Silviculture of northern forests through the adaptation lens

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Forest Adaptation Spectrum

- **Promote Change**
  - Resistance: Improve forest defenses against predicted changes or disturbance to maintain relatively unchanged conditions
  - Resilience: Accommodate some change, but encourage a return to prior or desired reference condition following disturbance
  - Transition: To facilitate change and encourage ecosystems to adaptively respond to new or changing conditions

- **Maintain current conditions**

**Reduce climate and forest health impacts**

**Facilitate adaptive responses**

Uncertainty in management approaches

Nagel et al. (2017)
Repackaging silviculture
Repackaging silviculture

Components of silvicultural systems for sustained management

- **Phase**
  - **Regeneration**
    - Component treatments
      - Natural
      - Artificial - seeding
      - Planting
  - **Tending**
    - Release treatments
      - Pruning
      - Thinning
    - Intermediate treatments
  - **Harvest**
    - Clearcutting method
    - Shelterwood method
    - Seed-tree method
    - Selection method
    - Other partial cuts
    - Two-aged methods

Nyland (1996)
“Optimal” watershed protection forest consists of three patch characteristics:
1. Regeneration for recovery following disturbance
2. Vigorous middle-aged trees and stands for nutrient uptake and biomass accumulation
3. Mature trees and stands for seed sources and amelioration of temp and moisture conditions
Applying the adaptation lens
Silvicultural outcomes and adaptation

1. Forest composition
   • Functional characteristics of species (drought tolerance, regeneration strategies, disturbance response)

2. Forest structural conditions
   • Resource levels and heterogeneity, size and cohort structures (disturbance and drought response)

3. Site conditions
   • Is adaptation a priority based on edaphic factors and disturbance vulnerability?
Shade tolerance is a common lens we use to evaluate stands—and general inverse relationship with drought tolerance.

Russell et al. (2013)
• Reduced drought tolerance under single-tree selection (opposite shade tolerance)
• Greater seed mass reflective of beech dominance in selection plots at BEF; decline at PEF due to increasing hemlock
• Homogenization towards vulnerable condition relative to projected changes in climate
Structural considerations

- Past vulnerability of managed and unthinned stands to known drought events (e.g., 2001)

Long-term silviculture studies at Penobscot Experimental Forest, ME

![Graph showing the relationship between resistance index and percent stocking (%SDI<sub>max</sub>). Selection stands and unthinned, even-aged stands are compared. Selection stands show no effect of drought on stand-level growth, while unthinned, even-aged stands show reduced growth during drought.]
Density management and drought

• Examining drought response across arid and temperate *Pinus*

• Fort Valley EF, AZ; Black Hills EF, SD; Cutfoot EF, MN
Bottero et al. (2017)
Structural considerations

- Past vulnerability of thinned and unthinned stands to known drought events (e.g., 1988)

Clark et al. (2016)
Varying within stand densities to provide range of adaptation opportunities:

**Single trees (thinned matrix)**
- Distributed mature habitat
- Lower drought sensitivity
- Lower fire vulnerability
- Higher vulnerability to wind

**Clumps**
- Potential refugia
- Greater drought sensitivity
- Lower wind vulnerability
- Greater selection pressure

**Openings**
- Increased vegetation cover
- Adaptation opportunities via natural and artificial regen
Regeneration considerations
### Regeneration considerations

Projected changes in suitable habitat by 2100 (Tree Atlas Mid-Atlantic-wide summary, Butler-Leopold et al. 2018)

<table>
<thead>
<tr>
<th>Decreasing</th>
<th>Increasing</th>
<th>New</th>
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</thead>
<tbody>
<tr>
<td>American beech</td>
<td>bitternut hickory</td>
<td>black hickory</td>
</tr>
<tr>
<td>bigtooth aspen</td>
<td>black oak</td>
<td>longleaf pine</td>
</tr>
<tr>
<td>black cherry</td>
<td>black walnut</td>
<td>overcup oak</td>
</tr>
<tr>
<td>eastern hemlock</td>
<td>cherrybark oak</td>
<td>Shumard oak</td>
</tr>
<tr>
<td>eastern white pine</td>
<td>hackberry</td>
<td>slash pine</td>
</tr>
<tr>
<td>sugar maple</td>
<td>mockernut hickory</td>
<td>Sugarberry</td>
</tr>
<tr>
<td>sweet birch</td>
<td>northern red oak</td>
<td>Turkey oak</td>
</tr>
<tr>
<td>yellow birch</td>
<td>pignut hickory</td>
<td>Scarlet oak</td>
</tr>
<tr>
<td></td>
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<td>shortleaf pine</td>
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Primarily intolerant and midtolerant species
New England Adaptive Silviculture for Climate Change
Dartmouth Second College Grant, NH

VLP-32c dual-return LiDAR of northern blocks

Resistance
Resilience
Transition
Moving forward with adaptation
"There are even fewer absolutes in ecology than in forestry, but an emerging operating maxim is *Simplification is rarely beneficial.*" (Franklin et al. 1986)
Building on the Era of Complexity

Revisiting two of several principles guiding our previous silvicultural "revolution"

1. **Continuity** - provision for continuity in forest structure, function, and biota between pre- and post-harvest (legacies, system "memory")

2. **Complexity** - create and maintain structural and compositional complexity and biological diversity through silvicultural treatments

(From Seymour and Hunter 1999, Franklin et al. 2007)
Building on the Era of Complexity

Ecological silviculture principles

<table>
<thead>
<tr>
<th>Principle</th>
<th>Linkages with Uncertainty and Adaptation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuity</strong></td>
<td>• Long-term options for regeneration and structure in face of uncertainty</td>
</tr>
<tr>
<td></td>
<td>• Amelioration of harsh environmental conditions</td>
</tr>
<tr>
<td></td>
<td>• Regeneration safe sites (shaded understory, well-decomposed dead wood)</td>
</tr>
<tr>
<td></td>
<td>• Micro-refugia for sensitive taxa</td>
</tr>
<tr>
<td></td>
<td>• Conservation of genetic diversity</td>
</tr>
</tbody>
</table>

Palik et al. (in press)
### Building on the Era of Complexity

#### Ecological silviculture principles

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| **Complexity** | • Reduced vulnerability to disturbance  
  • Spatial variability in fuels  
  • Heterogeneity in: 1) wind risk, 2) potential host species abundance, 3) within-species stress tolerance (tree size/age), 4) resource availability  
  • Multiple recovery/developmental pathways  
  • Diversity of seed sources and reproductive mechanisms  
  • Heterogeneity in microsites for new species |

- Reduced vulnerability to disturbance
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- Diversity of seed sources and reproductive mechanisms
- Heterogeneity in microsites for new species
Conclusions

- In many circumstances, adaptation will entail repackaging of silvicultural strategies with an eye towards increasing and maintaining ecosystem heterogeneity.

- Despite future change, understanding of past drivers and dynamics can still inform transition methods:
  - Use of regeneration methods that maintain overstory trees during regeneration phase to keep options on site and ameliorate extremes.
  - Build on decades of experience managing these systems, particularly with recent ecological approaches.
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