Pathway: Resistance

Resistance actions are designed to work against the effects of climate change and maintain the forest in its current condition. In this way, resistance actions can be seen as "playing defense" in trying to prevent changes from occurring. When forests have low vulnerability to climate change, it may be relatively easy to maintain the current forest condition while climate change impacts are minimal. However, as changes in climate intensify and impacts and as vulnerabilities increase, the resistance pathway becomes increasingly challenging. Although resistance actions may be appropriate for defending high-risk or high-value resources in the short term, such as rare species or unique habitats, these actions may require considerable time and resources to maintain effectiveness, ultimately becoming too costly to implement. Additionally, climate change may cause conditions in some areas to fundamentally change so that the resistance pathway is no longer feasible.

In southern New England oak forests, **resistance** actions may have the best chance of success in forests that are currently in good condition and have relatively low levels of risk from climate change and other forest disturbances. You may want to compare this option with the **resilience** and **transition** pathways to determine what option best meets your management goals and objectives, particularly if your forest is already being stressed by invasive species, drought, pests, or other stressors.

Actions for Forests Health and Productivity ⇳

Here are some examples of adaptation actions that can help maintain oak forests to meet objectives for general forest health to provide wood products and other benefits. The specific actions used in a particular location will vary based on local site conditions, management goals, and climate risks. Additional actions are described in the Adaptation Strategies and Approaches for Forests.

Condition	Adaptation Approach	Example Action
Ecosystem contains a high-quality native plant community or is of high conservation value	▪ 4.1 Prioritize and maintain unique sites ▪ 4.2 Prioritize and maintain sensitive or at-risk species or communities ▪ 5.4 Establish reserves to maintain ecosystem diversity	▪ Identify area for passive management (no harvest) reserve area when consistent with landowner goals and site capability ▪ Implement forest harvests at lower intensities (e.g., light thinning) to maintain desired composition
Invasive plants are present at low levels or nearby.	▪ 2.2 Prevent the introduction and establishment of invasive plant species and remove existing invasive species	▪ Remove existing invasive species with mechanical treatment to promote the current plant community

		▪ Use monitoring to support early detection and rapid response to eliminate new infestations
Site exposed to wind	▪ 3.3. Alter forest structure to reduce severity or extent of wind and ice damage.	▪ Use thinning or other silvicultural treatment to reduce tree density and increase the windfirmness of the residual trees
Stand is overstocked and/or susceptible to drought or forest pests	▪ 2.1. Maintain or improve the ability of forests to resist pests and pathogens. ▪ 1.4. Reduce competition for moisture, nutrients, and light.	▪ Thin trees or release crop trees to reduce tree density
Forest regeneration is desired; advance regeneration is dominated by maple, black birch or other mesic species	▪ 5.1. Promote diverse age classes. ▪ 5.2. Maintain and restore diversity of native species. ▪ 8.2. Favor existing genotypes that are better adapted to future conditions. ▪ 9.1. Favor or restore native species that are expected to be adapted to future conditions. ▪ 9.3. Guide changes in species composition at early stages of stand development.	▪ Harvest using shelterwood system to release crowns of overstory trees, tend advance regeneration, and allow for new regeneration ▪ Create reserves within harvest areas to protect rare species, sensitive sites, and topographically protected areas ▪ Retain cavity trees and down wood
Forest regeneration is desired; advance regeneration is primarily oak	▪ 5.1. Promote diverse age classes. ▪ 5.2. Maintain and restore diversity of native species. ▪ 8.2. Favor existing genotypes that are better adapted to future conditions.	▪ Use group selection, patch cuts, or final shelterwood cut to release oak regeneration ▪ Retain underrepresented species to increase diversity, emphasizing species expected to be suitable for future conditions ▪ Retain cavity trees and down wood
Forest regeneration is desired; no advance regeneration or lack or regeneration following harvest	▪ 8.1. Use seed, germplasm, and other genetic material from across a greater geographic range	▪ Harvest using shelterwood system to release crowns of overstory trees and create light conditions favorable for regeneration ▪ Create reserves within harvest areas to protect rare species, sensitive sites, and topographically protected areas

		▪ Plant existing oak species using seed stock from southerly populations (e.g., Mid-Atlantic states) for artificial regeneration ▪ Retain cavity trees and down wood

Actions for Wildlife

Here are some examples of adaptation actions that can help maintain oak forests to meet objectives for wildlife habitat. The specific actions used in a particular location will vary based on local site conditions, management goals, and climate risks. Additional actions are described in the Adaptation Strategies and Approaches for Wildlife (in review).

Condition	Adaptation Approach	Action
Forest lacks age class or structural diversity	▪ 8.1. Manage for plant species diversity and complexity	▪ Emphasize size class diversity and patchiness during forest harvests
Rare or sensitive species are present (e.g., plants, turtles)	▪ 8.4. Manage and create suitable microhabitats and microclimates ▪ 10.3. Select reserves that maximize biodiversity protection for a suite of species ▪ 10.7. Protect climate refugia across the landscape	▪ Protect and create small vernal pools in mesic forests. ▪ Implement forest management actions that promote diverse canopy cover, light environments, down woody habitat, and diversity of tree sizes. ▪ Retain snags of large-diameter trees that can be used as cavity nesting habitat. ▪ Establish reserves in high-quality ecosystems ▪ Buffer cool spots on the landscape that may be slower to change
Raptors present	▪ 8.7. Create or maintain sources of food, water, and cover in a variety of locations across the landscape	▪ Retain trees with multi-limbed tree crotches or “basket forks” in live hardwood crowns during harvest

Actions for Water

Here are some examples of adaptation actions that can help maintain oak forests to meet objectives for water resources. The specific actions used in a particular location will vary based on local site conditions, management goals, and climate risks. Additional actions are described in the Adaptation Strategies and Approaches for Forested Watersheds.

Condition	Adaptation Approach	Action

Riparian areas, vernal ponds, and other sensitive wetlands	▪ 1.5 Maintain and restore forested wetlands and lowland areas	▪ Use conservation easements or other land use restrictions to prevent land use change or development. ▪ Identify areas for no- or low- harvest buffers to reduce potential impacts to these systems ▪ Expand buffer areas around sites that may be more vulnerable to extreme weather and climate change ▪ Identify and manage cooler and wetter locations that are expected to be more resistant to changes in climate as refugia for maintaining native plant communities (e.g. Hemlock) in the future
Areas of low vegetative cover	▪ 3.1 Maintain or restore forest and vegetative cover in riparian areas ▪ 3.2: Promptly revegetate areas after disturbance	▪ Plant native vegetation to slow overland flows and improve water infiltration
Tree mortality in riparian areas	▪ 3.1 Maintain or restore forest and vegetative cover in riparian areas ▪ 3.7: Identify, maintain, and enhance important habitats for fish and wildlife	▪ Prioritize stream restoration activities in areas most likely to retain cool late-summer flows that may buffer the survival of aquatic organisms during extreme weather conditions, and at particular life history stages.
Man-made ponds, embankments, etc.	▪ 3.7: Identify, maintain, and enhance important habitats for fish and wildlife	▪ Use water control structures to maintain the hydrologic function and regulate water levels and open water conditions when necessary for migratory birds and wildlife breeding areas ▪ Remove unnecessary barriers to fish passage, such as check dams or failing culverts ▪ Retain woody debris and beaver dams in streams when possible to enhance

Actions for Recreation and Forest Roads and Trails ⇳

Here are some examples of adaptation actions that can help maintain oak forests to meet objectives related to forest roads and trails used for recreation and other purposes. The specific actions used in a particular location will vary based on local site conditions, management goals, and climate risks. Additional actions are described in the Adaptation Strategies and Approaches for Recreation.

Condition	Adaptation Approach	Action
Erosion on forest roads and trails following extreme rain	▪ 2.2 Enhance the capacity of natural systems to accommodate variable precipitation ▪ 2.3 Minimize impacts of existing roads and trails that are compromised by changing conditions	▪ Avoid machine or foot traffic in vulnerable areas ▪ Use water bars or increase number used to divert water from road surfaces ▪ Use vegetation or rock armoring along roadsides to minimize erosion and reduce risk of failure
Flooding of forest roads and trails	▪ 2.2 Enhance the capacity of natural systems to accommodate variable precipitation ▪ 2.3 Minimize impacts of existing roads and trails that are compromised by changing conditions	▪ Harden surfaces or elevate roads/trails
Water crossings missing or undersized on woods roads	▪ 2.2 Enhance the capacity of natural systems to accommodate variable precipitation	▪ Add or replace stream crossings to enhance drainage ▪ Use vegetation or rock armoring along roadsides to minimize erosion and reduce risk of failure

Actions for Forest Carbon

Here are some examples of adaptation actions that can help maintain oak forests to meet objectives for general forest health to provide carbon sequestration and storage, along with other benefits. The specific actions used in a particular location will vary based on local site conditions, management goals, and climate risks. Additional actions are described in the Adaptation Strategies and Approaches for Forest Carbon.

Condition	Adaptation Approach	Action
Potential for land use change	▪ 1.1 Avoid forest conversion to nonforest land uses	▪ Use conservation easements or other land use restrictions to prevent land use change or development.
Mix of agriculture and forest lands on property	▪ 1.4 Increase or implement agroforestry practices	▪ Integrate trees and shrubs into agricultural landscapes, such as within riparian buffers
Forest of high conservation value and large trees or healthy, mature forest subject to few stressors	▪ 5.1 Prioritize low-vulnerability sites for maintaining or enhancing carbon stocks ▪ 5.2 Establish reserves on sites with high carbon density	▪ Create no-harvest reserve areas (passive management) when consistent with landowner goals and site capability ▪ Expand buffers around riparian zones, wetlands, or other sensitive sites

		▪ Implement forest harvests at lower intensities (e.g., light thinning) ▪ Delay harvest or extend time between forest harvest entries
Stand is overstocked and/or susceptible to drought or forest pests	▪ 2.4: Maintain or improve the ability of forests to resist pests and pathogens	▪ Thin to reduce competition for light or soil moisture to enhance resistance to stressors
Forest harvest to meet other management goals (e.g., habitat, timber)	▪ 2.1: Reduce impacts to soils and nutrient cycling ▪ 2.2: Maintain or restore hydrology	▪ Minimize the area (footprint) of forest roads and trails ▪ Alter the timing of forest operations to reduce potential impacts on water, soils, and residual trees, especially in areas that rely on particular conditions for operations that may be affected by a changing climate ▪ Retain coarse woody debris (e.g., tree tops, harvest residue) to maintain soil moisture, nutrients, and enhance soil organic matter pools ▪ Use soil amendments to restore or improve soil quality ▪ Restore native herbaceous groundcover following management activities in order to retain soil moisture and reduce erosion

On-the-Ground Examples

- Adaptive Silviculture – Southern New England Oak Forests
    - The Adaptive Silviculture for Climate Change (ASCC) study sites in southern New England include resistance, resilience, transition, and no action treatments in oak forests that are representative of forests across much of the region. The treatments were developed by a team of scientists and managers working to identify options relevant to smaller parcel sizes and varied ownership.

- Mount Philo State Park: Climate Change and Rare Plants
    - This State Park in Vermont is home to many rare plant species, but managers are concerned that longer growing seasons and the park's popularity among the public will lead to increases in invasive plant species. Management actions are being taken to prevent the introduction and establishment of invasive plant species.

- Massachusetts Department of Conservation and Recreation: Tannery Road Timber Sale
    - Managers of this timber sale within Savoy Mountain State Forest were concerned that warmer, drier summers and increased windthrow could lead to wildfire conditions in an already degraded Norway spruce plantation. They thinned the Norway spruce plantations with rows oriented east-west in order to reduce the risk and/or severity of future wildfires.