Can genomic knowledge help climate-proof our tree crops?

Sally Aitken

Department of Forest Sciences
University of British Columbia

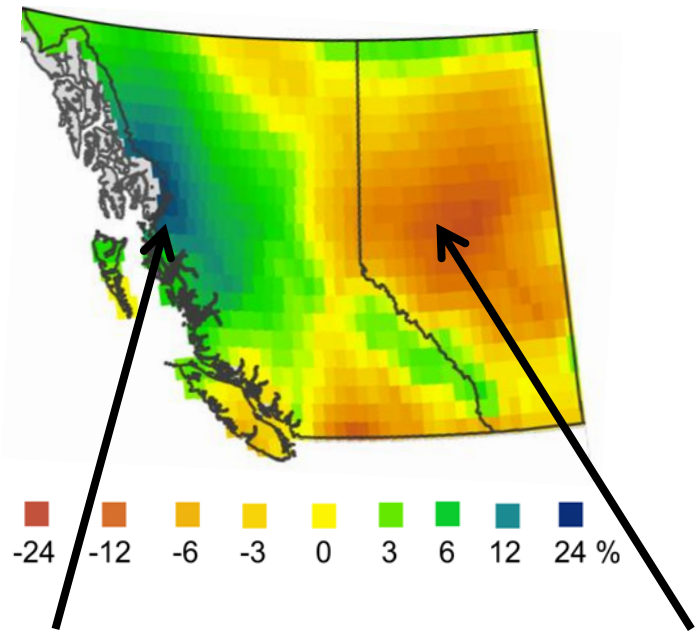
AdapTree

UBC Forestry
University of British Columbia

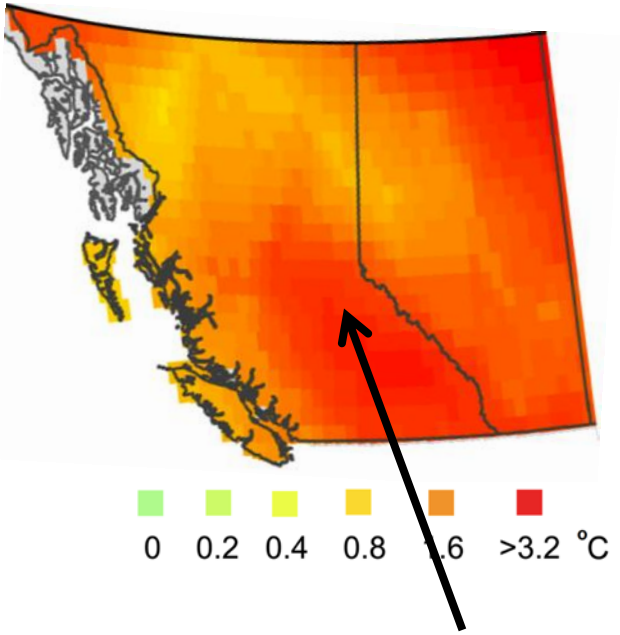
Genome BritishColumbia

Observed climate trends & impacts

25-year trend in precipitation



25-year trend in winter temperature



Dothistroma needle cast

Woods *et al.* 2006

Spruce & aspen dieback

Hogg *et al.* 2008
Michaelian *et al.* 2010

Mountain pine beetle

Allen *et al.* 2010

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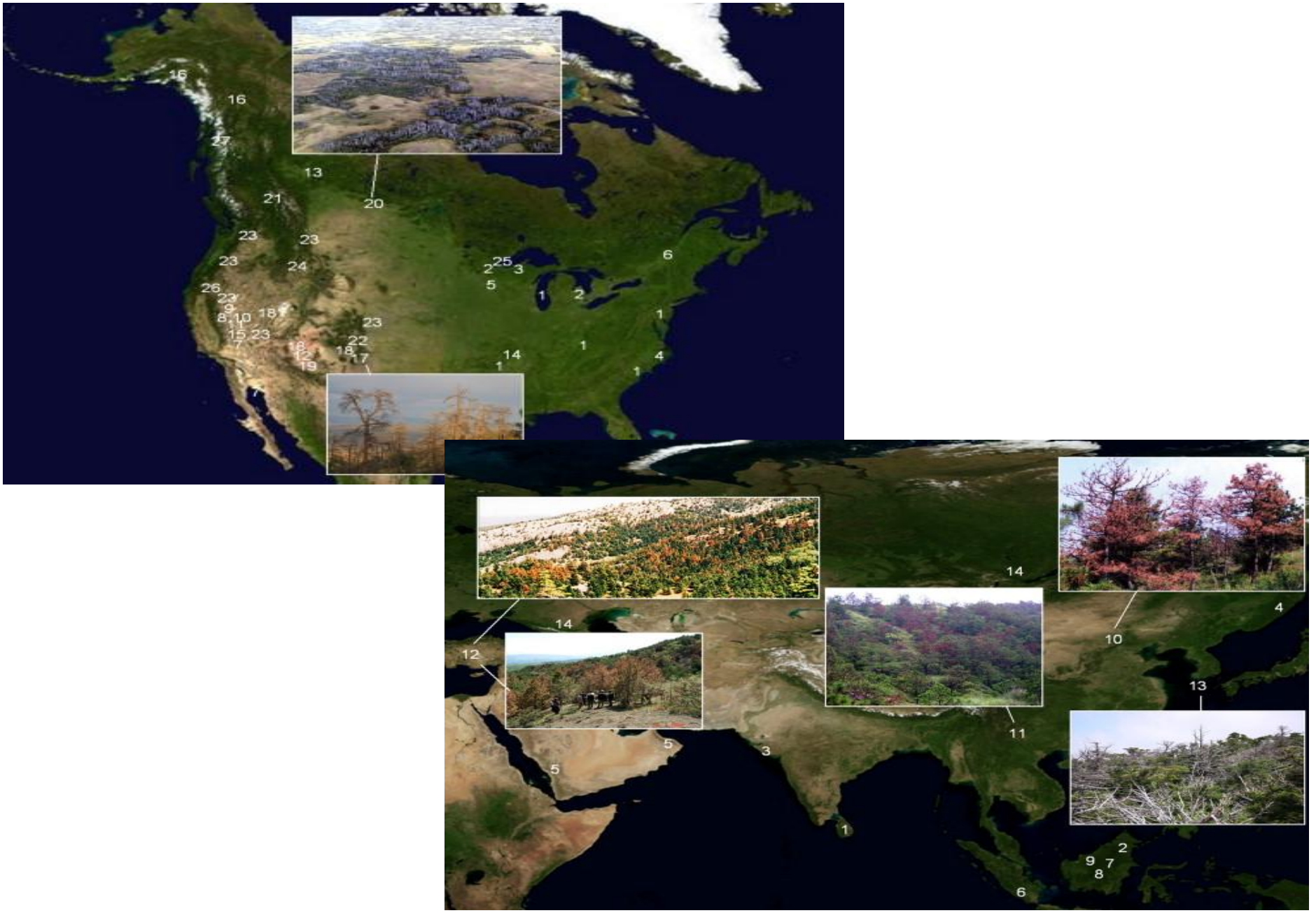
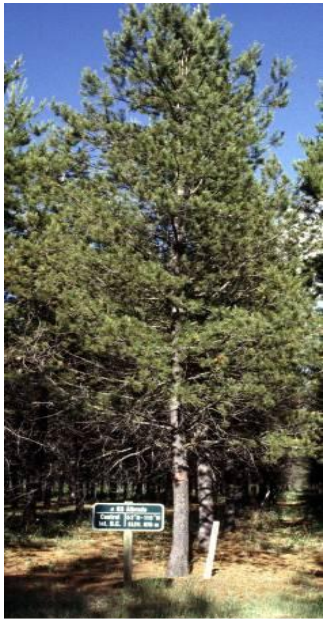


Allen et al. 2010. **A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests.** Forest Ecology and Management 259: 660 - 684

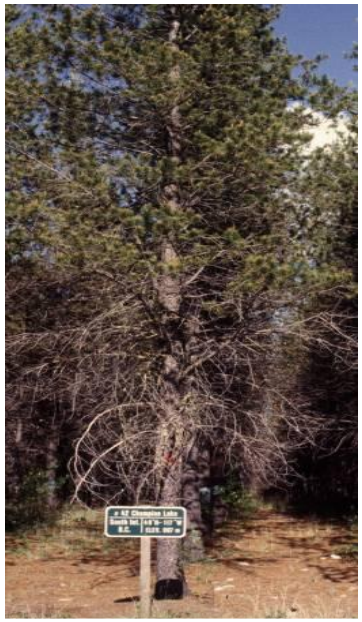
The growth of trees depends on where seed is collected

e.g., Lodgepole pine (*Pinus contorta)*

Manning
49°N
High elev



Albreda
52°N
Low elev



Champion
49°N
Low elev

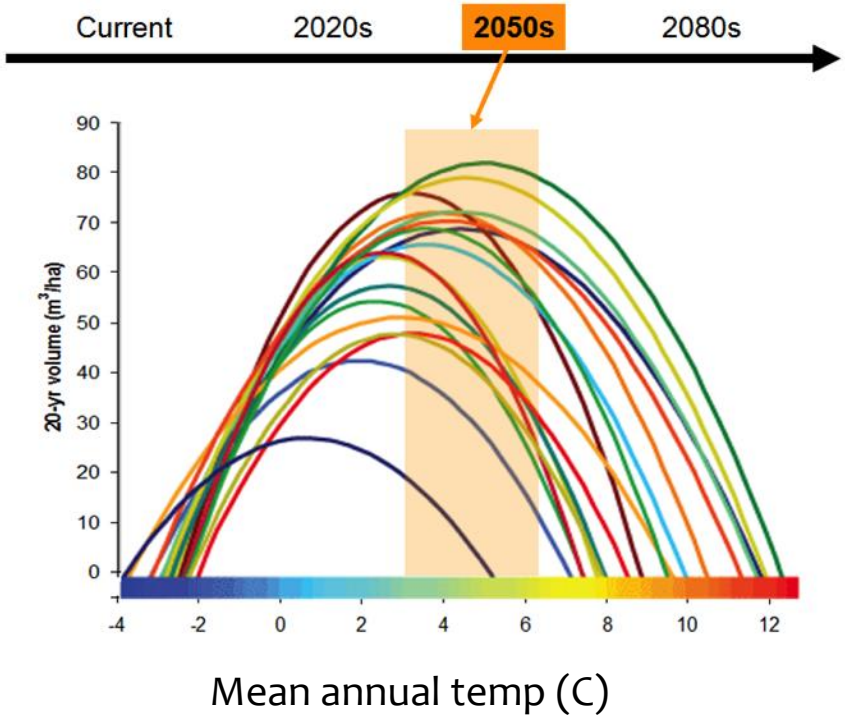
Takhini
60°N
Low elev

Provenance trial at 54°N

Wang et al. 2006. Global Change Biol.

Variation among populations of Balsam poplar (*Populus balsamifera)* – growing in common garden in Vancouver (Dr. Rob Guy, PopCan project)

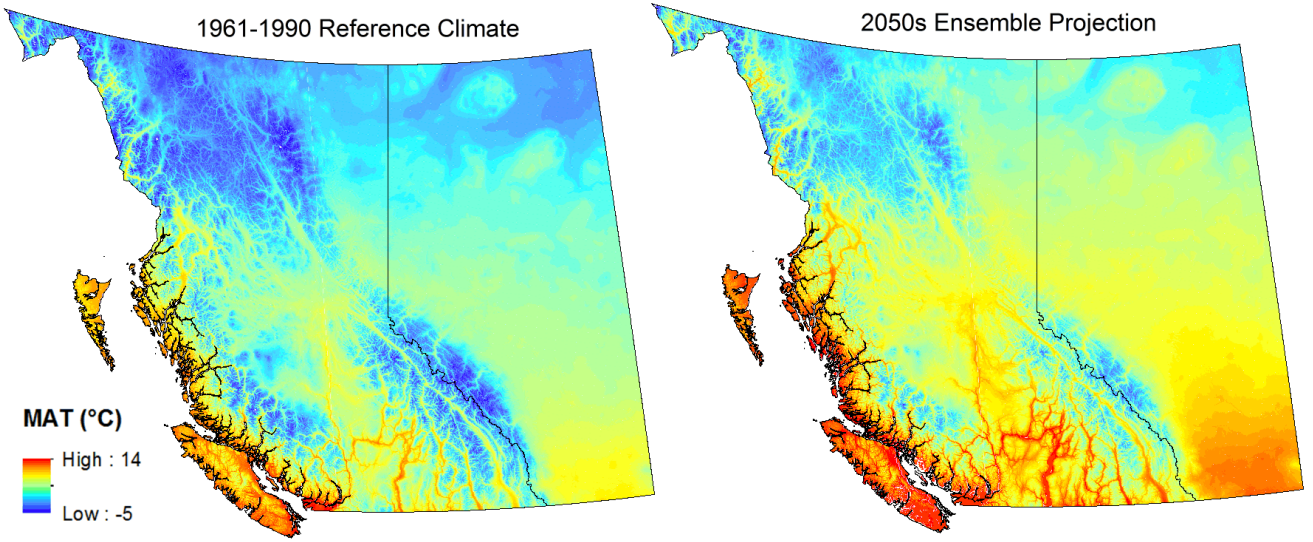
What seed should we use to ensure tree crops can tolerate current and future climates?

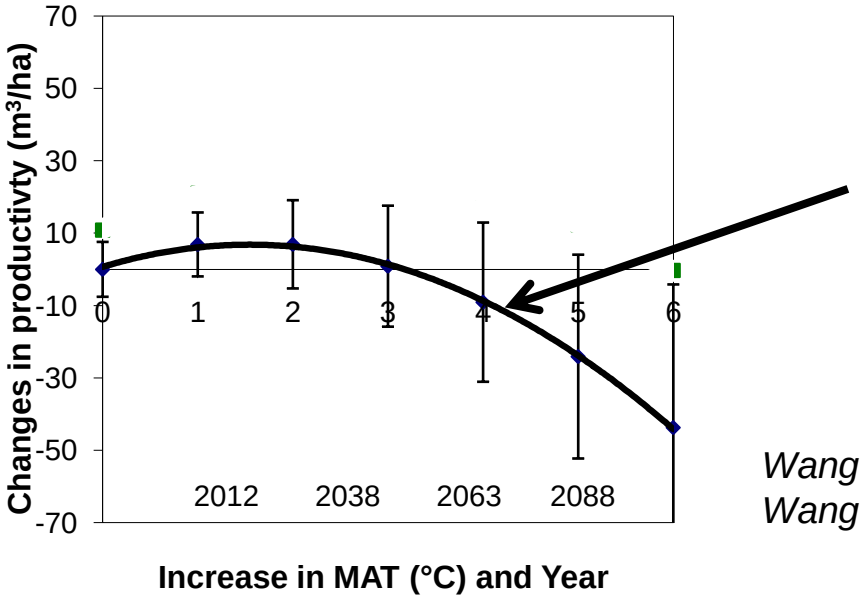


Results from the Illingworth Lodgepole Pine Provenance Trial

- 120 seed sources
- 60 test sites
- 35 years of measurement

Productivity is predicted to decline with warming if local populations are planted





Status-quo management

Wang et al. 2006. Global Change Biology
Wang et al. 2010. Ecological Applications

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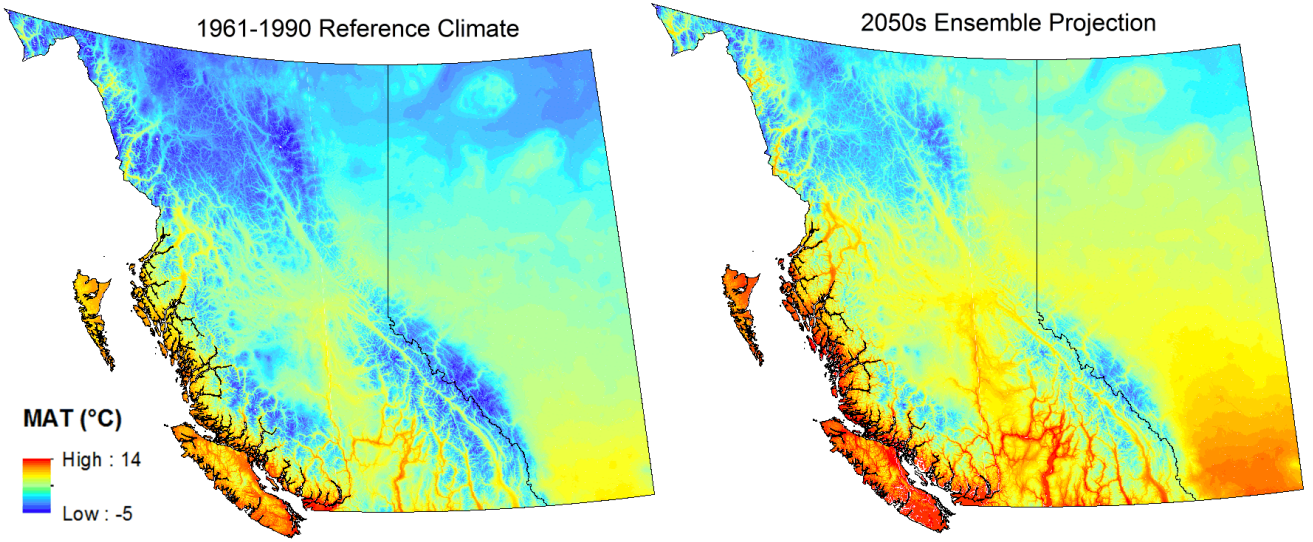
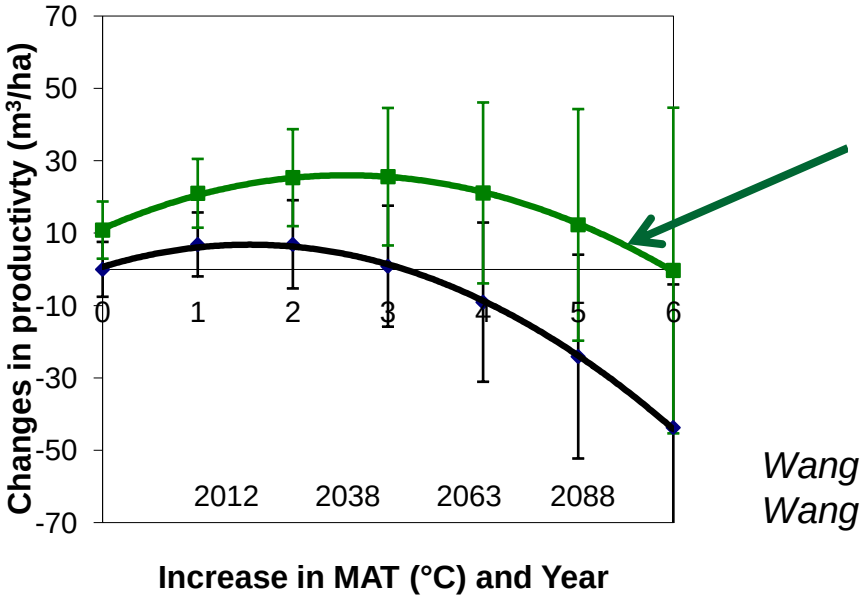
Genetic variation exists to adapt trees to new conditions...but may not be where it is needed





Optimal seed transfer

Wang et al. 2006. Global Change Biology
Wang et al. 2010. Ecological Applications

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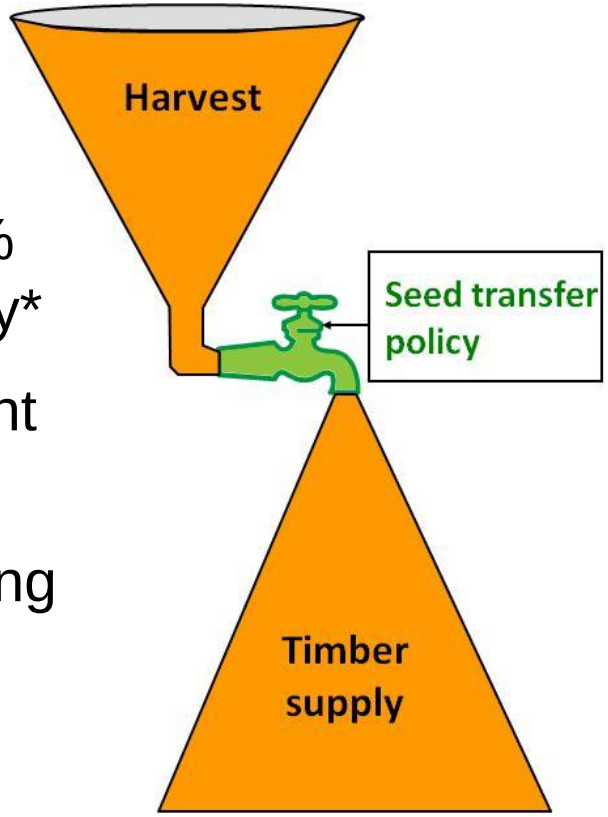
Large and widely distributed economic and ecosystem benefits

Wood supply is key to socioeconomic health and directly links to policy:

- 20% losses probable due to maladaptation*
- Reduction of these losses by even 15% mitigates loss by ~$200 million annually*
- Rural communities are highly dependent on forest goods and services
- Leverage of massive operational planting = low implementation costs



*Middle-of-the-road estimates from IPCC scenarios and effectiveness of policy changes

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Can we use genomics to understand adaptation to climate to substitute for long-term experiments?

Single nucleotide polymorphism (SNP)

Gene variant 1……ACCTGA**A**TACAGGATA…….

Gene variant 2……ACCTGA**G**TACAGGATA…….

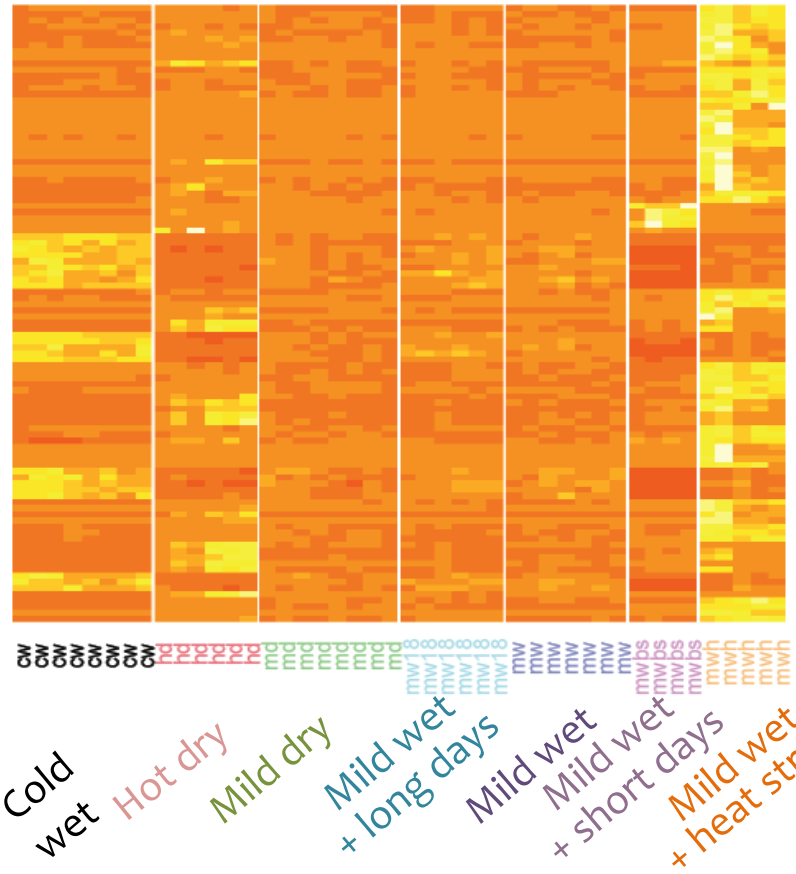
GG genotypes

AG genotypes

AA genotypes

Genomic complexity of adaptation

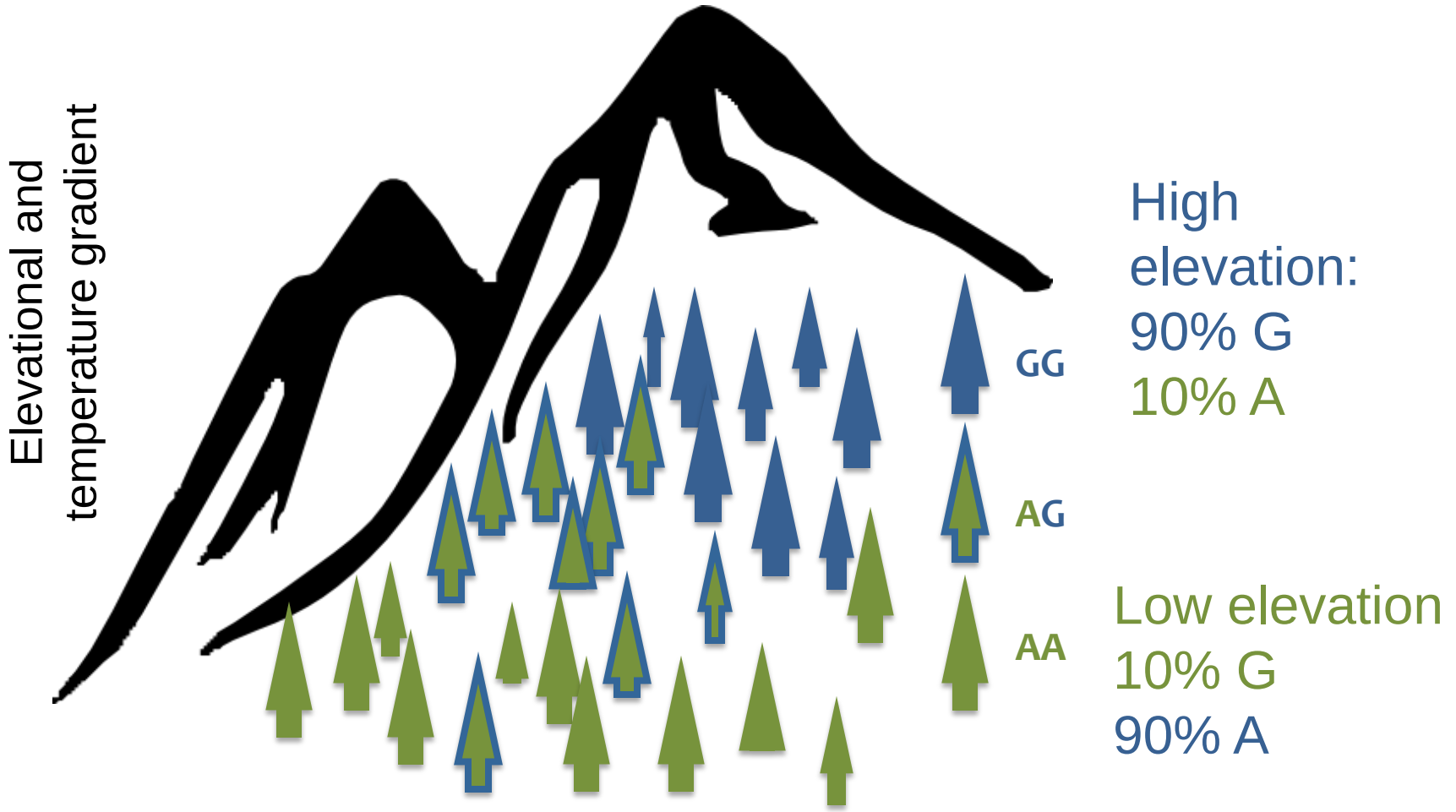
- Traits involved in adaptation to climate are determined by many genes
- Each explains a small amount of trait variation
- Need to study many genes simultaneously – single-gene biotechnology solutions unlikely to succeed



11,618 genes vary in expression among temperature and moisture treatments in lodgepole pine and 8,894 genes vary in interior spruce

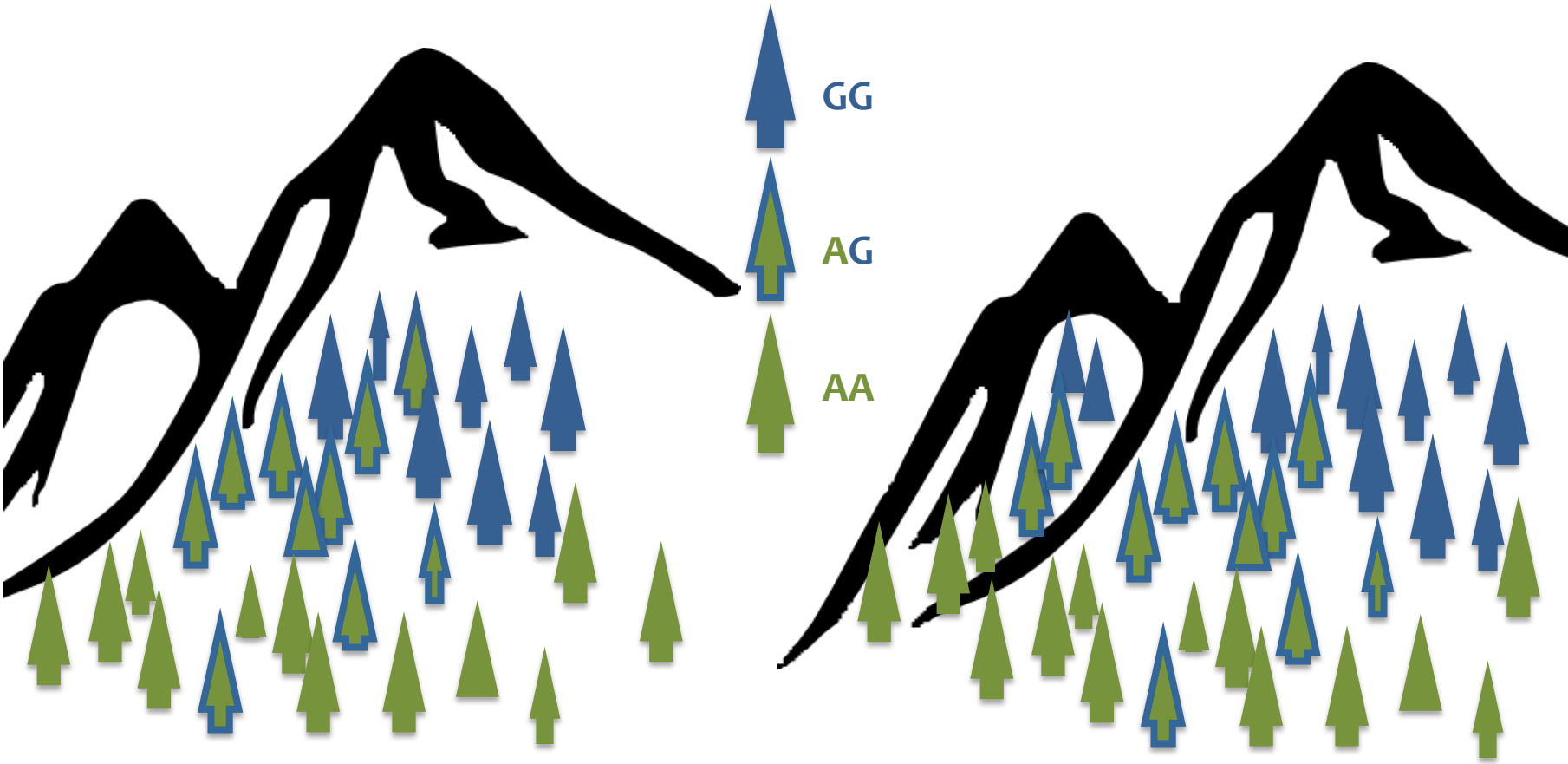
How can we tell if variation in DNA sequence (SNP) is involved in local adaptation to climate?

1) Correlation with climatic variables, latitude or elevation



How can we tell if a change in DNA sequence is involved in local adaptation to climate?

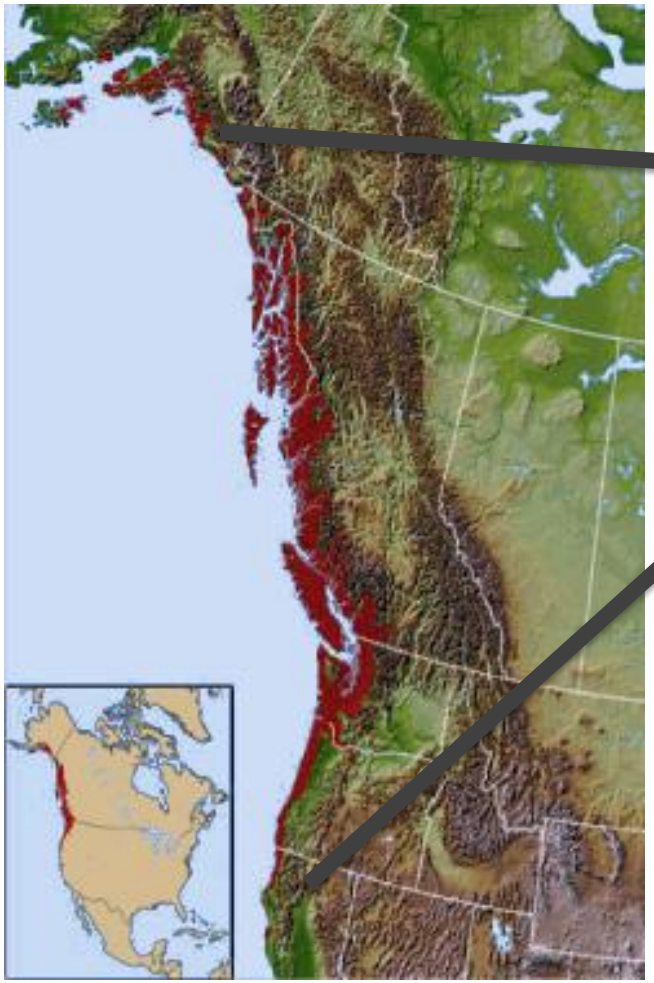
2) Repeated correlations with climate, latitude or elevation



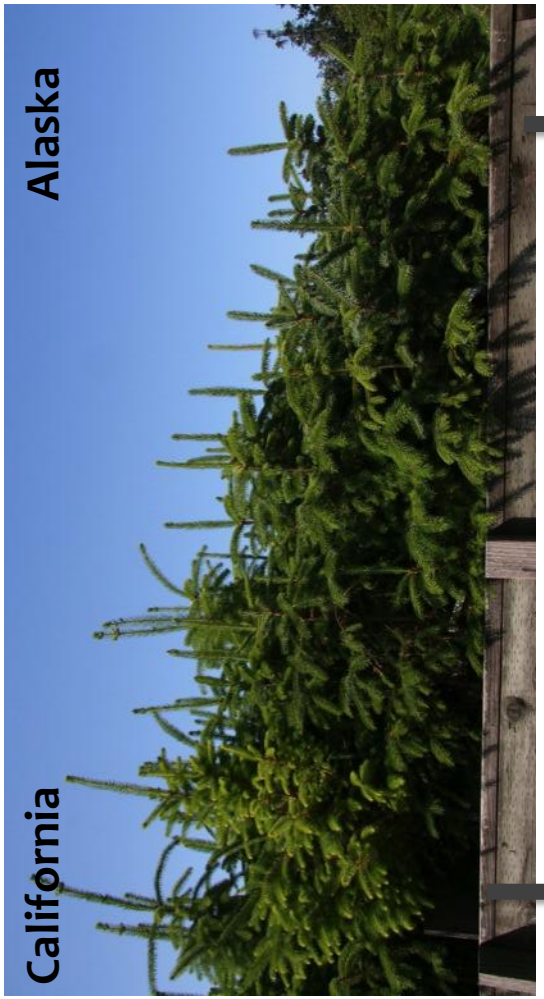
How can we tell if a change in DNA sequence is involved in local adaptation to climate?

3) Statistical associations between SNPs and climate-related traits

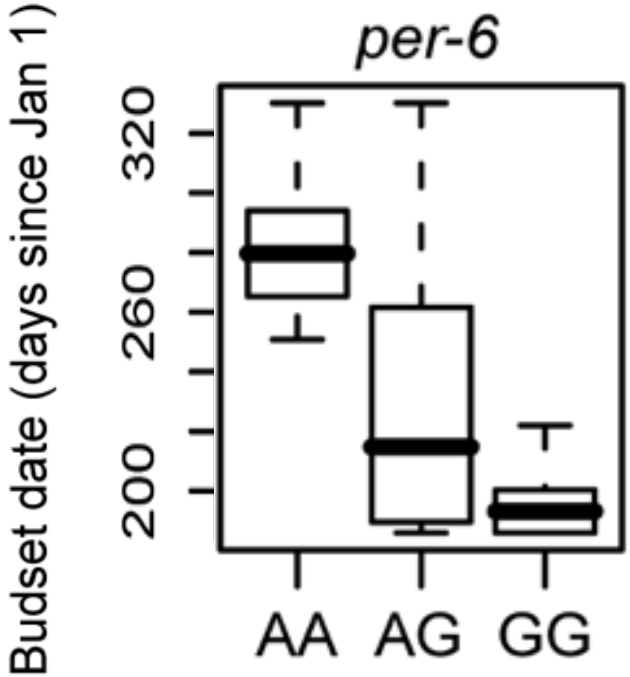
Proof of concept: Adaptation to climate in Sitka spruce



Proof of concept: Adaptation to climate in Sitka spruce

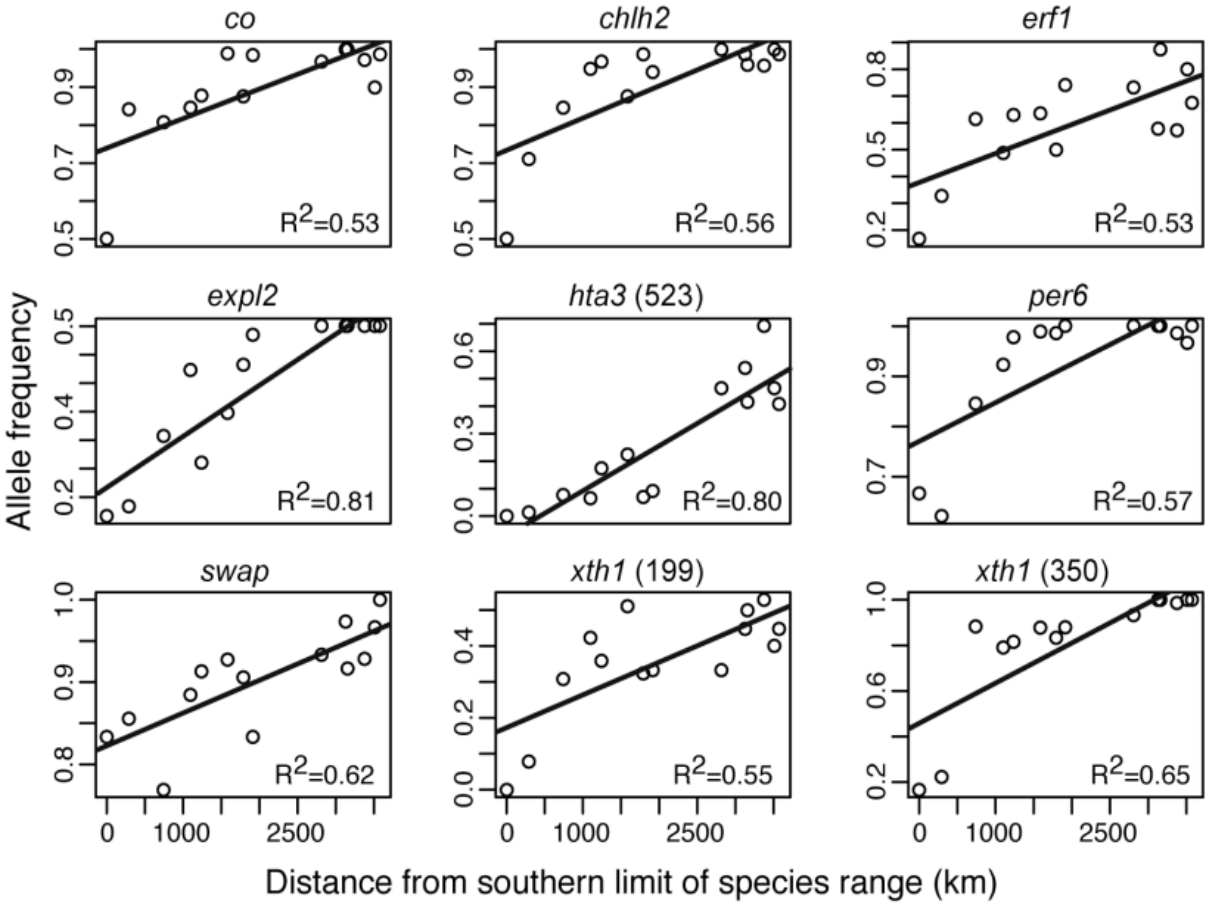


Significant associations between 35 SNPs and climate-related traits: timing of bud set and cold hardiness

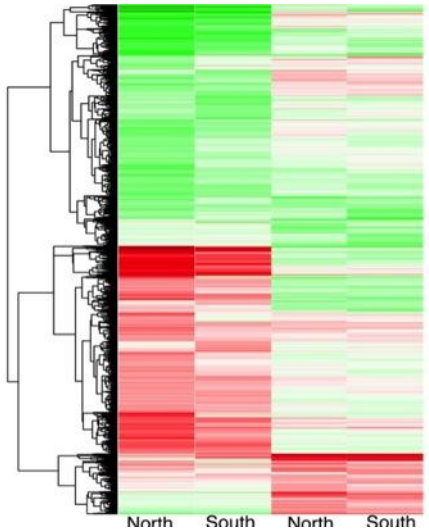


Holliday et al. 2010. New Phytologist

Frequencies of many SNPs associated with climate-relevant traits are correlated with temperature and latitude of source environments

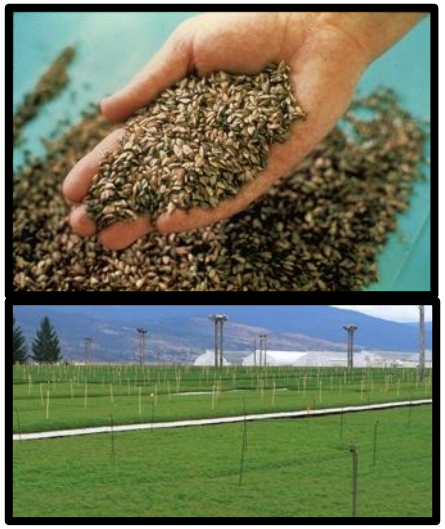


AdapTree: Assessing the adaptive portfolio of reforestation stocks for future climates



Objective:

Improve forest policy and reduce risk using genomic knowledge of climate-relevant variation.



Seed source dictated by policy

Quantity of wood determines value and employment

SHORT-TERM AND LONG-TERM COSTS OF MALADAPTATION HIGH

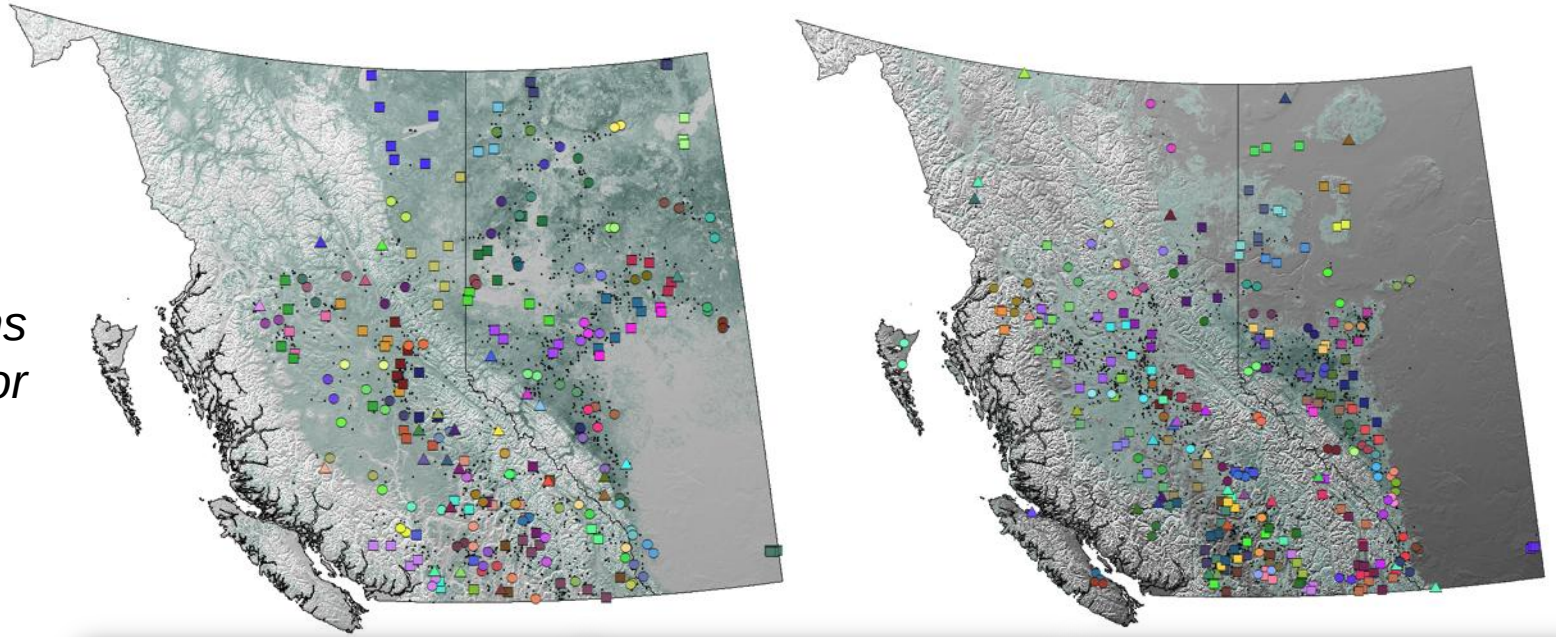
Adaptation affects reforestation success, cost

Growth determines harvest, ecosystem services & C fixation

Harvest requires reforestation of adjacent logged areas

Experiments with >250 populations of each of lodgepole pine and interior spruce will link genomic, climatic and trait variation

Populations sampled for AdapTree



Short-term growth chamber experiments

Mean annual temperature (MAT) 1°C

MAT 6°C

MAT 11°C

New genomic tools enable research not previously imaginable

- Assembled genes for lodgepole pine and interior spruce from ~300 billion bases of transcriptome data
- Re-sequencing ~30,000 genes in 1320 trees
- Phenotypic data and ~10,000 SNPs being collected for 22,000 trees grown in five different climatic treatments
- Will produce strategies for climate-based seed to maintain well-adapted tree crops
- Results will be used to develop more resource-effective approaches for other species

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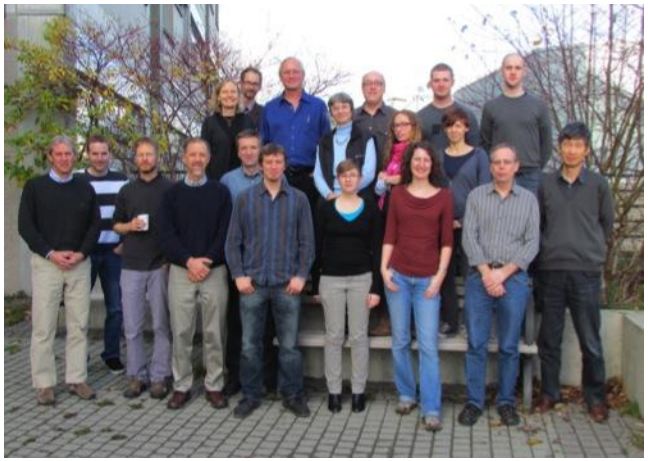
Acknowledgements

- Genome BC
- Tree Improvement Branch, BC Forest Service
- Alberta Innovates Bio Solutions
- Jason Holliday, Virginia Tech
- David Neale, UC Davis
- Jack Woods, Forest Genetics Council of BC
- AdapTree team members at UBC, University of Alberta, and Virginia Tech



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UBC Forestry
University of British Columbia

Genome BritishColumbia

University of Alberta

GenomeCanada

VirginiaTech

GenomeAlberta

FGC
Forest Genetics Council of British Columbia

The University of California Davis

Forest Service British Columbia

NSERC CRSNG