Adaptive Management in Response to Climate Change: A Synthesis of Research Findings and Observations from the Pacific Northwest Forests

Tim Sanders, World Forest Institute Fellow, Australia 2011

Introduction

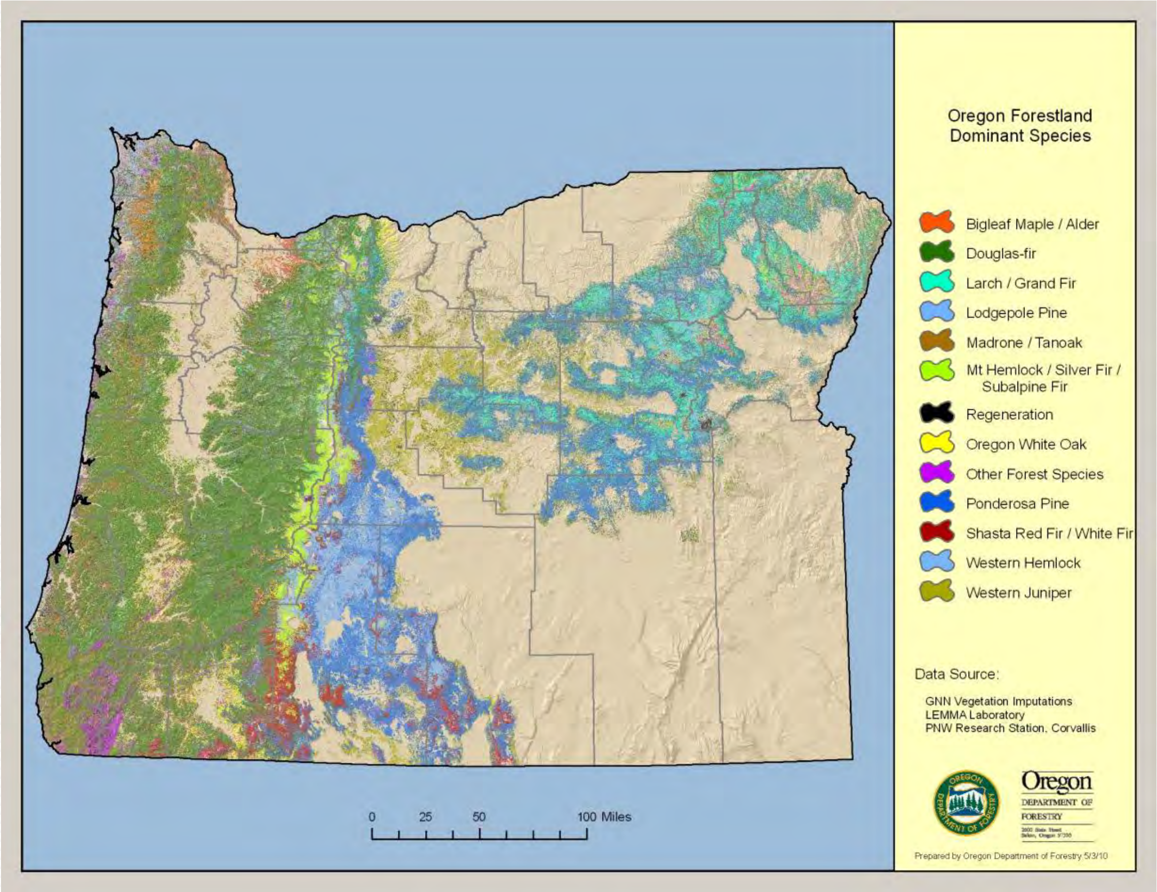
- This presentation draws on important research conducted to date, together with the author's observations in summarizing:
  - the projected changes in climate in the Pacific Northwest (PNW) region
  - the expected effects these changes will have on major tree species within the PNW forests
  - the types of silvicultural and genetic adaptation tools available to forest managers, to assist in ensuring the health and vigor of these populations are maintained
- Recommendations for improving commercial native forest silviculture in Victoria, Australia, together with concluding remarks will complete the presentation

The Pacific Northwest Forests of North America

- The Pacific Northwest (PNW) region of North America is loosely defined amongst literature
- For this presentation, all future references to the PNW refer to forested areas within the US states of Oregon and Washington, the coastal region of northern California, and the Canadian province of British Columbia

PNW Forests of North America (cont)

- They are distinct among the Northern Hemisphere temperate forests
- Composed mostly of conifers, these forests are adapted to the wet mild winters and warm-dry summers typical of the region (Chimura 2011)



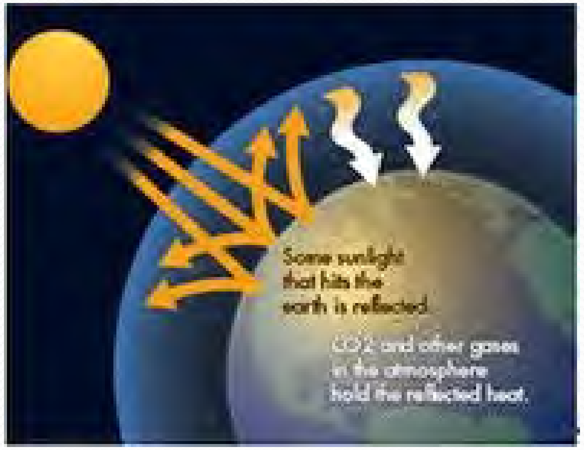
Source: http://www.oregon.gov

Forest Management in the PNW

- It is an important sector in the PNW
  - has a significant and direct impact on the economy, and the health and well-being of its citizens
  - provides timber products, freshwater, wildlife habitat and recreation (OCCRI 2011)
- PNW forests will continue to be an important part of the regional economy and play a significant role in carbon (C) sequestration and climate change mitigation (Chimura 2011)

Projected Changes to CO_2 Concentrations in the PNW

- CO_2 Levels
  - since the pre-industrial era, atmospheric CO_2 increased from approximately 280ppm to 390ppm
  - it is likely to reach 540–970ppm by the end of this century. Projected changes in atmospheric [CO2] at local scales are expected to track changes at the global scale (Chimura 2011)



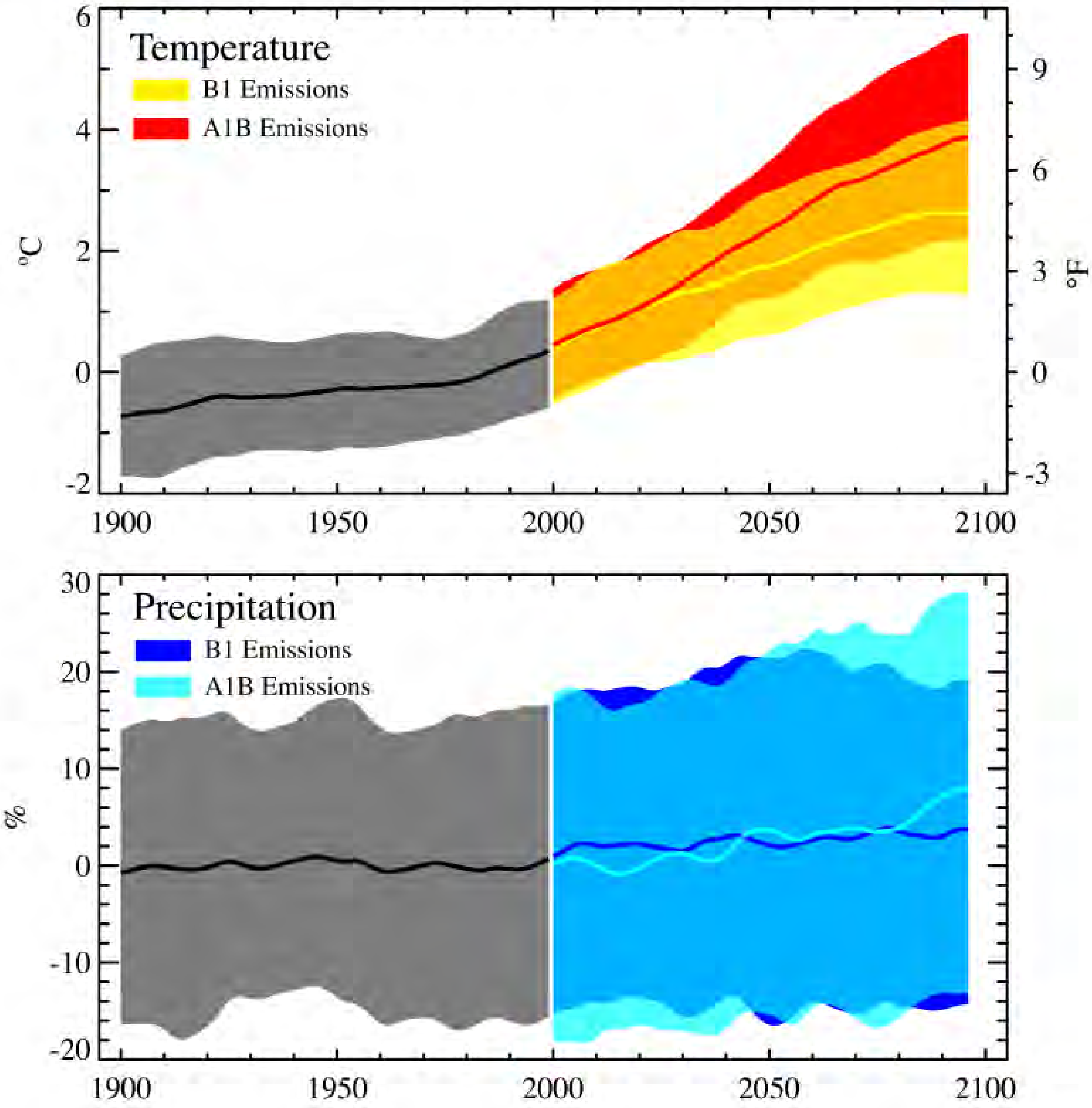
Projected Changes to Climate in the PNW

- Temperature
  - temperature in the PNW region has warmed 0.7-0.9 ◦C since 1920 (Littell 2011)
  - expected to warm a further 0.8–2.9 ◦C by 2050 and 1.6–5.4 ◦C by the end of the century (OCCRI 2011)
  - likely to be greater inland than near the coast, and more pronounced in summer (3.9 ◦C on average) than in winter (average of 2.7 ◦C) (Chimura 2011)
  - in British Columbia, projections for the end of the current century include a minimum temperature increase of 5 to 10 degrees Celsius (McKenney 2009)

Projected Changes to Climate in the PNW (cont)

- Precipitation
  - projected changes in regional precipitation are less certain than those for temperature
  - overall, small decreases in summer precipitation and small increases in winter precipitation are projected (Chimura 2011)
  - more winter precipitation will likely fall as rain compared to snow resulting in increased runoff and greater streamflows (OCCRI 2011)
  - summer runoff is likely to decrease and consequently reduce streamflows (Littell 2011)
  - in parts of British Columbia, annual precipitation is projected to increase by up to 10% (Johnston 2009)
  - the frequency of heavy precipitation events will also likely increase (Chimura 2011)

Temperature & Precipitation (cont)



source: Mote 2009

Effects of Climate Change on Forests in the PNW

- Increased Temperatures Impacting Growth
  - warming may result in more frequent and severe heat events that expose trees to heat injury (Chimura 2011)
  - at low elevation sites where moisture is limited, increased summer temperatures may lead to higher rates of evapotranspiration, which could decrease growth in Douglas-fir, Western Hemlock forests (Chimura 2011)
  - in high elevation e.g., Subalpine Fir, Mountain Hemlock forests where moisture levels are adequate, growth may be increased by extending the duration of temperatures favourable for growth (Littell 2011)

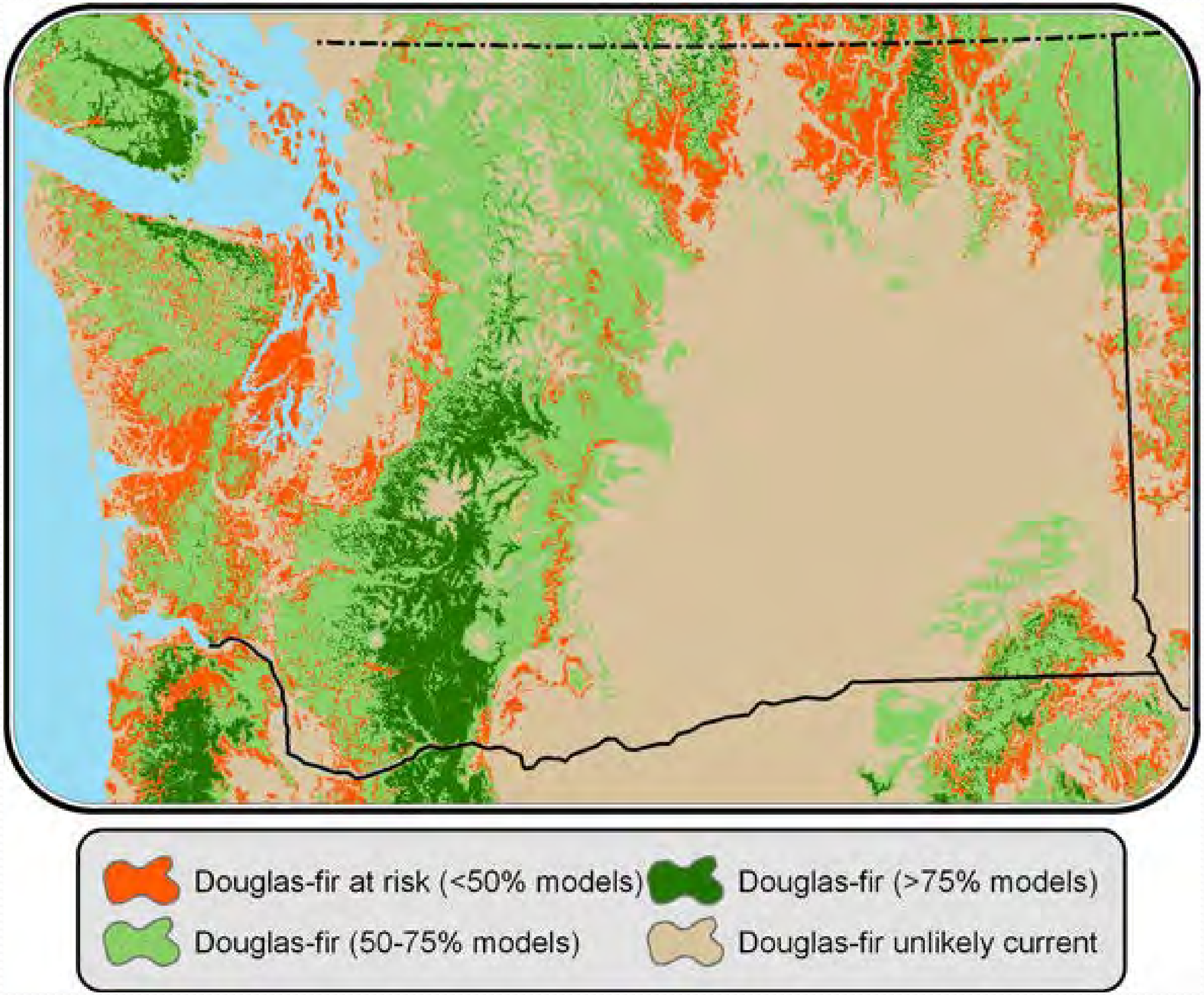
Effects of Climate Change on Forests in the PNW (cont)

- Increased T^{o} Impacting Regeneration
  - for some species, as long as future climates continue to satisfy their seed chilling (stratification) requirements, warmer spring temperatures may be favorable for seed germination
  - for other species, warmer fall (autumn) temperatures may enhance germination of non-dormant seeds, increasing winter mortality (Chimura 2011)
  - moderately warmer winters have been found to trigger earlier bud burst in Douglas fir, but much warmer winters could result in later bud burst than has occurred historically. Either of these scenarios could result in poor growth caused by late spring frosts or soil-moisture limitations (Parks 2010)

Effects of Climate Change on Forests in the PNW (cont)

- Precipitation
  - projected decreases in snowpack, earlier snowmelt, and increases in the frequency of heavy precipitation events, may increase the frequency of flood-related injuries (Chimura 2011)
    - The consequences of flooding, however, will depend on the timing and duration of the flood, and the quality of water

Effects of Climate Change on Forests in the PNW (cont)



Source: Littell 2010

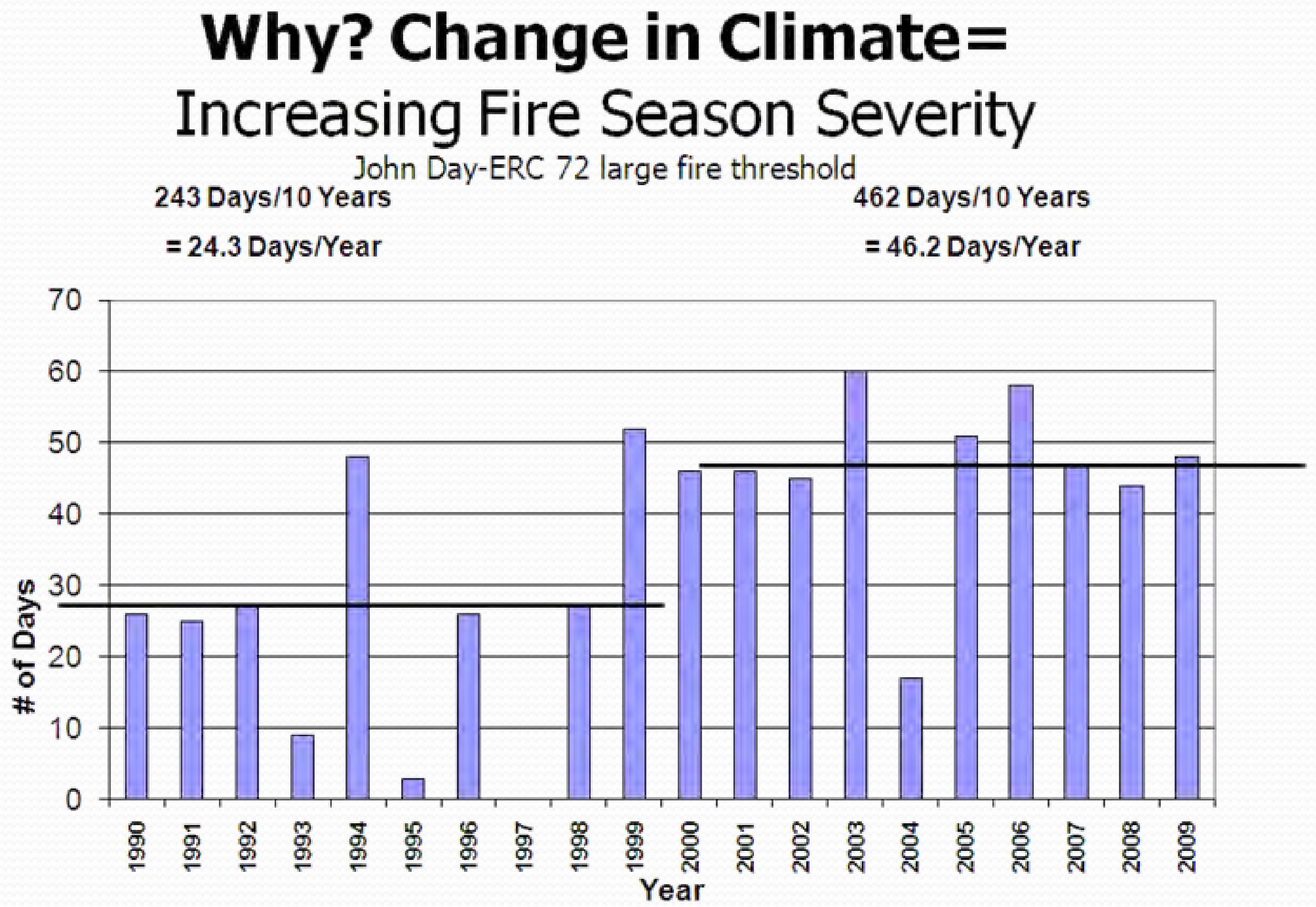
CC and its Effect on Disturbance Regimes within the PNW

- Drought
  - is a factor that leads to both wildfires and major insect outbreaks
  - is also an important disturbance agent in itself. Although most vegetation types in the PNW are well adapted to dry summers, projected future changes in the hydrological regime have the potential to cause large-scale tree mortality (Shafer 2010)
  - unclear as to how the directional change in climate and water availability will affect flowering and other reproductive processes in the longer term

CC and its Effect on Disturbance Regimes within the PNW (cont)

- Wildfire
  - an increase in fire activity is expected for all major forest types in the PNW. This in part is due to evidence suggesting increasing lightening activity under CC (Shafer 2010), as well as high temperatures and expected drought conditions (Chimura 2011)
  - for a mean temperature increase of 2 ◦C, the annual area burned by wildfires in western states is expected to increase by a factor of 1.4–5 (OCCRI 2011)

Wildfire (cont)



*Same significant change in Fire season severity is present in the other high fire districts

Source: D. Decker

CC and its Effect on Disturbance Regimes within the PNW (cont)

- Insect Pests and Diseases
- If the host is sufficiently stressed and weakened it may not have enough reserves to produce chemical defences
- Expected responses include (Johnston 2009):
  - changes in the type, amount and relative importance. With warming, some pests and diseases may be able to occur further north or at higher elevations than under current conditions
  - the epidemiology of plant diseases and pests will be altered. Prediction of outbreaks will be more difficult.
  - e.g. Mountain Pine Beetle, Swiss Needle Cast
- In general, warming is likely to encourage northward expansion of more southern insects and diseases, while longer growing seasons may allow more insect generations per year (Shafer 2010)

Adaptations of Tree Species

- As can be seen from the above findings, climate change will require trees to cope with new climatic and biotic environments
- To avoid extinction, populations will attempt to cope through three mechanisms (Chimura 2011)
  - acclimate (phenotypic plasticity)
  - migration
    - seed dispersal
    - pollen transfer
  - in situ evolution
    - mutation
    - natural selection

Adaptive Management Practices in Response to CC

- Silvicultural and genetic practices can be employed to assist in forest adaptation to climate changes, principally by influencing stand structure and species composition throughout stand development (Anderson 2009).
- There are 4 key steps to facilitate adaptation: (Peterson 2011)
  - review
  - rank
  - resolve (resistance, resilience and response)
  - observe
- In practice, these steps are best considered iteratively

Adaptive Strategies (within the “resolve” phase)

- These categories encourage thinking about the range of possible options and do not imply that a treatment fits into one specific category. Some treatments may reflect only one strategy whilst others may combine them (Millar 2007)
- *Resistance* - a set of tools to manage forest resources so that they are better able to resist the influence of climate change or forestall its undesirable effects (Millar 2007)

Adaptive Strategies (cont)

- *Resilience* - improves the capacity of the community to return to desired conditions after disturbance either naturally or with management assistance
- *Response* - intentionally accommodate change rather than resist it, with a goal of enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue

Case Studies

- I've chosen two case studies to demonstrate how scientific research and land management agencies can cooperate to develop and implement adaptation options for assisting forest ecosystems to adjust to rapid climate change
    1. Primarily silvicultural (Olympic National Forest)
    2. Genetic (Assisted Migration Adaptation Trial)

First Case Study – Olympic National Forest (ONF) in Washington state

- Consists of a mountain range and foothills surrounded by coastal waters to the west, north, and east, and low elevation forested land to the south
- Within this region, ONF is an area of approximately 257,000 ha surrounding the Olympic National Park
- Current management objectives are focused on restoring habitat, enhancing native biodiversity, promoting development of late-successional forests, controlling invasive species, and ongoing monitoring (Littell 2011)

Adaptation Strategies Developed for the Olympic National Forest

- *Resistance*
  - use early detection-rapid response to control exotic and invasive species

Resilience

- Continue to increase disease resistance in susceptible species, such as western white pine and whitebark pine
- Increase the amount of restoration thinning in young stands across large landscapes to reduce competition and drought stress, increase tree growth and vigor, insect resistance, structural complexity and species diversity
    - 3 field examples

Resilience – Restoration Thinning

Field Example 1 : The Nature Conservancy Site – Ellsworth Creek Preserve

Resilience – Restoration Thinning (cont)

Field Example 2: Olympic National Forest – "Two Flat" Thinning Site

Resilience – Restoration Thinning (cont)

Field Example 3: H J Andrews Experimental Forest – Blue River Landscape Study

Response

- Protect and conduct restoration treatments in riparian areas to provide corridors for species movement

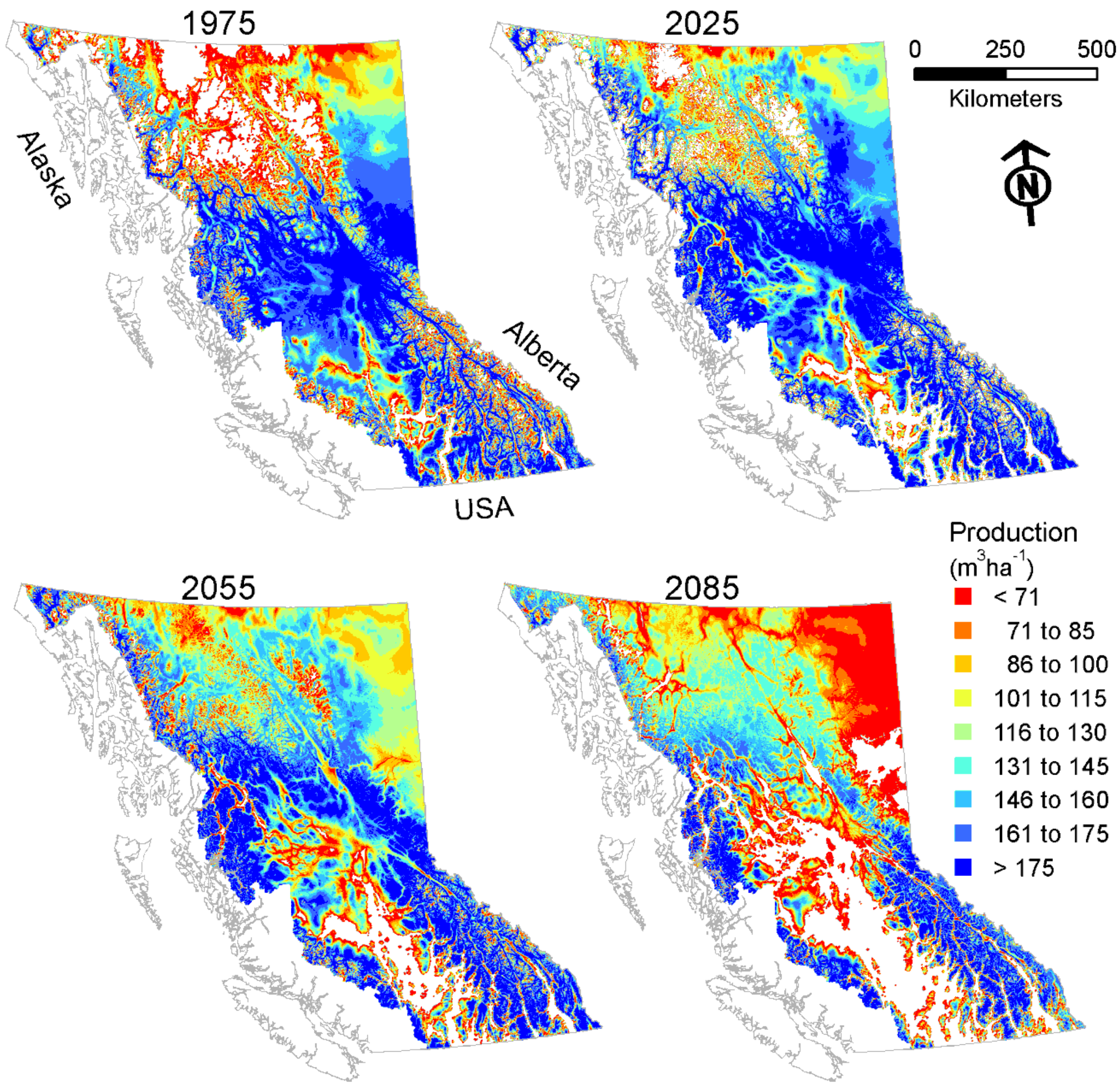
Response - Treat large-scale disturbance as a management opportunity

- In the ONF, large disturbances (e.g., blowdowns caused by cyclonic winds or large wildfires) can be used to influence the future structure and function of forests through planting and silviculture.
  - planning for future post-disturbance recovery
  - plan for and implement revegetation and silvicultural options appropriate for a warmer climate

Second Case Study – Assisted Migration of Populations and Species

- Why assisted migration?
  - risk of maladaptation – a reduction in productivity, poor stem form and wood quality, and increased susceptibility to pests and disease
    - expected to arise because trees' annual growth cycle will become increasingly unsynchronized with the annual climate cycles
  - is proposed as a key climate change adaptation strategy, because it addresses the issue of the uncoupling of plant adaptation to its environment

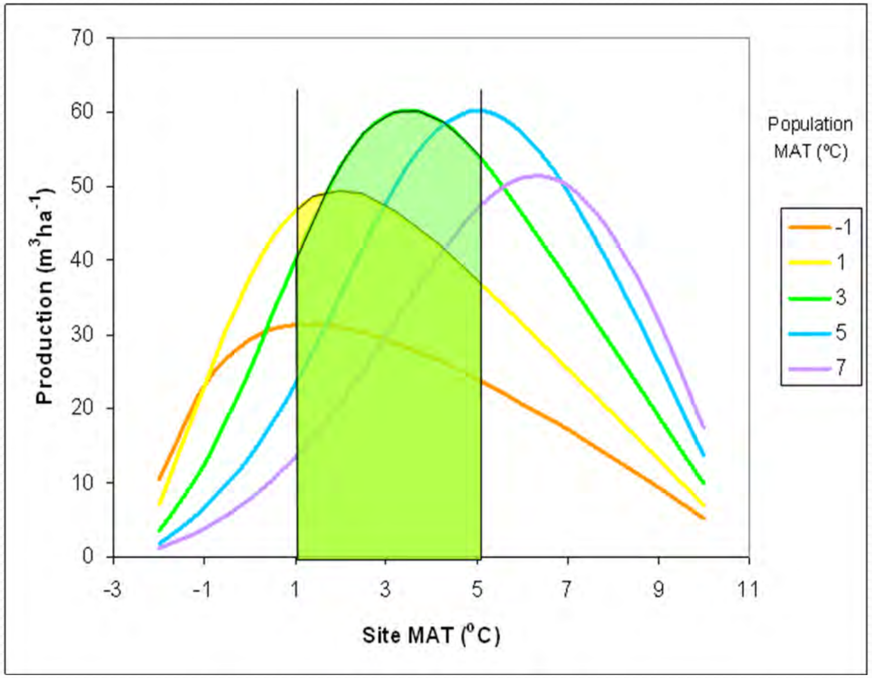
Why assisted migration? (cont)

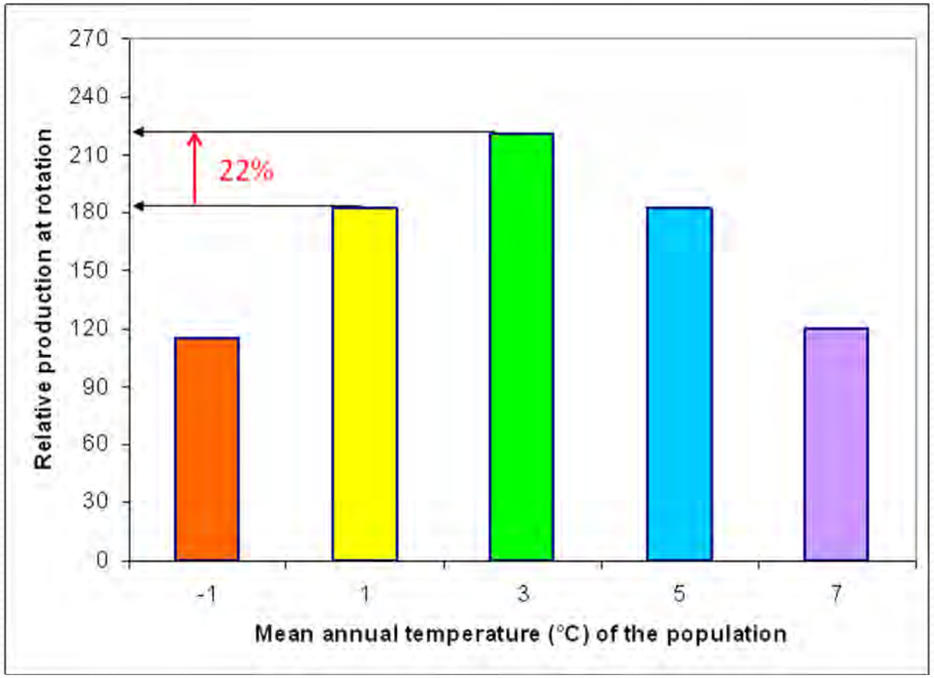


Source: O'Neill 2008

Why assisted migration? (cont)

- The strategy of assisted migration can be applied to both species and seedlots, and involves anticipating the climate expected at the planting site at approximately one third of the rotation into the future, and selecting both species and seedlots suited to that climate





Source: O'Neill 2011

Assisted Migration Adaptation Trial (AMAT)

- The primary focus of AMAT is to develop an understanding of the adaptation of seedlots from seed orchards, across a range of climatic and latitudinal environments
  - one element will test whether moving trees north will enable them to fare better as the climate changes around them
  - another turns the clock forwards by taking provenances and moving them south, forcing them to endure a warmer climate and quickly simulating years of climate change
- The project involves testing 48 seed sources representing 15 commercial tree species across 48 field test sites located between central Yukon and northern California
- Growth, health and wood quality will be measured every five years
- An intent is to push these trees to their survival limits, perhaps even killing some, to gain a better understanding of when productivity declines and sickness sets in

Two Similar Studies

- Spruce Provenance Trial
  - in 2003/04, white and Engelmann spruce from 128 different seed sources were planted in 18 different locations throughout Canada
  - growth responses are being measured every 3 years and will assist researchers in determining the most appropriate provenances for particular climatic conditions
- Douglas fir Provenance Trial
  - involves testing Douglas fir seedlings from 12 seed sources in northern California, Oregon and Washington at 9 sites in western Oregon and Washington
  - all sites were planted during the winter of 2008-09 and measurements recording phenology (budburst and budset), diameter, height and tree condition will be taken regularly
  - each test site has a weather station which logs air temperature, humidity, precipitation, and soil moisture and temperature

Revising Seed Transfer Guidelines

- To ensure forests being established today will be adapted to future climates, it is necessary to ensure systems of seed transfer guidelines are in place
- Incorporation of assisted migration will be most prudent and effective in those seed transfer systems that are based on climate (McKenney 2009)
- Seed selection is often based on fixed seed zones
- An alternative is the focal point seed zone approach
  - provides for greater deployability than the fixed zone
  - requires delineating a unique deployment zone around every seed source, or a unique seed procurement zone around every plantation
  - the size of the deployment or procurement zone is defined by a maximum climatic or geographic transfer distance

An Example of the Focal Point Approach

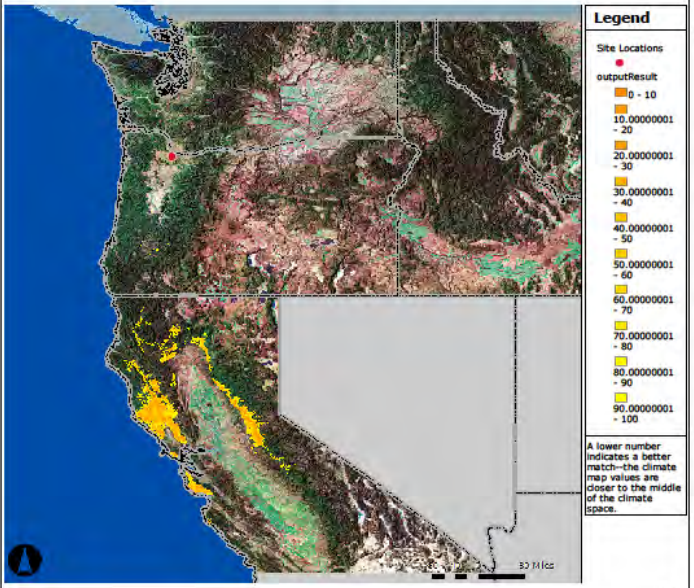
- Seed-lot selection tool

Map http://sst.forestry.oregonstate.edu/PNW/PrintView.aspx

Find Seedlots for my Planting Site

Map

Title



logo

Data set name: **Report_example**
Total cells meeting the criteria: 27886

Species: Douglas-fir
Method for determining transfer limit: Zone : Location coordinates used as the climatic center of output map

Transfer Limit

Name of climate variable	Present climate value	Climate value in target year	Target year	Transfer distance
Mean annual Temp (MAT)	119	144	2080	16
Mean annual Precip (MAP)	1169	1194	2080	512

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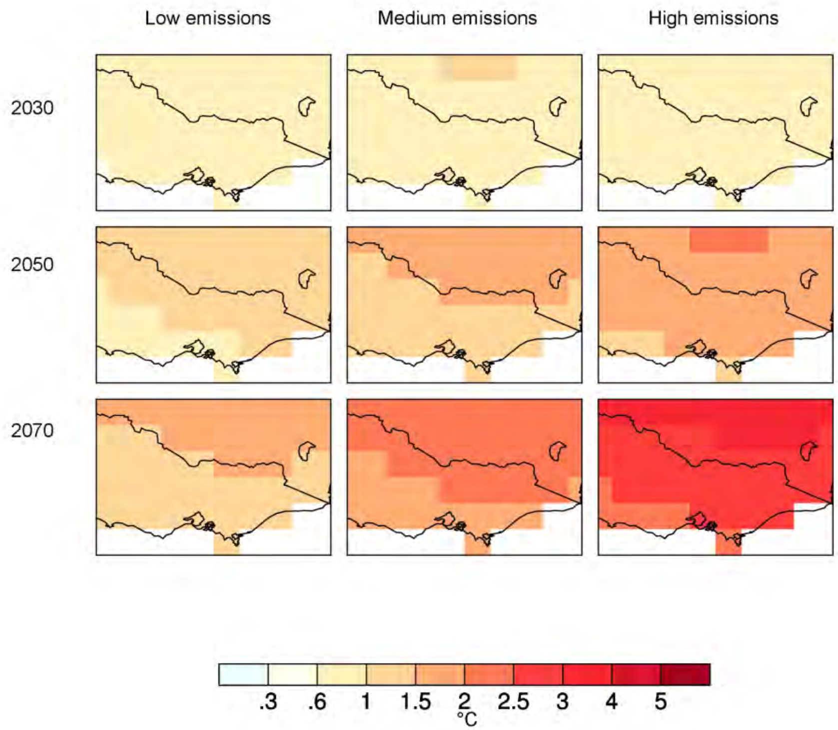
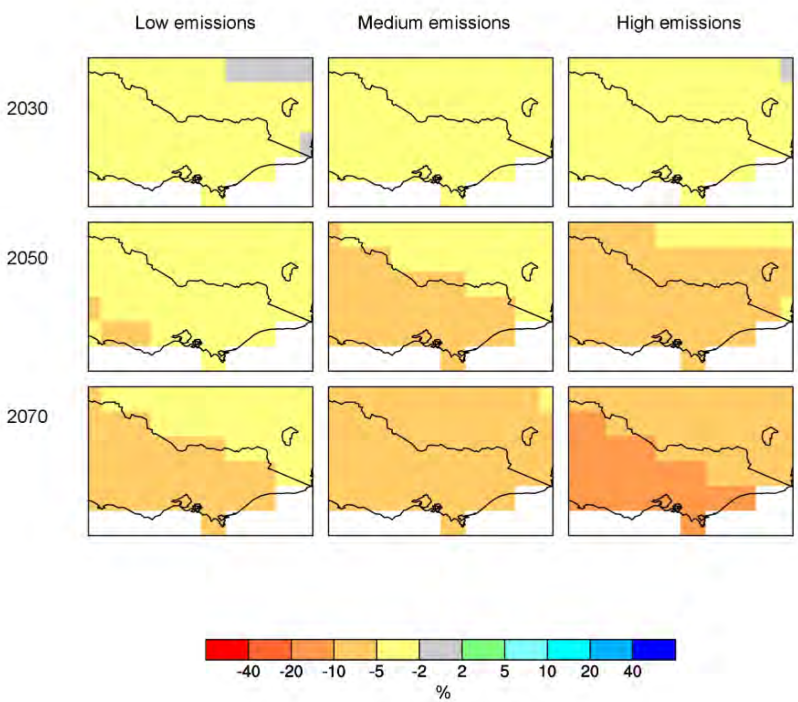
Report from the seed lot selection tool (cont)
Climate Variables
Name: Mean annual Temp (MAT)
Description: mean annual temperature 10ths deg C
Name: Mean annual Precip (MAP)
Description: mean annual precipitation millimeters
Location
Latitude (dd): 45.50483
Longitude (dd): 122.74381
Elevation (ft) at coordinates: 613
Zone Name: Douglas-fir OR modified (1996)
Zone Designation: 8
Zone Band: 0 to 1000 feet
Present Climate Model
GCM: n/a
Description: n/a
Emission Scenario: n/a
Downscale Method: ClimateWNA interpolation of PRISM
Current Data: 1971-2000 normals
Model URL:
Data URL:
www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html
Future Climate Model
GCM: CGCM3.1
Description: 3rd Gen Coupled GCM T63 run1
Emission Scenario: SRES A1B
Downscale Method: ClimateWNA interpolation of PRISM
Current Data: n/a
Model URL: www.cccma.ec.gc.ca
Data URL:
www.genetics.forestry.ubc.ca/cfcg/ClimateWNA/ClimateWNA.html
Constraints
Limit result to range of Douglas-fir

Lessons Learnt for Commercial Native Forest Silviculture in Victoria, Australia

Temperature



Rainfall



http://www.climatechangeinaustralia.gov.au

Lessons Learnt for Commercial Native Forest Silviculture in Victoria, Australia (cont)

1. Developing an inventory of high quality seed for a range of tree species, including rare species
2. Increase the amount of thinning in young stands to reduce competition, stress, and fire hazard, and improve growth and insect/disease resistance
3. Engage with the land management regulators to consider allowing thinning block boundaries to better resemble natural disturbances and reduce the incidence of administrative fragmentation
4. Increase the level and detail of provenance testing amongst seed-lots such that families adapted to a drier climate and/or greater variation in climate are identified and collected in larger volumes

Lessons Learnt for Commercial Native Forest Silviculture in Victoria, Australia (cont)

5. In previously harvested areas where the species composition has been altered, restore diversity following the second cut by ensuring less commercial species are sown during site establishment.
6. The restoration of riparian areas when the installation and/or replacement of bridges and culverts are undertaken. This includes the planting of riparian species and the use of woody debris in improving fish habitat.
7. The establishment of an assisted migration trial for the major eucalypt tree species
8. Working with the land management regulator to revise seed transfer guidelines to allow greater movement of seed-lots and hence an improved adaptability to a rapidly changing climate
9. The improvement of our current seed-lot database to include a seed-lot selection tool based on climate generated focal points

Conclusions

- It is difficult to address every impact of climate change. Forest managers need to focus on achieving realistic outcomes (Blate 2009)
  - identifying resilience thresholds for key species
  - determining which thresholds are likely to be exceeded
  - prioritising projects with a high probability of success
  - identifying species and vegetation structures tolerant of increased disturbance
- It is important to establish criteria for and participation in decision making through a consultative process that ensures the concerns of stakeholders are heard and considered
- Incorporating climate change into regional and national forest policy is a major step forward (Littell 2011)
- Dynamic and adaptive thinking needs to be integrated into the way we make planning and management decisions, including our learning from changing conditions (Spies 2010)

Questions?