Northern Institute of Applied Climate Science

- Provides practical information, resources, and technical assistance related to forests and climate change
- Supports the integration of climate change information into natural resource management

www.nrs.fs.fed.us/niacs/

Regional multi-institutional partnership among:

NIACS
Northern Institute of Applied Climate Science

www.nrs.fs.fed.us/niacs/
The climate is changing. How will you manage for it?

The region’s forests are a national asset; they contain:
- 42% of U.S. forests
- 32% of U.S. timberland
- 41% of U.S. population

Science delivery

The USDA Climate Sub Hub delivers science-based tools and information to land managers so they can make climate-informed decisions now.

The Sub Hub assists:
- Professional Resource Managers
- Cooperative Extension agents
- Private Landowners
- USDA Technical Service Providers

The Northern Forests Sub Hub assists natural resource managers, woodland owners, and others interested in forests with integrating climate change information into planning, decision making, and management activities.
March 16 – Agenda

1:45  Forest Adaptation Resources: an Introduction Southern New England’s Changing Climate

2:55  Break

3:20  Climate Change Effects on Forest Ecosystems

March 17 – Hands-on Training

An active, hands-on training, to assist natural resource professionals in incorporating climate change considerations and identifying actions for adaptation into their own real-world management and conservation projects. Join us tomorrow!
March 17 – Agenda

8:30    Climate Change Impacts on Forest Management Projects (Step 2)
10:00   Break
10:15   Challenges/Opportunities for Management (Step 3)
11:30   Identifying Forest Adaptation Approaches and Tactics (Step 4)
12:00   Lunch (BYO)
1:00    Identifying Forest Adaptation Approaches and Tactics (Step 4)
3:00    Break
3:15    Identifying Forest Adaptation Approaches and Tactics
4:00    Next Steps & Wrap-up
4:00    Adjourn
When we started...
Responding to Climate Change
Responding to Climate Change

There is not a single “answer”

Manager’s Guide  Decision Tree  E-Z Whiz-bang Tool

Critical to start with:

The place  Management goals & objectives
Invasives
Past Management History
And more!!

Natural Forest Dynamics
Desired Conditions
Plan & Project Requirements

Wildlife Habitat
Timber Sale Revenue
Forest Health
Disturbance: Past + Future

Recreation

Climate Change
Climate Change Response Framework

Structured, process oriented, works on multiple scales

**Components:**
- Partnerships
- Vulnerability Assessment
- Forest Adaptation Resources
- Adaptation Demonstrations

**Progress:**
- 75+ partner organizations (and counting)
- 3 published assessments, 3 more in press/revision
- Published in 2012, updated and online versions in prep
- 50+ demonstrations underway
Vulnerability Assessments

- High-quality information about future change in climate and potential effects on forest ecosystems
- In New England, synthesizing current state and regional assessments to highlight greatest risks
Forest Adaptation Resources

- Designed for a variety of land managers
- Does not make recommendations
- Menu of strategies & approaches for climate change adaptation
- Adaptation workbook process for implementation

Swanston and Janowiak 2012; www.treesearch.fs.fed.us/pubs/40543
Provides **structured process** to integrate climate change considerations into management planning and activities

1. DEFINE area of interest, management objectives, and time frames.
2. ASSESS climate change impacts and vulnerabilities for the area of interest.
3. EVALUATE management objectives given projected impacts and vulnerabilities.
4. IDENTIFY and implement adaptation approaches and tactics.
5. MONITOR and evaluate effectiveness of implemented actions.

Vulnerability assessments, scientific literature, and other resources

Adaptation Strategies and Approaches

Swanston and Janowiak 2012; [www.treesearch.fs.fed.us/pubs/40543](http://www.treesearch.fs.fed.us/pubs/40543)
**Forest Adaptation Resources**

Step-by-step *Adaptation Workbook* for planning

<table>
<thead>
<tr>
<th>Management Objectives</th>
<th>Challenges</th>
<th>Opportunities</th>
<th>Feasibility</th>
<th>Other Considerations</th>
</tr>
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<table>
<thead>
<tr>
<th>Adaptation Actions</th>
<th>Approach (From Chapter 2)</th>
<th>Tactic</th>
<th>Time Frame</th>
<th>Benefits</th>
<th>Drawbacks/Barriers</th>
<th>Recommend Tactic?</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
Ways the Adaptation Workbook can be used:

- Coordinator facilitates individual or small group

- Forest Adaptation Planning and Practices workshop
  - General (state agencies; SFEC)
  - Tribal (Sault; Menominee)
  - Conservation (WCS; DU)

- Managers use the workbook independently
  - Online version soon!!
Adaptation Demonstrations

- Provide **real-world examples** of forest management activities that:
  - Enhance the ability of forests to cope with changing conditions
  - Achieve land owner management goals
- Foster **cross-ownership** dialogue and learning
- Illustrate **diverse goals** and approaches

[www.forestadaptation.org](http://www.forestadaptation.org) Click ‘Demonstration Projects’
Adaptation Demonstrations

60+ PROJECTS UNDERWAY

www.forestadaptation.org

Click ‘Demonstration Projects’
Chequamegon-Nicolet NF: Aspen
Step 1: DEFINE area of interest, management goals and objectives, and time frames.

Management Goals & Objectives
- Early-successional habitat
- Scenic Integrity
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

Impacts: Potentially drier growing season conditions
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Challenges
- Aspen in long-term
- Few tree species
- Productivity issues
- Hazel competition
- Windthrow

Opportunities
- Site suitable for pine in future?
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

Overall Approach: Enhance future options within existing management trajectory

- Aspen will regenerate now, but is likely to fare poorly over the long term.
- Maintain plans for clearcut for aspen regeneration
- Additional actions to promote diversity and provide future options: plant red oak and white pine
- Pro-active on invasives and disturbance planning
Step 5: MONITOR and evaluate effectiveness of implemented actions.

- Post clearcut stocking*
- Survival of planted trees*
- Species composition for trees* and seedlings/saplings
- Intensified inventory (?)

*existing monitoring item
Chequamegon-Nicolet Aspen: Status

- Stands are marked
- Winter harvest – this winter
- Then: underplant native future-adapted species
Menominee Tribal Enterprises: Oak Wilt

Photo: College of Menominee Nation SDI
Step 1: DEFINE area of interest, management goals and objectives, and time frames.

Management Goals
- Foster diversity
- Favor sawtimber species
- Provide cultural uses
- Restore oak wilt pockets
Step 2: ASSESS climate change impacts
Step 3: EVALUATE management objectives

Treatment
- Harvest affected & adjacent oaks
- Pull stumps
- Harvest other species in pocket
Step 2: ASSESS climate change impacts
Step 3: EVALUATE management objectives

Treatment
- Harvest affected & adjacent oaks
- Pull stumps
- Harvest other species in pocket
**Step 4:** IDENTIFY and adaptation approaches and tactics for implementation.

<table>
<thead>
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<th>Adaptation Approach</th>
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<tbody>
<tr>
<td>• Reduce biological stressors</td>
</tr>
<tr>
<td>• Maintain and enhance diversity</td>
</tr>
<tr>
<td>• Promote future-adapted species</td>
</tr>
<tr>
<td>• Enhance genetic diversity</td>
</tr>
</tbody>
</table>

Restore sites with future-adapted species
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

Climate Change Tree Atlas

**Projected Habitat Increases**
- American beech
- **American elm**
- American hornbeam
- Bitternut hickory
- **Black cherry**
- Black locust
- Black oak
- Black willow
- Boxelder
- **Bur oak**
- Eastern cottonwood
- Silver maple
- Slippery elm
- White ash
- **White oak**

**Projected New Habitat**
- Black hickory
- **Black walnut**
- Blackjack oak
- **Chinkapin oak**
- Eastern red cedar
- Eastern redbud
- Flowering dogwood
- **Hackberry**
- Honeylocust
- Mockernut hickory
- Ohio buckeye
- Osage-orange
- Post oak
- Shingle oak

Also shrub & understory plants
Menominee Oak Wilt: Status

Last Summer
• Selected sites
• Site prepped
• Oaks planted

This Summer and Next
• Additional tree species
• Non-tree species of cultural value

Monitor
• Seedling success
• Forest health and stressors
• Forest composition
• Cost of treatment
Real-world Examples

60+ PROJECTS UNDERWAY

Click ‘Demonstration Projects’
Learning through Examples

- Diversity in lands, owners, and objectives
- Acknowledge difference, build on similarities
- Demonstrate shared perspectives
Learning through Experimentation

Adaptive Silviculture for Climate Change (ASCC)

- Experimental silvicultural trials in multiple forest types across the US
- How will forests respond to a range of climate change adaptation actions?

Photos: L. Nagel & M. Roske
What does adaptation look like?

Using new information and ideas

Beginning to take small steps

Being creative and flexible

Working and learning with others
Atlas Timberlands
Step 1: DEFINE area of interest, management goals and objectives, and time frames.

Management Goals
- Sustainable forestry
- Conservation
Current Management with Adaptation Benefits

- Follow BMPs for water quality
- Increase coarse woody material
- Increase tree species diversity
- Increase forest structural diversity
- Ensure adequate seedling regeneration
- Control invasives
- Minimize roads & trails
Step 2: ASSESS climate change impacts

Step 3: EVALUATE management objectives

Challenge: Shorter and more variable winter
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

Potential Barriers:
- More planning
- Higher cost
- Will it even work??

Adaptation Tactic: Summer harvest
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

Spring/Early Summer 2014
- Timber marking
- Road layout
- Pre-sale road work
- Temporary bridge installation

Harvested Summer 2014 (when the weather cooperated!)
Step 5: MONITOR and evaluate effectiveness of implemented actions.
CLIMATE CHANGE EFFECTS ON NORTHEAST FOREST ECOSYSTEMS & HABITATS
New England Synthesis

1) Introduction
2) Contemporary Landscape
3) Observed Climate Change
4) Future Climate Change
5) Impacts on Forests
6) Conclusions

Timeline = in progress, draft this spring
How has climate changed over the past century?
Observed Climate Trends

Warmer temperatures

- CT temperatures increased more than 2.5°F since 1895
- Winter has warmed most
- Extremely hot days have increased
- Longer growing season
- Plants flowering more than a week earlier at Walden pond since 1880s
Seasonal Mean Temperature Change

- **Winter** (Dec-Feb): 3.5°F increase
- **Spring** (Mar-May): 2.2°F increase
- **Summer** (Jun-Aug): 2.2°F increase
- **Fall** (Sep-Nov): 1.8°F increase
Observed Climate Trends

Altered Precipitation

- CT precipitation increased nearly 3” since 1895
- Extremely high variability from year to year
- Slight decrease in spring; increase of 2” in fall
- Substantial increases in extreme rain events: 71% increase across northeast since 1958

[Graph showing annual precipitation change since 1895]

Increase in Extreme Rain Events since 1958

NOAA, Melillo et al. 2014
Annual Precipitation Change (1901-2011)

- 0.06 inches per year = 6.9 inches over 110 years
- Substantial inter-annual fluctuation
Seasonal Precipitation Change (1901-2011)

- **Winter** (Dec-Feb): 0.6 in
- **Spring** (Mar-May): 1.6 in
- **Summer** (Jun-Aug): 1.7 in
- **Fall** (Sep-Nov): 3.0 in
Extreme Precipitation Events

The amount of precipitation falling in single events increased between 1948 and 2007

Spierre and Wake 2010
Sea-level Rise

- Sea level rose about 1 foot since 1900
- Increases in coastal flooding

Horton et al. 2014 (NCA)
Phenological Changes

**Bird Range Expansion**
Migratory birds are arriving earlier and breeding earlier, and several species have shifted their ranges northward (Rahbeck et al. 2007, Waite and Strickland 2006).

**Lake Ice**
Lake ice-out dates have advanced across Maine, with many dates now two weeks earlier than in the 1800s (Jacobson et al. 2009).

**Green Canopy Duration**
Trees at Hubbard Brook Experimental Forest have about 10 more days per year of green canopy (Richardson et al. 2006).

**Flowering Dates**
The date of first flowering is a week earlier on average compared to Thoreau’s records from the mid-1800s. Highbush blueberries and yellow wood sorrel are flowering several weeks earlier (Miller-Rushing and Primack 2009).
How is the climate expected to change over the next century?
How is the climate expected to change over the next century?
Future Changes – inherent uncertainty

IPCC 2007
Climate Scenarios Used

- Two scenarios show the range of possible change
  - PCM B1: Low emissions scenario + less sensitive GCM
  - GFDL A1FI: High emissions + more sensitive GCM
- Projections are consistent with other data sets
- Think of them like bookends:
Temperature Change Projections

Entire Northeast Region

Kunkel et al. 2013
Seasonal Temperature Projections

Winter

Spring

Low

High

Change in 30-year average (°F) 2070-2099 vs. 1971-2000
Seasonal Temperature Projections

Change in 30-year average (°F) 2070-2099 vs. 1971-2000

Summer

Fall

Low

High
Precipitation Change Projections

Entire Northeast Region

Kunkel et al. 2013
Seasonal Precipitation Projections

Winter

Spring

Change in 30-year average (°F) 2070-2099 vs. 1971-2000

Low

High
Seasonal Precipitation Projections

Change in 30-year average (°F) 2070-2099 vs. 1971-2000

Summer

Low

High

Fall
Extreme Precipitation Events

- Extreme precipitation has increased dramatically
  - Precip in heaviest 1% of events increased 71% between 1958 to 2012
- Trend expected to continue/increase

Change in 2-inch Precipitation Events (late 21st century)

Kunkel et al. 2013; Figure: Center for Climatic Change, [http://ccr.aos.wisc.edu/resources/data_scripts/LCC/](http://ccr.aos.wisc.edu/resources/data_scripts/LCC/)
Anticipated Climate Changes

Warmer temperatures

- 3-9°F increase annually

Altered precipitation

- High variability: slight decrease to more than 15% increase
- Generally increasing in winter & spring
- Potential decreases or less substantial increases in summer & fall
- More extreme rain

Sea-level Rise

- 12 to 23” by end of century

CT DEEP 2011, Climatewizard.org
How could ecosystems be affected?
9 WAYS THAT CLIMATE CHANGE WILL AFFECT FORESTS

A Synthesis of Anticipated Impacts
Climate Change Impacts

1) Longer Growing Season
2) Shorter Winters
3) Potential for Summer Drought
4) $\text{CO}_2$ Fertilization
5) Changes in Suitable Habitat
6) Extreme Events
7) Wildfire Risk
8) Forest Pests and Diseases
9) Invasive Plants
1: *Longer Growing Seasons*

Warmer temps result in longer growing seasons

- Projected to increase 3-7+ weeks by 2100

Growing Season– End of Century Change

1: **Longer Growing Season**

Warm temps result in longer growing seasons

- Evidence of phenological shifts
- Projected to increase 3-7+ weeks

Longer period for plant growth

Melillo et al. 2014, Nelson Center 2014
1: Longer Growing Season

Warmer temps result in longer growing seasons
- Projected to increase 3-7+ weeks
- Evidence of phenological shifts

Longer period for plant growth

Potential risks:
- Early bud break/loss of cold hardening
- Frost damage during spring freezing

Melillo et al. 2014, Nelson Center 2014
2: **Shorter Winter (Less Snow)**

Projected decreases in snowfall, cover, and depth

- 30-70% decreases in snowfall
- Greatest snowfall decreases in December or January

Percent change in snowfall (late 21st century)

Notaro et al. 2014; Figure: Center for Climatic Change, [http://ccr.aos.wisc.edu/resources/data_scripts/LCC/](http://ccr.aos.wisc.edu/resources/data_scripts/LCC/)
2: **Shorter Winter (Less Snow)**

**Decreased snowpack**
- Increased soil frost and root damage in cold temps
- Warmer soil temperatures and altered processes

*Wisconsin Frozen Ground*

**Frozen Ground Season**
- Annual data
- Trend

**Frozen Ground Days**
- Annual data
- Trend

Source: C. Rittenhouse (UConn) and A. Rissman (UW-Madison), in review
2: **Shorter Winter (Less Snow, More Rain)**

Precipitation is projected to increase = more rain

2: **Shorter Winter (Less Snow, More Rain)**

Precipitation is projected to increase = more rain

**Altered streamflow timing and amount**

- Earlier spring peak flows
- Potential increases in flashiness and episodic high flows
- Potential declines in summer seasonal stream flow

3: *Potential for Summer Drought*

Greater uncertainty about future precipitation, but increased risk of summer moisture stress

- Water loss from soils (evaporation)
- Water loss from trees (transpiration)
- Precipitation
- Runoff
- Groundwater recharge
3: Potential for Summer Drought

Greater uncertainty about future precipitation, but increased risk of summer moisture stress

Warmer temps increase water loss

Water loss from soils (evaporation)

Water loss from trees (transpiration)

Precipitation

Runoff

Groundwater recharge
4: CO$_2$ Fertilization

Benefits

- Increased photosynthesis
- Increased water use efficiency

[Diagram]

Limits to CO$_2$ fertilization

- Varies by species and site
- Nutrient deficiencies (especially N)
- Sensitive to ozone pollution
- Limited sink strength
- Limited evidence of long-term sequestration
- Any productivity increases may be offset by reductions from increased drought stress or disturbance

5: Changes in Suitable Habitat

Habitat based on:
- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect
- Land use
- Competition
- Past management
5: Changes in Suitable Habitat

Habitat based on:

- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect
- Land use
- Competition
- Past management

Climate Change Atlas:
What happens to tree and bird habitat when climate changes?

- 134 Trees
- 147 Birds

www.fs.fed.us/nrs/atlas/

Iverson et al. 2008; Atlas website: www.fs.fed.us/nrs/atlas/
5: Changes in Suitable Habitat

Habitat based on:

- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect

White Pine: Current Habitat (modeled)

www.fs.fed.us/nrs/atlas/
5: Changes in Suitable Habitat

Habitat based on:
- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect

White Pine: Current Habitat (modeled)

PCM B1 (Less Change)

GFDL A1FI (More Change)

www.fs.fed.us/nrs/atlas/
5: Changes in Suitable Habitat

Habitat based on:
- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect

Red Spruce: Current Habitat (modeled)

PCM B1 (Less Change)

GFDL A1FI (More Change)

www.fs.fed.us/nrs/atlas/
5: Changes in Suitable Habitat

Habitat based on:

- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect

www.fs.fed.us/nrs/atlas/
5: Changes in Suitable Habitat

- Immense lag times
  - Range shifts ≠ instant catastrophic dieback

- Factors causing change will increase over time
  - Temperature
  - Moisture
  - Competition

- Mature and established trees should fare better
  - Developed root system
  - Greater carbohydrate reserves

- Game changers: Disturbance, Land use, ...

Dale et al. 2001, Iverson et al. 2008
Use the Climate Change Atlas to:

- Evaluate how suitable habitat may change for species
  - Species more likely to decline or increase
  - Consider multiple scenarios
  - Consider local conditions and anticipated impacts

- Identify factors driving the modeled changes

- Generate ideas for potential future-adapted species

Dale et al. 2001, Iverson et al. 2008
5: Changes in Suitable Habitat

Iverson et al. 2007, Rustad et al. 2012
6: Extreme Events

- Heavy precipitation
- Ice storms
- “Events” are not well modeled
- Heat waves/droughts
- Wind storms
- Hurricanes
## 7: Wildfire Risk

### Fire may increase:
- Warmer/drier summers
- Increased stress or mortality from less suitable conditions
- Shift toward fire-associated species like oaks and pines

### Fire may not change:
- Spring/early summer moisture
- Current regeneration of more mesic species
- Spatial patterns of land use and fragmentation
- Fire suppression

![Prescribed fire – MASS DCR](image)
8: *Forest Pests and Diseases*

**Indirect:** Stress from other impacts increases susceptibility

**Direct:**
- Pests migrating northward
- Decreased probability of cold lethal temperatures
- Accelerated lifecycles

Hemlock Woolly Adelgid

- Habitable range:
  - Higher-emissions scenario
  - Lower-emissions scenario
  - Current

HWA lethal temp: -20 to -30°F

9: **Invasive Plants**

**Indirect:** Stress or disturbance from other impacts can affect the potential for invasion or success

**Direct:**

- Expanded ranges under warmer conditions
- Increased competitiveness from ability of some plants to take advantage of elevated CO$_2$

Invasives Plants Atlas of New England (www.eddmaps.org)

Dukes et al. 2009, Rustad et al. 2011
Climate Change Impacts

1) Longer Growing Season
2) Shorter Winters
3) Potential for Summer Drought
4) CO₂ Fertilization
5) Changes in Suitable Habitat
6) Extreme Events
7) Wildfire Risk
8) Forest Pests and Diseases
9) Invasive Plants

What conclusions can we draw from all this?
Vulnerability: *Forest Communities*

Forest communities will be affected differently

**May have greater risk:**
- Low diversity
- Static
- Threatened, rare, or endangered
- Already in decline
- Fragmented

**May have less risk:**
- More diversity (species, genetics, ...)
- Adapted to disturbance
- Wider ecological range of tolerances
- Currently increasing
- Larger, contiguous blocks
Vulnerability: **Hardwood Forests**

**Impacts:**
- Extreme storms
- Several diseases, pests, invasives
- Several northern species projected to decline

**Adaptive Capacity:**
- Mixed species forests
- Several southern species projected to increase
- Extensive type, exists farther south

Vulnerability rated as low (central hardwoods) or moderate (northern hardwoods) based on species and location.

Vulnerability: Pitch Pine-Scrub Oak

Impacts:
- Less affected by warm temperatures, drought, or wildfire
- Pitch pine habitat suitability not projected to change much

Adaptive Capacity:
- Limited to sandy, nutrient-poor soils
- Affected by development, fragmentation, fire suppression

Generally rated as low-moderate vulnerability.
Vulnerability: *Local Considerations*

Research and assessments describe **broad trends** but **local conditions** make the difference.
Vulnerability: *Spruce-fir*

**Impacts:**
- Warm temperatures
- Declines in boreal tree species
- Extreme storms

**Adaptive Capacity:**
- Generally slow to adjust to change
- Constrained by elevation/latitude
- Isolated mountaintops

Generally rated as **most vulnerable forest community**, especially at southern extent of range.

**Step 1:** DEFINE area of interest, management goals and objectives, and time frames.
Workbook Instructions

1. DEFINE area of interest, management objectives, and time frames.
2. ASSESS climate change impacts and vulnerabilities for the area of interest.
3. EVALUATE management objectives given projected impacts and vulnerabilities.
4. IDENTIFY and implement adaptation approaches and tactics.
5. MONITOR and evaluate effectiveness of implemented actions.
Purpose:

- Define the scope of the project

Where are you working?
What are your current management goals and plans for this area?
Step 1: DEFINE area of interest, management goals and objectives, and time frames.

Area of Interest
Location
Forest Type(s)
Management Goals
Management Objectives
Time Frames

Identifies the project area, including geographic location and topic area.

For example:
- Property
- Unit, stand, compartment
- Program/issue (e.g., invasives, fire)
Step 1: DEFINE area of interest, management goals and objectives, and time frames.

Area of Interest
Location
**Ecosystem Type(s)**
Management Goals
Management Objectives
Time Frames

Describes different ecosystems within the area of interest.

For example:
- Spruce-fir forest
- Headwater streams
- Marshlands
## Step 1: Define area of interest, management goals and objectives, and time frames.

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<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Goals:</strong> broad, generally not quantifiable</td>
<td><strong>Objectives:</strong> specific, outline planned results</td>
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<td></td>
<td></td>
<td>• Enhance wildlife habitat</td>
<td>• Create 10 acres of early successional habitat by...</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Restore wetland function</td>
<td>• Upgrade infrastructure to increase water flow...</td>
<td></td>
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Describes intent.

**Goals:** broad, generally not quantifiable
- Enhance wildlife habitat
- Restore wetland function

**Objectives:** specific, outline planned results
- Create 10 acres of early successional habitat by...
- Upgrade infrastructure to increase water flow...
**Step 1:** DEFINE area of interest, management goals and objectives, and time frames.

Area of Interest
Location
Forest Type(s)
Management Goals
Management Objectives

**Time Frames**

Identifies approximate timing of activities and for achieving goals/objectives

For example:
- Harvest—within 3 years
- Regeneration—10 years
- Improved habitat—long-term (30+ years)
**Step 1:** DEFINE area of interest, management goals and objectives, and time frames.

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<tr>
<td>SOUTH Camp Four Project Park Road Sale Stand 1089-025</td>
<td>East of Park Falls along FR1903, Newman Lake Road</td>
<td>– Mature aspen, mixed ages&lt;br&gt;– Planted white spruce along road&lt;br&gt;– Maple understory</td>
<td>– Desired landscape conditions, MA 4A: even-aged management maintains early to mid-successional communities. Aspen is over-represented; transitions to conifer species are encouraged.&lt;br&gt;– Maintain healthy forest and tree vigor&lt;br&gt;– Appropriate age class distribution: redistribute toward younger aspen&lt;br&gt;– Safe, efficient road infrastructure&lt;br&gt;– Provide wood through environmentally responsible harvest</td>
<td>– Maintain healthy white spruce along Newman Lake Road to achieve desired scenic conditions and diversity&lt;br&gt;– Maintain healthy hardwoods to achieve desired landscape conditions and age class distribution&lt;br&gt;– Protect against annosum root rot to maintain a healthy forest and tree vigor&lt;br&gt;– Provide scenic integrity (moderate SIO)&lt;br&gt;– Maintain consistency with Forest Plan Standards and Guidelines (e.g., reserve trees)</td>
<td>– Marking is immediate (Oct.)&lt;br&gt;– Harvest operations would occur in the short-term&lt;br&gt;– Management goals would be achieved in the short- (white spruce) and medium- to long-term (hardwoods)</td>
</tr>
</tbody>
</table>
Workbook Instructions

1. DEFINE area of interest, management objectives, and time frames.
2. ASSESS climate change impacts and vulnerabilities for the area of interest.
3. EVALUATE management objectives given projected impacts and vulnerabilities.
4. IDENTIFY and implement adaptation approaches and tactics.
5. MONITOR and evaluate effectiveness of implemented actions.
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

Purpose:
- Uses local expertise to determine how climate change may specifically affect the project area.

How might the area be uniquely affected by climatic change and subsequent impacts?
**Step 2:** ASSESS climate change impacts and vulnerabilities for the area of interest.

**General (Broad-scale) Impacts & Vulnerabilities**

Climate Change Impacts and Vulnerabilities for the Area of Interest

Vulnerability Determination

Information on regionally-relevant climate change effects.

From vulnerability assessments, literature, etc.

For example:

- Increased likelihood of extreme rain events
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

General (Broad-scale) Impacts & Vulnerabilities

Climate Change Impacts and Vulnerabilities for the Area of Interest

Vulnerability Determination

Site-based assessment of risk to regionally-relevant climate change impacts.

For example:
- Steep stream banks and poorly-sized culverts are at increased risk; impacts already being observed during large rain events.
**Step 2:** ASSESS climate change impacts and vulnerabilities for the area of interest.

**General (Broad-scale) Impacts & Vulnerabilities**

**Climate Change Impacts and Vulnerabilities for the Area of Interest**

**Vulnerability Determination**

How vulnerable is the site to the effects of climate change?

**High:** Impacts exceed ability of ecosystem to cope; functions and services disrupted.

**Moderate:** Impacts will cause changes, but systems can cope.

**Low:** Ecosystems can readily cope with impacts; relatively few/minor negative impacts.
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

Vulnerability Determination

- Adaptive Capacity of Ecosystem
- Potential Impacts

- High Vulnerability
- Moderate Vulnerability
- Low Vulnerability
- High Vulnerability
**Step 2:** ASSESS climate change impacts and vulnerabilities for the area of interest.

<table>
<thead>
<tr>
<th>Broad-scale Impacts and Vulnerabilities</th>
<th>Climate Change Impacts and Vulnerabilities for the Area of Interest</th>
<th>Vulnerability Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual temperatures are projected to increase by about 6.5 °F to 10.5 °F over the next century</td>
<td>In NE Price County, winter temps projected to increase 12F from 1980 to 2090 (A2); summer temps projected to increase 9.75F</td>
<td>Low to Moderate</td>
</tr>
<tr>
<td>Growing seasons have become longer and this trend is expected to continue</td>
<td>Growing seasons have become longer and this trend is expected to continue</td>
<td></td>
</tr>
<tr>
<td>Precipitation patterns may change, which may impact hydrologic regimes</td>
<td>Highly uncertain. Model average projects 0.75” increase in precip in the winter from 1980-2090; 0.25” decrease in the summer (A2); increase in extreme precipitation events</td>
<td></td>
</tr>
<tr>
<td>Altered hydrologic regimes may contribute to drier soils during summer and increased potential for drought</td>
<td>Altered hydrologic regimes may contribute to drier soils during summer and increased potential for drought</td>
<td></td>
</tr>
<tr>
<td>Increases in drought, rain and wind storms, wildfire, and other disturbances may contribute to successional changes or loss of forest cover</td>
<td>Increases in drought, rain and wind storms, wildfire, and other disturbances may contribute to successional changes or loss of forest cover</td>
<td></td>
</tr>
<tr>
<td>Carbon dioxide and ozone pollution currently cause changes to forest productivity</td>
<td>Maria look up concentration maps and leaf symptoms</td>
<td></td>
</tr>
<tr>
<td>Increases of invasive plant species, herbivores, and disease agents may contribute to reduced productivity or adult mortality</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Step #2 (Activity): Assess climate change impacts and vulnerabilities for your project area.

<table>
<thead>
<tr>
<th>Points (20 Total)</th>
<th>General Climate Change Impacts and Vulnerabilities</th>
<th>Climate Change Impacts and Vulnerabilities for the Project Area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>General climate change impacts across the Northeast US and Eastern Canada:</strong></td>
<td>How might broad-scale impacts and vulnerabilities be affected by conditions in the <strong>project area</strong>?</td>
</tr>
<tr>
<td></td>
<td>Warmer temperatures (annual and seasonal)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More days with extreme heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fewer days with extreme cold</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increased annual precipitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered seasonal changes in precipitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>More frequent heavy precipitation events</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less snow/shorter winter season</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Altered stream flows</td>
<td></td>
</tr>
</tbody>
</table>
Adaptation Example:
Chequamegon-Nicolet National Forest—Aspen
**Step 1:** DEFINE area of interest, management goals and objectives, and time frames.

**Area of Interest & Location**
- Forested stand near Park Falls, WI

**Forest Type**
- Aspen (mature)
**Example: Chequamegon-Nicolet National Forest—Aspen**

**Step 1:** DEFINE area of interest, management goals and objectives, and time frames.

<table>
<thead>
<tr>
<th>Area of Interest &amp; Location</th>
<th>Forest Type</th>
<th>Management Goals &amp; Objectives</th>
<th>Time Frames</th>
</tr>
</thead>
</table>
| Forested stand near Park Falls, WI | Aspen (mature) | **Early-successional habitat**  
- Desired landscape conditions/age classes  
- Ruffed grouse, other spp.  
- Maintain forest health & productivity  
- Provide sustainable wood  
**Scenic Integrity**  
- Road to recreation area |  
- Harvest (short term)  
- Achieve mgmt. goals (long term) |
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

Broad-scale Impacts & Vulnerabilities

- Warmer temps, altered precip, drier summers
- Declines in many common northern species

How might broad impacts be different in the area of interest?
Step 2: ASSESS climate change impacts and vulnerabilities for the area of interest.

Broad-scale Impacts & Vulnerabilities
- Warmer temps, altered precip, drier summers
- Declines in many common northern species

Impacts & Vuln. for Area of Interest
- Site is fairly dry now
- Mesic hardwoods are more susceptible
- Can regenerate aspen now, but maybe not in next rotation

Overall vulnerability: Moderate - High
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.
Workbook Instructions

1. DEFINE area of interest, management objectives, and time frames.

2. ASSESS climate change impacts and vulnerabilities for the area of interest.

3. EVALUATE management objectives given projected impacts and vulnerabilities.

4. IDENTIFY and implement adaptation approaches and tactics.

5. MONITOR and evaluate effectiveness of implemented actions.
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Purpose:
- Realistically assess the ability to meet goals and objectives under current management.

Can current management achieve goals?
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Management (Conservation) Objective

Challenges
Opportunities
Feasibility under Current Management
Other Considerations

From Step 1
**Step 3:** EVALUATE management objectives given projected impacts and vulnerabilities.

Management Objective

Challenges

Opportunities

Feasibility under Current Management

Other Considerations

How climate change impacts and vulnerabilities may make it more difficult to achieve the objective.

For example:

- Reduced suitable habitat for target species
- Reduced winter access
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Management Objective

Challenges

Opportunities

Feasibility under Current Management

Other Considerations

How climate change impacts and vulnerabilities may make it easier to achieve the objective.

For example:
- Reduced competition
- Increased growth
**Step 3:** EVALUATE management objectives given projected impacts and vulnerabilities.

<table>
<thead>
<tr>
<th>Management Objective</th>
<th>Challenges</th>
<th>Opportunities</th>
<th>Feasibility under Current Management</th>
<th>Other Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Is current management adequate for meeting the objectives given climate change?</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>High: we can do it!</strong> Opportunities&gt; Challenges</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Low: We’ll need more resources or effort.</strong> Challenges&gt;Opportunities</td>
<td></td>
</tr>
</tbody>
</table>
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Management Objective
Challenges
Opportunities
Feasibility under Current Management
Other Considerations

Social, administrative, financial, or other factors that also affect the ability to meet the objectives.

For example:
• Rare species or high social value—we’ll manage for it regardless
• Best chance of success—go for the long shot
Step 3: EVALUATE management objectives given projected impacts and vulnerabilities.

Slow down!

Are you going to continue with the management objectives that you have identified?
## Example: Chequamegon-Nicolet National Forest—Aspen

<table>
<thead>
<tr>
<th>Management Objective (Step #1)</th>
<th>Challenges to Meeting Management Objective with Climate Change</th>
<th>Opportunities for Meeting Management Objective with Climate Change</th>
<th>Feasibility of Meeting Obj. under Current Management</th>
<th>Other Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achieve desired landscape conditions and age class distribution via aspen regeneration</td>
<td>• Longer-term maintenance of stand may be more difficult under a changed climate (lower productivity, faster break-up)</td>
<td>• Future site conditions may be more conducive to pine (MA focus), if source was available</td>
<td>Short term: High Long term: Moderate</td>
<td>Likelihood of follow-up on stand in first 20-30 years is low, so harder to do add’l needed treatments</td>
</tr>
<tr>
<td>Maintain a healthy forest and tree vigor via aspen regeneration</td>
<td>• Observed productivity issues (worms?, drought?) may make site more vulnerable to climate change</td>
<td></td>
<td>Short term: High Long term: Low</td>
<td></td>
</tr>
<tr>
<td>Provide wood through environmentally responsible harvest via aspen regeneration</td>
<td>• Low diversity. Few other species to fall back on</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Provide scenic integrity along Newman Lake Road</td>
<td>• Hazel present, and may become more competitive as site dries (?)</td>
<td>• Mixed areas along the road might fare better and currently look good</td>
<td>Short term: High Long term: Low (high uncertainty)</td>
<td></td>
</tr>
<tr>
<td>Maintain consistency with Forest Plan Standards and Guidelines (e.g., reserve trees)</td>
<td>• Low diversity of stand increases the stand’s vulnerability</td>
<td>• More snags and den trees? • Non-aspen reserve trees will add diversity and may be better adapted to future conditions</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>
ADAPTATION EXAMPLE:
CHEQUAMEGON-NICOLET NATIONAL FOREST—ASPEN
**Step 3:** EVALUATE management objectives given projected impacts and vulnerabilities.

**Mgmt. Obj.**
- Regenerate aspen
- Scenic integrity

**Challenges**
- Long-term maintenance
- Few tree species
- Productivity issues
- Hazel competition
- Reserve strips more vulnerable to windthrow

**Opportunities**
- Future site may be suitable for pine
- Mixed areas along road look better

**Feasibility of Meeting Obj. (Current Mgmt)**
- Short term: High
- Long-term: Low
- High
Identifying Adaptation Actions
What actions can be taken to enhance the ability of an ecosystem to cope with change while meeting conservation goals and objectives?
Uncertainty and Risk

Design actions that are robust across a range of potential future conditions
Adaptation

Adaptation is the adjustment of systems in response to climate change.

Adaptation activities can build on sustainable management, conservation, and restoration of forests

Parry et al. 2007, SCBD 2009, Groves et al. 2010
Adaptation Actions

Manage for Change:
Ecosystems will fundamentally become something different

Manage for Persistence:
Ecosystems will still be recognizable as being the same system (character)
MANAGE FOR PERSISTENCE

RESISTANCE

Improve the defenses of the forest against effects of change.

- Short-term
- High-value

Photo: USFS

Millar et al. 2007
MANAGE FOR PERSISTENCE

RESILIENCE

Enhance the ability of a system to maintain or return to a particular ecological state following disturbance.

Holling 1973, Millar et al. 2007, NWF 2014
MANAGE FOR CHANGE

TRANSITION

Intentionally encourage change, help ecosystems respond in a targeted fashion

Millar et al. 2007
When you might emphasize...

Persistence (Same/Similar)
- High ecological value or unique/rare condition
- High social value associated with current condition
- Inherent ability to buffer changes
- Highly vulnerable, but place represents best chance of success

Change (Future-adapted)
- High likelihood that current conditions will fail, making change is necessary
- Changes are already occurring, and can be enhanced
- Good opportunity to try something new
Forest Adaptation Resources

Strategies & Approaches
Provides a menu of adaptation actions

Adaptation Workbook
Provides a structure for considering climate change in management

Swanston and Janowiak 2012; www.treesearch.fs.fed.us/pubs/40543
1. DEFINE area of interest, management objectives, and time frames.

2. ASSESS climate change impacts and vulnerabilities for the area of interest.

3. EVALUATE management objectives given projected impacts and vulnerabilities.

4. IDENTIFY and implement adaptation approaches and tactics.

5. MONITOR and evaluate effectiveness of implemented actions.

Can we use this approach for other resource areas?
Adaptation Strategies & Approaches

A “menu” of possible actions that allows you to decide what is most relevant for a particular location and set of conditions.
Adaptation Strategies and Approaches

- Resistance
- Resilience
- Transition
A menu of Strategies and Approaches provides a way to translate broad Options into locally-relevant Tactics.
Adaptation Strategies and Approaches

CONCEPT

Option

Resistance:
Forestall change

Resilience:
Rebound from change

Transition:
Facilitate change

Start with an Option

Strategy

Approach

Tactic
Adaptation Strategies and Approaches

Option
Strategy
Approach
Tactic

Resistance
(forestall change)
Adaptation Strategies and Approaches

Sustain fundamental ecological functions
Adaptation Strategies and Approaches

Maintain or restore hydrology
Adaptation Strategies and Approaches

CONCEPT

Option

Strategy

Approach

Tactic

ACTION

Harvest in winter on frozen/snow-covered ground to minimize disturbance
Use water control structures to maintain key wetland habitats
Adaptation Strategies and Approaches

CONCEPT

Option
Strategy
Approach
Tactic

ACTION

Use water control structures to maintain key wetland habitats
Adaptation Strategies and Approaches

- **Option**
- **Strategy**
- **Approach**
- **Tactic**

Start with a Tactic
Work backwards to show intentionality
Adaptation Strategies and Approaches

- **Option**
- **Strategy**
- **Approach**
- **Tactic**

Establish future-adapted species on south-facing slopes
Adaptation Strategies and Approaches

Emphasize drought- and heat-tolerant species & populations
Adaptation Strategies and Approaches

Facilitate community adjustments through species transitions
Adaptation Strategies and Approaches

CONCEPT

Option
Strategy
Approach
Tactic

ACTION

Transition (facilitate change)
Adaptation Strategies and Approaches

Helps connect the dots from broad concepts to specific actions for implementation.
▪ It doesn’t matter whether you start with approaches or tactics.
▪ It is important to connect the two: shows how your action is related to climate change.
Step 4: IDENTIFY adaptation approaches and tactics for implementation.
Workbook Instructions

1. DEFINE area of interest, management objectives, and time frames.
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4. IDENTIFY and implement adaptation approaches and tactics.
5. MONITOR and evaluate effectiveness of implemented actions.
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

Purpose:

- Select potential adaptation actions

What actions can be taken to enhance the ability of the area to cope with change and meet management goals/objectives?
Two Questions

1. What actions can help achieve my management objectives and address the potential climate change impacts?
2. Will future managers know what we were trying to do?
Step 4: IDENTIFY adaptation approaches and tactics for implementation.

Adaptation Approach

Tactic

Time Frame

Benefits

Drawbacks and Barriers

Practicability

Recommend Tactic?

Select from the menu of adaptation strategies and approaches.

Pick any that seem to make sense and help address the challenges.
**Step 4:** IDENTIFY adaptation approaches and tactics for implementation.

<table>
<thead>
<tr>
<th>Adaptation Approach</th>
<th>Tactic</th>
<th>Time Frame</th>
<th>Benefits</th>
<th>Drawbacks and Barriers</th>
<th>Practicability</th>
<th>Recommend Tactic?</th>
</tr>
</thead>
<tbody>
<tr>
<td>How the adaptation approach will be implemented.</td>
<td>For example:</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>• Restore fire through prescribed burn</td>
<td></td>
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<tr>
<td></td>
<td>• Increase genetic diversity by acquiring seed from IL</td>
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<tr>
<td>Note: There may be multiple approaches for a single tactic, or vice versa.</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
**Step 4:** IDENTIFY adaptation approaches and tactics for implementation.

<table>
<thead>
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<th>Practicability</th>
<th>Recommend Tactic?</th>
</tr>
</thead>
</table>
|                     |        | Timing for the tactics | For example:  
|                     |        |  • Summer 2014  
|                     |        |  • Winter 2013-2016  
|                     |        |  • Within 3 years of...  
|                     |        |  • After...  |

- **Timing for the tactics**
- **For example:**
  - Summer 2014
  - Winter 2013-2016
  - Within 3 years of...
  - After...
### Step 4: IDENTIFY adaptation approaches and tactics for implementation.

<table>
<thead>
<tr>
<th>Adaptation Approach</th>
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<th>Recommend Tactic?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Why it’s good</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>For example:</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Addresses biggest or multiple challenges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cheap, easy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Co-benefits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Likely to succeed</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Step 4:** IDENTIFY adaptation approaches and tactics for implementation.

<table>
<thead>
<tr>
<th>Adaptation Approach</th>
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<th>Drawbacks and Barriers</th>
<th>Practicability</th>
<th>Recommend Tactic?</th>
</tr>
</thead>
</table>

**Why it’s not so good**

For example:

- Negative side effects
- High cost or effort
- Social, financial, or other barriers
- Uncertainty of success
### Step 4: IDENTIFY adaptation approaches and tactics for implementation.

<table>
<thead>
<tr>
<th>Adaptation Approach</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Is it both effective and feasible?*

**High:** Yes to both!

**Moderate:** Yeah, but it will take some additional effort or planning...

**Low:** No, the barriers/drawbacks seem too big or the benefits too small.
Step 4: IDENTIFY adaptation approaches and tactics for implementation.

**Adaptation Approach**

**Tactic**

**Time Frame**

**Benefits**

**Drawbacks and Barriers**

**Practicability**

**Recommend Tactic?**

Given all this, is this tactic likely to be helpful?

Also consider: trade-offs, urgency, likelihood of success, cost, and effort...

Yes: look to integrate into plan, prescription, or other activities

No: not useful at this time
Step 4: IDENTIFY adaptation approaches and tactics for implementation.

Slow down!

Are you going to continue with the adaptation tactics that have been selected?
### Adaptation Approach

<table>
<thead>
<tr>
<th>Tactic</th>
<th>Time Frames</th>
<th>Benefits</th>
<th>Drawbacks &amp; Barriers</th>
<th>Practicability of Tactic</th>
<th>Recommend Tactic?</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2 — Maintain or improve the ability of forests to resist pests and pathogens.</td>
<td></td>
<td>▪ Young aspen is generally less susceptible to pests and diseases than mature aspen&lt;br&gt;▪ May help reduce patchiness of aspen in stand</td>
<td></td>
<td>Extremely High</td>
<td>Yes</td>
</tr>
<tr>
<td>Clearcut aspen in winter to promote vigorous regrowth</td>
<td>Short term (harvest)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.2 — Favor or restore native species that are expected to be better adapted to future conditions.</td>
<td></td>
<td>▪ Species seems like it would be well-adapted to site&lt;br&gt;▪ Add diversity and a future adapted species</td>
<td>▪ Not sure whether competition could be controlled sufficiently&lt;br&gt;▪ Not good place to put oak where it can get the right amount of light at the right time&lt;br&gt;▪ Emphasis is aspen, so sinking lots of effort into oak doesn’t make sense&lt;br&gt;▪ Not specified in NEPA</td>
<td>Low (effectiveness and feasibility are both low) Additional steps would be needed to prep for oak planting</td>
<td>Yes</td>
</tr>
<tr>
<td>Plant red oak in select areas to introduce a small component to stand and add species diversity, especially in reserve areas near road. Consider deer protection for oak.</td>
<td>Short-term (harvest)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.2 — Favor existing genotypes that are better adapted to future conditions</td>
<td></td>
<td>▪ Stock might be better adapted to future conditions.&lt;br&gt;▪ Stock would be within the same seed zone.</td>
<td>▪ Overall suitability for this stand is unknown.&lt;br&gt;▪ Haven’t done this before. Low probability of success?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For any planted red oak, consider selecting acorns from trees that have survived drought and other stressors (e.g., Twin Ghost areas of oak mortality)</td>
<td>Short term</td>
<td></td>
<td></td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>8.4 — Emphasize drought- and heat-tolerant species and populations.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXAMPLE: CHEQUAMEGON-NICOLET NATIONAL FOREST—ASPEN**
ADAPTATION EXAMPLE:
CHEQUAMEGON-NICOLET NATIONAL FOREST—ASPEN
Step 4: IDENTIFY and adaptation approaches and tactics for implementation.

What actions can be taken to enhance the ability of the area to cope with change and meet management goals?

Example: Chequamegon-Nicolet National Forest—Aspen
**Overall Approach: Enhance future options within existing management trajectory**

- Aspen will regenerate now, but is likely to fare poorly over the long term.
- Maintain plans for clearcut, with additional actions to promote diversity and provide future options.
- Pro-active on invasives and disturbance planning.
**Step 4:** IDENTIFY and adaptation approaches and tactics for implementation.

<table>
<thead>
<tr>
<th>Adaptation Approach</th>
<th>Tactic</th>
<th>Consider:</th>
<th>Recommend Tactics?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain or improve the ability of forests to resist pests and pathogens.</td>
<td>Clearcut aspen</td>
<td>Benefits</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Thin roadside aspen</td>
<td>Drawbacks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plant white pine and red oak (to become minor component)</td>
<td>Barriers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Favor future-adapted species on site</td>
<td>Practicability</td>
<td></td>
</tr>
<tr>
<td>Favor or restore native species that are expected to be better adapted to future conditions.</td>
<td></td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>
Step 5: MONITOR and evaluate effectiveness of implemented actions.
1. DEFINE area of interest, management objectives, and time frames.

2. ASSESS climate change impacts and vulnerabilities for the area of interest.

3. EVALUATE management objectives given projected impacts and vulnerabilities.

4. IDENTIFY and implement adaptation approaches and tactics.

5. MONITOR and evaluate effectiveness of implemented actions.
A Few Thoughts About Monitoring...

- Be VERY CLEAR about your information needs and the kind of monitoring that might help you get that information:
  - Implementation monitoring = Did we do the action?
  - Surveillance/impact monitoring = What change is occurring over time?
  - Effectiveness/adaptation monitoring = Did our action actually have the desired effect?
  - Scientific research = Is this outcome statistically significant compared to a control? Could we expect similar results elsewhere?
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**Purpose:**

- Practice adaptive management

How do we know if the selected actions were effective?

What can we learn from these actions to inform future management?

**Step 5:** MONITOR and evaluate effectiveness of implemented actions.
Step 5: MONITOR and evaluate effectiveness of implemented actions.

**Monitoring Item**

**Monitoring Metric**

**Criteria for Evaluation**

**Monitoring Implementation**

Item that can tell you whether you have achieved your management goals or objectives.

If possible, use an item that also helps evaluate the effectiveness of the tactics.

For example:

- Planted seedling survival
Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Item

Monitoring Metric

Criteria for Evaluation

Monitoring Implementation

What you’re monitoring or measuring.

For example:
• Percentage success at 1, 2, 5, and 10 years after planting.
Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Item

Monitoring Metric

Criteria for Evaluation

Evaluation of success

For example:
• 60% survival of non-local genotypes
Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Item

Monitoring Metric

Criteria for Evaluation

Monitoring Implementation

How the monitoring will actually get done.

Note: use existing monitoring when possible

For example:
- Regular post-planting stocking surveys.
- Supplemental surveys at 10 years.
ADAPTATION EXAMPLE:
CHEQUAMEGON-NICOLET NATIONAL FOREST—ASPEN
**Step 5:** MONITOR and evaluate effectiveness of implemented actions.

<table>
<thead>
<tr>
<th>Monitoring Item</th>
<th>Monitoring Metric</th>
<th>Criteria for Evaluation</th>
<th>Implement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post clearcut stocking*</td>
<td>Stems/acre</td>
<td>Established criteria</td>
<td>Stocking surveys</td>
</tr>
<tr>
<td>Survival of planted trees*</td>
<td>Seedling survival</td>
<td>Established criteria</td>
<td>Survival surveys</td>
</tr>
<tr>
<td>Spp. composition for trees &gt;1” diameter*</td>
<td>n/a</td>
<td>n/a</td>
<td>Regular stand exam</td>
</tr>
<tr>
<td>Intensified inventory before harvest to establish baseline (?)</td>
<td>n/a</td>
<td>n/a</td>
<td>Before harvest, then revisit</td>
</tr>
</tbody>
</table>

*Standard monitoring item
How can we better use inventory data?

- Evaluate success of management in achieving goals
- Evaluate effectiveness of adaptation actions
- Integrate monitoring and evaluation into forest management plan

Images: www.magazine.nature.org
Forest Inventory: Climate Change Filter

Common Measures
- Species
- Diameter
- Merchantable height

Key Ecological Attributes
- Stocking/Density
- Structure
- Large live trees
- Species richness/evenness

Can also tell you...
- Proportion of forest at risk of decline from climate change
- Stocking of desirable or future-adapted trees
Forest Inventory: Climate Change Filter

**Extra Measures**
- Tree condition class
- Tree crown ratio
- Regen
- Snags
- Browse severity
- Woody/vegetative competition

**Can also tell you...**
- Tree health/vigor (sort of)
- Established seedlings of desirable or future-adapted species
### Forest Inventory: Climate Change Filter

**Stand 25 – Trees at risk of declining from climate change**

<table>
<thead>
<tr>
<th>TREES</th>
<th>BA/Ac</th>
<th>TPA</th>
<th>IV</th>
<th>At Risk?</th>
<th>At Risk BA PCM</th>
<th>At Risk BA GFDL</th>
<th>At Risk TPA PCM</th>
<th>At Risk TPA GFDL</th>
<th>At Risk IV PCM</th>
<th>At Risk IV GFDL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balsam Fir</td>
<td>2.3</td>
<td>11.8</td>
<td>7.1</td>
<td>yes</td>
<td>2.3</td>
<td>11.8</td>
<td>7.1</td>
<td>7.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basswood</td>
<td>5.1</td>
<td>9.3</td>
<td>7.2</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Black Ash</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>yes</td>
<td>0.0</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Black Spruce</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>yes</td>
<td>0.6</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Hemlock</td>
<td>4.0</td>
<td>5.7</td>
<td>4.8</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>Ironwood</td>
<td>0.6</td>
<td>2.1</td>
<td>1.3</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Paper Birch</td>
<td>0.6</td>
<td>0.8</td>
<td>0.7</td>
<td>yes</td>
<td>0.6</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Quaking Aspen</td>
<td>4.6</td>
<td>8.5</td>
<td>6.5</td>
<td>yes</td>
<td>4.6</td>
<td>8.5</td>
<td>6.5</td>
<td>6.5</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Red Maple</td>
<td>22.2</td>
<td>59.9</td>
<td>41.1</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Red Oak</td>
<td>1.1</td>
<td>0.5</td>
<td>0.8</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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</tr>
<tr>
<td>Sugar Maple</td>
<td>38.2</td>
<td>76.9</td>
<td>57.6</td>
<td>yes</td>
<td>0.0</td>
<td>38.2</td>
<td>0.0</td>
<td>76.9</td>
<td>0.0</td>
<td>57.6</td>
</tr>
<tr>
<td>White Cedar</td>
<td>5.7</td>
<td>8.3</td>
<td>7.0</td>
<td>yes</td>
<td>0.0</td>
<td>5.7</td>
<td>0.0</td>
<td>8.3</td>
<td>0.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Yellow Birch</td>
<td>14.8</td>
<td>23.4</td>
<td>19.1</td>
<td>yes</td>
<td>0.0</td>
<td>14.8</td>
<td>0.0</td>
<td>23.4</td>
<td>0.0</td>
<td>19.1</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>100.4</strong></td>
<td><strong>207.9</strong></td>
<td><strong>154.1</strong></td>
<td><strong>At-Risk Value:</strong></td>
<td><strong>8.0</strong></td>
<td><strong>67.3</strong></td>
<td><strong>21.5</strong></td>
<td><strong>130.6</strong></td>
<td><strong>14.8</strong></td>
<td><strong>98.9</strong></td>
</tr>
<tr>
<td><strong>Proportion at Risk:</strong></td>
<td><strong>8%</strong></td>
<td><strong>67%</strong></td>
<td><strong>10%</strong></td>
<td><strong>63%</strong></td>
<td><strong>10%</strong></td>
<td><strong>64%</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Monitoring Items</td>
<td>Monitoring Metric(s)</td>
<td>Criteria for Evaluation</td>
<td>Monitoring Implementation</td>
<td></td>
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</tr>
<tr>
<td>Effectiveness of clearcut to see whether site is adequately stocked (STANDARD)</td>
<td>Stems per acre</td>
<td>Established criteria</td>
<td>- First-year stocking survey (Post-harvest survey to assess condition of midstory and see if follow-up actions are needed)</td>
<td></td>
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<td></td>
<td></td>
<td>- Additional stocking surveys at 3 and possibly 5 years</td>
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<td></td>
<td>- FACTS database tracks activity</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Survival of planted species (STANDARD)</td>
<td>Seedling survival</td>
<td>Established criteria</td>
<td>- Survival survey at 1 and 3 years</td>
<td></td>
<td></td>
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<td></td>
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<td>- FACTS database tracks activity</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Post-sale and post disturbance monitoring of invasives - See tactics #2,10</td>
<td>Presence/absence</td>
<td>Plant ecologist evaluation</td>
<td>- Two years after close of sale</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(IN ADDITION TO STANDARD)</td>
<td></td>
<td></td>
<td>- Two years after any large disturbances</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- TESP Invasives would record invasives if present</td>
<td></td>
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<td></td>
<td>- FACTS database tracks activity</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Stand exam – relative amounts of major stand components. Trees greater that 1”</td>
<td>n/a</td>
<td>n/a</td>
<td>- Every 10 years.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Seedlings optional. (STANDARD)</td>
<td></td>
<td></td>
<td>- Recorded in FSVEG</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Certification of release for planted trees following TSI (STANDARD)</td>
<td>Survival/condition</td>
<td>Forester/silviculturist evaluation</td>
<td>- Concurrent with final (2\textsuperscript{nd} or 3\textsuperscript{rd}) release</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>- FACTS database tracks activity</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breeding birds (STANDARD)</td>
<td></td>
<td></td>
<td>Breeding bird plots nearby</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPTIONAL: Intensified stand exam or veg survey before harvest to identify</td>
<td>n/a</td>
<td>n/a</td>
<td>- Before harvest: additional “intensified stand exam” in this stand and possibly 1-2 control stands within sale area. Measure marked stand before harvest to collect “pre/post” harvest data. Preferably by plant ecologist in summer to collect other veg data. Use intensified stand exams in future to collect data over long-term. Recorded in FSVEG</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>baseline conditions (ADDITIONAL)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Monitoring Items

- Proportion of young forest habitat
- Effectiveness of invasives control
- Desired tree species composition
- Desirable seedling species (and abundance)
- Planted seedling survival (by species or genotype)
- Condition/health of white pine
- Understory herbaceous species diversity
- Experience interactions/contact hours for education
- Herbivory
- Wildlife (?)