Effects of Climatic Variability and Change on Vegetation and Disturbance in the Blue Mountains

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Climate Change and Vegetation

- Climate change is expected to alter vegetation structure and composition, ecosystem processes, and the delivery of important ecosystem services
- Climate drives
  - vegetation patterns at broad scales
    - Landscape and local-scale variables are important too, especially at finer scales
  - abundance of species, biotic interactions, and ranges of species
  - Disturbance processes
How can we begin to understand what might happen to vegetation in the future?

- Multiple sources of information for vegetation change and altered disturbance regimes
  - Paleoecological records
  - Studies: tree growth, establishment, fire scars, trends with recent warming, CO₂ response, climate and fire history studies
  - Model output
Vegetation Assessment Units (PVGs)

• We used Potential Vegetation Groups (Powell et al. 2007), to organize vegetation for discussion
  • similar to plant functional types used for global biome vegetation modeling
    – E.g. cold upland forest moist upland forest, dry upland forest (11 upland PVGs)
  • Special habitats: aspen, GDEs
  • Species of concern: whitebark pine, limber pine, mountain hemlock, Alaska yellow cedar, exotic species
• Species responses to climate are individualistic and no-analog plant communities should be expected in the future
  – but broad vegetation types (e.g. biomes, PVGs) will still exist in the future and occupy similar types of sites across the landscape
Presentation

• Trends with recent warming (vegetation)
• Paleoecological Data
• Disturbance
• Model Output (John Kim)
• Summary
Trends with Recent Warming

- Most plant response to recent warming have involved alterations of phenology (timing of life history stages)
  - Shifts in timing of flowering, decoupling of plant-insect relationships
- Shifts in species distributions, generally upward in elevation/poleward
- Upward movement of tree lines has been documented
Trends with Recent Warming

• Subalpine conifers have been documented as infilling alpine tundra and meadows—thought to be related to climate change

• Frequency of drought related tree mortality increasing
  – Drought related mortality is not common, drought stress leaves forests more vulnerable to other disturbance agents

Massive die-off of pinyon pine that occurred during a recent drought, 2002 (left), May 2004 (right) (Photo credit: Craig D. Allen, U.S. Geological Survey)
Trends with Recent Warming

• Forests can be partitioned into energy-limited versus water limited domains
  – Energy limiting factors are chiefly light and temperature
  – Cold and moist upland forests are largely energy limited
    • Tree growth in energy limited ecosystems appears to be responding positively to warming temperatures over the past 100 years
Trends with Recent Warming

- Dry forests are water rather than energy limited
  - Water stress during the warm seasons is the primary factor limiting tree growth in the Pacific Northwest

Productivity in water-limited systems is expected to decline with warming temperatures, as negative water balances constrain photosynthesis, although this may be partially offset if CO2 fertilization significantly increases water-use efficiency in plants.
CO$_2$ Fertilization

• Some species may respond positively to higher concentrations of CO2 due to increased “water use efficiency”

• Proven in laboratory
  – Response in the field harder to document as other factors become limiting
Paleoecological Data

- Pollen from Carp Lake and phytoliths in loess sections
- Early Holocene: warmer and drier than today
  - Analog for the future?

Whitlock and Bartlein 1997, Blinnikov et al. 2002
Forested Sites in the Mid-Holocene

- RBM-1 site supported an *Agropyron* dominated grassland/ponderosa pine transition or parkland
- VM-1 was dominated by ponderosa pine (Figure 2)
- Carp Lake supported a Pine/Oak woodland
- Mid-Holocene conditions may be drier than currently projections from global climate model
- The rate of future climate change may be faster than any in the Holocene record (500 – 1000 years).
- Many stands today originated in the Little Ice Age
Non-forested Sites in the Mid-Holocene

The forest-steppe ecotone was at least 100 km north of present position and higher in elevation.

In general, evidence suggests an increase in *Artemisia* with warming.

Grasslands at lower elevations shifted in dominance towards more drought tolerant species (e.g. less *Festuca*).

Other data: Dry climatic periods tend to result in regional declines of juniper, with wet (particularly summer precipitation) and mild (mild winters) periods resulting in expansion (Miller et al. 2005).
Disturbance

• Forests had long-lived dominant species
  – compositional changes could be slow even in a rapidly warming climate
  – mature individuals can survive at the edges of their ranges

• Disturbance is expected to be the principal agent of change
Disturbance drives ecosystem change

Climate change
- Warmer temperature
- More severe droughts

New disturbance regimes
- Fire season ↑
- Area burned ↑
- Extreme events ↑
- Insect and disease activity ↑

Species responses
- Annuals and weedy species ↑
- Deciduous and sprouting species ↑
- Fire-sensitive species ↓
- Specialists with restricted ranges ↓

Habitat changes
- Landscape homogeneity ↑
- Fire-adapted species ↑
- Forest cover ↓
- Species refugia ↓

Fire resets succession, alters temporal scale of fire effects.

Mature trees buffer effects of warmer climate.

The disturbance pathway is faster
Extremes matter

Frequency, extent, and severity of disturbances may be affected by climate change, altering the mean and variability of disturbance properties.

A shift of 1 standard deviation changes a 1 in 40 yr event to a 1 in 6 yr event.

A shift in distribution of disturbance properties has a larger relative effect at the extremes than near the mean.

It’s all about the tail!
How will climate change affect wildfire?

- Climate and fire are coupled across multiple scales...
  - Years with widespread fire and fire extent are associated with warmer and drier spring and summer conditions in the West
  - Wet years, followed by dry years allow burning abundant fuels
  - Fire activity also related to interdecadal climate variability
Area burned in 11 Western states, 1916-2012

From J. Littell
In most of the West, annual area burned will be 2-3 times higher.

From J. Littell
How will climate change affect insect and disease outbreaks?

- Climate warming influences biotic disturbance through direct and indirect effects on
  - Physiology of insects and pathogens
    - Temperature is the dominant abiotic factor directly affecting herbivorous insects as it directly affects development, survival, range, and abundance
  - Tree defenses and tolerance
  - Interactions of insects and pathogens with enemies, competitors and mutualists

Recent pine butterfly outbreak in the southern Malheur NF
Mountain pine beetle

Warmer temperature has favored MPB by:

• Increasing its reproductive rate
• Expanded geographic range, also up in elevation
• Whitebark pine
• Less is known about defoliators compared to bark beetles
• Budworm habitat has improved as the forest has changed from pine to fir
  – In BC, budworm outbreaks occurred during years with a dry winter followed by a warm spring
  – Climate change may allow high over-winter survival rates and a longer growing season
  – Duration of outbreaks may increase in the future
Multiple stressors in WA and OR

Climate departure before 2030 was not mapped in the Blues, BUT climate is projected to exceed the historic temperature by 2040!

Other important stressors: grazing, exotic species, human land-use, fragmentation, etc.
Exotic Plants

- Exotics have invaded higher elevations of the Blues; mountain ecosystems are not as resistant to plant invasions as once believed.
- Assessment focused on annual grasses: cheatgrass, medusa head, North Africa grass
  - These species have become naturalized across areas of grasslands, shrublands, woodland, and low elevation dry forest types
- Currently these species are increasing
- Future climate change will most likely increase invasion of forests and rangelands:
  - Increased ecosystem disturbance
  - The impact of warming on species distributions
  - The enhanced competitiveness of invasive plants due to elevated CO2
Blue Mountain Plant Survey

• In 2007 and 2012 understory vascular plant species were surveyed along 3 mountain roads in the Blue Mountains of Eastern Oregon
• Transects (n=60) were stratified over elevation (range = 904 - 2264 m)

Objectives:

1. Determine the main drivers of plant invasions into high elevations of the Blue Mountains.
2. Evaluate patterns of non-native species distributions relative to native species along an elevation gradient.
3. Establish permanent vegetation monitoring for plant species distributions.

Catherine Parks, PNW La Grande
Blue Mountain Exotic Plant Survey Results

- Exotic richness peaked lower elevations near roadsides
  - Grass and shrub dominated sites
    - These sites most likely to harbor dominant introduced annual grasses

- Most species positively associated with more intense land use and disturbance

- Closed canopy forests and subalpine sites were the least invaded sites
Model Output

- Five models: three species distribution models (SDMs), one “hybrid” model (3-PG), and one dynamic global vegetation model (MC2)
  - SDMs are VERY COMMON
    - May not be as robust as process models
    - Constrained by statistical relationships only; don’t deal well with novel conditions

- Models output is “climate habitat” not actual species ranges

- View as “what-if scenarios” not predictions!

Output for PIPO; data from Plant Hardiness website (above), and Moscow lab below; similar GCMs. Different generations
<table>
<thead>
<tr>
<th>Potential Vegetation or Species</th>
<th>Common Name</th>
<th>Model Output Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abies lasiocarpa</td>
<td>subalpine fir</td>
<td>moderate to complete loss of climate habitat, potential refugia in Wallowa Mountains</td>
</tr>
<tr>
<td>Picea engelmannii</td>
<td>Engelmann spruce</td>
<td>moderate to complete loss of climate habitat, potential refugia in Wallowa Mountains</td>
</tr>
<tr>
<td>Abies grandis</td>
<td>grand fir</td>
<td>some loss to complete loss</td>
</tr>
<tr>
<td>Abies concolor</td>
<td>white fir</td>
<td>major to complete loss of climate habitat</td>
</tr>
<tr>
<td>Pinus albicaulis</td>
<td>whitebark pine</td>
<td>moderate to complete loss of climate habitat</td>
</tr>
<tr>
<td>Pinus contorta</td>
<td>lodgepole pine</td>
<td>major to complete loss of climate habitat</td>
</tr>
<tr>
<td>Pinus flexilis</td>
<td>limber pine</td>
<td>complete loss</td>
</tr>
<tr>
<td>Pinus monticola</td>
<td>western white pine</td>
<td>some loss to major; other models show shifts and minor loss</td>
</tr>
<tr>
<td>Pseudotsuga menziesii</td>
<td>Douglas-fir</td>
<td>variable – increases to major loss</td>
</tr>
<tr>
<td>Callitropsis nootkatensis</td>
<td>Alaska cedar</td>
<td>variable – minor increase to complete loss</td>
</tr>
<tr>
<td>Larix occidentalis</td>
<td>western larch</td>
<td>minor to complete loss of habitat</td>
</tr>
<tr>
<td>Tsuga mertensiana</td>
<td>mountain hemlock</td>
<td>moderate to complete loss of habitat</td>
</tr>
<tr>
<td>Pinus ponderosa</td>
<td>ponderosa pine</td>
<td>moderate to major loss of habitat</td>
</tr>
<tr>
<td>Juniperus occidentalis</td>
<td>western juniper</td>
<td>major to complete loss of habitat</td>
</tr>
<tr>
<td>Juniperus scopulorum</td>
<td>rocky mountain juniper</td>
<td>major to complete loss of habitat</td>
</tr>
<tr>
<td>Populus tremuloides</td>
<td>aspen</td>
<td>major to complete loss of habitat</td>
</tr>
<tr>
<td>Artemisa tridentata</td>
<td>sagebrush</td>
<td>complete loss of all habitat</td>
</tr>
<tr>
<td>Cercocarpus ledifolius</td>
<td>mountain mahogany</td>
<td>complete loss of all habitat</td>
</tr>
<tr>
<td>Purshia tridentata</td>
<td>bitterbrush</td>
<td>complete loss of all habitat</td>
</tr>
</tbody>
</table>
Summary

- Species with life histories suitable for frequent disturbance and stressed environments will be more dominant.
- Pine and sagebrush may increase, but found at higher elevations.
- Forest steppe ecotone may move north and up in elevation.
- Subalpine systems vulnerable – may be replaced by lower elevation moist forests or high elevation grasslands.
Summary

• Increase in plant productivity, but interactions with fire
• Decrease in carbon stocks in forests through mid-21st century
• Lower elevation biomes (shrublands, grasslands, woodlands) may increase
• Potential increase in beetle outbreaks; defoliators?
• Large increase in wildfire occurrence and area burned
• Interaction of drought/insects/wildfire.
Q&A