# Forestry in a Changing Climate: What Do We Know and How Can We Mitigate Future Climate Risks?

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# What Factors Affect Forest Survival and Growth

**Tree Growth is Influenced By:**

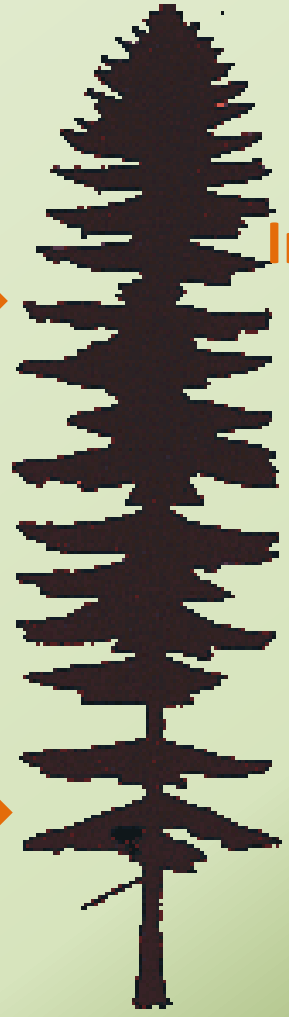
The Genetic Characteristics of Individual

X

The Environment Under Which the Individual is Grown

X

Biotic Factors



The Various Interactions Between These Factors Influence Growth

OR

# Different Plant Genotypes Possess Different Combinations of Traits

- For each species or individual genotypes within a species, different combinations of morphological and physiological traits influence growth and survival.

# Physiological and Morphological Mechanisms Influencing Survival and Growth

**Key process related functions affecting growth include:**

- **Differences in tree phenology, leaf area growth and morphology.**
- **Leaf and whole-tree photosynthetic capacity.**
- **Individual tree respiration rates.**
- **Key differences in specific biochemical pathways.**
- **Stomatal morphology and behavior.**

# Physiological and Morphological Mechanisms Influencing Survival and Growth

**Key structural factors affecting growth include:**

- **Total leaf area, leaf area duration, and leaf area display patterns.**
- **Root morphology and root allocation patterns.**
- **Total tree leaf area, branch, stemwood, and root allocation patterns.**

# Macro-Climatic Variables Affecting Forests

- Annual and seasonal precipitation patterns
- Length of the growing season.
- Growing season light availability.
- Absolute minimum and maximum temperatures affecting species distributions.
- Seasonal temperatures fluctuations.

# Macro-Climatic Variables Affecting Forests

- Growing season temperature regimes that affect respiration rates.
- Vapor pressure deficits during the course of the growing season.
- Atmospheric $CO_2$ concentrations.

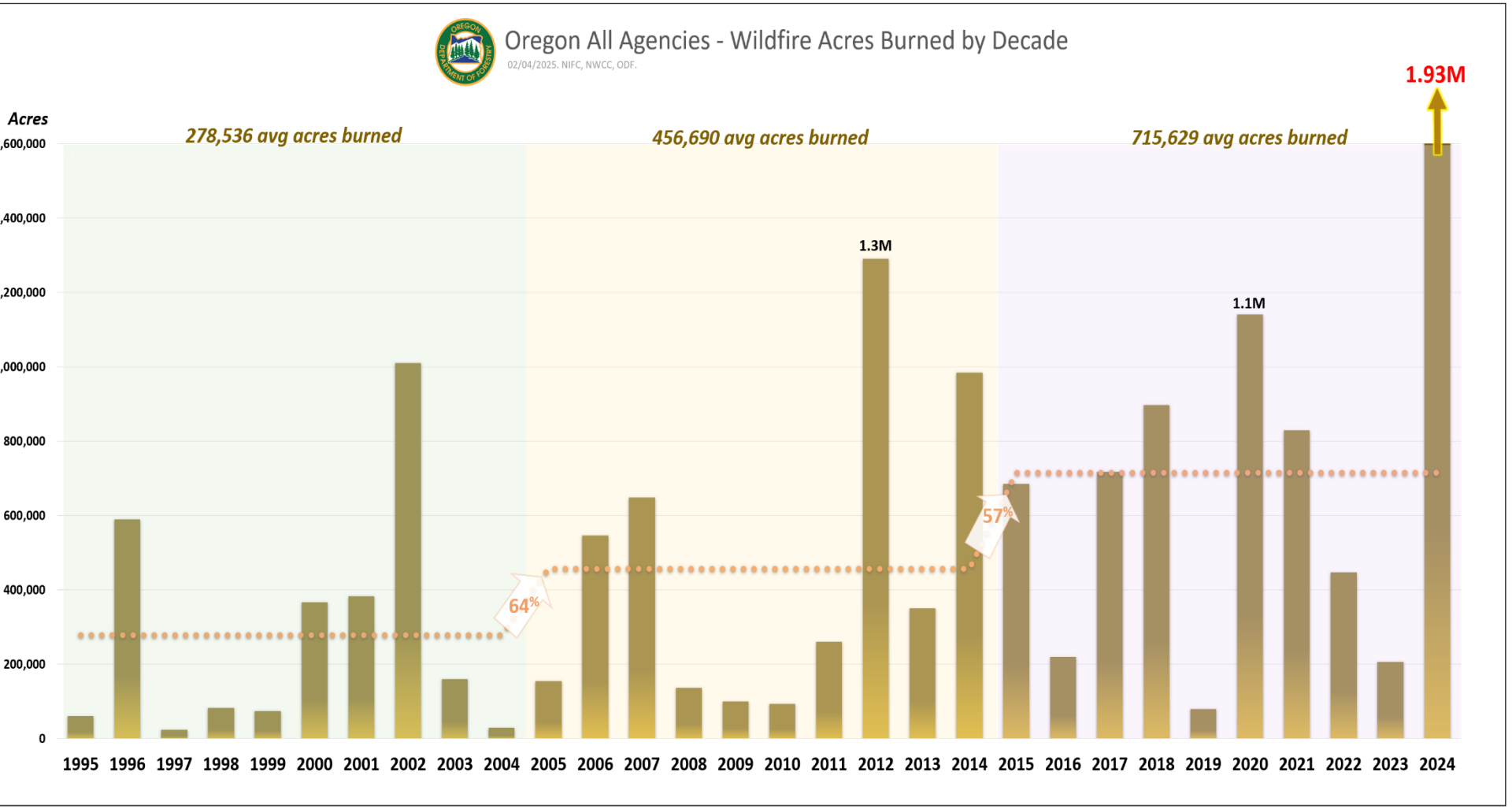
# How Much Has Climate in the PNW Been Altered to the Present Time?

- Global $CO_2$ concentrations are increasing. From 1850 to present, increased from 280 ppm to 420 ppm.
- From 1895 to present, average warming of 1.3°F has occurred.
- Slight increases in precipitation have occurred (10% increase overall, but 30-40% in Eastern WA and Northern ID).

# How Much Has Climate in the PNW Been Altered to the Present Time?

- Very slight increases in sea levels (1.5 to 2 mm per year, 0.6 to 0.8” per decade).
- Decreased winter snowpack.
- Increased growing season length by an average of 35 days across the region.

# Fire Frequency in Oregon Has Increased Over the Last 30 Years

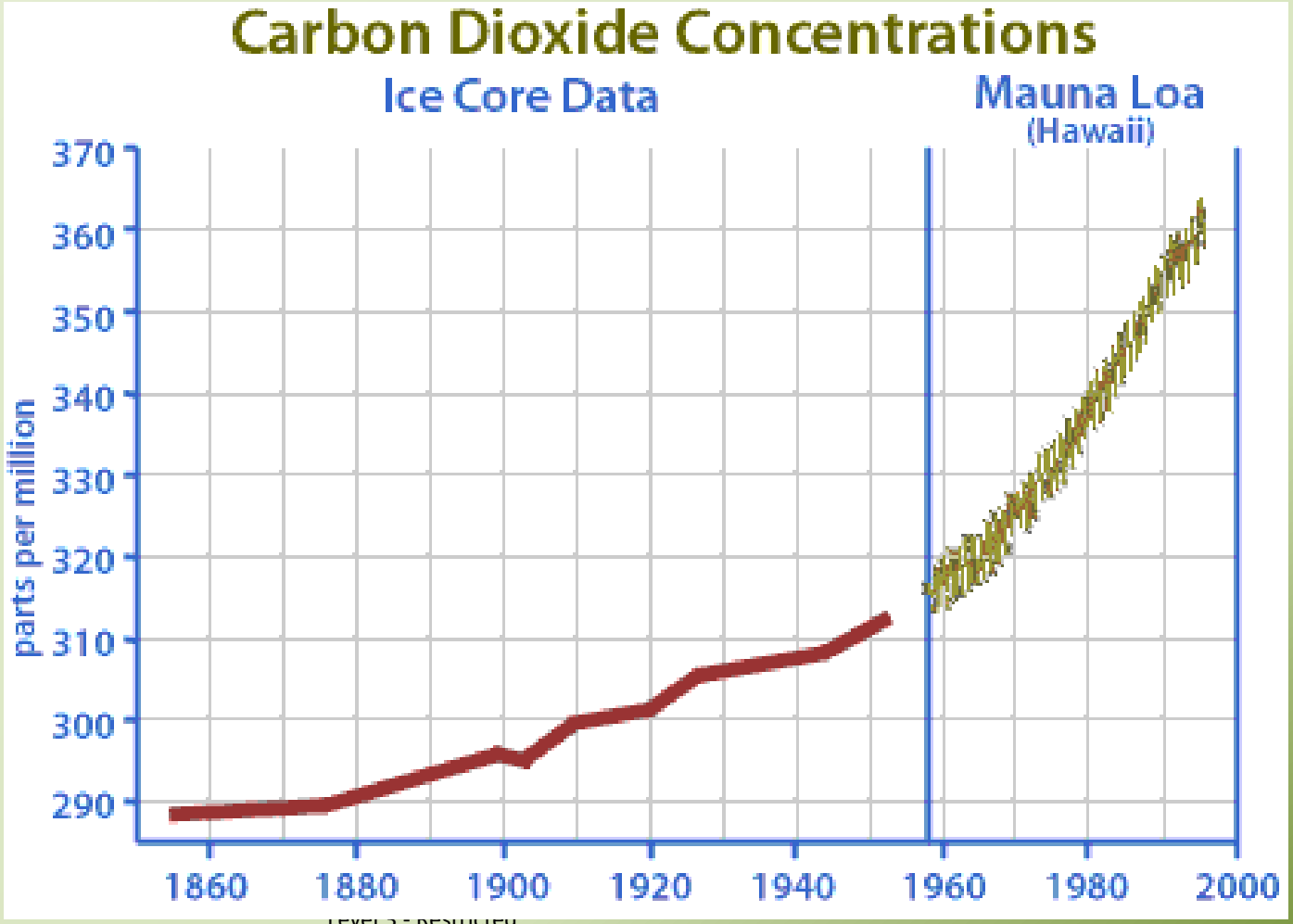


# Climate Change Assessments: Caveats

- Any projected changes are highly dependent upon the model selected and the data inputs into individual models.
- Model Projections can vary widely. Consistency is often lacking.

# Changing Global $CO_2$ Concentrations From 1850 to 2000

**Atmospheric carbon dioxide concentration has risen from pre-industrial levels of 280 ppm to over 420 ppm in 2024.**



# Climate Change Assessments: Caveats

- Global Carbon models are not particularly "tight". Inputs and pools sizes do not balance.
- Averages may be less important than extremes
- Natural climate variations does occur. "Little Ice Age" from 1300-1850. Estimated to have decreased global temperatures on 1.4°F.

# How Much Has Climate Changed and What Are Future Climate Projections?

# Little Ice Age: Effects on History

- Severe winters and abnormally cool spring, summers, and falls persisted from the early 1300's to mid 1800's.
- Believed to be the underlying cause of the Great Irish Potato Famine sparking emigration to the US.
- In the US, declining agricultural productivity in New England sparked westward expansion.
- Eventually led to the concept of Manifest Destiny for America.
- Washington wintering at Valley Forge and crossing the partially frozen Delaware River during the Revolutionary War.

# Little Ice Age: Effects on History

- Sparked food shortages and increased unrest in Europe and across the globe.
- Food shortages and malnutrition may have exacerbated the effects of the plague in Europe in the 1350's.
- Viking settlements in Greenland failed after 400 years of settlement. Last wedding recorded in 1408. Settlements were unable to adapt to worsening climate.
- French Revolution was sparked in part by food shortages caused by crop failures related to particularly bad growing seasons during the late 1780's and 1790's.

# Little Ice Age:Effects on History

- Mary Shelly wrote “Frankenstein” during the cold summer in Geneva, Switzerland with the overall feeling of the cold, wet climate being captured in the book.
- The wood used in violins, particularly Stradivarius violins, is believed to have been harvested from trees that grew during the Little Ice Age. The Little Ice Age created wood with unique properties that contribute to the instruments' sound quality.
- During Roman settlement of Britain, they are a major wine producer. After colder climate change, beer and mead become most significant alcoholic drinks across British Isles because it became too cool for wine production.

# 1812 Was Called The Year Without a Summer

- In New “England “all was froze" and the hills were "barren like winter".
- Temperatures fell below freezing almost every day in May.
- The ground froze on June 9; on June 12, the Shakers had to replant crops destroyed by the cold.
- In New Hampshire, on June 7, "exceedingly cold. Ground frozen hard, and squalls of snow through the day. Icicles 12 inches long in the shade of noon day."
- An abrupt change from summer to winter by August 21, when a meager bean and corn crop were killed. "The fields were as empty and white as October”. .

# Baring Any Other Changes, Increased Atmospheric $CO_2$ Concentrations Will Lead To:

- Increased plant growth rates.
- Increased Photosynthetic rates.
- Increased water use efficiency by altering stomal behavior.
- Preferential allocation to below ground plant tissues. May partially offset drought stress.

# While Rising $CO_2$ Concentrations Will Not Suppress Plant Growth Directly, Growth May Be Limited By:

- Changing rainfall patterns.
- Altered temperature regimes.
- Changes in vapor pressure deficits altering plant water use pattens or plant moisture stress.

# Determining Plant Responses to Rising $CO_2$ Concentrations, Increasing Temperatures, and Altered Precipitation Is Far More Complex

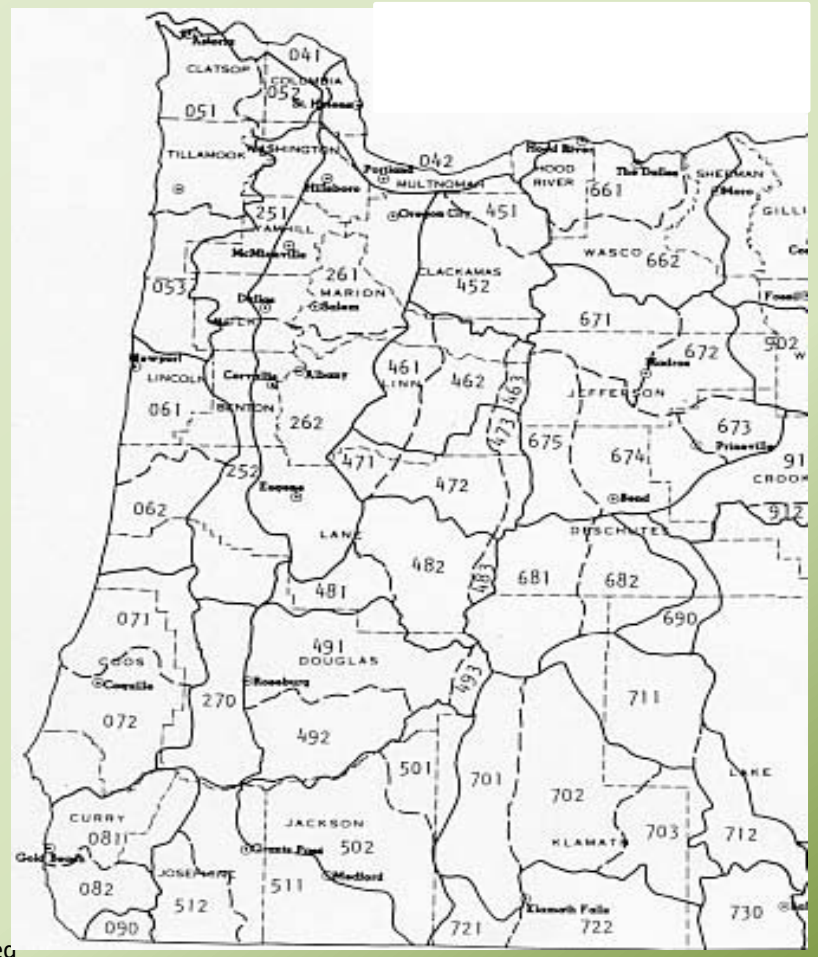
- Exact responses can vary by species and plant ages. Young Forests may respond differently than mature forests.
- Exact responses can be limited by other needed plant resources (growing space, nutrient availability, water availability, etc.)

# History of Tree Improvement in Oregon

- To facilitate the deployment of genetically superior forest tree species, tree improvement programs in the Pacific Northwest were initiated in the late 1950's.
- Tree improvement of Douglas-fir was the first to begin and is generally the most advanced program.
- Other commercially important tree species with active and long-standing tree improvement programs include western hemlock, western red cedar, and ponderosa pine.

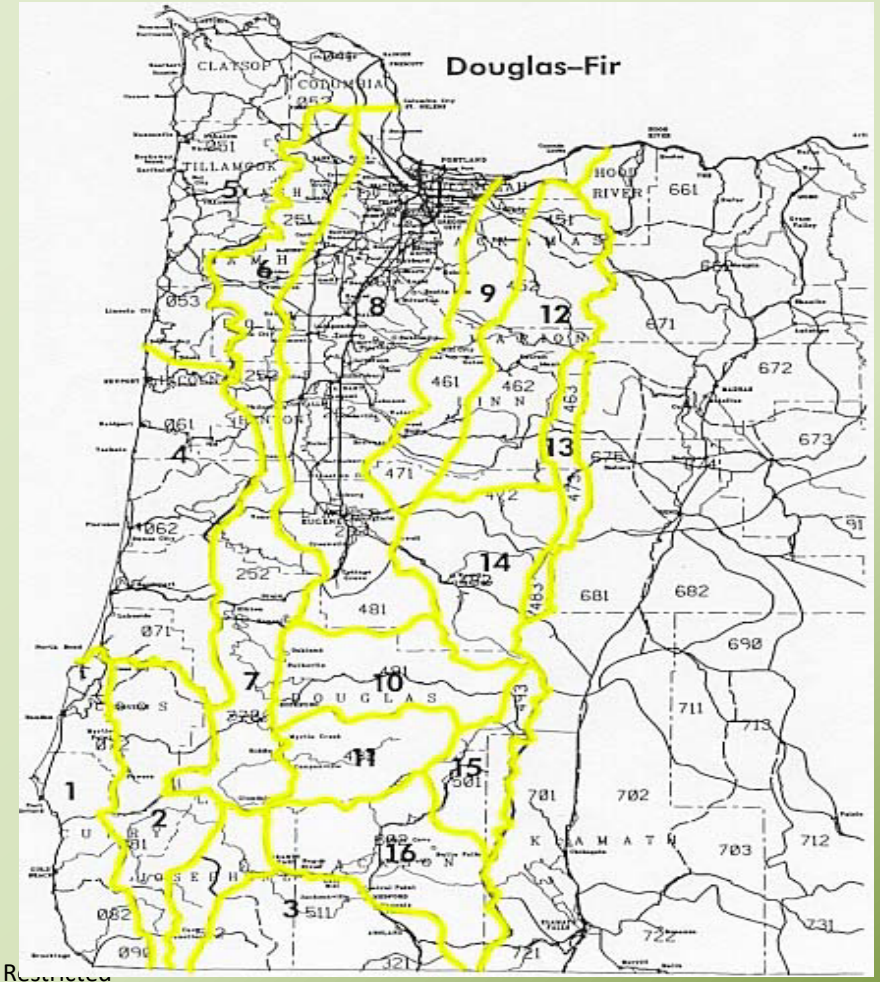
# What are the Appropriate Seed Zones for Douglas Fir?

- **In the early stages of tree improvement work with Douglas-fir, a very conservative approach was taken in defining seed collection zones resulting in 37 different collection zones in western Oregon alone.**

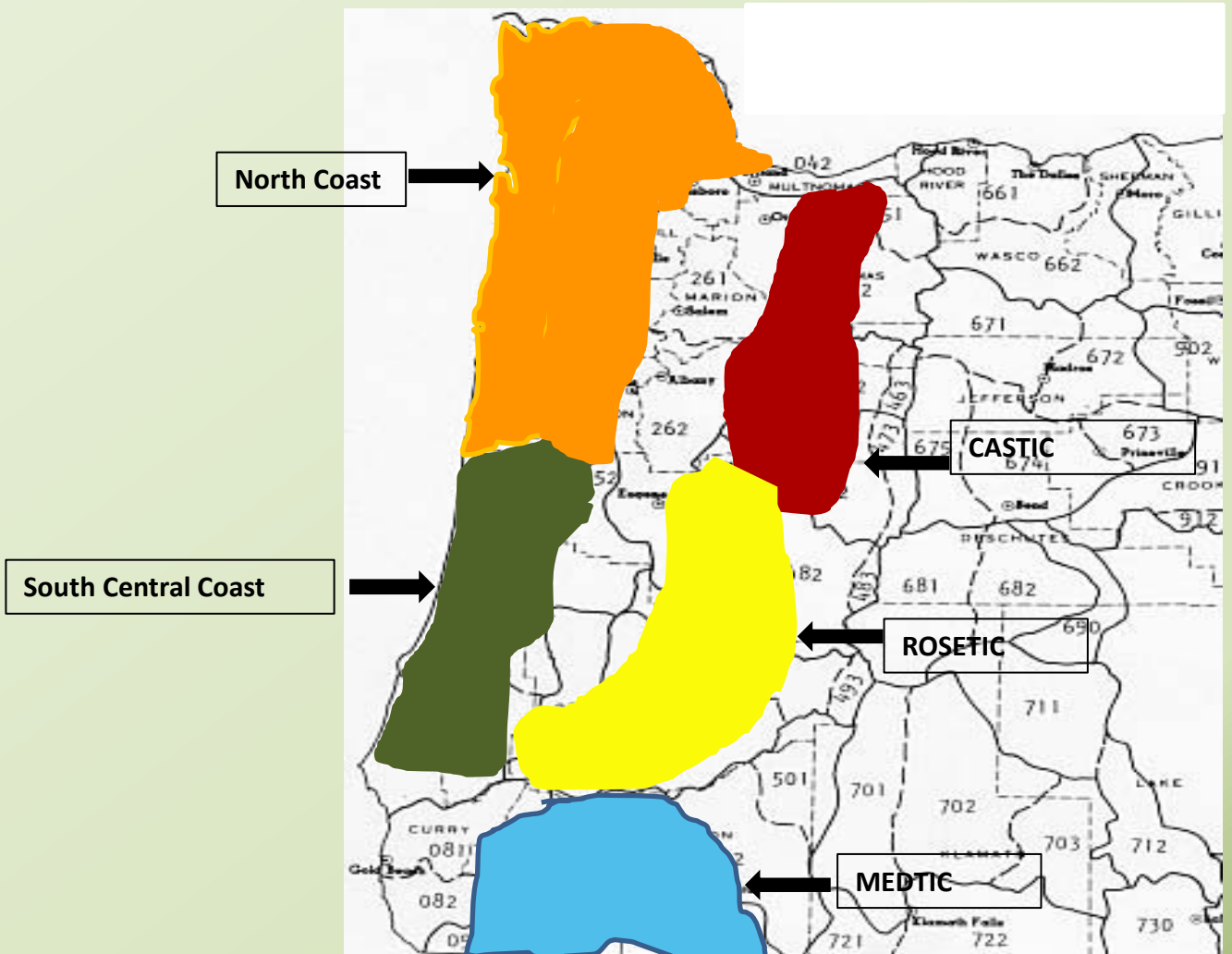


# What are the Appropriate Seed Zones for Douglas Fir?

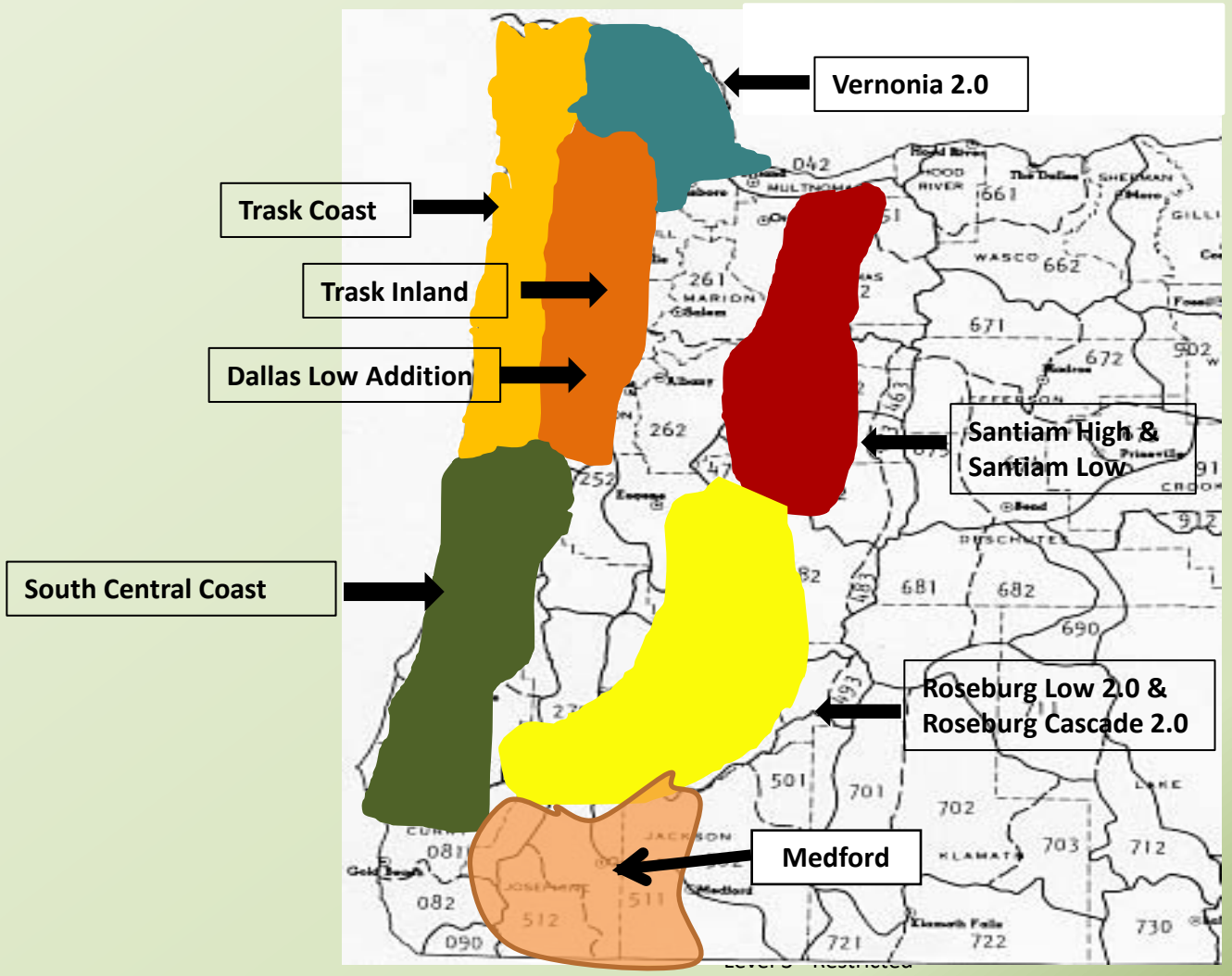
- It became clear that the many, small seed zones pictured were overly conservative and that many of the zones could be combined into larger zones. This resulted in the 16 larger seedling zones for Douglas-fir.



# Various Douglas Fir Breeding Cooperatives in Western Oregon



# Schroeder Seed Orchards for Douglas Fir



# What are the Net Effects of These Changing Breeding Zones?

- We are breeding and deploying across larger, more diverse ecotones.
- More genotypes are being brought together to support breeding programs potentially leading to unique combinations of characteristics that could be better adapted changing climate.
- Broad-based, recurrent testing identifies genotypes best-adapted to current conditions.

# Overall Schroeder Seed Orchard Composition

- Approximately 130 acres of active orchards.
- There are 26 different cooperators in orchards at Schroeder.
- There are 47 different seed orchards at Schroeder.
- 32 Separate Douglas Fir seed orchards covering western Oregon and Washington.
- 5 Separate western hemlock seed orchards covering western Oregon and Washington.
- 3 high terpene western red cedar seed orchards.
- 1 Valley Pine seed orchard.
- 1 eastern OR Ponderosa pine seed orchard (new)
- 2 eastern Oregon Douglas Fir seed orchards (new)
- 2 western larch orchards (new)
- 1 western red alder clonebank.

# Advantages of Orchard Seed Production

- Orchard conditions produce seed more reliably than wild seed collections.
- Uncertain growth, form and disease and insect susceptibility of wild seed collections raise risk.
- In the last 10 years, over 95% of the Douglas-fir seedlings produced in the PNW have been produced from Improved seed.

# Specific Traits Being Improved Through *Traditional Breeding*

- No GMO's.
- Adaptability.
- Increased Growth.
- Increased insect and disease resistance.
- Increased wood quality.
- Increased resistance to animal browse (WRC)

# Douglas-Fir Seed Orchard

# Western Hemlock

# Willamette Valley Ponderosa Pine

# What Are the Advantages of Improved Seed?

- The degree of improvement upon the intensity of selection, the degree to which these traits are passed to subsequent generations, and the relative levels of tree improvement.
- Each cycle of tree improvement should result in a certain percentage of gain.
- Trees produced from any population of seeds will exhibit a range of characteristics from very poor to outstanding in the shape of a bell-shaped curve.
- The majority of seedlings would be expected to have medium performance with relatively few individuals with very poor or outstanding performance.

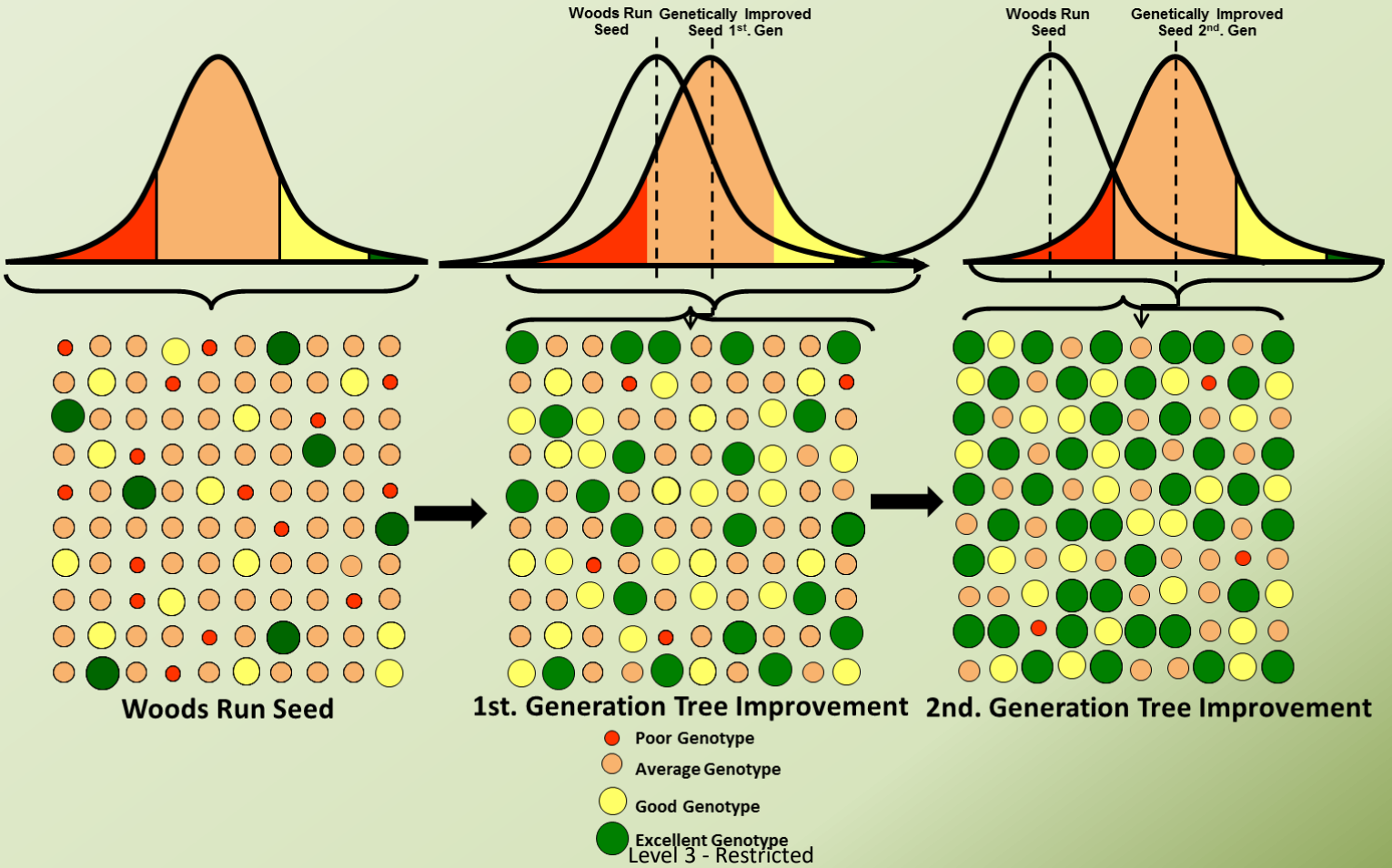
# What Are the Advantages of Improved Seed?

- If a landowner plants out 10,000 seedlings they would expect to see this entire range of characteristics.
- Each cycle of a tree improvement program would be expected to shift the curve forward for the traits of interest.
- The relative proportion of good and outstanding trees relative to poor trees would increase. This shifting of performance levels would be expected to occur in each subsequent tree improvement cycle.

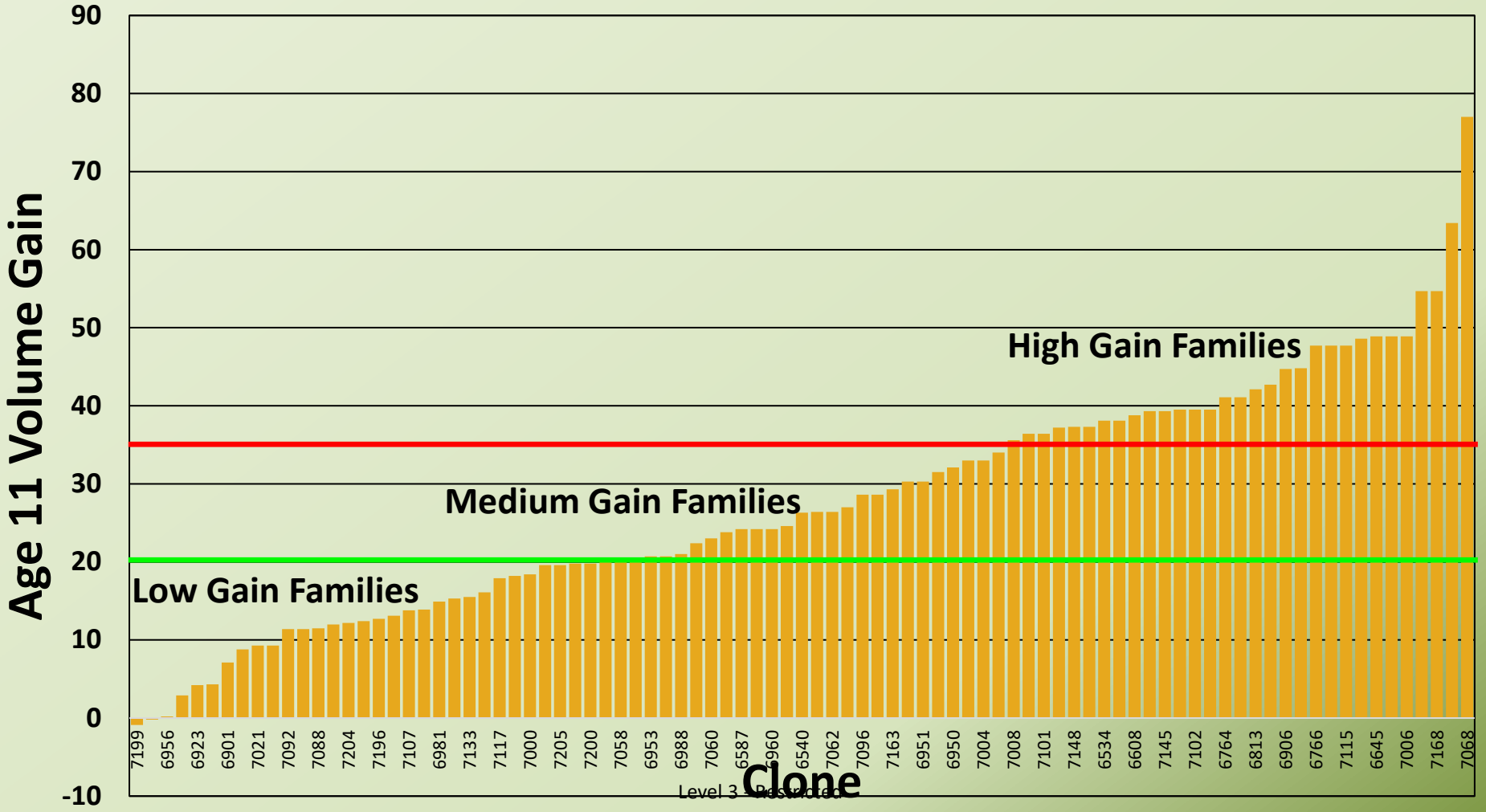
# How Much Improvement Can Occur?

- 1st. Generation Seed Orchards up to 50% greater volume at age 15 compared to Wood's Run.
- 2nd. Gen 25% > 1st. Gen.
- 3rd. Gen 22% > 2nd. Gen.

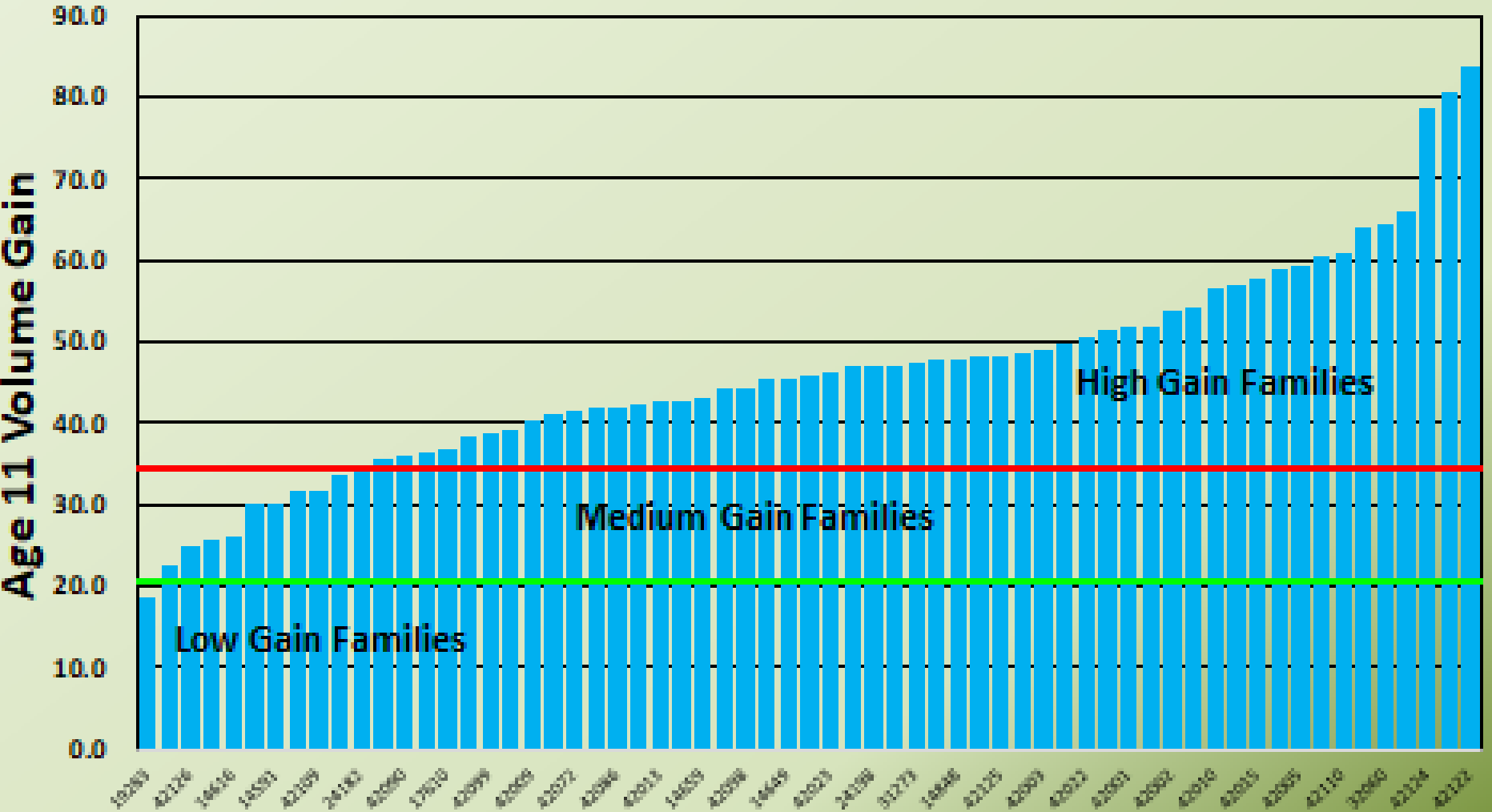
# How Do Population Characteristics Change Over Time?



# Nehalem (1st. Gen) Seed Orchard Volume Gains by Family



# Trask Coast Seed Orchard
# Volume Gains by Family



# How Much Improvement Can Occur?

# Potential Ways to Mitigate Climate Change

- Change Silvicultural regimes (Stocking levels, competition control, etc.) to mitigate climatic changes.
- Switch species to match projected future climate conditions.
- Assisted Migration: Move seed from existing natural stands or breeding zones to new areas based on climate model projections.

# Potential Ways to Mitigate Climate Change

- Traditional tree improvement and breeding work with breeding and testing designs appropriate to meet climate change responses.
- Hybrid designs combining features of the above items.

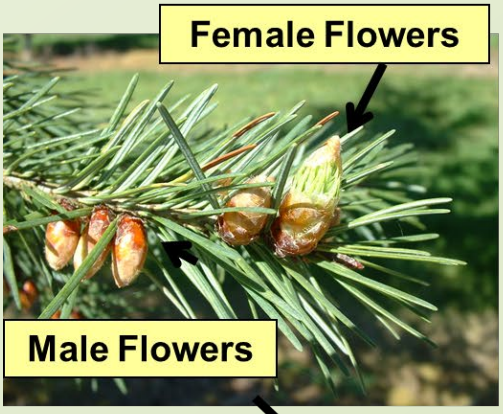
# How Can Ongoing Tree Improvement Programs Help Mitigate Climate Change?

- Constant, recurrent testing helps identify new genotypes best adapted to changing climate conditions.
- Specifically designed studies can be used to impose “stress” conditions on specific genotypes to identify resistance or susceptibility.
- Expanded seed or breeding zones and wide-cross breeding can bring together unique combinations of traits to meet changing environments.

# The North Coast Tree Improvement Cooperative

- This comprehensive breeding effort includes at least 12 separate entities (Private industrial, State, Federal, University, etc.) and covers a landbase of approximately 950,000 acres.
- Breeding efforts are based on 500, 1st. and 2nd. Generation parents being bred in a subline-based breeding program consisting of 26 separate sublines. Over 800 crosses were made is this large-scale breeding program.

# Douglas Fir-Flowering to Seed Production




Fertilized Cones

Mature Cones

# Steps in the Production of Superior Seed

# Young Douglas Fir Seed Orchard

# Young Breeding Orchard

# Excellent Breeding and CMP Opportunities

# Mature Douglas Fir Seed Orchard

# 2nd. Crop on 3 acre Orchard Produced Over 800 Bushels of Cones in 2016.

# Goal: Early, Heavy, Consistent, High Gain Seed with Low Cost of Production

# Example of Subline TV-1 in North Coast Breeding Program

| TV-1 | 1556 | 1742 | 98449 | 98462 | 98468 | 98470 | 98471 | 98472 | 98474 | 98489 | 98493 | 98893 | 98897 | 98903 | 98912 | 98913 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1556 | | 0 | 578 | 608 | 252 | 150.25 | 0 | 384 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1742 | 0 | | 0 | 0 | 0 | 0 | 420 | 0 | 0 | 0 | 0 | 0 | 172 | 249 | 277 | |
| 98449 | 578 | 0 | | 895 | 0 | 0 | 207 | 0 | 1888 | 237 | 1003 | 0 | 0 | 0 | 0 | 0 |
| 98462 | 608 | 0 | 895 | | 74 | 0 | 0 | 274 | 249 | 0 | 0 | 0 | 35 | 0 | 0 | 0 |
| 98468 | 252 | 0 | 0 | 74 | | 0 | 162 | 0 | 0 | 333 | 0 | 0 | 0 | 0 | 0 | 0 |
| 98470 | 150.3 | 0 | 0 | 0 | 0 | | 0 | 4 | 0 | 498 | 25 | 0 | 0 | 0 | 0 | 0 |
| 98471 | 0 | 420 | 207 | 0 | 162 | 0 | | 0 | 1052 | 0 | 0 | 0 | 1051 | 0 | 0 | 0 |
| 98472 | 384 | 0 | 0 | 274 | 0 | 0 | 0 | | 0 | 0 | 512 | 0 | 0 | 0 | 0 | 0 |
| 98474 | 0 | 0 | 1888 | 249 | 0 | 4 | 1052 | | | 731 | 0 | 0 | 491 | 0 | 0 | 0 |
| 98489 | 0 | 0 | 237 | 0 | 333 | 498 | 0 | 0 | 731 | | 0 | 0 | 324 | 0 | 0 | 0 |
| 98493 | 0 | 0 | 1003 | 0 | 0 | 25 | 0 | 512 | 0 | 0 | | 175 | 0 | | | |
| 98893 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 175 | | 0 | 218 | 0 | 6 |
| 98897 | 0 | 172 | 0 | 35 | 0 | 0 | 1051 | 0 | 491 | 324 | 0 | 0 | | 0 | 0 | |
| 98903 | 0 | 249 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 218 | 0 | | 182 | 134 |
| 98912 | 0 | 277 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 182 | | 168 |
| 98913 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 6 | 0 | 134 | 168 | |

# Subline TV-1 in North Coast Breeding Program. Full Performance Data is Available for All Families

| Affiliation | Subline14 | SubOSU | Gen | IndexTVR7 | NWTIC | PolnCG>15 | PolnODF>15 | PCT | @ODF | Fem16 | Male16 | FPgid | MPgid | V7 | V12 | Xgid |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NC | TV-1 | 1 | 1.50 | 9.75 | 1556 | 0 | 14.50 | | 8 | | | 183 | | 46.2722 | 28.28 | |
| NC | TV-1 | 1 | 1.50 | 17.00 | 1742 | 0 | 2.50 | | | | | 910 | | 56.2298 | 36.57 | |
| NC | TV-1 | 1 | 2.00 | 22.19 | 98449 | 0 | 8.00 | | 7 | | | 1543 | 1644 | 55.7102 | 28.17 | 98066 |
| NC | TV-1 | 1 | 2.00 | 19.71 | 98462 | 0 | 34.00 | | 6 | | | 1583 | 1588 | 60.811 | 40.36 | 98103 |
| NC | TV-1 | 1 | 2.00 | 14.14 | 98468 | 0 | 0.50 | | 7 | | | 1558 | 1742 | 52.6794 | 34.74 | 98083 |
| NC | TV-1 | 1 | 2.00 | 12.89 | 98470 | 0 | 6.50 | | 5 | | | 1547 | 1556 | 53.9586 | 30.43 | 98068 |
| NC | TV-1 | 2 | 2.00 | 17.21 | 98471 | 0 | 17.00 | | 4 | | | 1583 | 1588 | 54.6168 | 27.60 | 98103 |
| NC | TV-1 | 1 | 2.00 | 16.23 | 98472 | 0 | 17.50 | | 5 | | | 1511 | 1709 | 51.1189 | 29.99 | 98019 |
| NC | TV-1 | 1 | 2.00 | 14.82 | 98474 | 0 | 8.50 | | 6 | | | 1512 | 1742 | 45.9331 | 37.46 | 98022 |
| NC | TV-1 | 1 | 2.00 | 23.27 | 98489 | 0 | 7.00 | | 7 | | | 1588 | 1659 | 52.4724 | 39.59 | 98108 |
| NC | TV-1 | 2 | 2.00 | 24.63 | 98493 | 0 | 22.00 | | 6 | | | 1588 | 1659 | 52.6582 | 48.09 | 98108 |
| NC | TV-1 | 2 | 2.00 | 10.21 | 98893 | 0 | | | 8 | | | 1547 | 1556 | 58.8312 | 33.53 | 98068 |
| NC | TV-1 | 1 | 2.00 | 17.16 | 98897 | 0 | 11.00 | | 4 | | | 1538 | 1644 | 43.3694 | 26.81 | 98059 |
| NC | TV-1 | 1 | 2.00 | 7.89 | 98903 | 0 | | | | | | 1589 | 13168 | 43.1836 | 23.23 | 98110 |
| NC | TV-1 | 1 | 2.00 | 16.36 | 98912 | 0 | | | | | | 1557 | 1728 | 46.1083 | 23.71 | 98081 |
| NC | TV-1 | 1 | 2.00 | 15.92 | 98913 | 0 | | | | | | 1511 | 1758 | 43.1465 | 26.85 | 98020 |

# The USDA FS, OSU, and the Conservation Biology Institute developed a web-based tool to match seedlots to sites based on projected climatic information

- Seedlot Selection Tool can be used to match seedlots to planting sites. Using natural seed collections, it tends to recommend large seed movements.
- Using improved seed, smaller geographic movements are recommended.

# Assisted Migration Using Untested, Wild Seed Sources May Result in Large Reductions in Growth Rates or Incorporation of Other Undesirable Traits

- Wild seed collections do not have the advantage of extensive tree improvement programs behind them. Natural Seed Production is highly variable and seed may not be available.
- Adaption to a given environment can be a complex trait and may extend much farther than simply hotter and drier during the summer months.

# Aggressive Tree Improvement Programs Can Be Used to Better Select Genotypes Able to Adapt to the Changing Environment

- Our 2nd Generation Douglas Fir North Coast Trees Improvement Cooperative tested over 112,000 unique genotypes to select less than 200 of the best genotypes in our 2nd Generation seed orchards (Less than 0.2% selection rate).
- We are breeding and testing our more extensive 3rd Generation tree improvement programs over larger, more diverse ecotomes.
- Our 3rd Gen North Coast Douglas Fir improvement program has over 800 crosses over 400 of the best families.

# Aggressive Tree Improvement Programs Can Be Used to Better Select Genotypes Able to Adapt to the Changing Environment

- Rigorous testing programs assures that the best, widely adapted families are included in our new seed orchards.
- First 3rd. Gen Seed Orchard was grafted in spring of 2024 for South Central Coast. Seed expected in 2030.

# Aggressive Tree Improvement Programs Can Be Used to Better Select Genotypes Able to Adapt to the Changing Environment

- New, 3rd Gen Douglas Fir seed and western hemlock orchards will be rapidly developed for additional breeding zones (next 5-12 years).
- Thorough, recurrent testing identifies genotypes best-adapted to current conditions.

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# Seed Supply Needs to Be Increased for Many Minor Species

- Orchard seed can supply all the needed seed for western OR and WA.
- Seed for many minor species is in short supply.
- Orchard production could alleviate these shortages.
- Beginning in 2022 we planted new orchards of western larch and east Oregon Ponderosa pine.

# Seed Supply Needs to Be Increased for Many Minor Species

- In 2025, we plan on producing seedlings for new orchards of Incense cedar, Valley pine, and giant sequoia.
- In 2026, we plan on producing seedlings for new orchards of Port Orford cedar, grand fir and red alder.
- Once these orchards begin producing, this should dramatically increase seed supplies for these species.

# Additional Information:

- Forest Seedling Catalog: https://www.oregon.gov/odf/documents/workingforests/seedling-catalog.pdf
- Schroeder Seed Orchard Brochure: https://www.oregon.gov/odf/Documents/workingforests/seed-orchard-brochure.pdf

Oregon Seed Bank Brochure:

- https://www.oregon.gov/odf/Documents/workingforests/seed-bank-brochure.pdf

# Additional Information:

- Oregon Seed Bank Seed List https://www.oregon.gov/odf/working/documents/family-forest-landowners-seed-for-sale-list.pdf
- ODF State Forest Surplus seed list https://www.oregon.gov/odf/working/documents/all-customers-seed-for-sale-list.pdf
- Don Kaczmarek: Don.KACZMAREK@odf.oregon.gov

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# Questions or Comments?