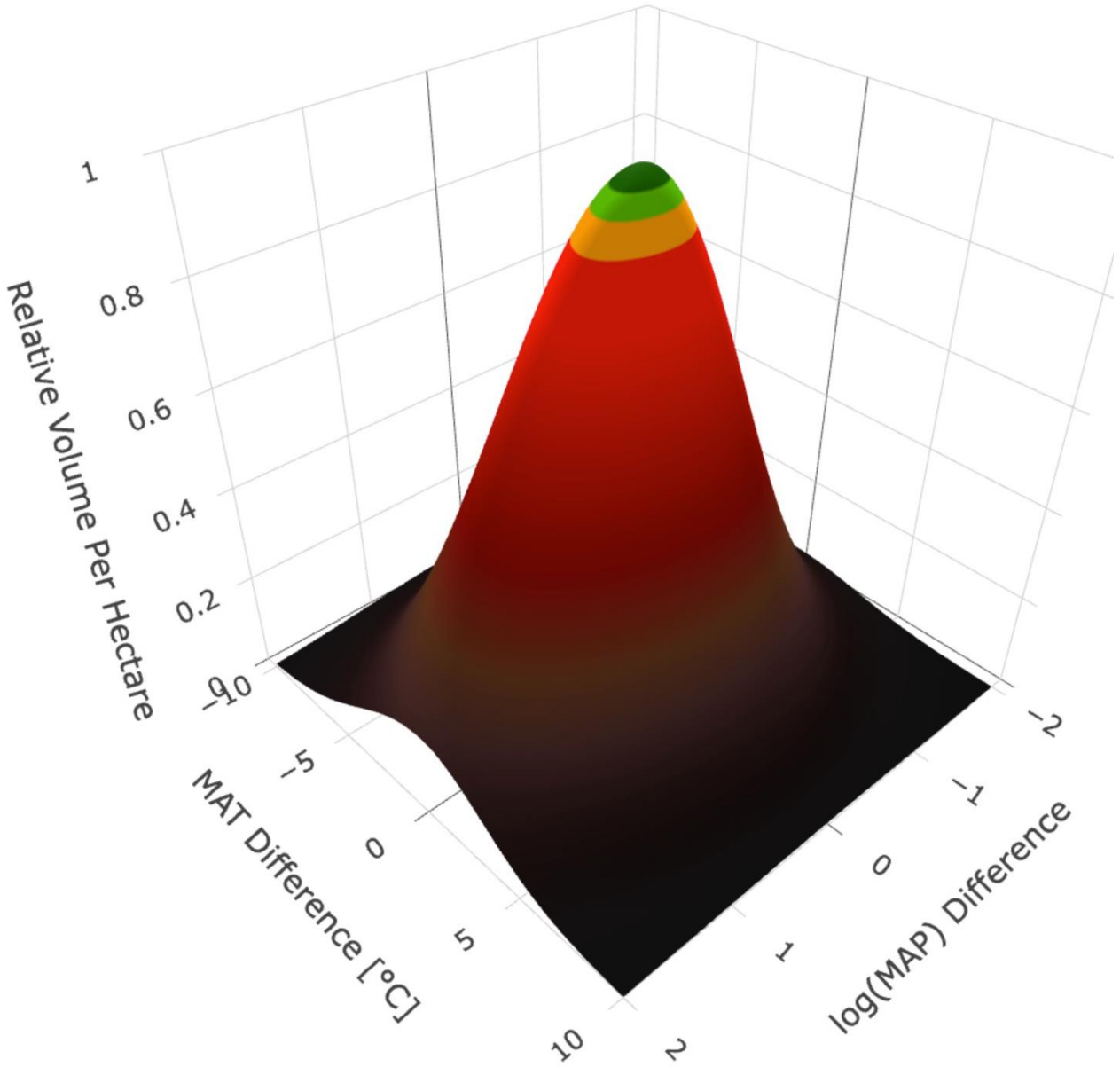
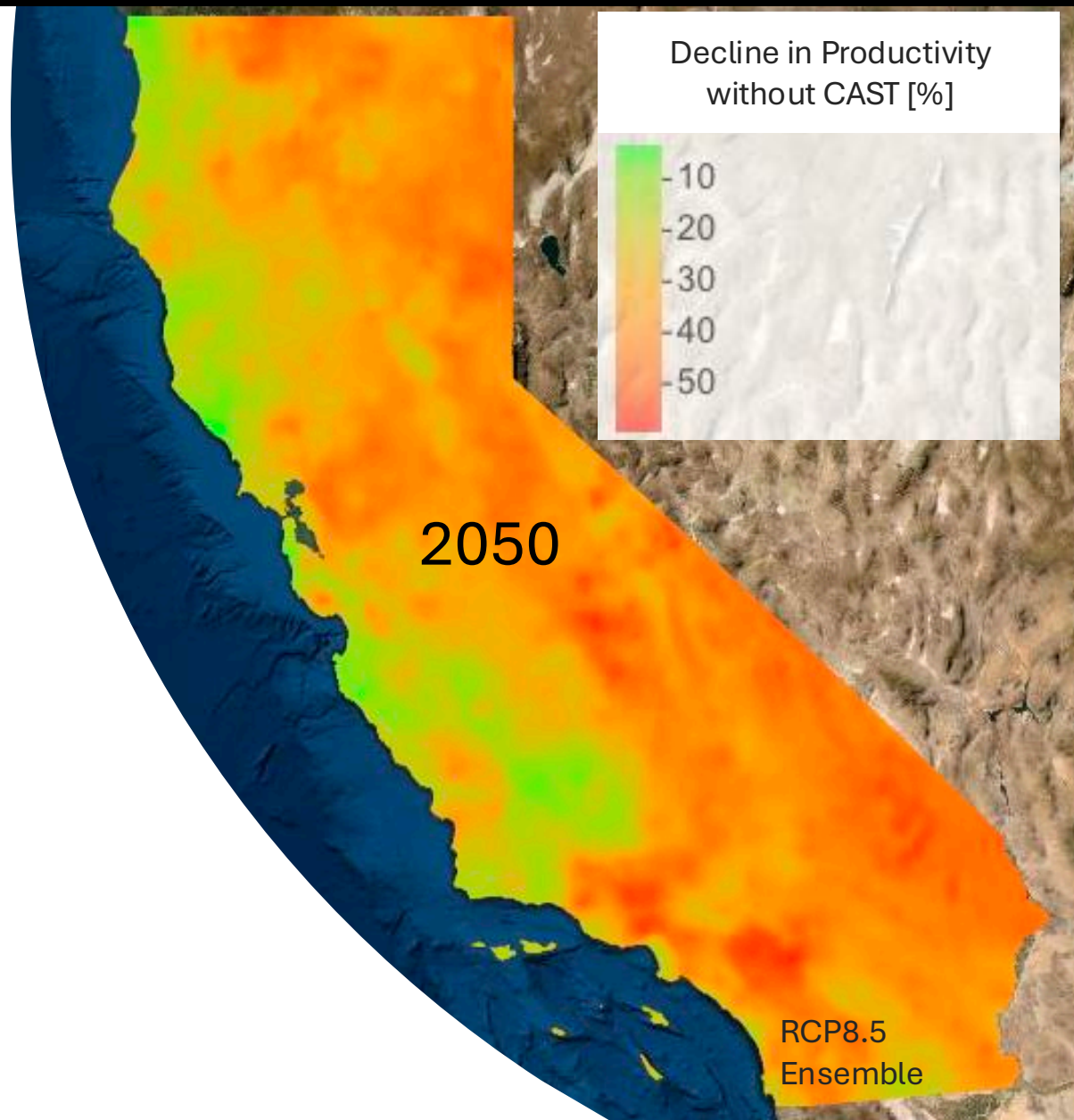


Photo Courtesy Greg O'Neill

Crisis and Opportunity



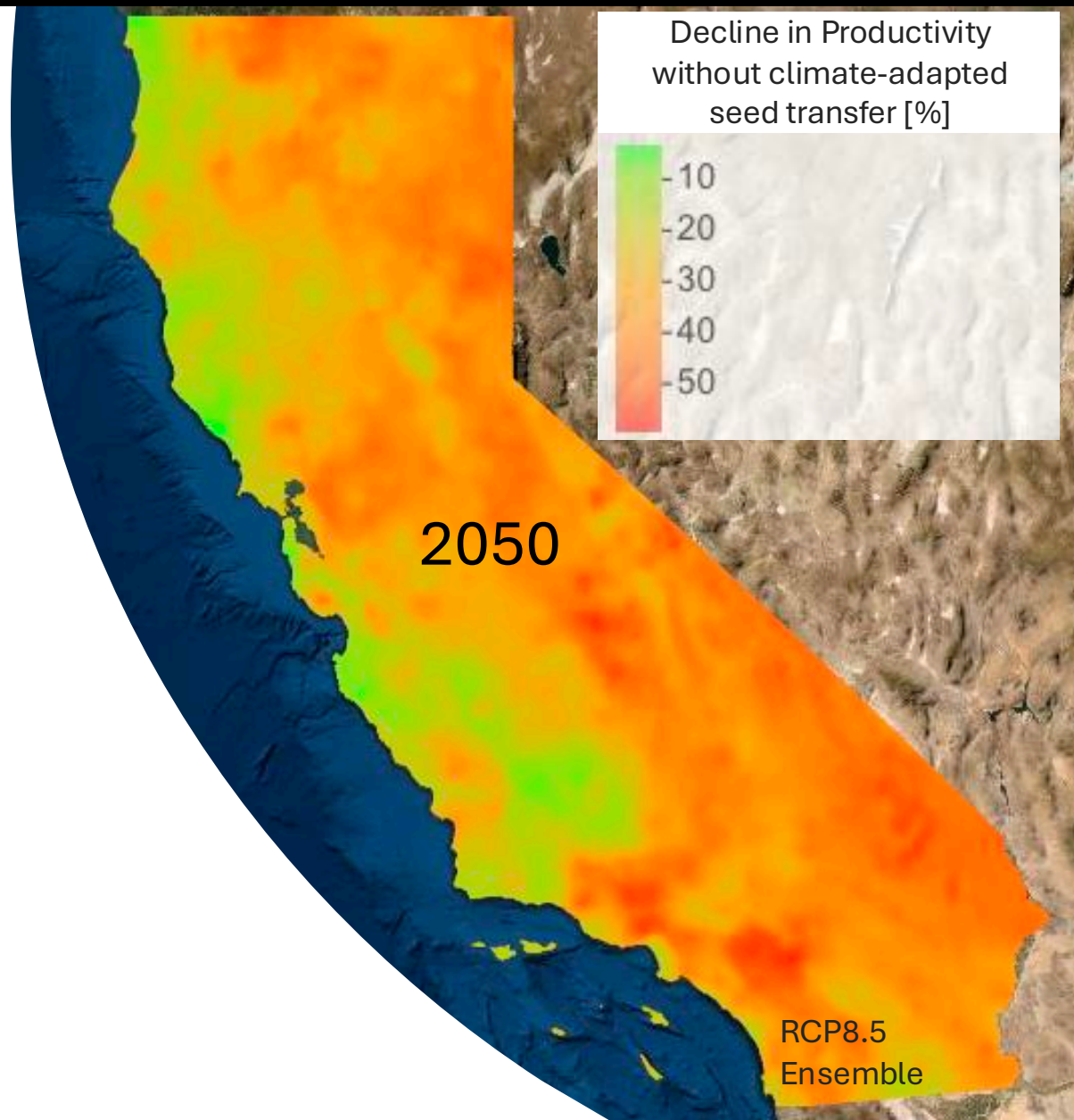


Crisis and Opportunity

Impact of Climate-Adapted Seed Transfer

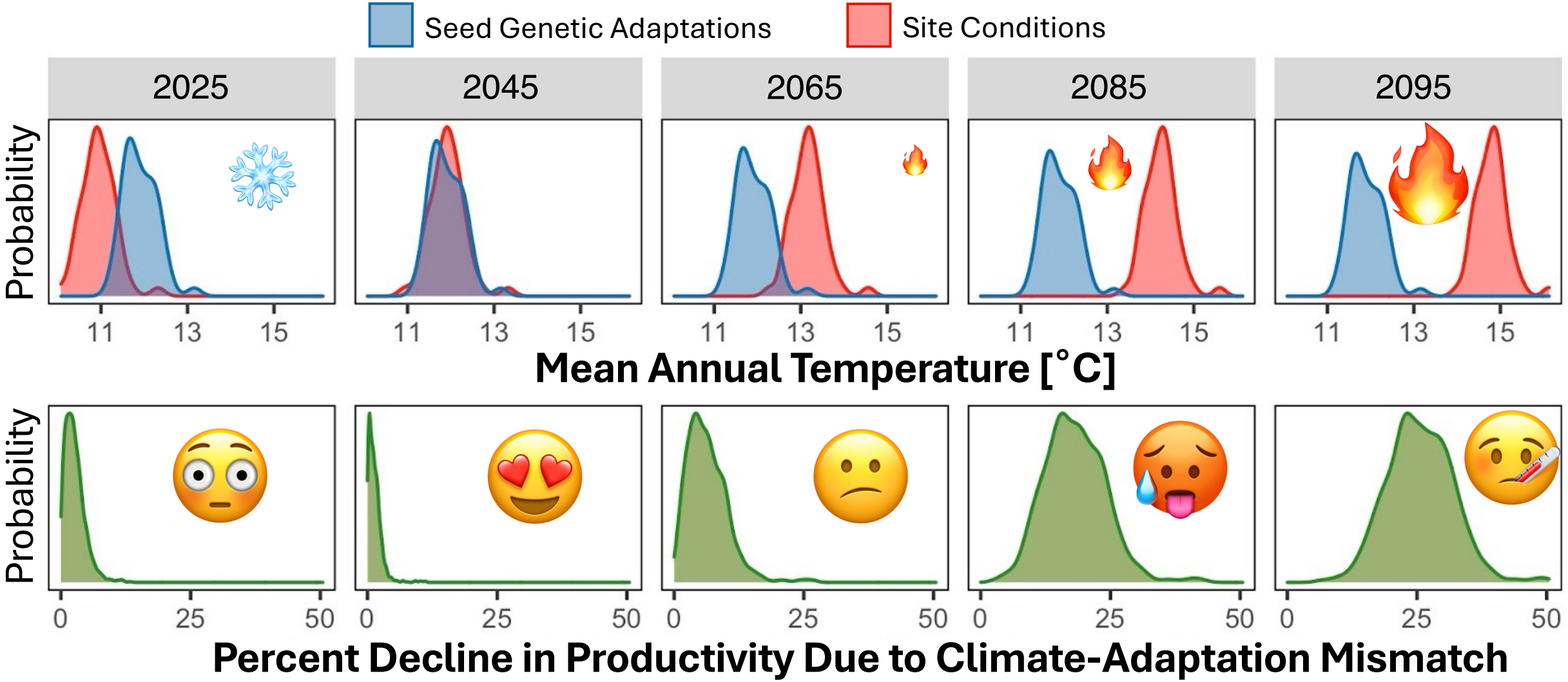
If deployed across private land in CA:

	By 2050	By 2060
Additional CO2 Sequestered [*million* tonnes/yr]	2.3	4.1
Market Value of Additional CO_2 Sequestered [*million* USD/yr]	$77	$138
Percent of net 2018 CA GHG Emissions [%/yr]	.5%	1%
Additional Timber Production [*million* board-ft/yr]	142	256



Climate is a Moving Target

CAST defaults to optimizing for expected climate ≈ 20 years in the future.

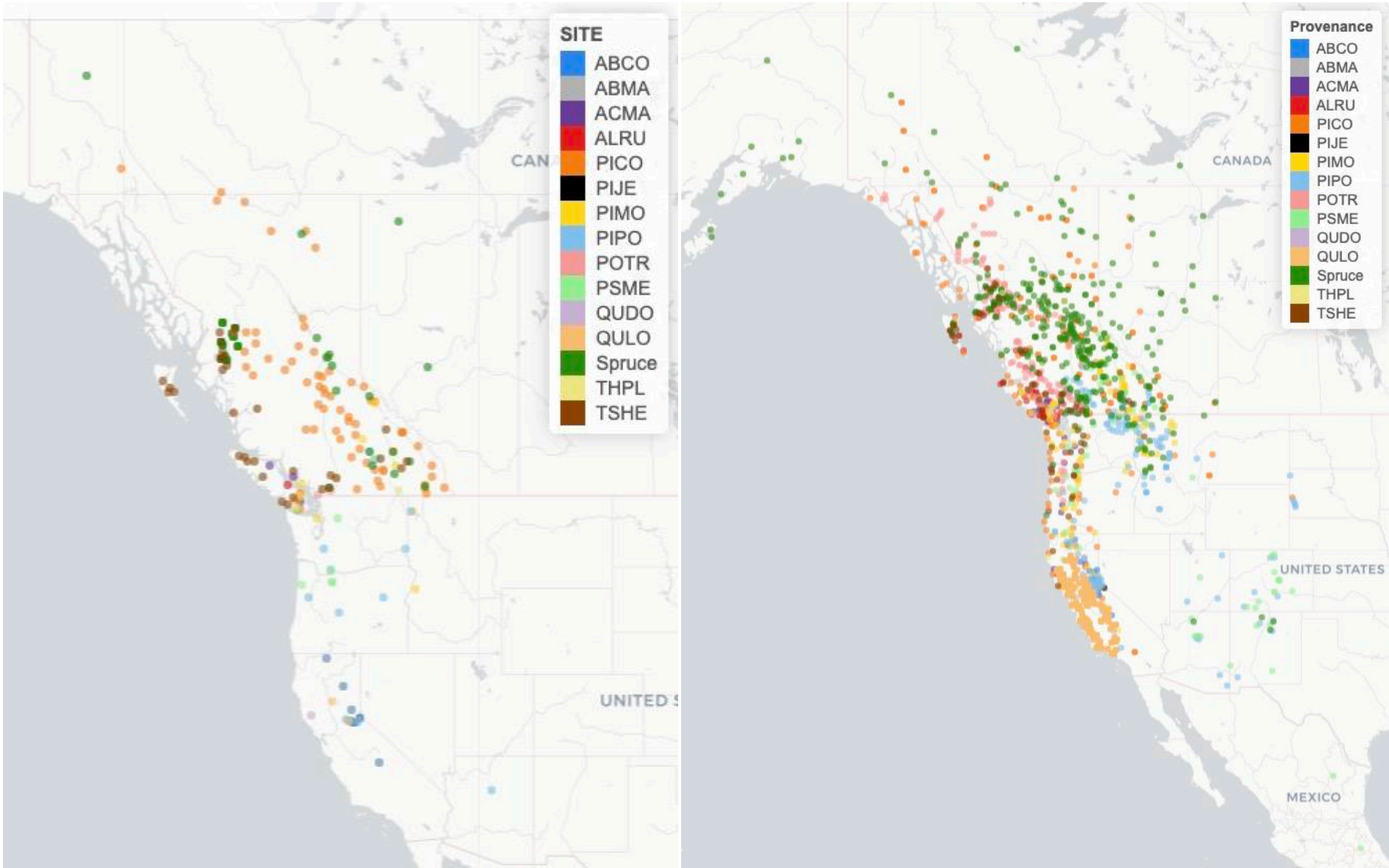


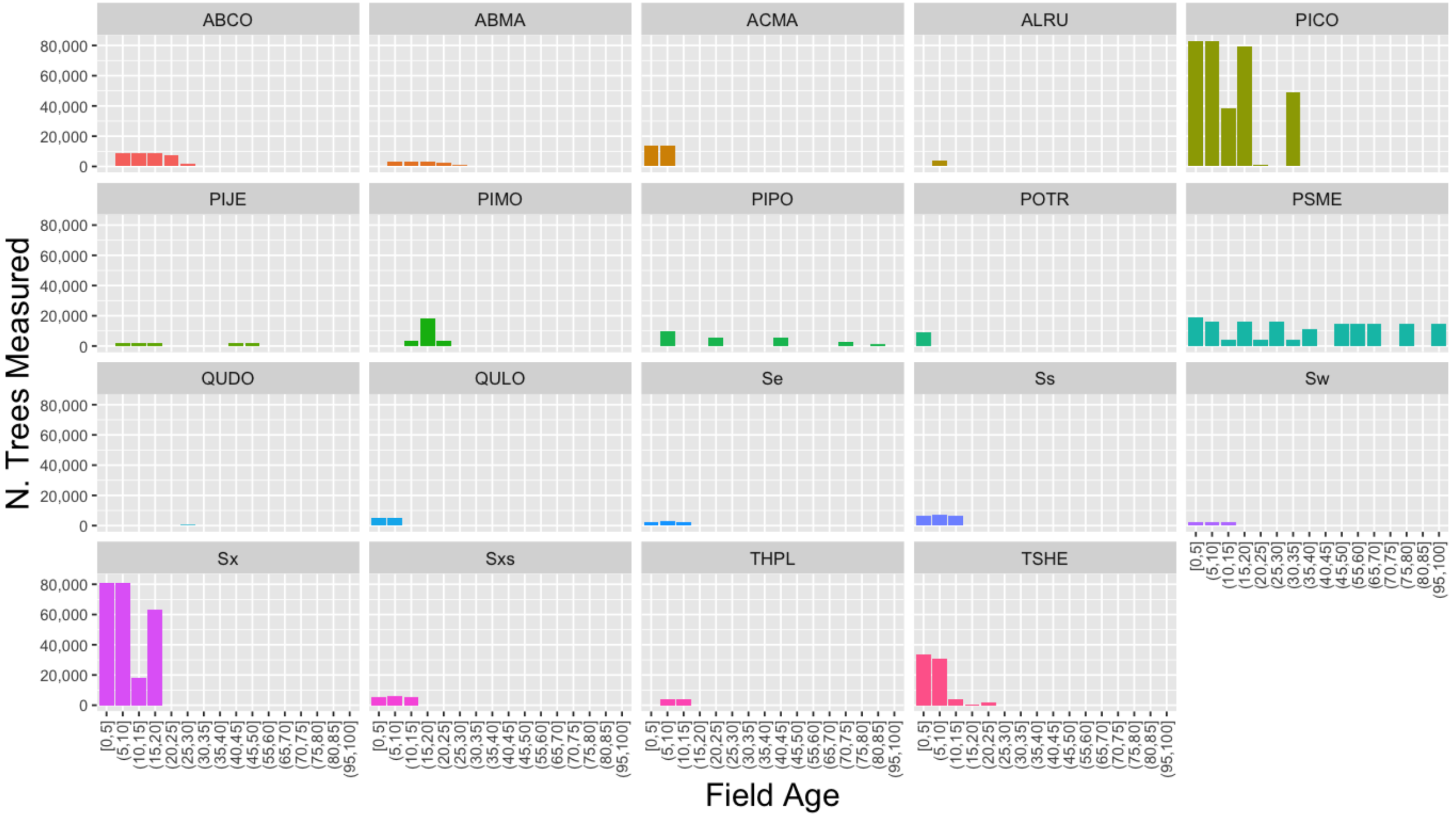
Assembling Common Garden Datasets

Species	abco	abma	acma	alru	pico	pije	pimo	Spruce	pipo	potr	psme	qulo	thpl	tshe
N. Provenances	14	9	43	47	183	3	145	356	187	180	77	658	10	64
N. Sites	5	5	3	2	66	3	8	65	16	3	6	2	6	32
N. Trees	9.1k	3.3k	13.8k	4.1k	90.2k	1.9k	22.1k	101.8k	11.5k	9k	19.5k	6k	4.1k	37.9k
Last Meas. Age [field-years]	18-26	18-26	10	10	6-32	47-48	16-21	10-16	3-80	3-5	35-99	6-9	15	5-25
Planting Year(s)	1975-1978	1975-1978	2008-2009	1995	1972-1974	1972-1974	1984 - 1988	2000-2005	1910 - 1992	2000-2007	1915-1975	2014	1991	1993-2001

Assembling Common Garden Datasets

- All data are now in common format!
- ≈ 350,000 trees, 15 species, measured for up to ≈ 100 years.




ABCO
ABMA
ACMA
ALRU
PICO
PIJE
PIMO
PIPO
POTR
PSME
QUDO
QULO
Se
Ss
Sw
Sx
Sxs
THPL
TSHE
80,000
60,000
40,000
20,000
0
N. Trees Measured
[0,5]
(5,10]
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(20,25]
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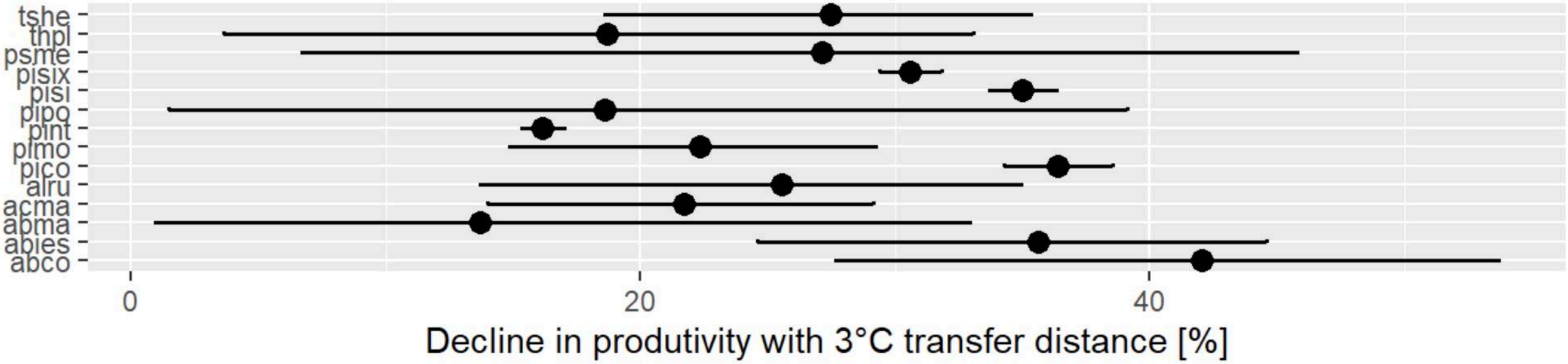
(30,35]
(35,40]
(40,45]
(45,50]
(55,60]
(65,70]
(70,75]
(75,80]
(80,85]
(95,100]
Field Age

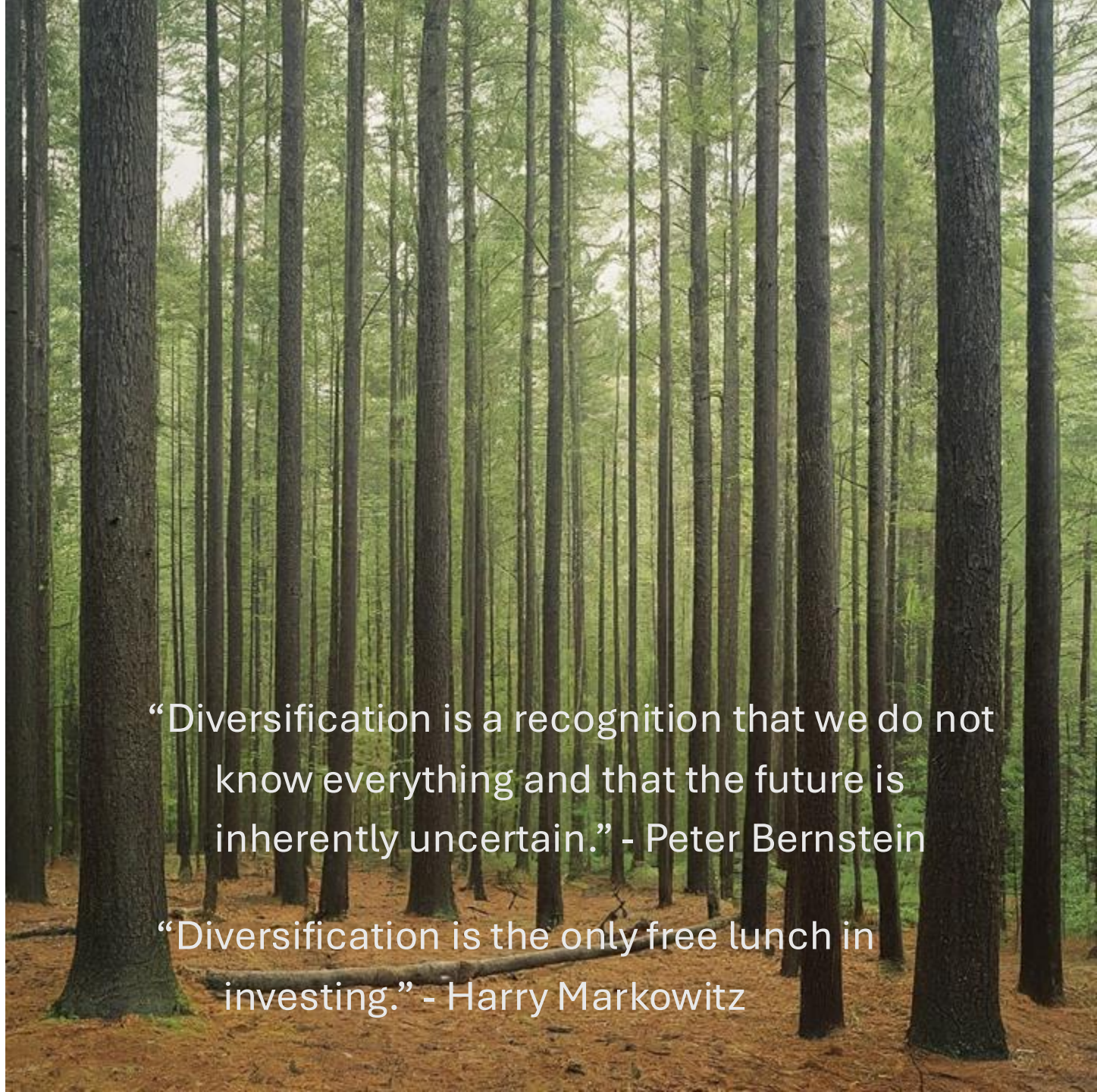
Differences between species?



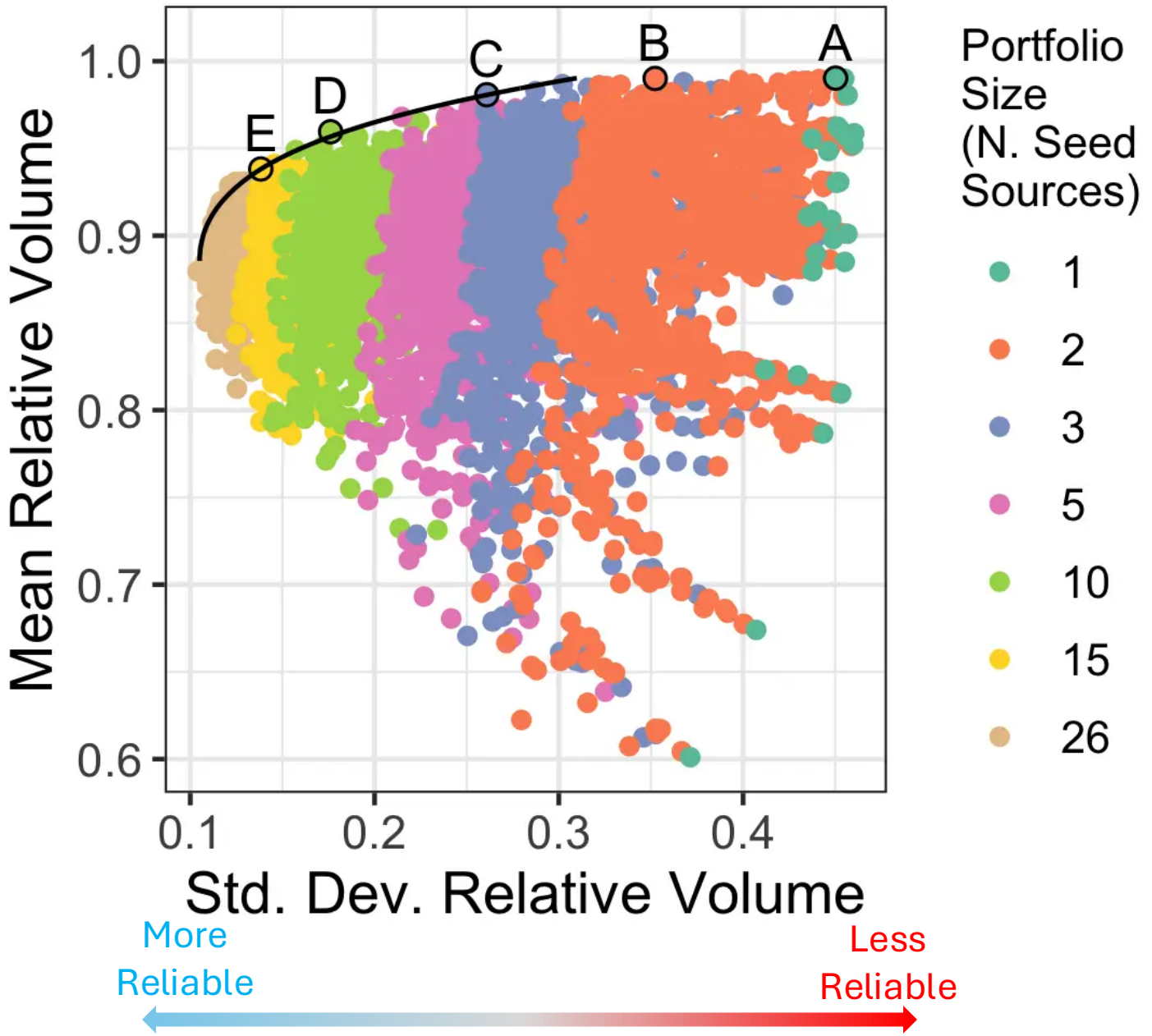
- Simplified analysis (e.g., focusing on mean annual temperature only).
- In this context there do appear to be differences between species, but 95% CIs often overlap.
- Preliminary analyses indicate multidimensional climate transfer functions perform well in leave-one-species-out cross validation.
- Working hypothesis is that while differences between species are important, there is more commonality than difference in transfer functions and local adaptation to climate.

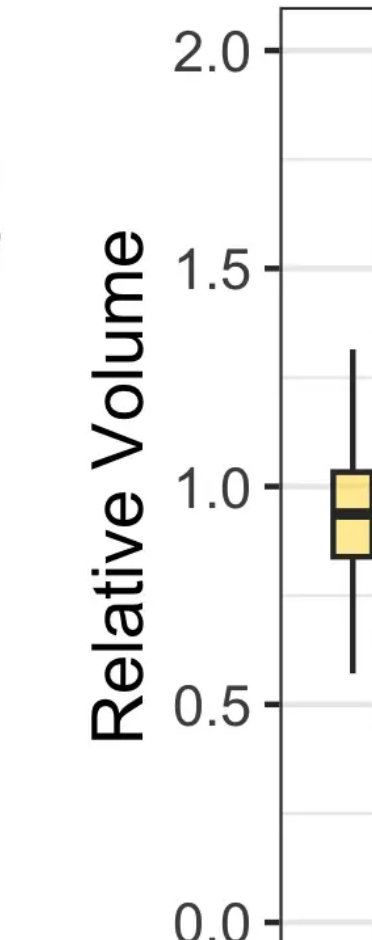
Diversification

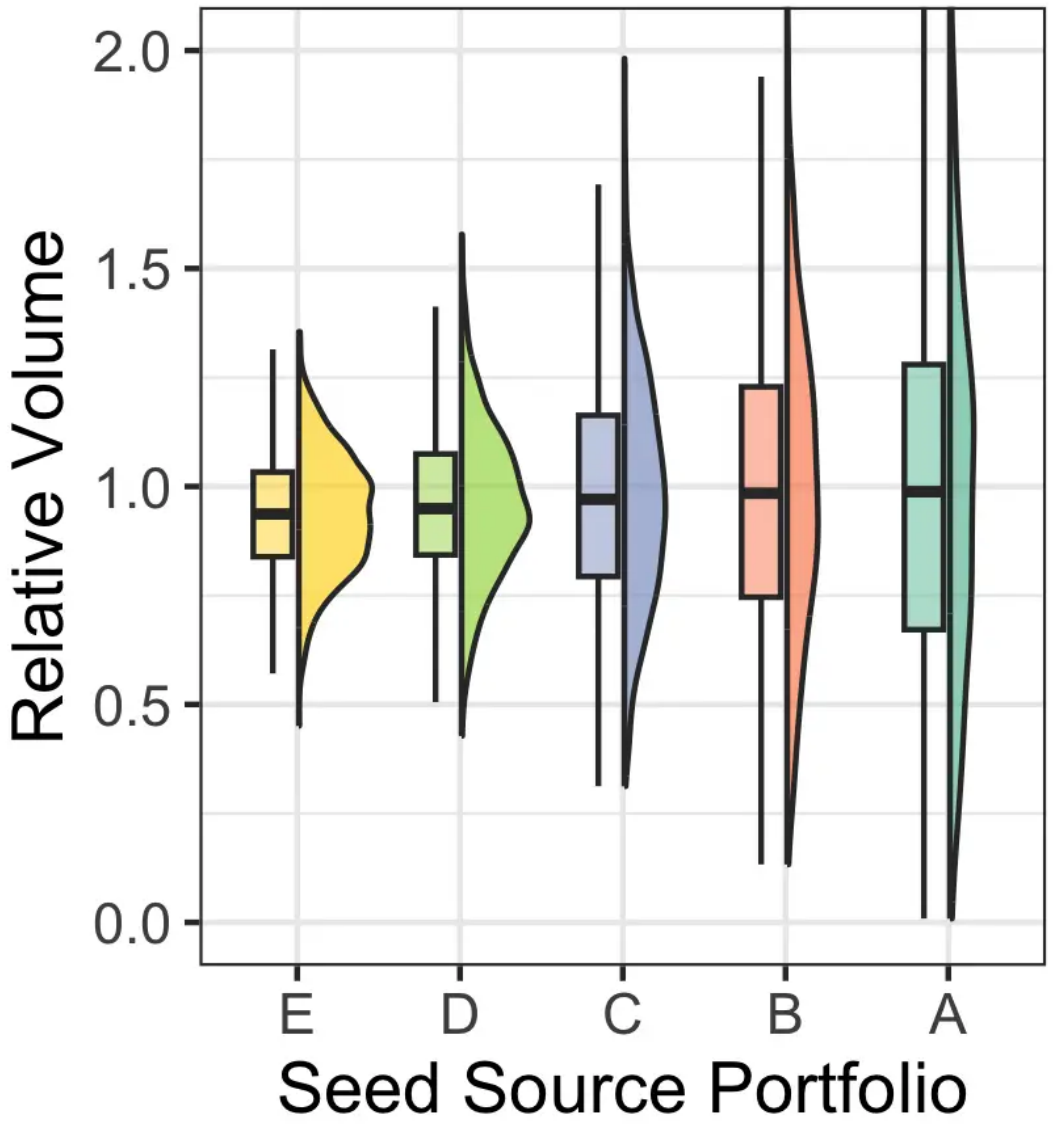
- Reduced risk and increased resilience to to future climate uncertainty.
- More consistent growth and survival.
- Can be tailored to specific goals and risk tolerances.



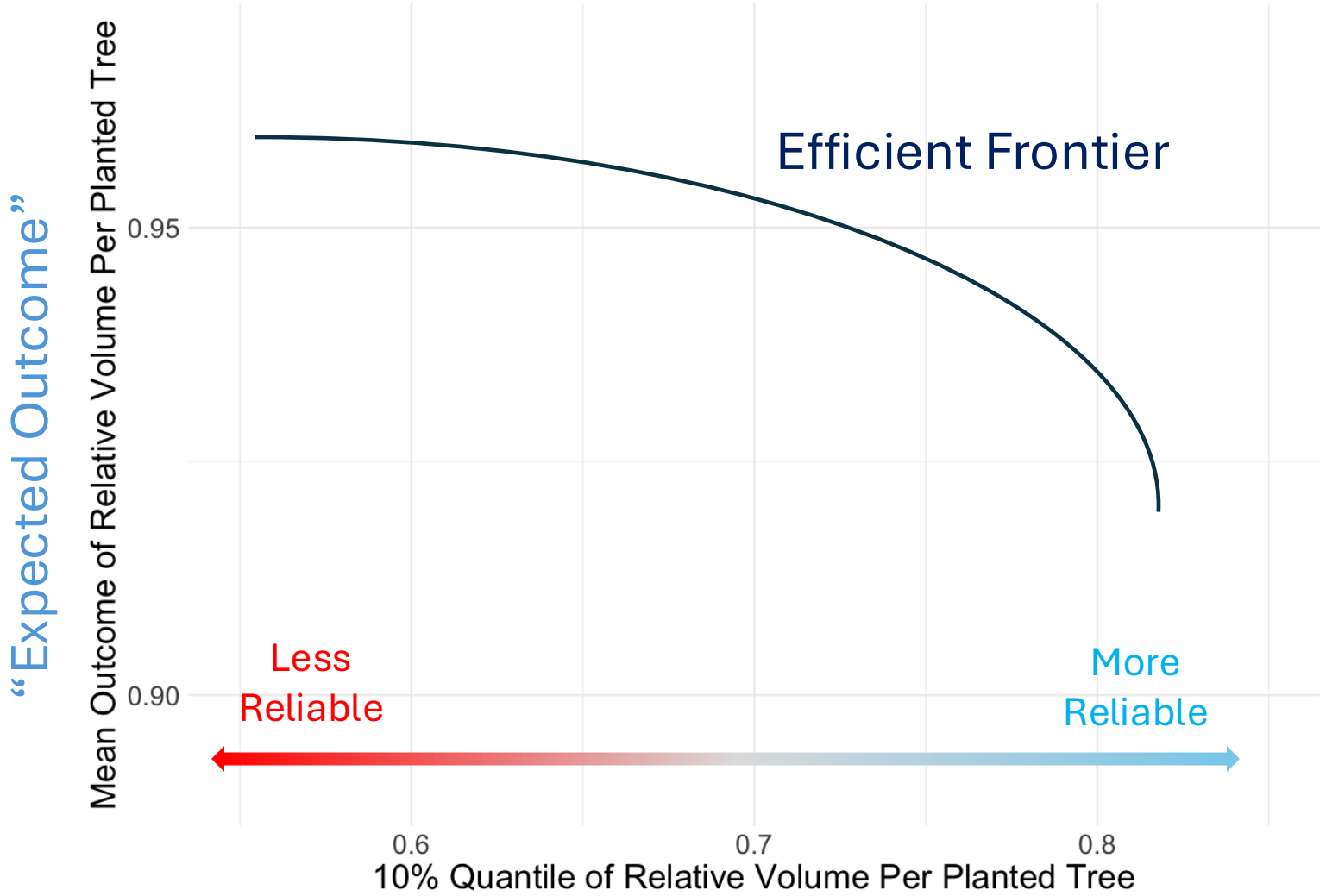
Diversification







How to present risk level to users?



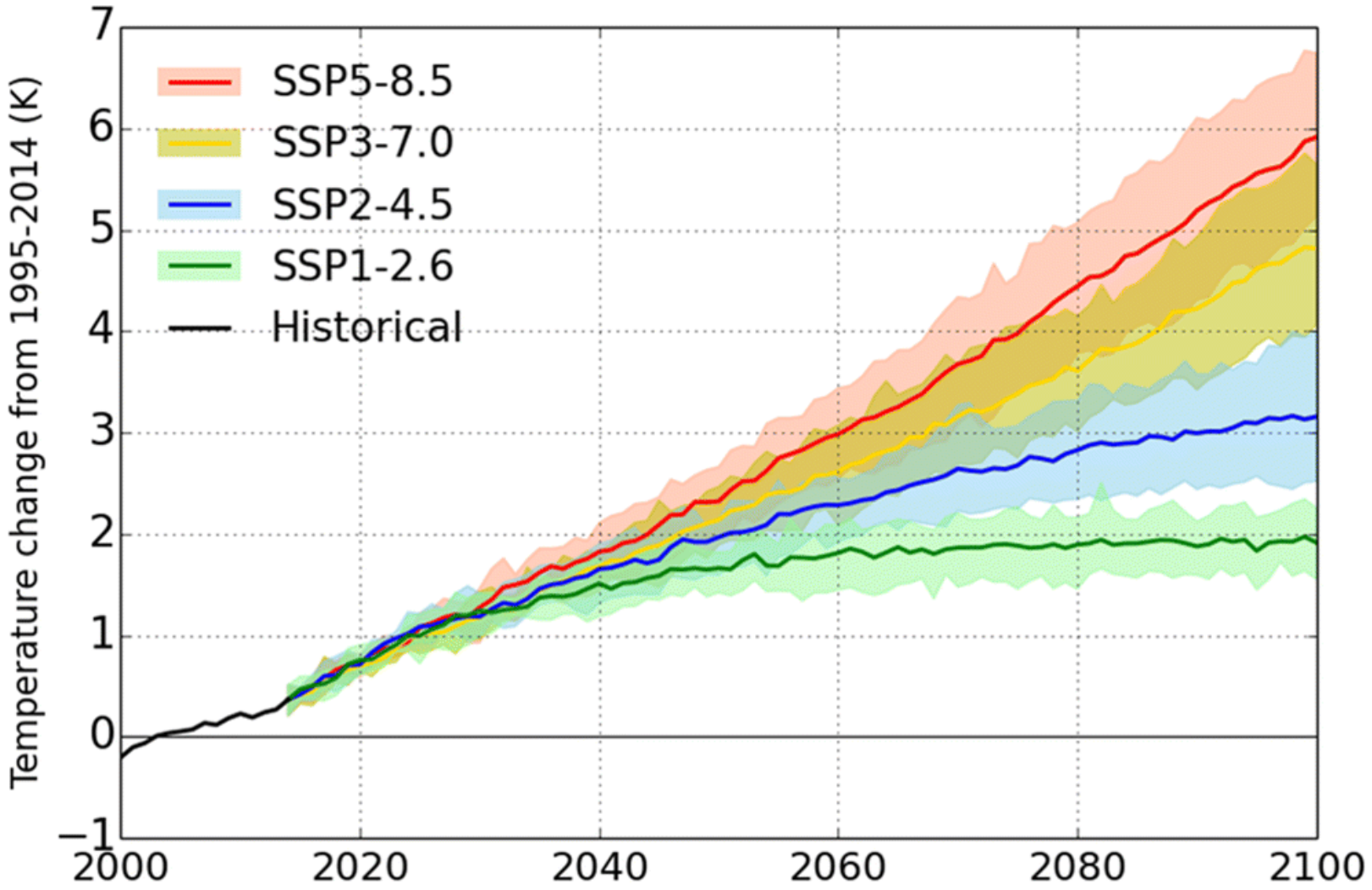
Academic research indicates most people have:

- Intuitive understanding of quantiles.
- Poor grasp of standard deviation and probability density.

"Unfavorable Outcome" / "10% Worst Case Scenario" / "There's a 90% chance that your outcome will be better than this and 10% chance your outcome will be worse."

Sources of Uncertainty

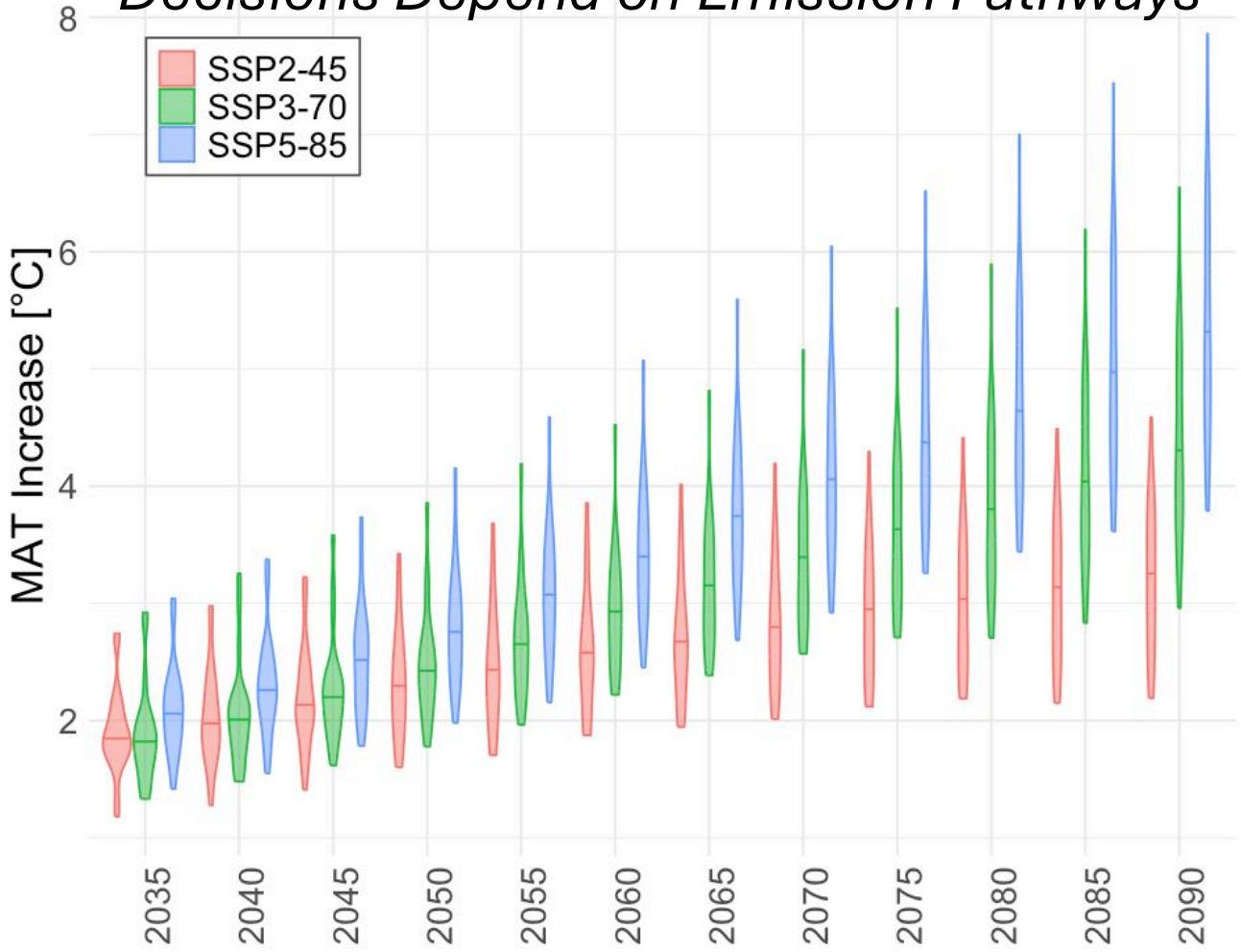
- Climate
- Geographic
- Model
- Sampling



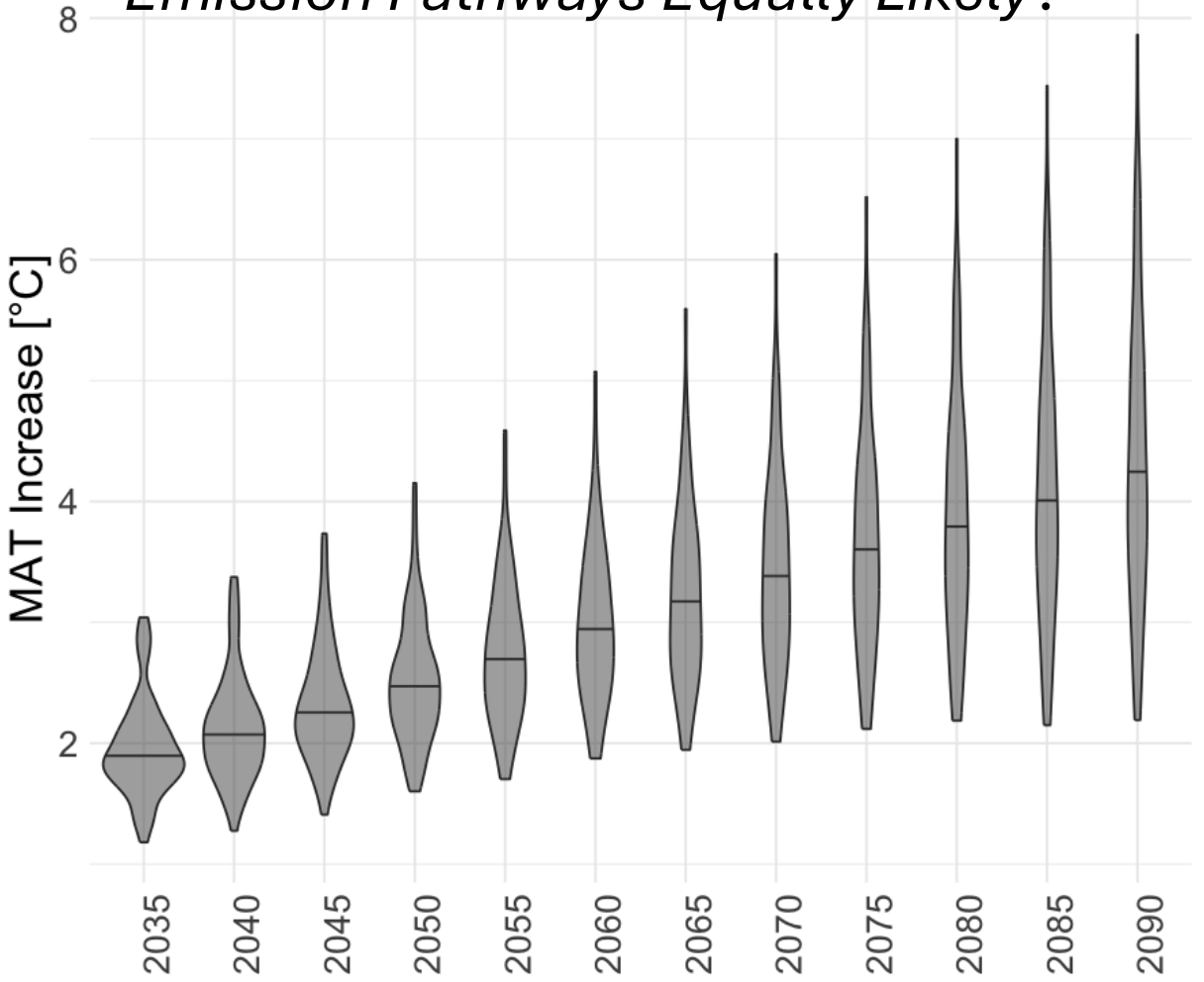
Sung et al 2021

Future Climate Uncertainty

Decisions Depend on Emission Pathways



Emission Pathways Equally Likely?



Future climate uncertainty approximated by:

- Sampling from scenarios (*e.g.*, 21 GCMs x 3 SSPs)
- Multivariate skewed normal distribution fit to scenarios.
- Synthetic scenarios from multivariate skewed normal distribution.

Change from Historical Climate

Sources of Uncertainty

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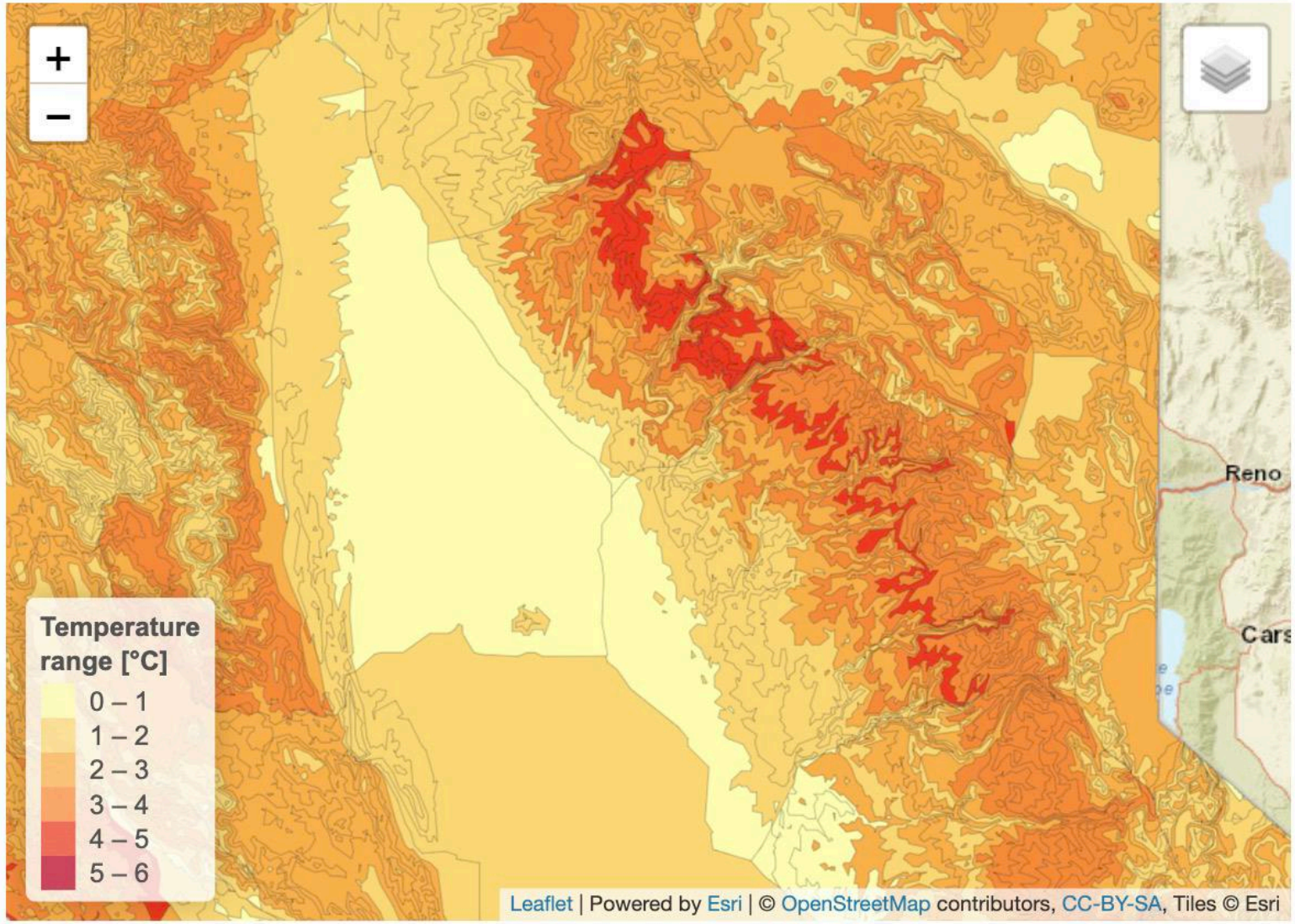
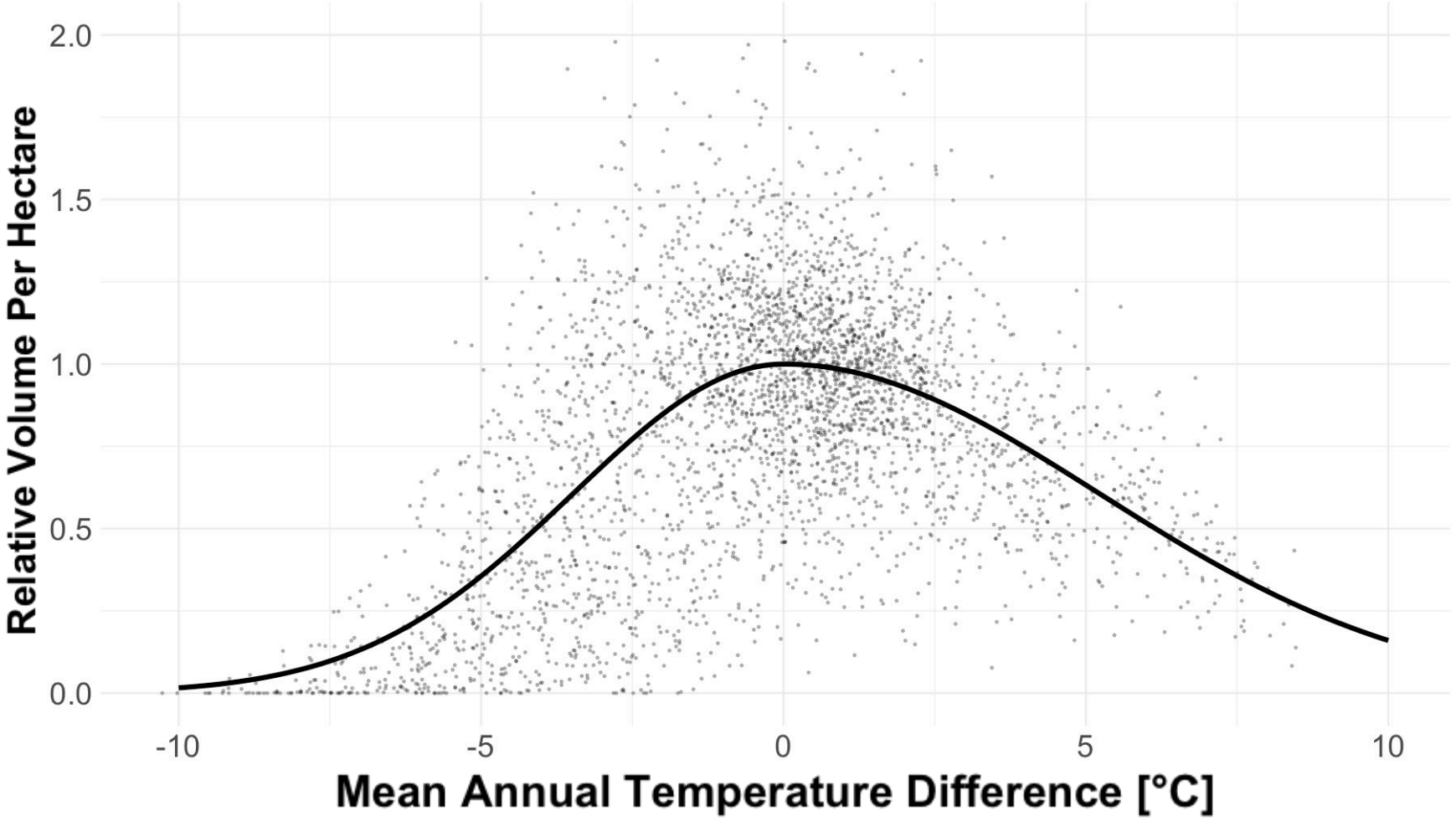
Seed Zone-elevations-bands are climatically heterogenous



Sources of Uncertainty

- Climate
- Geographic
- Model
  - Residual
  - Spatially Correlated Residuals
- Sampling

Statistical models provide accurate predictions of mean outcomes.
Predictions for individual combinations of seed source and planting site are imprecise.



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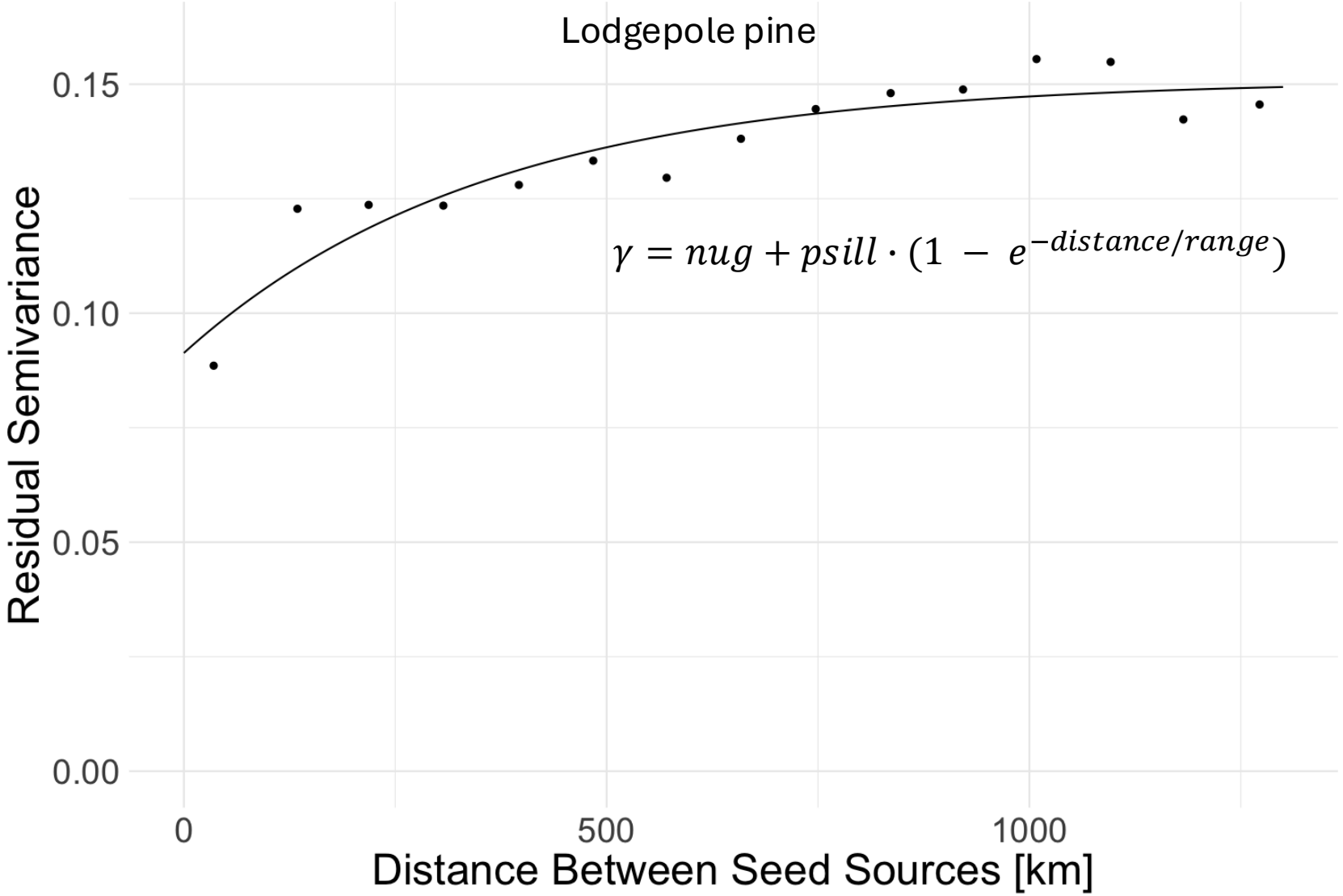

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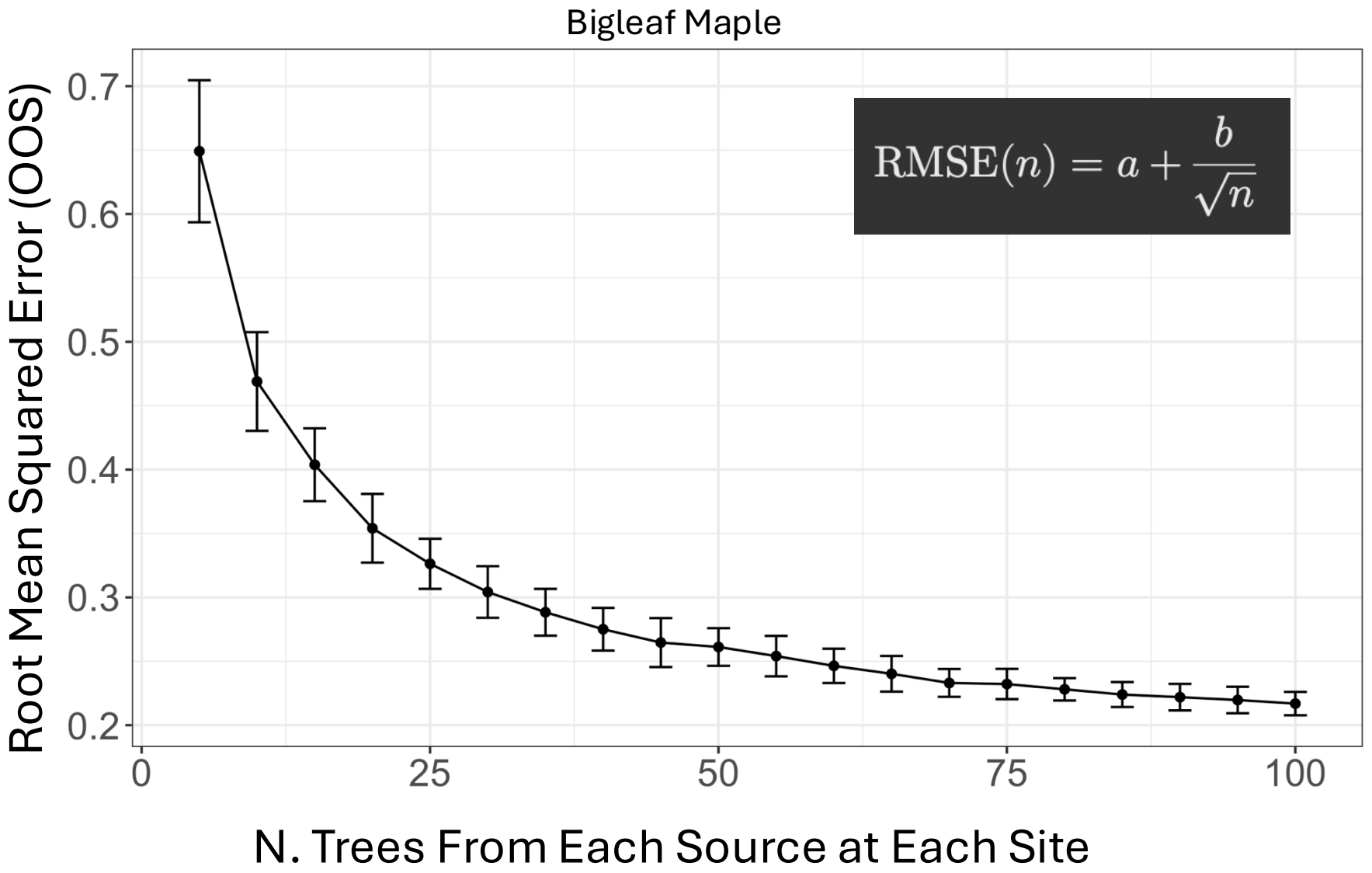
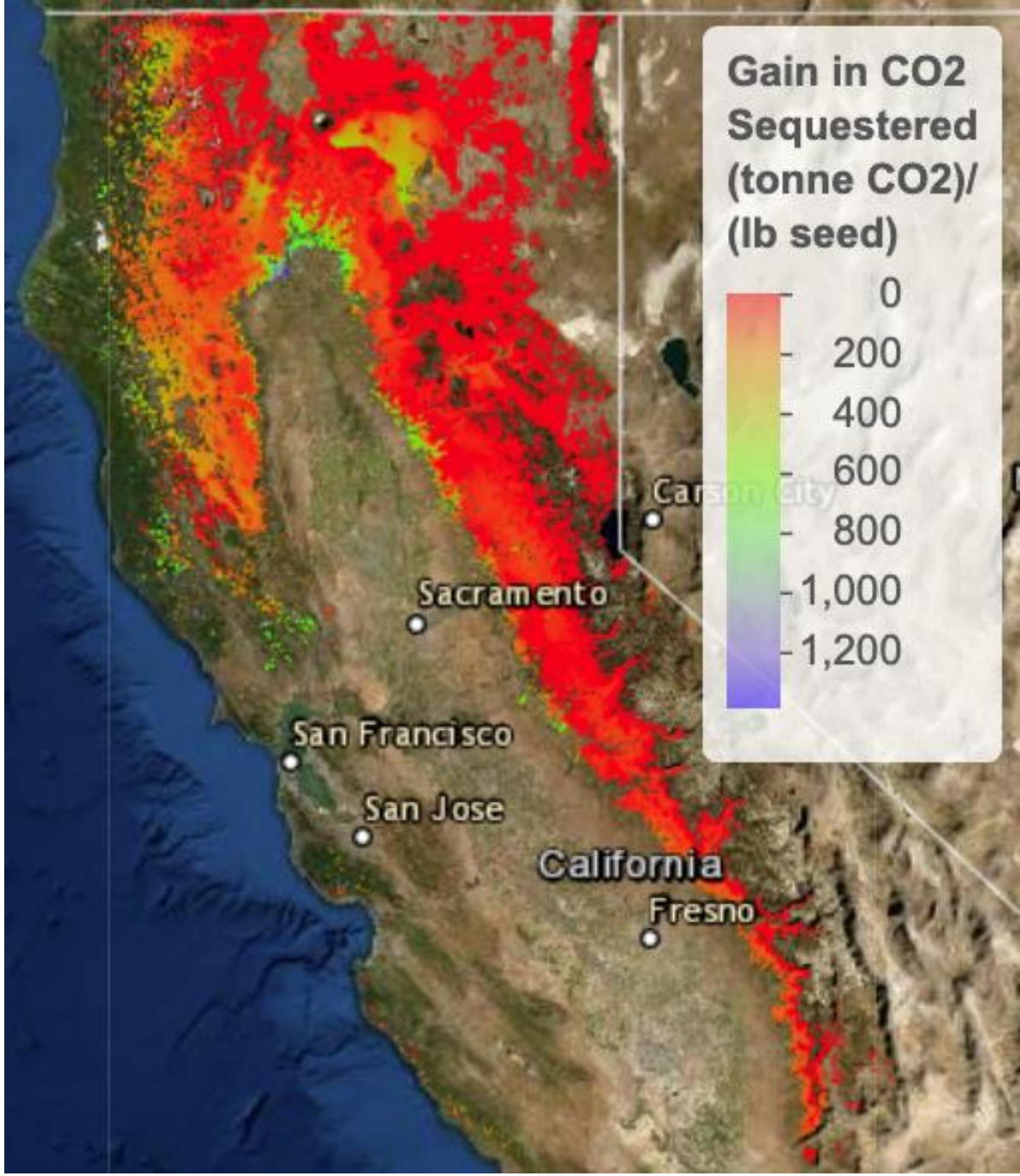


Progress on CAST Portfolio Reliability Optimizer

Source of Uncertainty	Status
Climate	Accounted For
Geographic	Accounted For
Model	Accounted For
Spatial autocorrelation	In progress
Sampling	In progress

Climate-Adapted Seed Collection Prioritization

- Prioritize collection locations with metrics that are directly relevant to management (gain in CO2 sequestered, timber produced).
- Optimize collection for deployment to full range of potential planting locations (probabilistic).
- Big differences in benefit of seed collection within seed zone elevation bands.



Ponderosa Pine; First 100 lb of seed collected

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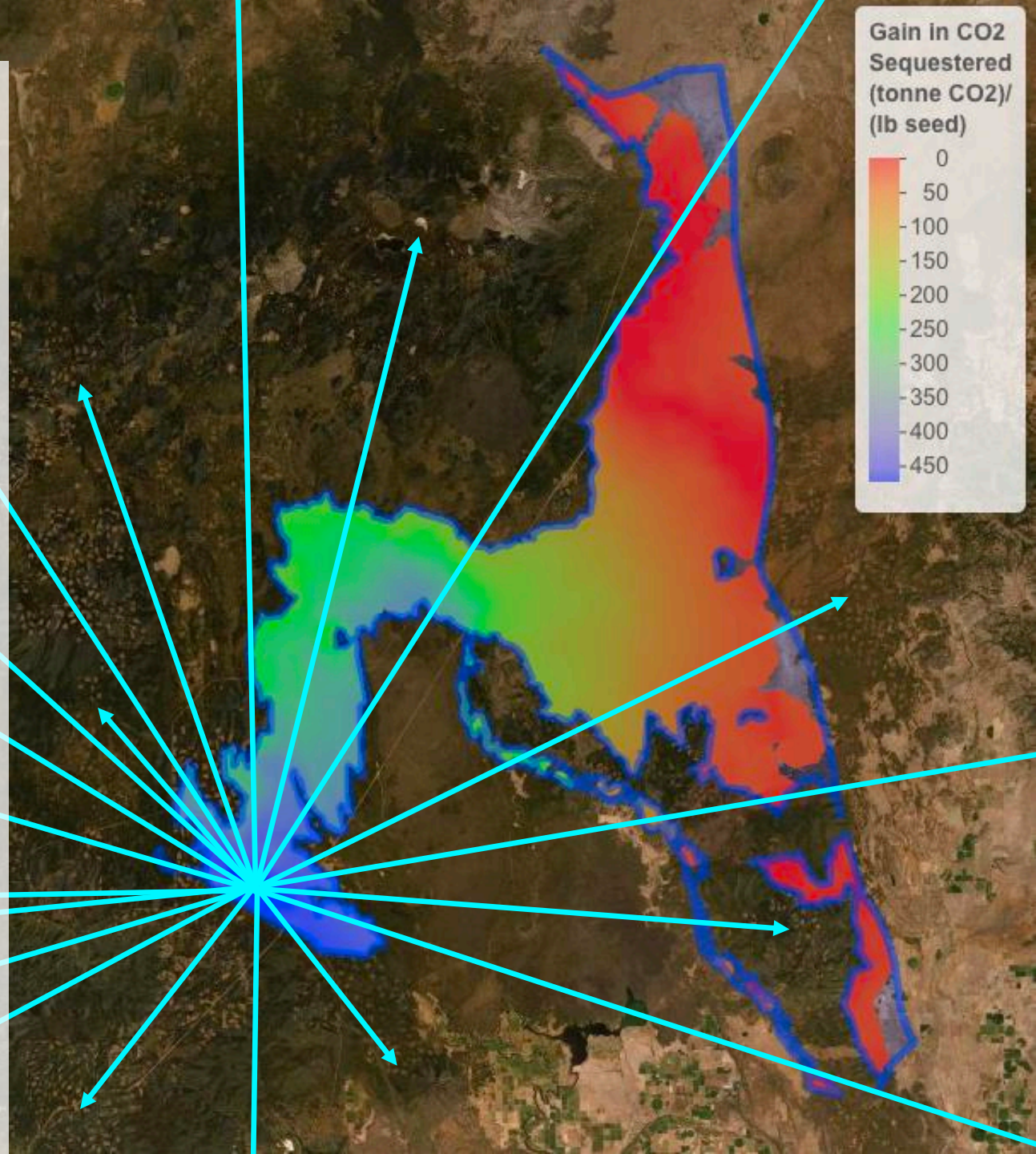

www.reforestationtools.org/ucop_stakeholder