OPPORTUNITIES AND CHALLENGES OF CLIMATE CHANGE ADAPTATION IN FORESTRY

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Outline

- Introductory comments.
- Climate change in the global context
  - How big are the changes?
  - Who is affected by a changing climate?
- How will a changing climate affect forests and forestry
- Climate change adaptation options in forestry
  - Brief review of different aspects of forestry
  - **Adaptation through forest genetics and choice and use of forest reproductive materials**
- Prerequisites for a successful climate change adaptation program.

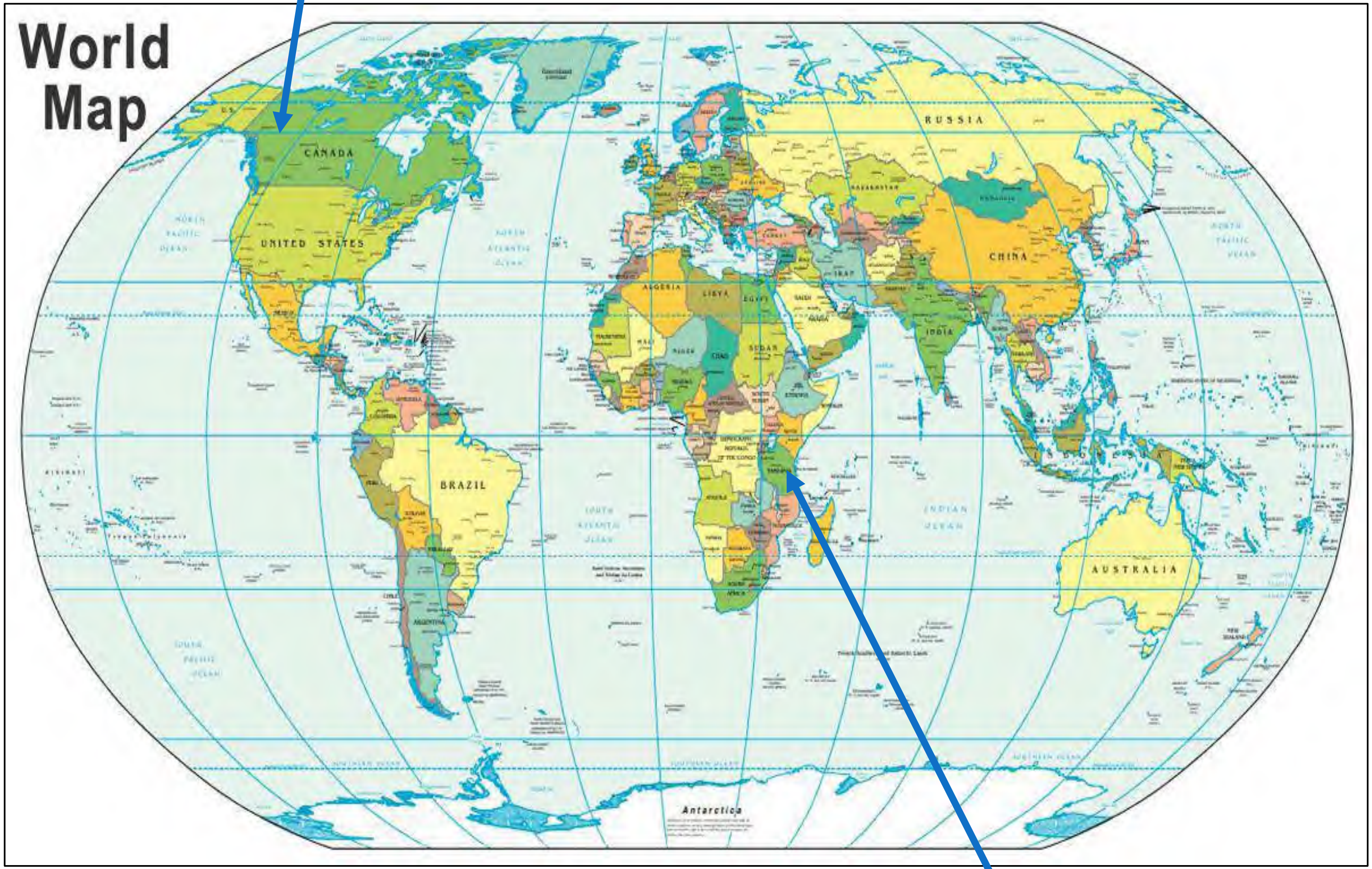
Introductory comments

- Most of the information and case examples in this seminar are based on the work done in Canada, so may only be partly applicable in Tanzania where species, forests, and forestry practices are different from that of North America.

- The purpose of this seminar is to promote discussion and sharing of knowledge about forestry and climate adaptation even if the environments in which we practice forestry in North America and Tanzania are different.

- Students may find the content of this seminar relevant for some of their forestry and biology courses; ask for a copy of this document if you need it.

Western Canada



Tanzania

Alberta, Canada –examples for this seminar are based in the work done in Alberta

Climate change in a global context

- Global changes in temperature from 1884 to 2017

- Global warming trend (see NASA Climate Machine)

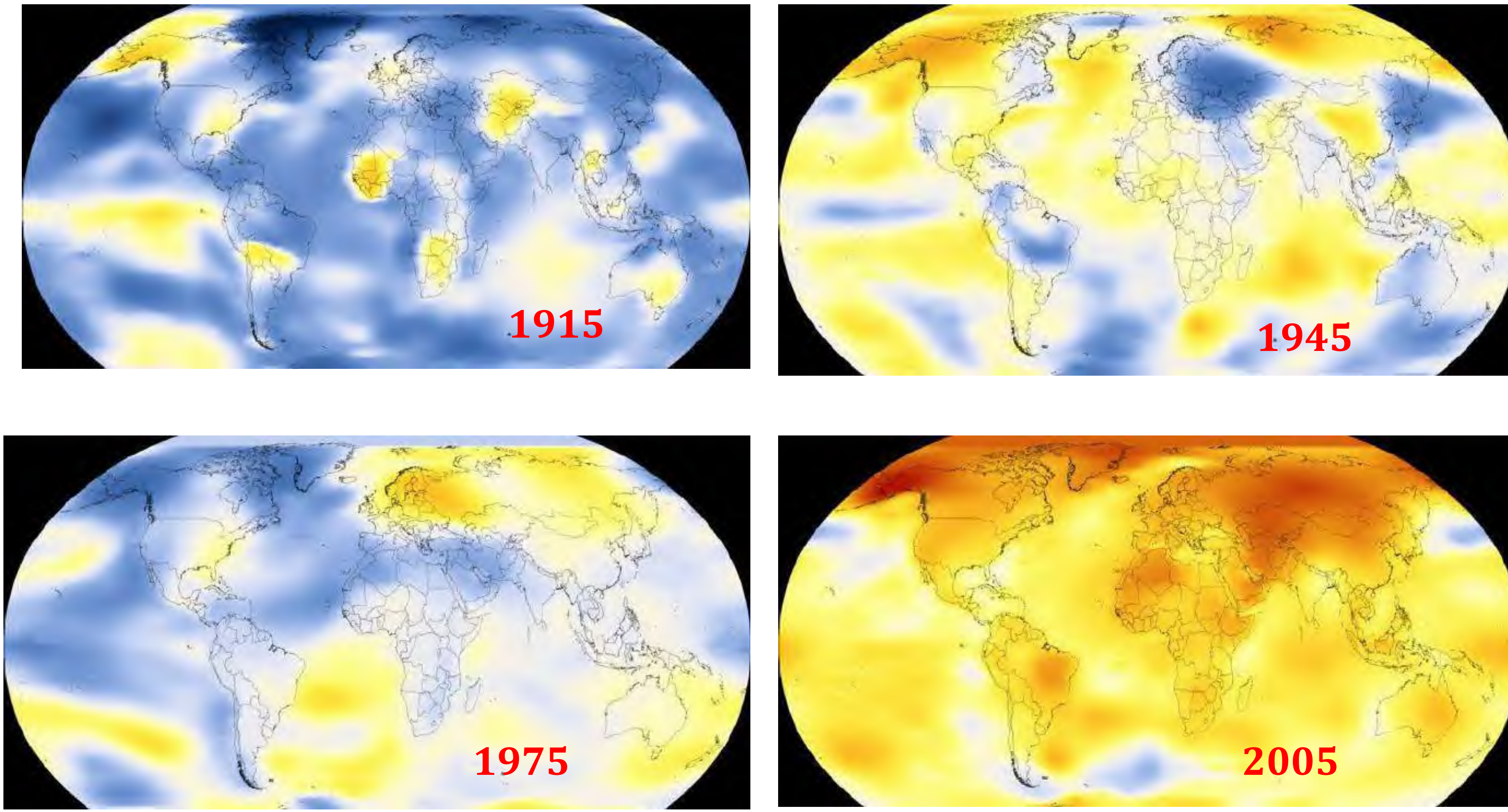
https://climate.nasa.gov/interactives/climate-time-machine

See next slide:

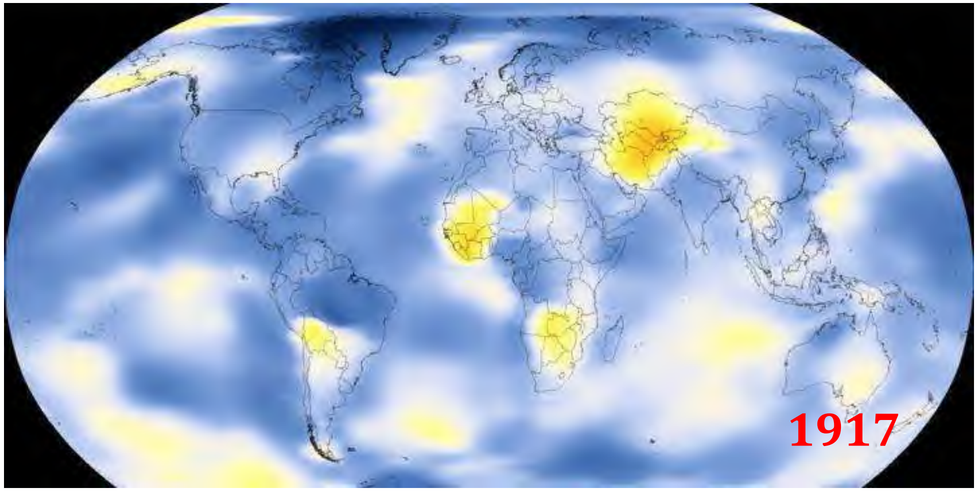
- **Dark blue** –areas with cooler than average temperature (^oF)

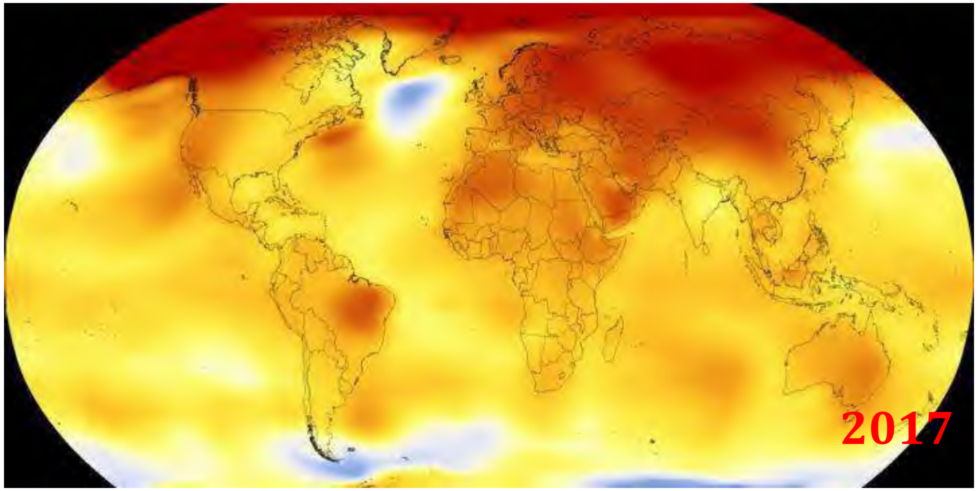
- **Deep red** –areas with warmer than average temperature (^oF)

Climate change in a global context



Climate change in a global context





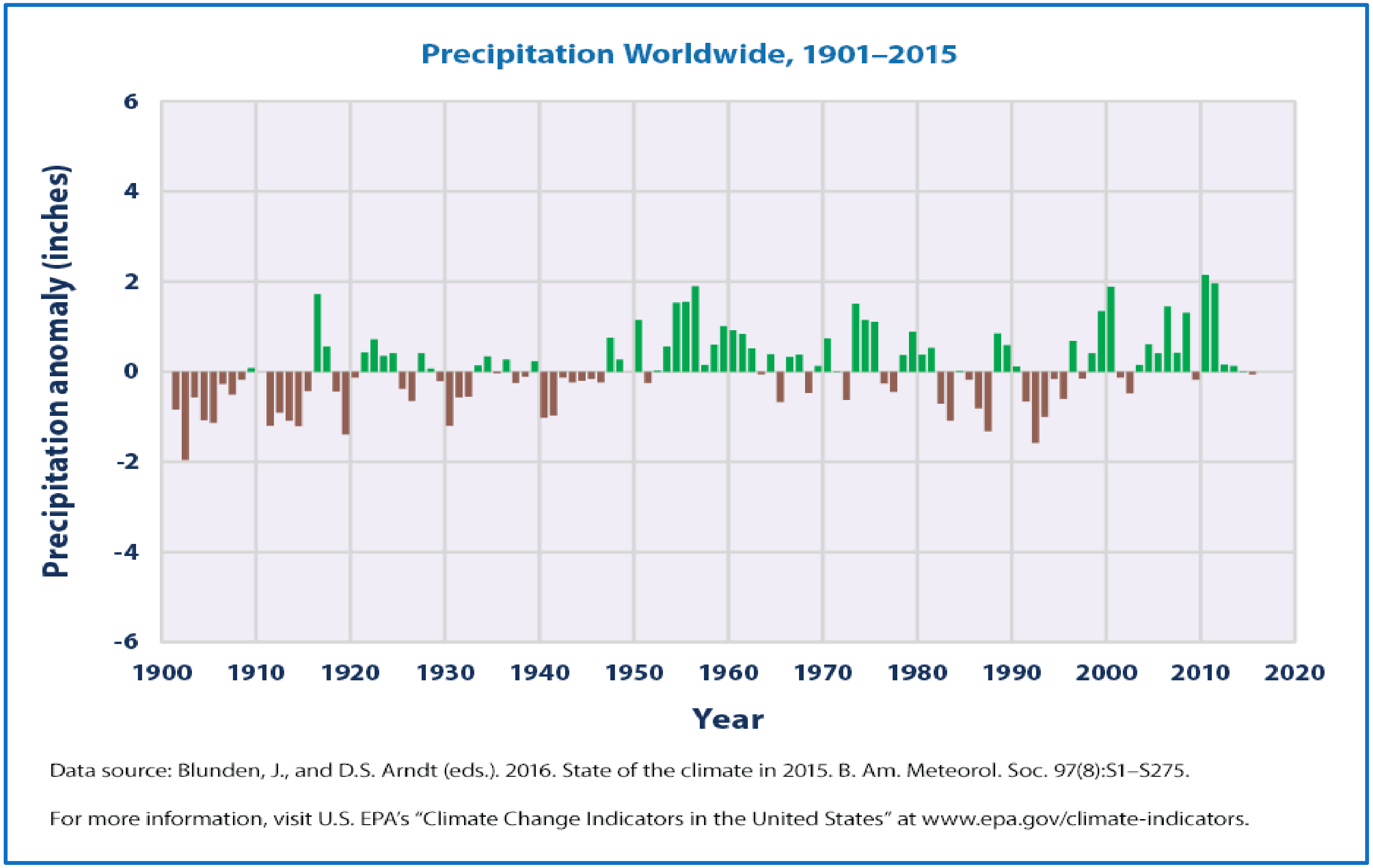
- Change in a 100-year period.
- Highest change is occurring in the north

Climate change in a global context

CANADIAN CITY	LATITUIDE (°N)	ELEVATION (m)	PERIOD (YEARS)	MAT (°C)	SUMMER (°C)	WINTER °C)
Toronto, ON	43.65	77	1900-2013	1.8	1.8	2.2
Halifax, NS	44.65	23	1900-2013	1.2	1.6	1.4
Ottawa, ON	45.30	114	1900-2013	1.7	1.0	2.6
Montreal, QC	45.50	37	1900-2013	2.0	1.4	2.7
Fredericton, NB	45.83	21	1900-2013	1.4	1.4	2.0
Charlottetown, PE	46.24	6	1900-2013	0.5	0.3	1.0
Quebec City, QC	46.78	24	1900-2013	0.6	0.0	1.1
St. John's, NL	47.57	144	1900-2013	0.6	1.2	0.9
Victoria, BC	48.45	29	1900-2013	0.6	0.6	1.1
Vancouver, BC	49.25	82	1900-2013	1.5	2.0	1.4
Winnipeg, MB	49.90	239	1900-2013	1.0	0.8	1.5
Regina, SK	50.45	577	1900-2013	1.9	1.5	3.1
Edmonton, AB	**53.91**	645	1900-2013	**2.0**	**2.3**	**3.1**
Whitehorse, YT	**60.73**	707	1940-2013	**2.1**	**0.2**	**6.0**
Yellowknife, NT	**62.45**	206	1942-2013	**4.0**	**2.2**	**7.4**
Iqaluit, NU	**63.75**	34	1946-2013	1.3	1.1	**2.9**

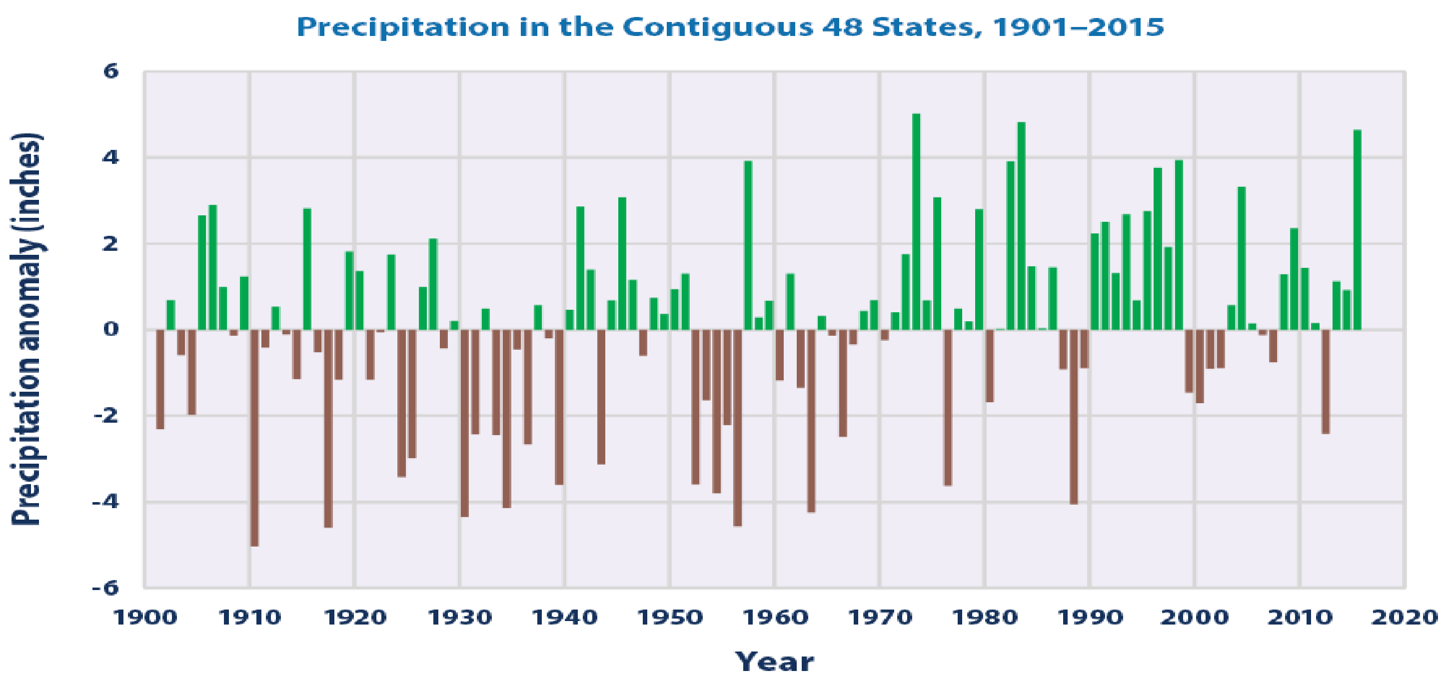
SOURCE: https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/data-scenarios-synthesis-recent-observation/chapter-2.html

Climate change in a global context



SOURCE: https://www.epa.gov/sites/production/files/styles/large/public/2016-07/precipitation-download2-2016.png

Climate change in a global context



Data source: NOAA (National Oceanic and Atmospheric Administration). 2016. National Centers for Environmental Information. Accessed February 2016. www.ncei.noaa.gov.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

SOURCE: https://www.epa.gov/sites/production/files/styles/large/public/2016-07/precipitation-download1-2016.png

Climate change in a global context

Lessons from global temperature and precipitation:

- The temperature is increasing mainly at higher latitudes, especially during winter months.
- Precipitation is random with cyclical periods (years) of below and above average annual precipitation.
- If temperature is consistently increasing while precipitation is cyclical, expect increase in drought events.
- Rapid changes in temperature, precipitation, and cycles of drought will impact most of the things we do.

A changing climate will affect everything

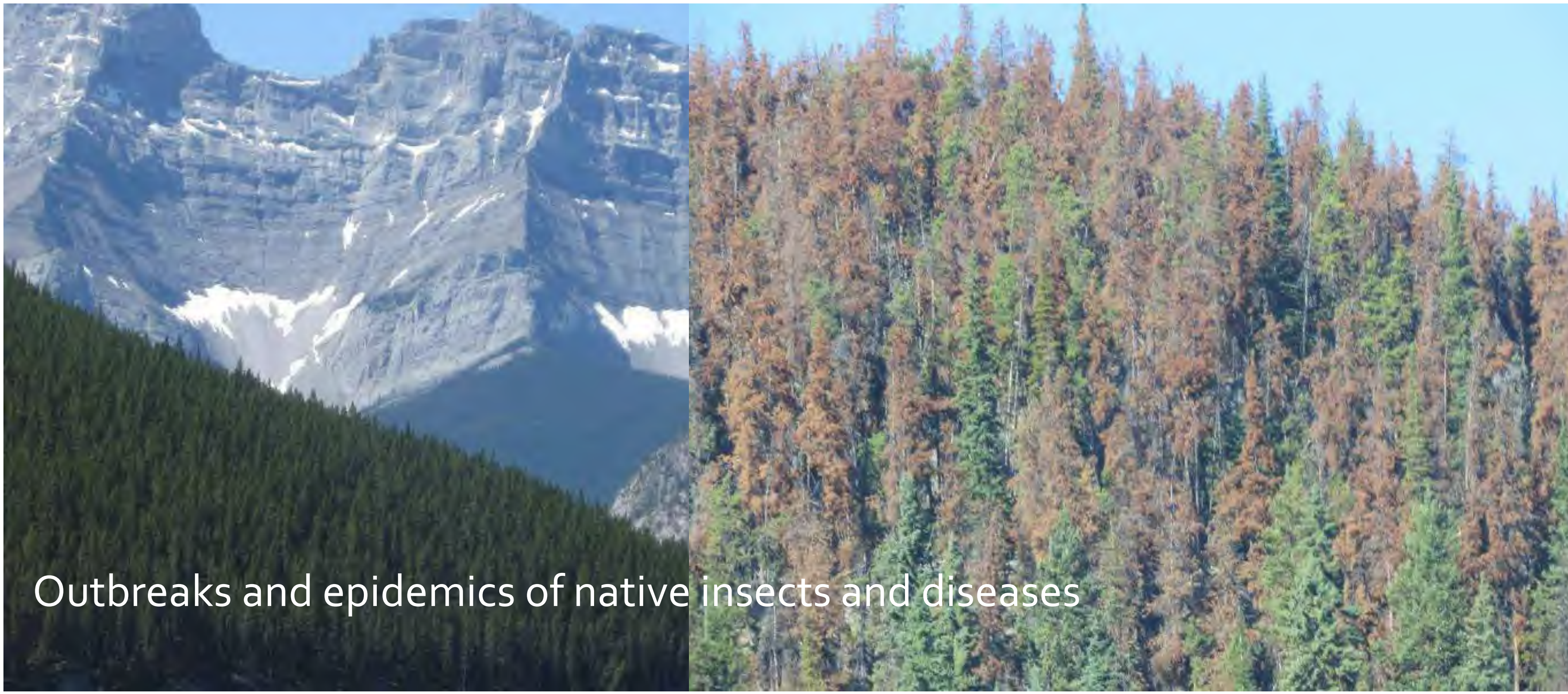
- Most of the natural processes and human activities are adapted and/or programed around variation in climate and weather. So, a rapid change in climate will affect everything.
  - Distribution of species of plants and animals follow variation in climate.
  - The population genetic variation in plants and animals follow variation in climate.
  - Annual cycles of insects, vectors, and diseases of humans, livestock, crops and forests follow predictable seasonal changes in weather.
  - In most communities, agriculture, forestry and operations in mining and other natural resource extractions are already programed around seasonal changes in weather,
  - Etc.
- Therefore, it is easier to see why a rapid change in climate and disruption of weather patterns would seriously affect living organisms and our ways of life.

Effects of climate change in forests and forestry

- Increase in incidences and severity of wild forest fires.
- Increase in outbreaks and epidemics of native forest insects and diseases.
- Spread of insects and diseases in countries and regions where they have never been found in the past.
- Increases in invasive plants, insects and animals –disruption of natural ecosystems.
- Global extinction or local extinction (extirpation) of species & loss of biodiversity.
- Expansion or shrinkage of species natural ranges & loss of forest ecosystems –transformation to woodland or grasslands.
- **Plantation failures and/or loss of wood production**

Effects of climate change in forests and forestry

Effects of climate change in forests and forestry



Damage of *Pinus contorta* (lodgepole pine) by Mountain Pine Beetle in Canada and USA, Canada, 2018

Adaptation to a changing climate
(Climate change adaptation)

Climate change adaptation has two elements

- Raising the threshold (bar or level) that must be exceeded before the system fails or things go permanently wrong. In forestry examples could be:
  - Control of forest fires.
  - Successful reforestation (planting trees and have them survive).
  - Maintaining a tree species we need in the environment we have.
  - Sustaining wood production in our forests.
  - Etc.
- Taking advantage of the opportunities presented by a changing climate. Examples in forestry could be:
  - Ability to grow productive forests in places that were previously too cold to support economically acceptable annual growth.
  - Ability to grow new tree species that were impossible in the past climate.
  - Etc.

Adaptation to a changing climate
(Climate change adaptation)

Therefore, climate change adaptation refers to actions or measures we take to:

- Reduce negative consequences of a changing climate

and/or

- Take advantage of the opportunities a changing climate presents

Examples of climate change adaptation options in forestry		
NO	Effect due to climate change	Example of climate change adaptation options
1	Increase in frequency and intensity of wildfires	▪ Improve monitoring and forecasting (weather, fire behavior, potential of fire occurring, etc.). ▪ Fire-smarting (fuel management) in high risk areas (near human settlements, industrial areas, sensitive ecosystems, etc.). ▪ Manage forest disturbances that increase risk of fire (massive forest damage by insects and diseases, etc.) ▪ Public education (many fires are started by humans while camping, hunting, recreation, etc.). ▪ Etc.
2	Forest insects & diseases	▪ Monitoring and prevention of accidental introduction of non-native species. ▪ Monitoring and eradication of outbreaks of native species. ▪ Developing and use of resistant/tolerant populations and varieties (genotypes) of native tree species. ▪ Public education (new pests are introduced by human activities, international trades, etc.). ▪ Introduce new tree species if the native species fail.

Examples of climate change adaptation options in forestry	
Effect due to climate change	Example of climate change adaptation options
Loss of species & biodiversity	▪ Assisted migration of endemic species to track suitable habitats (*conservation strategy*). ▪ Assisted population translocation (*conservation strategy*). ▪ In situ and ex situ gene conservation. ▪ Manage forest disturbances (e.g., harvesting, fire, etc., in ecologically sensitive areas and margins on the species natural range increase the risk of species replacement by more competitive & invasive species if climate has changed). ▪ Etc.
Invasive species (trees, weeds, other plants, insects, diseases, etc.)	▪ Monitoring and prevention of accidental introduction of non-native species. ▪ Managing forest disturbances in the margins of the species natural range and sensitive ecosystems (Note: disturbed forests are more likely to be invaded than intact ones). ▪ Public education (invasive species are introduced by humans)
Contraction of the species natural range	▪ Managing disturbances at the receding (trailing) edge of the species range (**debatable** –if the species highly productive populations are on the trailing edge, range contraction is preventable by managing disturbances).

Effects of climate change in forests and forestry

The applicability and success of climate change adaptations options listed here will vary depending on:

- **Tree species.**
  - Not all species have known discrete natural range where they can be managed individually.
  - Ecosystem complexity –easier to manage problems in single or few species mixed stands (common in North America, Europe, Eurasia) than multispecies complex ecosystems (characteristic of tropical ecosystems).
  - Real or perceived economic and/or ecological importance of the species.
- **Advances in forest management and environmental protection**.
  - Not all countries are willing or able to manage their forests sustainably and address climate change.
  - To some communities, other social need may be of higher priorities that addressing climate change in forestry.
- **Land and forest tenure (ownership)**.
  - Easier to address forestry and environmental problems in publicly-owned and government-regulated operations.
  - Easier to address problems in forest managements units with fewer players (e.g., large multinational commercial companies).
  - Harder to address problems in forest management with multiple small land owners.

Climate change adaptation planted forests

Climate change presents challenges and opportunities for planted forests because:

- Planted forests have known genesis (beginning) and destiny (ending)
  - We decide which species to use –for most part the stand is single species.
  - We decide the seed source (could be wild or seed orchard from tree a breeding program).
  - We decide the stand structure –mostly is single-species, even-aged stand.
  - We know the rotation age (could be 25 years in tropics or 100 years in Canada).
  - We decide where the plantation should be –mostly land not suitable for agriculture (cold and dry environments, poor soils, remote areas, etc.).
- This degree of control a forester has over a planted forest presents an opportunity to:
  - Reduce the negative impacts of climate change (especially plantation failure and loss of wood productivity).
  - Increase forest productivity in areas where climate change (warming) is creating an environment that support commercial forestry.

Climate change adaptation planted forests

Climate change adaptation planted forests

- We differ in the tree species we use in forestry –largely determined by where you live.

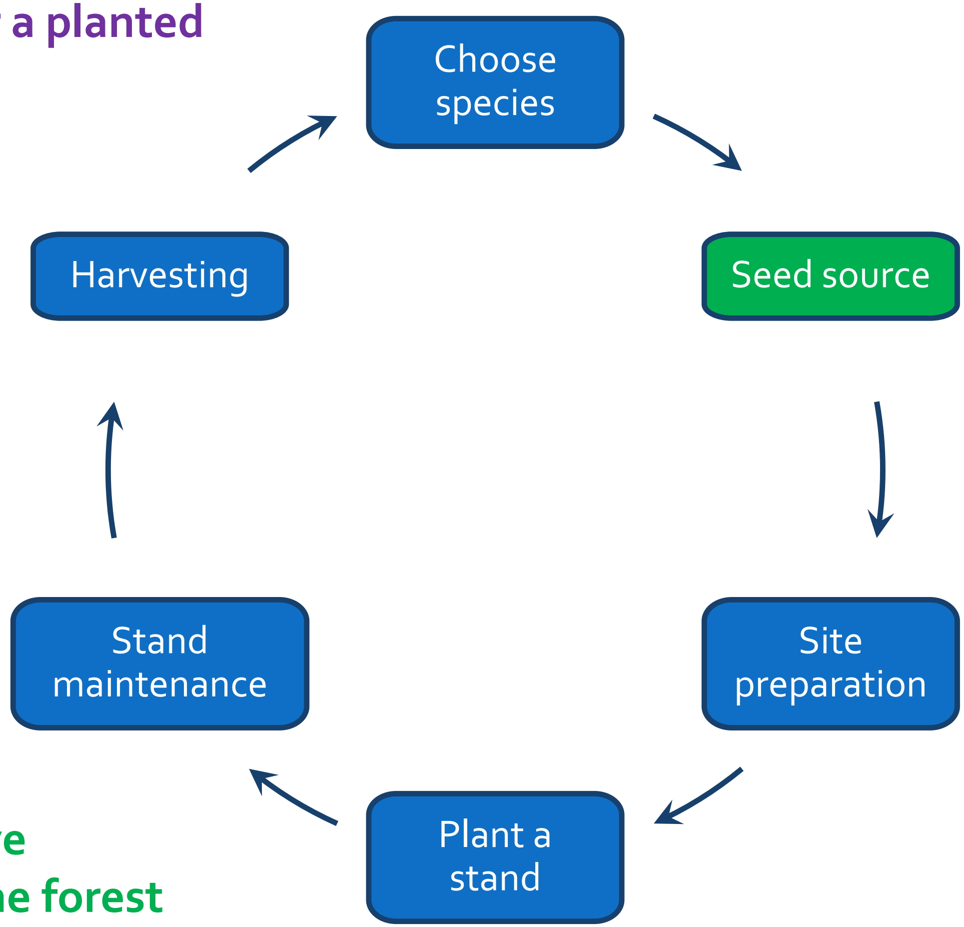
- We may differ in how we practise forestry depending on the environment we operate and degree of silvicultural mechanization.

- We may differ for the reasons we grow trees (timber/lumber; pulp and paper; fuelwood; bioenergy, etc.).

BUT: We have common generic decision making system or path to follow when managing planted forest.

Climate change adaptation planted forests

Decision system for a planted forest stand



Seed or reproductive material is where the forest come from

Climate change adaptation planted forests

Nothing in biology makes sense except in the light of evolution

(Theodosius Dobzhansk, 1964)

- If the environment (climate, soils, etc.) was uniform throughout, the land would be occupied by a single genetically uniform population.
- Through natural selection, a climatically heterogeneous environment produces population genetic differentiation (variation) within species.
- While other evolutionary forces (mutation, gene flow, & random genetic drift) and historical events (e.g., founder effect) play a role in shaping the population genetic structure of the species, **natural selection** mediated through variation and changes in the environmental (climate, photoperiod/day length) is the main driver of evolution.

Climate change adaptation planted forests

- The realization and exploitation of genetic variability in nature is central to success in:
  - Forestry
  - Agricultural crop production (agronomy)
  - Livestock management
- It is for this reason we:
  - Select and in some countries regulate seed collection, registration and use in reforestation.
  - Breed trees for desired forest management goals.
  - Conserve forest genetic resources as an insurance policy against future environmental changes or changes in forest management goals.

Message: A concept of **provenance (origin)** or seed source has been a cornerstone of forestry for over 200 years

Climate change adaptation planted forests

- From this point forward, I illustrate with case examples, the exploitation of population genetic variation and provenance trials in selection and use of seed sources (provenances /populations) for climate change adaptation.
- This is current topic in North America and Europe where the environment and forestry practices are conducive for a collective action to control and regulate acquisition and use of forestry reproductive materials.

Rweyongeza et al. (2010)
Silvae Genetica 59: 158 – 169
https://doi.org/10.1515/sg-2010-0019

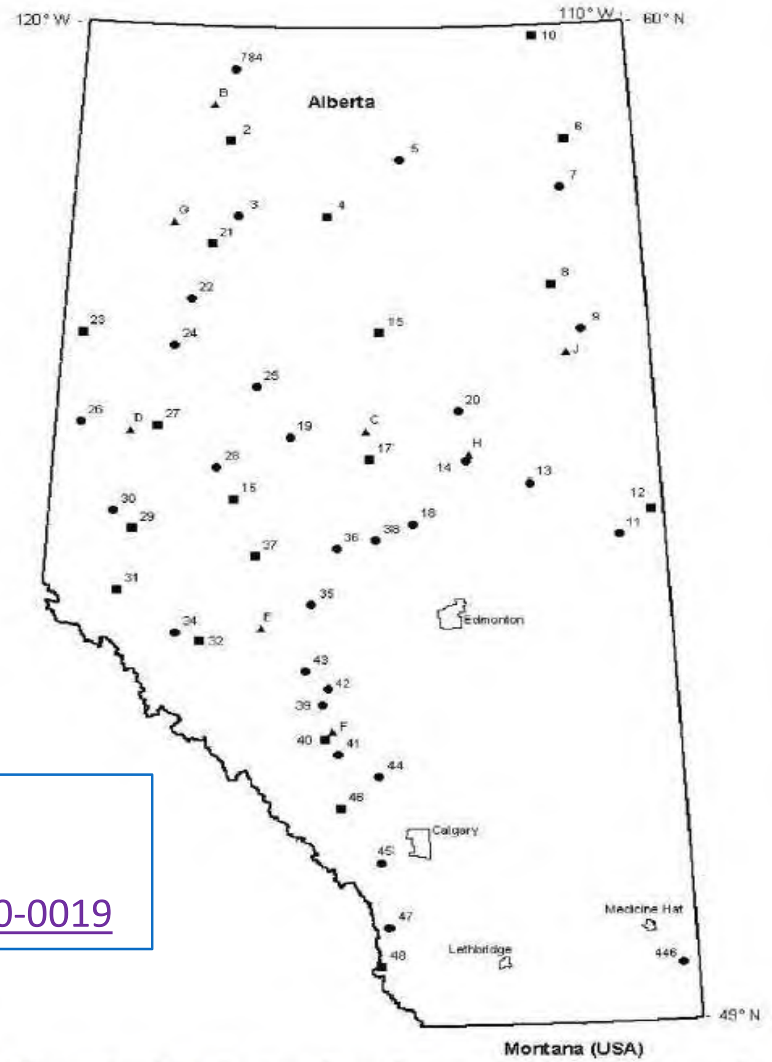
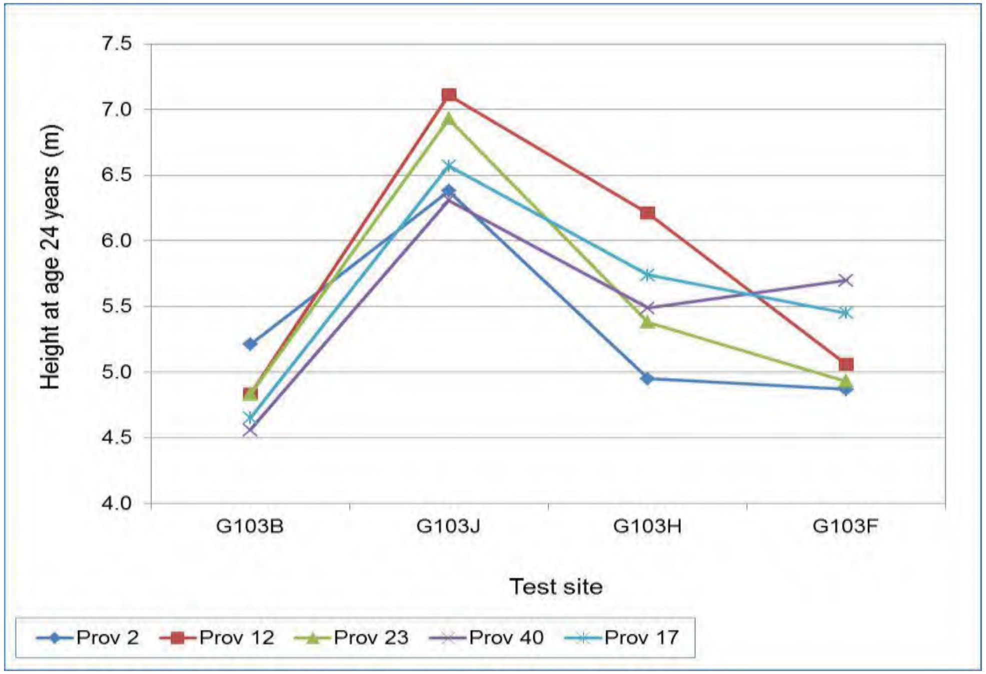


Figure 1. – Distribution of populations (numeric ID; dot markers) and test sites (character ID; triangle markers) in a white spruce series of provenance trial in Alberta, Canada. Populations covered in this article are identified by numeric ID and square markers.

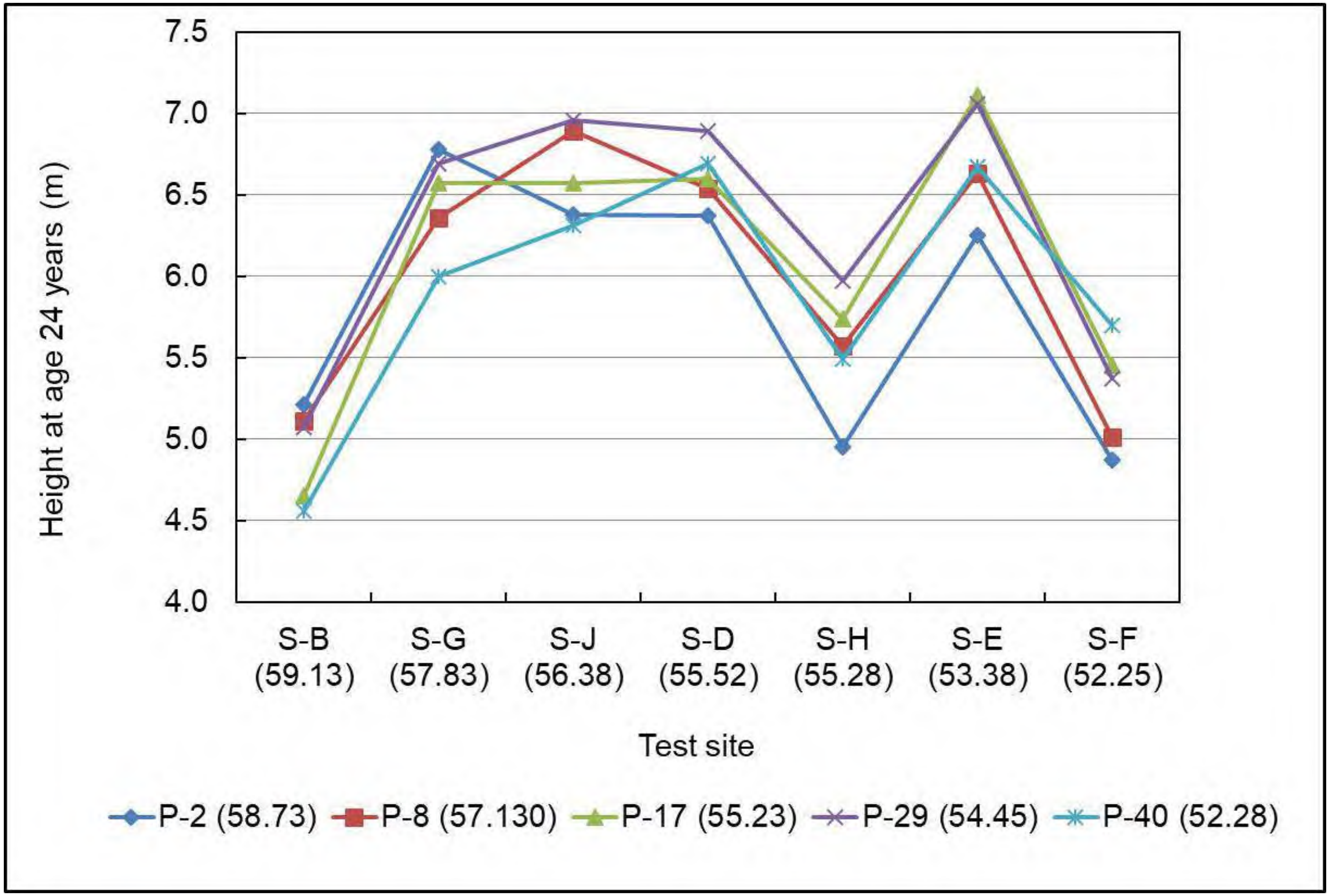
Prov	Latitude (°N)	Elevation (m)
2	58.73	335
23	56.57	762
17	55.23	610
12	54.63	610
40	52.17	1341
G103B	59.13	370
G103J	56.38	540
G103H	55.28	625
G103F	52.25	1220

	Height growth at age 24 yrs (m)			
Prov	G103B	G103J	G103H	G103F
2	**5.21**	6.38	4.95	4.87
12	4.83	**7.11**	**6.21**	5.06
17	4.65	6.57	5.74	5.45
23	4.83	**6.93**	5.38	4.93
40	4.56	6.31	5.49	**5.70**



- Demonstration of genetic variation and genotype-by-environment interaction in Alberta populations (provenances) of white spruce.
- Notice that the tallest population on a given site (**green**) is either a local or one that has been transferred from a lower latitude or a lower elevation by a limited distance.

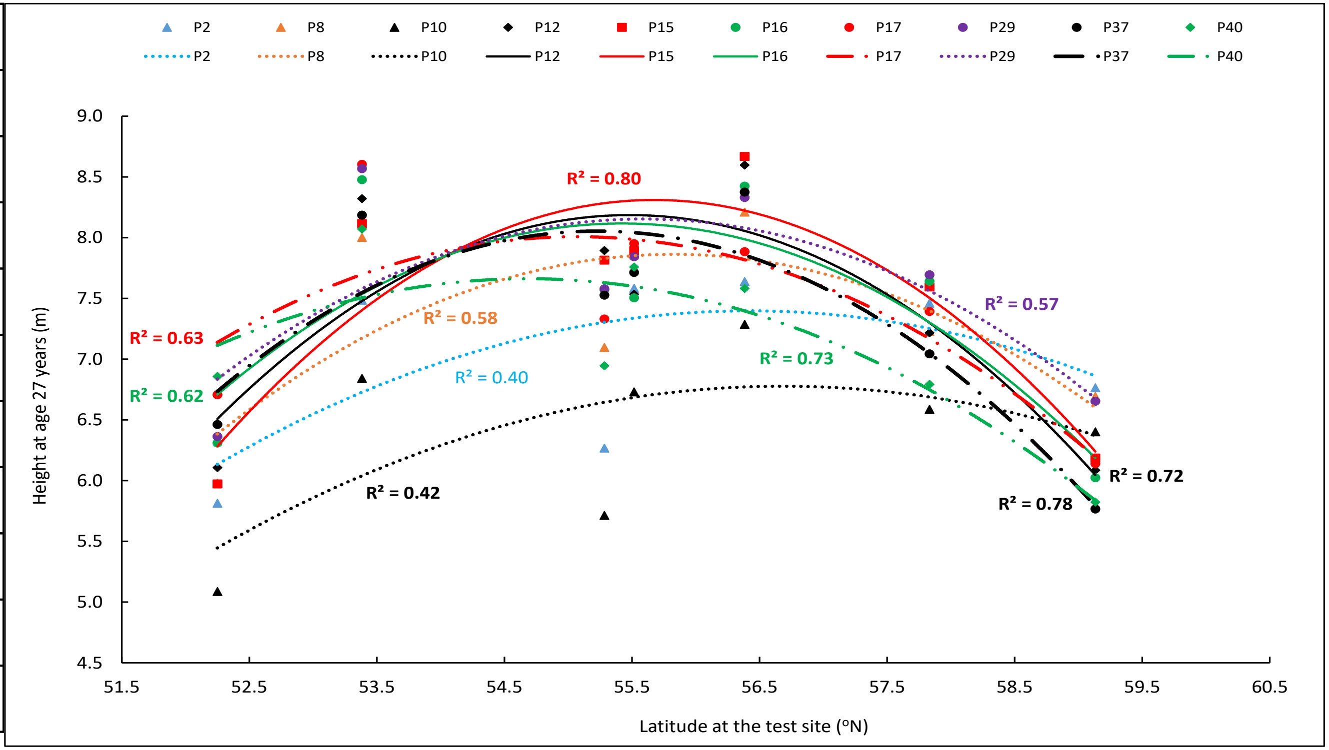
Message: Matching a seed source to a planting site is necessary in plantation forestry.



LEGEND:

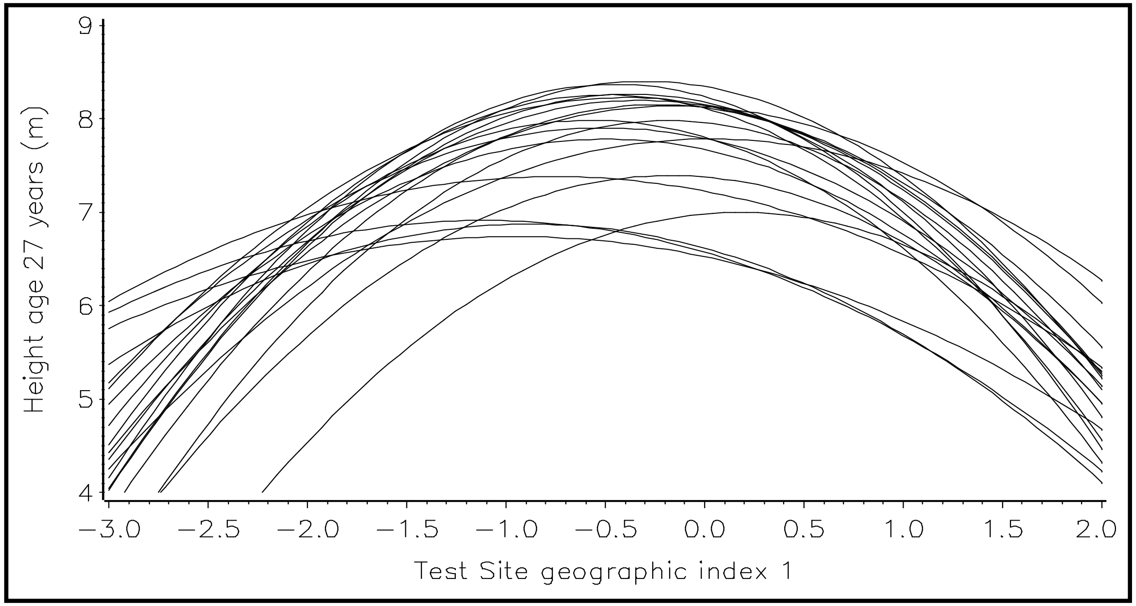
- P-2 to P-40 = provenance 2 to 40
- S-B to S-F means Site B to F
- Number in parentheses = northern latitude

PROV	LAT (°N)	LONG (°W)	ELEV (m)
2	58.73	117.40	335
8	57.13	111.63	274
10	59.88	111.72	183
12	54.63	110.22	610
15	56.63	114.58	731
16	54.80	116.98	731
17	55.23	114.77	610
29	54.45	117.63	940
37	54.18	116.62	945
40	52.17	115.47	1341



EXAMPLE: White spruce (*Piceal galuca* [Moench] Voss)

- Each line is a norm of reaction (response function) of an individual population expressed as a regression of height growth on a latitude of a planting site (7 sites).
- Notice that height of a population change as it is transferred across a range of environment (simulating a changing climate).
- Notice that response functions are not parallel(they cross each other = genotype by environment interaction)



White spruce populations in Alberta, Canada

Location descriptors of environmental variation are surrogates for climatic descriptors of environmental variation

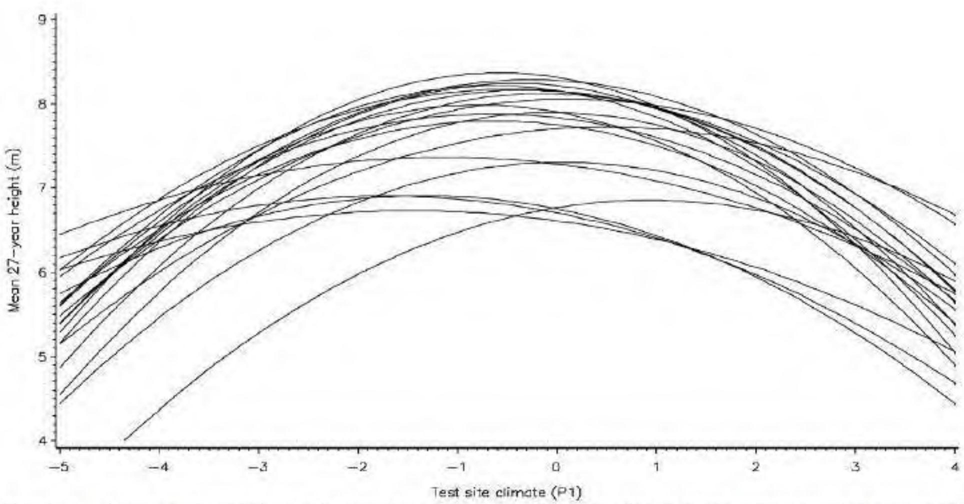


Figure 2. – Graphic presentation of 27-year height response functions for 19 white spruce populations planted at seven sites in Alberta, Canada. Similar response functions were observed for height growth at previous ages (see *Table 4* for r^2).

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Rweyongeza et al. (2010).
Silvae Genetica 59: 158 – 169

https://doi.org/10.1515/sg-2010-0019

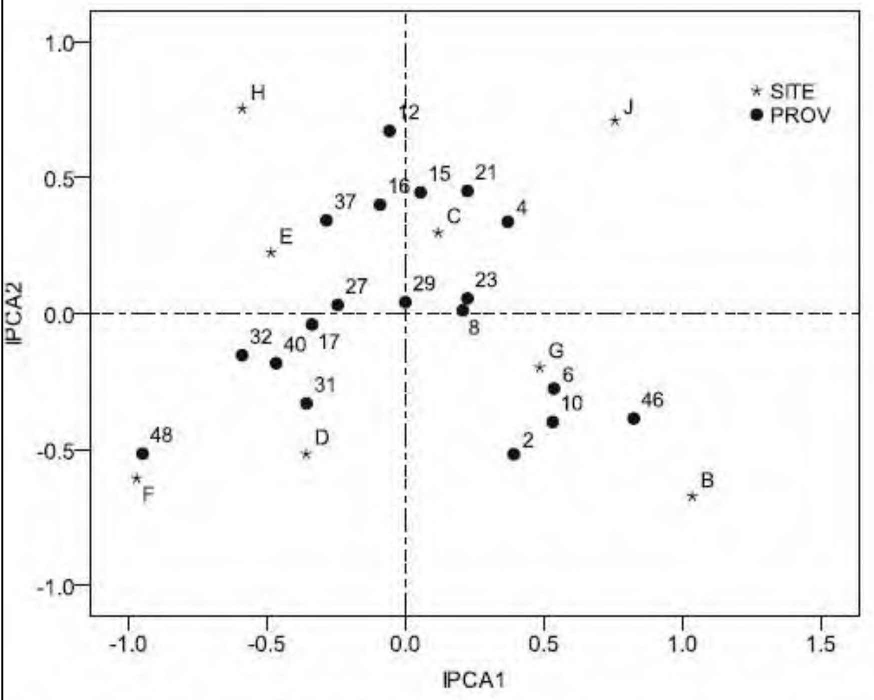


Fig. 4 Biplot for the first and second interaction principal component axes illustrating the association of test site with provenances of similar origin

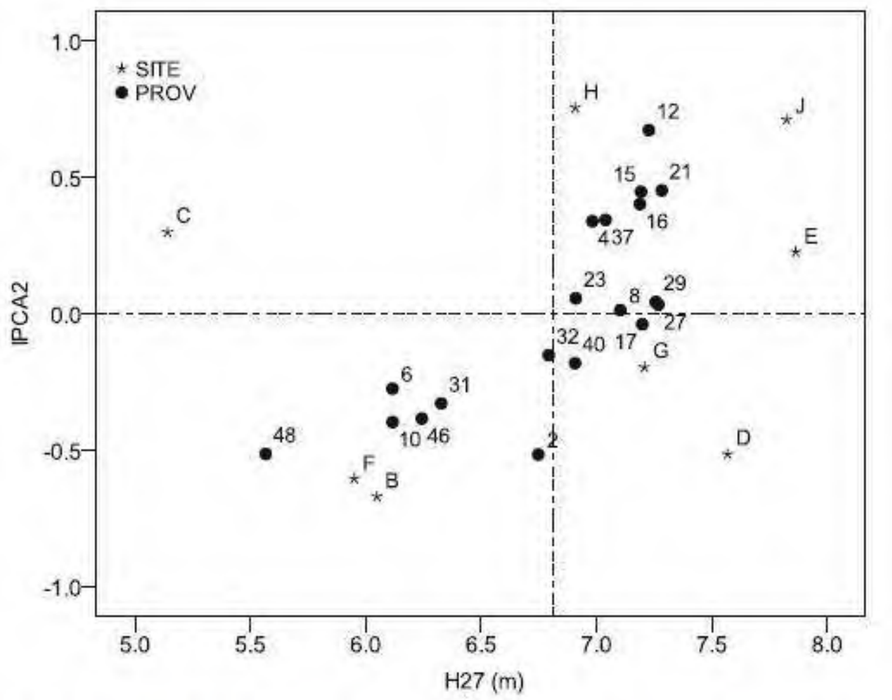


Fig. 5 Biplot for height growth and second interaction principal component axes illustrating the association of GEI with provenance growth potential and site productivity

Rweyongeza (2011). Annals of Forest Science 68: 245 - 253

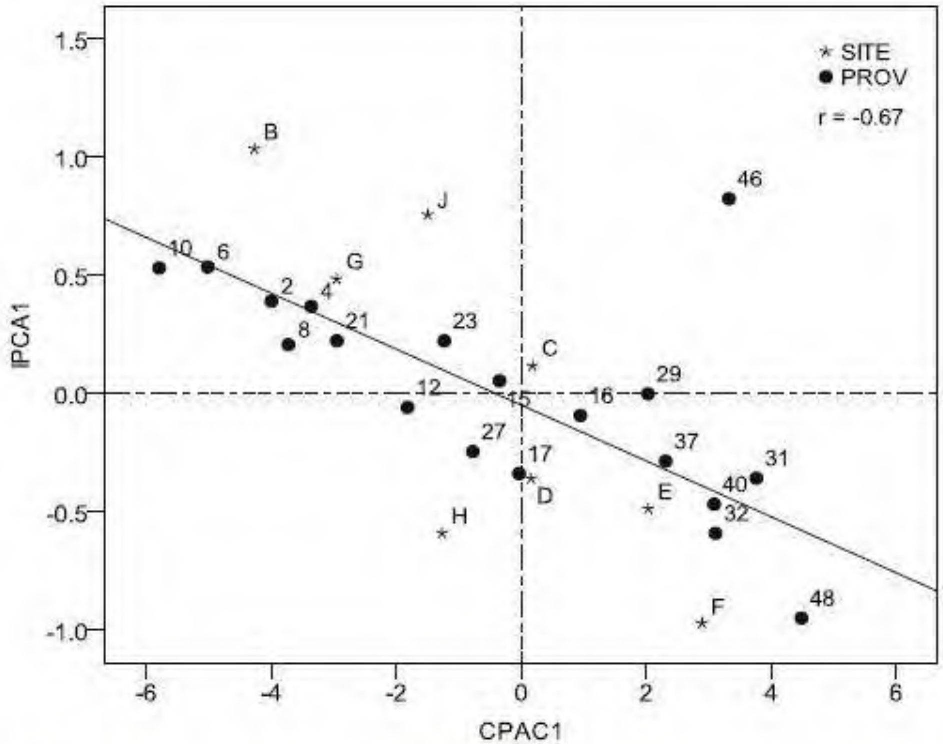
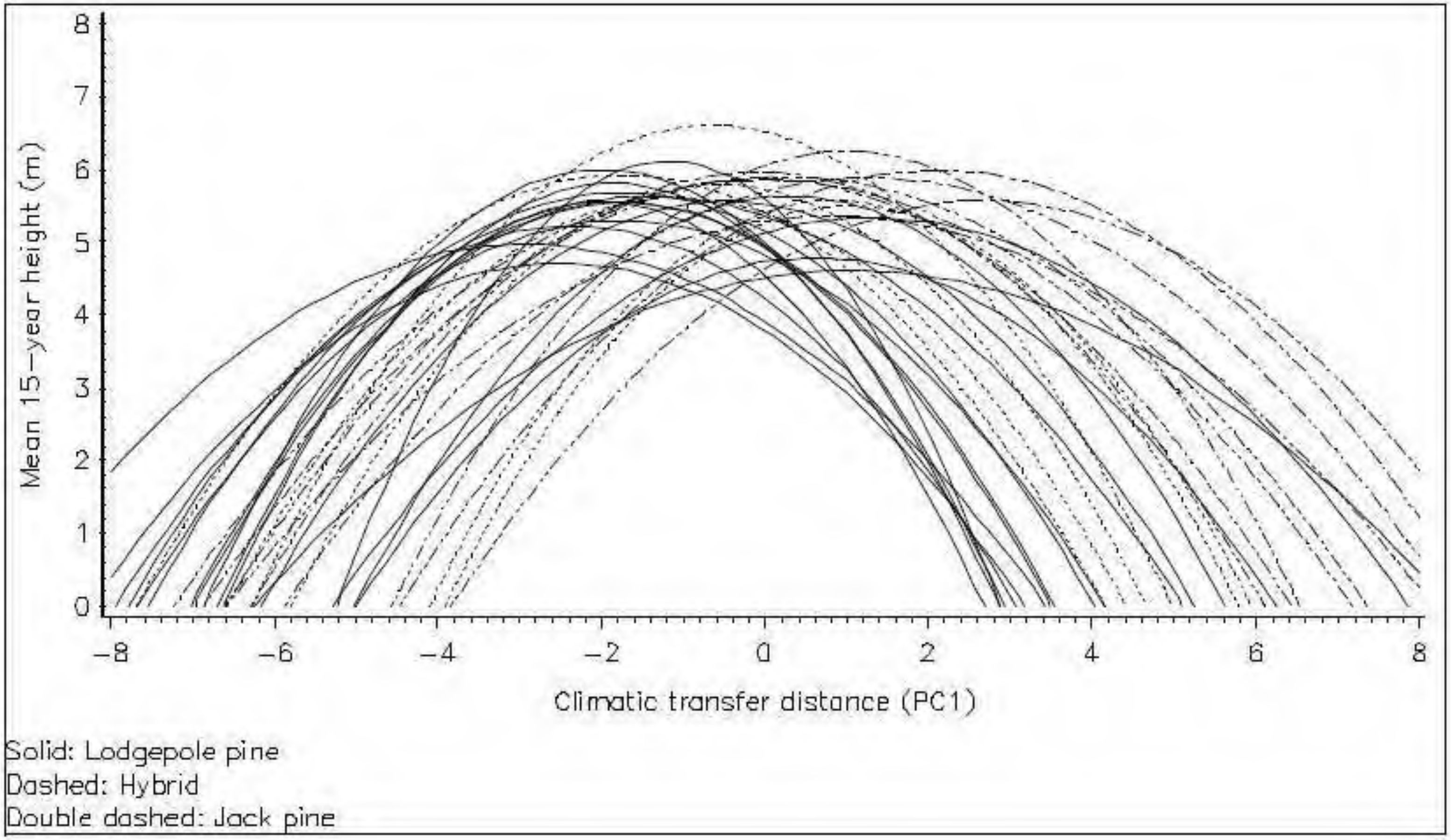


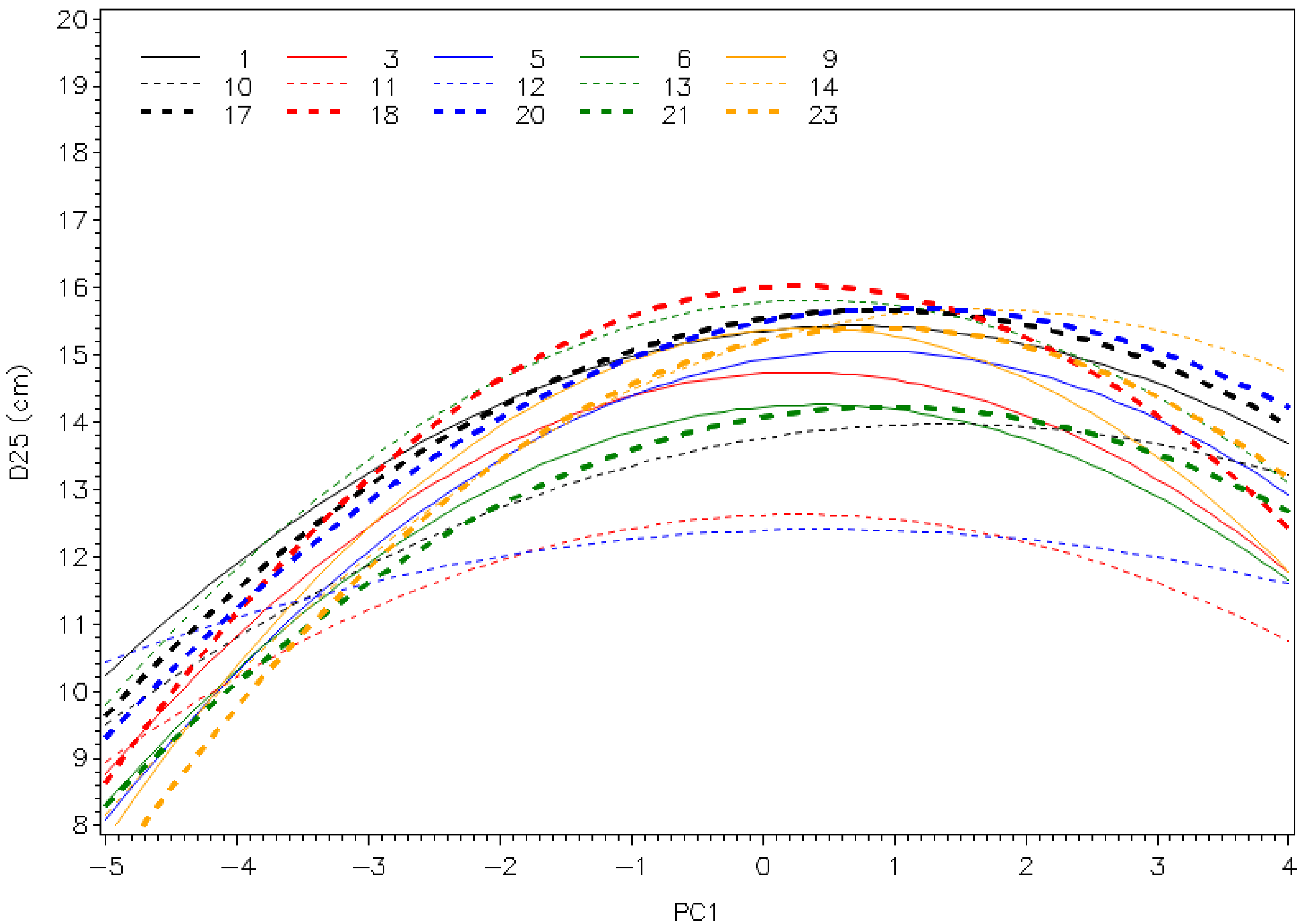
Fig. 6 Biplot for IPCA1 and CPCA1 illustrating the relationship of GEI with provenance and site climate characterized by winter temperatures and precipitation

Rweyongeza (2011). Annals of Forest Science 68: 245 - 253



Pinus contorta & ***Pinus banksiana*** provenance trial on 8 sites in Alberta, Canada
Notice that the population growth is highest within a limited transfer distance from its native location.

Source: Rweyongeza et al. (2007); Canadian Journal of Botany 85: 545 – 556



Diameter at breast height (25 years) of 15 populations of tamarack (*Larix laricina*) across 6 test sites in Alberta, Canada

PC1 = Test site climatic index from 10 climatic variables

23 Page 8 of 12 Tree Genetics & Genomes (2016) 12:23

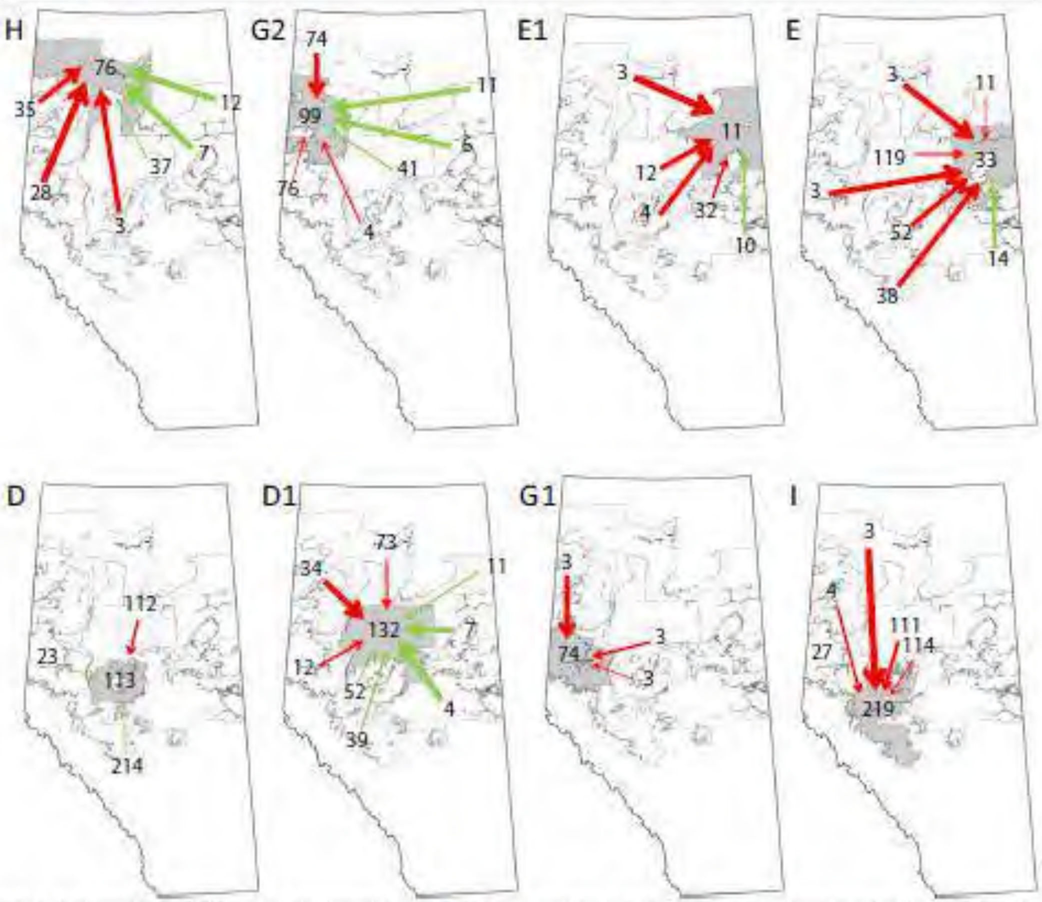


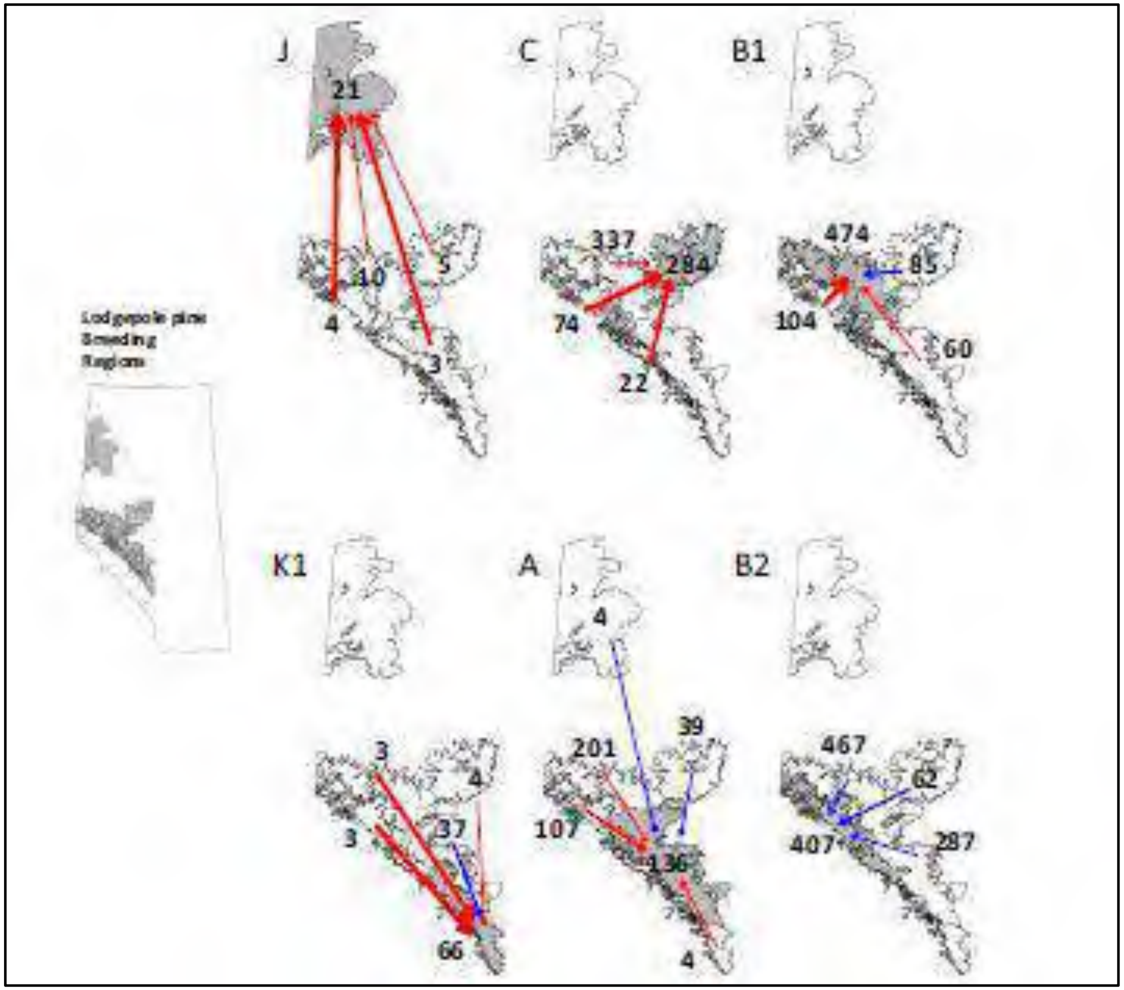
Fig. 3 Relative performance of progeny from parents when tested within the local and alternate regions, with *red* and *green* arrows representing below and above average performance compared to the local populations, respectively, based on percentage from the mean region performance for height. The *width* of the arrows represents the magnitude of performance provided in Table 3. The number of unique collections transferred and used to calculate performance is located at the start of each arrow while the *number* located in the middle of the breeding region represents the number of local unique collections

EXAMPLE: Options to transfer seed among tree breeding regions for white spruce in Alberta, Canada.

RED –transfer reduce growth in the target region

GREEN –transfer increase growth in the target region

Gray et al. (2016). Tree Genetics & Genomes 12: 23



EXAMPLE: Options to transfer seed among tree breeding regions for lodgepole pine (*Pinus contorta*) spruce in Alberta, Canada.

RED –transfer reduce growth in the target region

BLUE –transfer increase growth in the target region

Gray et al. (2016). Forest Ecology and Management 377: 128 - 138

Other related work

Rweyongeza et al. (2007). Silvae Genetica 56: 117-127

Rweyongeza et al. (2007). Canadian Journal of Botany 85: 545 – 556

Azcona et al. (2018). Forest Ecology and Management 433: 544 – 552

Azcona et al. (2018). Ecology and Evolution 8: 1758 - 1768

Lessons learned from provenance trials

- Variation in temperature is a strong natural selection pressure driving population genetic differentiation in forest tree species and other plants.
  - ✓Predictable environmental patterns cause genetic variation in plants.
  - ✓This is the reason for latitudinal and elevation clinal (directional) genetic variation in adaptive characteristics of plants.
  - ✓North – south changes in day length has the same natural selection effect in trees and other plants as temperatures.
- In temperate and other cooler northern environment population genetic differentiation in forest trees is strongly associated winter temperatures
  - ✓Again plants responds to predictable environmental attributes than random ones
  - ✓Hardly you find meaningful association between genetic variation and precipitation (rainfall) pattern that is not confounded with variation in cool season temperature.
- Population genetic variation between costal and interior populations observed mostly in tropical and subtropical areas is likely continental
  - ✓Some element of moisture gradient
  - ✓Some elements of temperature gradient

Climate change adaptation planted forests
(Use of provenance trials)

What is the relationship between provenance trials and climate change?

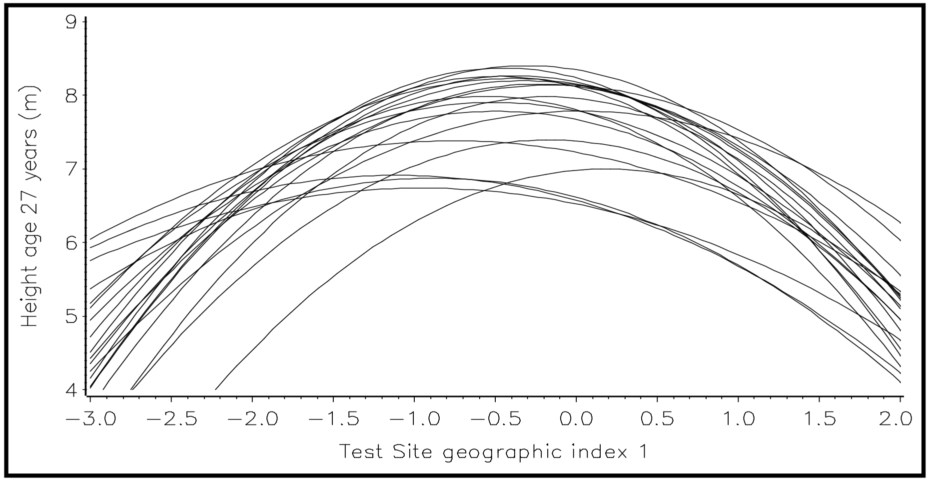
- In **traditional application**, provenance trials show us
  - The best population(s) for a given planting site or location –we know this by fitting a transfer function (most foresters ends here).
  - How expression of the trait changes (e.g., growth) with a change in climate (phenotypic plasticity) –we know this by fitting a response function (norm of reaction).
  - How populations vary (differ) in their phenotypic plasticity –this variance of phenotypic plasticity is called genotype by environment interaction (GEI).

✓In this regard, provenance trials show us how populations of forest trees respond to climate change in space (climate change due to a change of location).

Climate change adaptation planted forests

(Use of provenance trials)

- **New application** –if we were to plant say 100 populations (provenances) at a given site or location A and measure periodic changes in climate at this location A (climate change in time) and height growth increment of these 100 populations every 5 years for a period of 100 years (that is 20 measurements in total = 20 X,Y data points for each population), we would fit response functions (regression of height growth on climate) of these populations at site A, similar to the response functions we get by fitting response functions when trees are planted at many locations in one period of say 10 years (climate change in space).
- THEREFORE, the response of tree populations to climate change in space which we already know simulates how the same tree populations could respond to climate change in time (this is what we mean when we talk about climate change due to global warming).
- This is why foresters have gained interest in the use of provenance trials for climate change adaptation.



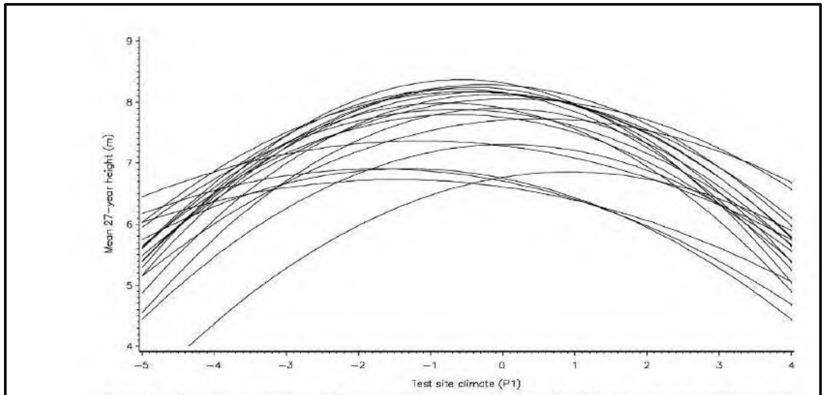


Figure 2. – Graphic presentation of 27-year height response functions for 19 white spruce populations planted at seven sites in Alberta, Canada. Similar response functions were observed for height growth at previous ages (see *Table 4* for r^2).

- **From** 59º08'N; 370m **to** 55º35N; 805m ~ 26% (H27) and 49% (DBH),
- **From** 52º15'N; 1220m **to** 55º35N; 805m ~ 28% (H27) and 34% (DBH),
- Provenances differ in their response to environmental (geographic/climatic displacement:
  - H27: R^2 = 0.63 (0.37 – 0.94); Optimum = -0.401 (-1.110 to 0.936)
  - D27: R^2 = 0.77 (0.45 – 0.96); Optimum = -0.149 (-0.596 to 1.076)

- This figure demonstrates the average change in height and diameter (DBH) in response to a climate in space.
- Same response is expected if climate were to change at similar rates at one location (climate change in time).

Climate change adaptation planted forests
(Use of provenance trials)

Climate change adaptation **we can** currently implement based on climate change adaptation

- We can potentially increase forest productivity in regions where climate change creates better environment for tree growth, if these regions have good moisture & soils.
  - Move populations from a lower to a higher latitude
  - Move populations from a lower to a higher elevation
- This is taking opportunity climate change presents –these opportunities exists in temperate and cool northern environments; may not exist in the tropics where drought is likely a problem.
- **NOTE**: Part of the limitations to transfer populations and increase forest productivity in northern environments has always been a need to balance (trade-off) the potential increase in annual growth and the risk of frost/cold damage. –a warming climate reduces this risk.





Survival, growth and reproduction in extreme seasonal changes in temperature is part of adaptation and a criterion for forest management decisions.

Climate change adaptation planted forests
(Use of provenance trials)

Climate change adaptation **we cannot** currently implement based on existing provenance trials:

- Cannot say with certainty that we know populations that are better adapted to drought stress than others, because:
  - The provenance trials we have were not setup to test variation in drought stress tolerance. They were established to measure variation in growth potential within a productive forestry environment when climate change was not anybody's concern.
  - Also, the fact that the current pattern of population differentiation is best explained by winter temperatures NOT precipitation makes it harder to use existing provenance trials in climate change adaptation for drought tolerance.

Survival, growth and reproduction in extreme seasonal changes in temperature is part of adaptation and a criterion for forest management decisions.

We are establishing new provenance trials targeting:

- Populations from drier areas
- Testing in drier environments

Picture: Example trial of 300 populations of white spruce on 5 sites in Alberta, Canada.

Other genetic climate change adaptation initiatives

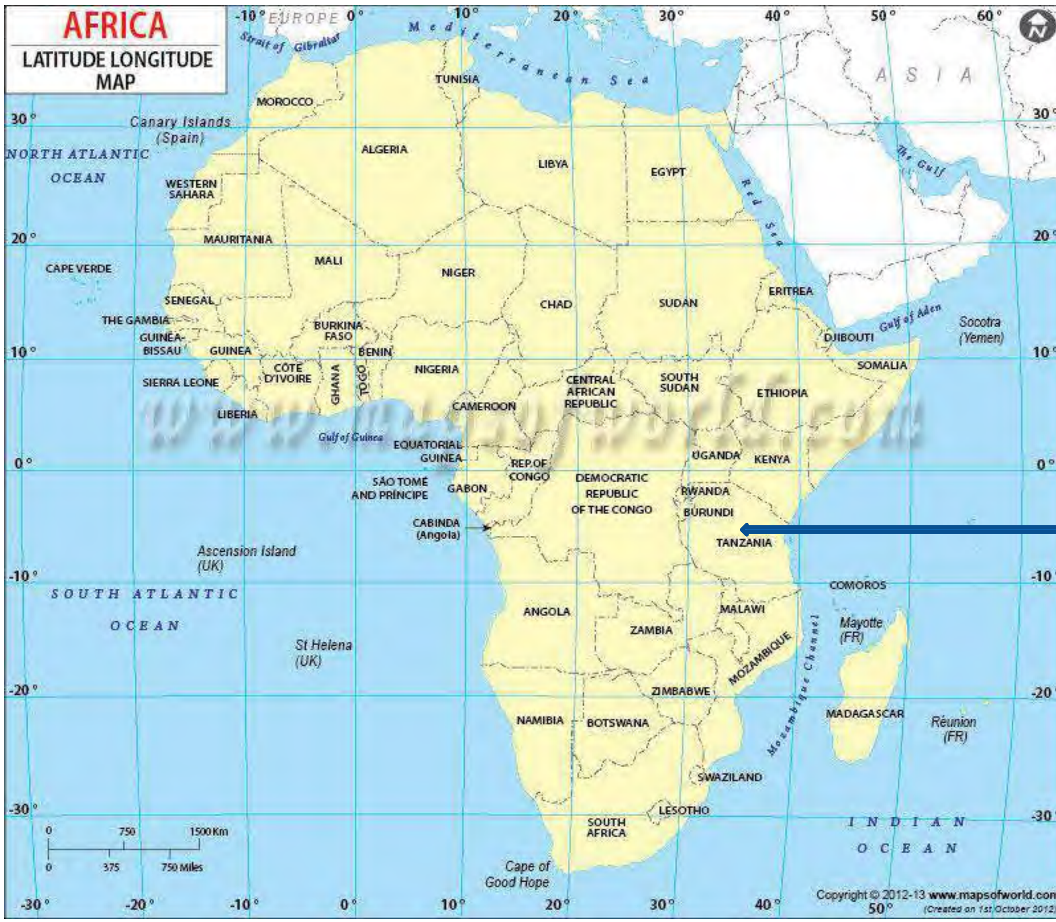
NOTE: All these initiatives are looking at understanding the mechanisms of tree populations response to changes in temperature, precipitation and drought stress & use that information to select populations for reforestation in a future drier climate.

- Studies of carbon isotope ratios ($^{13}C/^{12}C$) in tree needles/leaves and wood (out of scope of the this seminar).

- Genomic studies and genomic selection (molecular biology –DNA, RNA, metabolomics, proteomics, etc.) –out of scope of the current seminar.

- NOTE: Tree breeding is always an option when the desired trait cannot be found naturally.

Climate change adaptation in tropical forestry
(Think of Tanzania as an Example)



Tanzania

- Obviously **no risk** for low temperature to forestry
- Obvious **high risk** for drought for forestry and agriculture.
- Your forestry **differ** from that of North America, Europe and part Asia (e.g., extensive use of exotic species in commercial forestry)

What is there for you in what I have presented here?

- The origin of seed is very important even if the context is different!

Source: Google maps

Climate change adaptation in tropical forestry
(Think of Tanzania as an Example)

Characteristics of the forestry sector in Tanzania: -FORESTS

- Commercially actively managed plantation forestry –exotic species (pines, cypress, teak, eucalyptus, etc.).
- Commercially harvested but not much commercially managed forestry –native deciduous (hardwood /broadleaf species).
  - Complex multi-species ecosystems
- Forest reserves and water catchment areas –leave for nature to run its course.
- Agroforestry –mixture of agriculture, forestry and livestock production
  - Think of this as non-intensive land management system

Climate change adaptation in tropical forestry
(Think of Tanzania as an Example)

Characteristics of the forestry sector in Tanzania: -OWNERSHIP

- **Government**
  - Exotic coniferous & deciduous plantations
  - Natural forests
- **Private corporations**
  - Exotic coniferous & deciduous plantations
- **Family-owned woodlots**
  - Exotic coniferous & deciduous woodlots
  - Agroforestry

Question: assuming that this complex system of forestry and its ownership contribute to the national timber and wood fibre needs & environmental protection, who is responsible for climate change adaptation?

- ➢ How to implement climate change adaptation?

Climate change adaptation in tropical forestry
(Think of Tanzania as an Example)

An environmentally resilient forest requires:

- Suitably genetically adapted seed sources (provenances / populations)
- Genetically diverse populations –think of this as a buffer against the unknowns and periodic changes

Question: at a level of complexity in species and forest ownership Tanzania has, do you know if you have the right seed sources and level of genetic diversity in planted forests to provide resilience against a changing climate?

Climate change adaptation in tropical forestry
(Think of Tanzania as an Example)

Gene conservation & climate change adaptation

- Conservation of genetic resources is an insurance policy against unknown future including a changing climate.
- Need conservation programs aimed at protecting genetic diversity of important species (assuming you cannot protect everything in a multi-species environment of a tropical forest).

Question: Are your current forest reserves designed to protect species and their genetic diversity or simply to protect water resources, wildlife sanctuaries, and tourism-oriented benefits?

Climate change adaptation

(Dealing with changes in forestry)

Education

- Like managing all other organizational vulnerabilities and risks, a good educational foundation in forest biology and management is essential in addressing threats of climate change in forestry.

Question: Does your current forestry curriculum (SUA, other universities & colleges) provides a proper foundation for dealing with environmental-driven biological stresses?

TAKE HOME MESSAGE

Climate change adaptation in forestry will depend on the nature of our own forests, ownerships, and degree of regulatory control of the forestry sector.

Thank You!

Questions?

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