Climate Change Adaptation Plan

Forest Management on Rattlesnake Hill Wildlife Management Area

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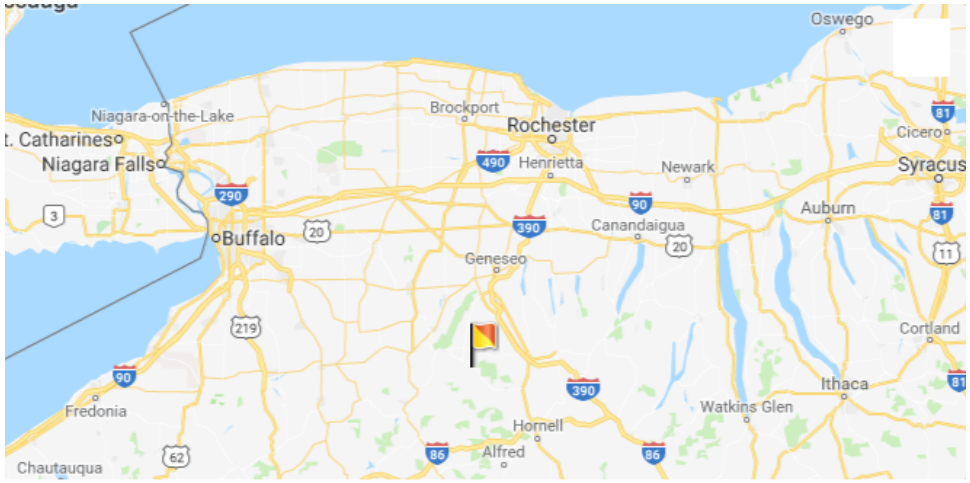
Prepared by Michael Palermo

Prepared using the Adaptation Workbook - AdaptationWorkbook.org



Property details

Acres: 362

Ownership: State

Rattlesnake Hill WMA is located in western New York, comprises 5,160 mostly forested acres, and contains multiple forest types, including oak, aspen, northern hardwoods, hemlock, conifer plantations, and young forest. A Habitat Management Plan was produced in 2016 which outlines habitat objectives for the property, with a focus on increasing the young forest component. Approximately 362 acres of young forest habitat are planned to be created here over the next ten years.

Table of Contents

1. Project Goals and Objectives

Management goals and objectives capture fundamental information about the project area or property and provide a starting point for considering climate change.

1a. Young Forest Habitat: Goals and Objectives

Approximately 362 acres of this habitat type are planned to be created on Rattlesnake Hill WMA over the next ten years.

Goal	Objectives and Timeframes
Provide more young forest habitat on the WMA	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

1b. Non-native Invasive Vegetation: Goals and Objectives

Several species of invasive plants occur on the WMA, including barberry, buckthorn, honeysuckle, multiflora rose, and autumn olive. These species have degraded habitat in some areas and are a risk to other areas prone to invasion.

Goal	**Objectives and Timeframes**
Control non-native invasive vegetation to maintain forest biodiversity	• Reduce understory invasive plant cover to 5% or less in project area *(5 years)* • Maintain 5% or less invasive plant cover in young forest stands *(15 years)*

1c. Oak Regeneration: Goals and Objectives

Several stands on the WMA are a Transition Oak forest type with declining oak. These oaks need to be regenerated soon or the stand will further transition to northern hardwoods / beech thicket.

Goal	Objectives and Timeframes
Regenerate oak stands that are declining or are susceptible to decline in the near future	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

1d. Red Pine Plantations: Goals and Objectives

Most red pine plantations on the WMA were planted approximately 70 years ago and several are declining, with minimal live crown. Habitat values have decreased here as evergreen cover has declined, and the understory is relatively devoid of desirable vegetation.

Goal	**Objectives and Timeframes**
Convert red pine plantations to natural stands	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

2. Climate Change Impacts and Vulnerabilities

Climate change will not affect all places in the same way. This section describes the anticipated effects of climate change within a region, and then provides additional details how specific places within the project area may be affected.

2a. Regional Climate Impacts and Vulnerabilities

Potential Climate Impact - Regional	Property or Project Area Considerations
Temperatures in the Mid-Atlantic are projected to increase 2.2 to 7.6 °F by the end of the century, with the greatest warming expected to occur during summer and fall. (34, 17)	Warmer temperatures could increase tree respiration and productivity, which would be beneficial. Heat stress could negatively impact species with low tolerance of extreme temperatures or that have a maximum temperature threshold. Soil moisture decline caused by an increase of evapotranspiration could be negative, and could lead to moisture stress to species on already dry sites, or species that require consistently wet sites. Sugar maple and beech are present in young forests and the understory of most oak stands in the project area, and their range may shift northward, hindering future establishment.
The growing season in the Mid-Atlantic is generally expected to increase by 21 days or more by the end of the century, due to fewer days with a minimum temperatures below 32°F. (34, 17)	The longer growing season could be beneficial by increasing growth and possibly improving regeneration establishment. Phenology shifts could favor non-natives, or may cause early bud break in natives that then is susceptible to spring frost damage. There could be a possible misalignment between pollinators and bloom timing if the phenology of one shifts and the other does not.

Potential Climate Impact - Regional	Property or Project Area Considerations
The Mid-Atlantic winter season will be shorter with milder winters, with less precipitation falling as snow and reduced snow cover and depth. (25, 34, 17)	Milder winters could allow non-cold hardy invasive plants to colonize. It could also allow nearby HWA populations to increase. Mild winters could alter timber harvest timing if the ground is not adequately frozen. Less snow pack could cause streams to warm sooner and possibly dry up sooner. Less snow pack could increase soil freezing, causing root damage to some trees and possibly declining soil arthropods. False warm periods could disrupt hibernation for amphibians, causing some to migrate to breeding pools too early, and then leave them susceptible to freezing.
Precipitation patterns will be altered in the Mid-Atlantic, with projected increases in annual precipitation and potential for reduced growing season precipitation. (34, 17)	Spring/summer drought could negatively impact seedling establishment. Overall increased precipitation could cause flooding or soggy soils, interfering with management ability. Longer periods between rain events could lead to moisture stress that allows other pests or diseases to attack.
Intense precipitation events will continue to become more frequent in the Mid-Atlantic. (34, 35, 36)	Heavy storms could damage trees, this is especially of concern for oaks, as oak wilt was recently found within 50 miles of the project area. Flooding could damage WMA infrastructure, disrupting management access. Soil erosion would likely increase on slopes in the project area. Large storm events that cause stand-replacing disturbance could favor invasive vegetation if they are already present in the understory.
Soil moisture patterns will change in the Mid-Atlantic with the potential for drier soil conditions later in the growing season. (37, 36)	This could cause regeneration failure of desired species. Drought stress could allow other forest health issues to attack trees (insects, pathogens).
Many invasive species, insect pests, and pathogens in the Mid-Atlantic will increase or become more damaging. (38, 39)	Competing invasive vegetation will outcompete native plants, reducing habitat values and biodiversity, and will interfere with desirable forest regeneration. Other climate-related disturbances could provide more favorable conditions for invasive establishment.

Potential Climate Impact - Regional	Property or Project Area Considerations
Southern or temperate species are expected to be favored by climate change in the Mid-Atlantic Region. (29, 22)	Some species in the project area are already near the northern limits of their range (flowering dogwood, chestnut oak, cucumber magnolia, black birch), so this could be a beneficial shift, allowing forests here to be more diverse and resilient.
Northern and boreal species are expected to face increasing stress from climate change in the Mid-Atlantic Region. (29, 22)	The loss of sugar maple, quaking aspen, hemlock, and white pine overtime would be negative for the project area. Especially the loss of native conifers.

2b. Young Forest Habitat: Climate Impacts and Vulnerabilities

Potential Impacts: Mixed/Neutral **Adaptive Capacity:** Moderate-High **Vulnerability:** Moderate

Potential Climate Impact - Young Forest Habitat	Property or Project Area Considerations
Less precipitation during the growing season.	
Non-native invasive vegetation will likely increase.	

2c. Non-native Invasive Vegetation: Climate Impacts and Vulnerabilities

Potential Impacts: Disruptive **Adaptive Capacity:** Low-Moderate **Vulnerability:** High

Potential Climate Impact - Non-native Invasive Vegetation	Property or Project Area Considerations
Non-native invasive vegetation will likely increase.	
Warmer temperatures will lead to a longer growing season.	

2d. Oak Regeneration: Climate Impacts and Vulnerabilities

Potential Impacts: Disruptive **Adaptive Capacity:** Moderate **Vulnerability:** Moderate

Potential Climate Impact - Oak Regeneration	Property or Project Area Considerations
More frequent intense storms.	
Soil moisture deficits and frequent, prolonged droughts.	

2e. Red Pine Plantations: Climate Impacts and Vulnerabilities

Potential Impacts: Disruptive **Adaptive Capacity:** Low-Moderate **Vulnerability:** High

Potential Climate Impact - Red Pine Plantations	Property or Project Area Considerations
Non-native invasive vegetation will likely increase.	

3. Evaluation of Management Objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

3a. Young Forest Habitat: Evaluation of Management Objectives

Management Goal: Provide more young forest habitat on the WMA

Management Objective	Challenges and Opportunitities	Feasibility
Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)*	**Challenges:** • More frequent drought periods in summer and fall could stress desired seedlings and cause regeneration failure following management treatment. • Longer growing seasons could put newly germinated seedlings at risk of spring frost damage. • Milder winters could reduce snow pack and worsen deer browse pressure on young seedlings. **Opportunities:** • Warmer temperatures could increase growth and productivity, improving regeneration success and allow seedlings to grow past deer browse height. • Southern species present in or near the project area could be favored and would improve species diversity.	**Feasibility:** Medium **Feasibility Comment:** This goal is feasible under current management techniques because suitable seed sources are present to establish a diverse young forest community that should be resilient of these various stressors. An increase of competing invasive vegetation would require adapting management techniques. **Other Considerations:** We occasionally get questions from the public regarding cutting down trees to create young forest and how that affects carbon sequestration. These questions will likely continue and carefully explaining existing habitat/species vulnerabilities, and how creating young forests can also create future forests with improved climate resilience (higher species diversity) can help.

Management Goal: Provide more young forest habitat on the WMA

Management Objective	Challenges and Opportunitities	Feasibility
Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*	**Challenges:** • Non-native, invasive plants are expected to increase and could outcompete desired species. **Opportunities:** • Increased vigor and productivity related to warmer temperatures could allow natives to better compete with invasives.	**Feasibility:** High **Feasibility Comment:** Feasibility is reasonable at the moment using current methods. In the future, if invasives are more abundant, an increase of monitoring and control (mechanical, herbicidal) would be required to remain feasible. **Other Considerations:** No other considerations

3b. Non-native Invasive Vegetation: Evaluation of Management Objectives

Management Goal: Control non-native invasive vegetation to maintain forest biodiversity

Management Objective	Challenges and Opportunitities	Feasibility
Reduce understory invasive plant cover to 5% or less in project area *(5 years)*	**Challenges:** • The projected increase of invasive plants could allow new species to colonize the site that are better able to invade undisturbed understories. • Longer growing seasons and shifting phenology may favor invasives, increasing their abundance and rate of spread. • Already present "naturalized" non-native plant species may begin to exhibit "invasive" biology traits as climate changes. • Increased storm intensity could create disturbances that facilitate colonization of invasives into otherwise unoccupied stands. **Opportunities:** • Increased productivity may allow natives to better compete against invasives.	**Feasibility:** Medium **Feasibility Comment:** An increase of invasives would require an increase of monitoring and control actions. The goal would still be feasible, but would be more time-consuming and costly. **Other Considerations:** The public often asks us about herbicide use, and generally accepts our explanation that we use it sparingly and only as necessary. If it becomes routinely necessary and high volume, the public may be less agreeable. All the more incentive to stop invasives before they become a significant component of the property.

Management Goal: Control non-native invasive vegetation to maintain forest biodiversity

Management Objective	Challenges and Opportunitities	Feasibility
Maintain 5% or less invasive plant cover in young forest stands *(15 years)*	**Challenges:** • Same as Goal #1 **Opportunities:** • Same as Goal #1	**Feasibility:** Medium **Feasibility Comment:** If adequately controlled prior to timber harvest, then follow-up control should remain feasible. **Other Considerations:** No other considerations

3c. Oak Regeneration: Evaluation of Management Objectives

Management Goal: Regenerate oak stands that are declining or are susceptible to decline in the near future

Management Objective	Challenges and Opportunitities	Feasibility

Management Goal: Regenerate oak stands that are declining or are susceptible to decline in the near future

Management Objective	Challenges and Opportunitities	Feasibility
Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*	**Challenges:** • Increased drought and moisture stress could lead to decline of mature oak stands, reducing their regeneration potential (seed production). • Mid-summer/fall drought could cause regeneration failure of young oak seedlings after timber harvest. • Late summer drought could cause failure of annual mast crops. This is especially challenging since some sylvicultural treatment is best if it coincides a good mast year. • More frequent intense storms with high winds could cause tree damage during the growing season that could improve conditions for the spread of oak wilt. **Opportunities:** • Oak is generally tolerant of drought once established, and increased growth may allow seedlings to grow deep enough tap roots quickly to withstand dry periods. • Several oak species are expected to be favored under future conditions, including those present in the project area and others that could be introduced if necessary.	**Feasibility:** High **Feasibility Comment:** At the moment, oak stands in the project area are in good condition and regeneration potential should not be limited by oak decline for at least 10 years. **Other Considerations:** Even if in the future we needed to plant seedlings or direct seed some parts of the site, because seed trees have declined, this should not be cost-prohibitive to meet this goal.

3d. Red Pine Plantations: Evaluation of Management Objectives

Management Goal: Convert red pine plantations to natural stands

Management Objective	Challenges and Opportunitities	Feasibility
Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*	**Challenges:** • Low overstory and understory species diversity increases overall vulnerability to climate impacts, such as drought or insect/disease outbreaks, prior to management actions. • Low diversity of these stands are more vulnerable to invasive plants following a disturbance. • Increased drought stress in summer and fall could effect the establishment of desired tree seedlings. • Many of these stands are red pine, which is expected to do poorly in the future in the mid-Atlantic. • Native conifers of the project area (hemlock and white pine) are projected to do poorly in future climate. **Opportunities:** • Future climate may favor southern pine species (Virginia, Pitch) that could be planted into these stands to ensure mixed conifer component. • Increased growth could improve the establishment of naturally regenerating hardwood seedlings.	**Feasibility:** Medium **Feasibility Comment:** Natural regeneration of some desirable tree species in these stands will remain feasible; however, ensuring that there is a conifer component may be more challenging. This may require the direct planting of conifers projected to thrive under future scenarios. **Other Considerations:** No other considerations

Management Goal: Convert red pine plantations to natural stands		
Management Objective	**Challenges and Opportunitities**	**Feasibility**
	• Norway spruce will likely continue to be a viable option for planting and natural regeneration in the project area under future climate scenarios.	

4. Adaptation Tactics

After considering the challenges and opportunities climate change might present for this management objective, these actions were identified to help prepare for climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches, which provide connections to more general concepts related to forest management and conservation. Tactics that are recommended can be implemented or explored further.

4a. Young Forest Habitat: Adaptation Tactics

Tactic: Creating a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Maintain or improve the ability of forests to resist pests and pathogens	**Benefits:** By creating young forest and regenerating stands, it will establish young trees with improved vigor, and will improve structural diversity of the greater mature forest that is not part of this project. In some cases these young forests will have increased tree species diversity. **Drawbacks and Barriers:** None that I can think of. The only concern is that if we do not implement this tactic soon enough that oak stands may decline and have reduced oak regeneration potential.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)*

Tactic: Promoting abundant regeneration of multiple species in order to supply more browse than herbivores are expected to consume. Using tree tops from forest harvest or plantings of nonpalatable tree species as locations for "hiding" desirable species from herbivores to reduce browse pressure. *(10 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Manage herbivory to promote regeneration of desired species	**Benefits:** This is already a technique incorporated in our timber harvests and will benefit several objectives. **Drawbacks and Barriers:** The practicability of this is rated medium just because in some smaller cuts it may be hard to supply enough browse to overwhelm deer. If invasive vegetation is not adequately controlled prior to establishing young forest, it can reduce available browse favored by deer, causing them to seek out desired seedlings.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

Tactic: Retain coarse woody debris to maintain moisture, soil quality, and nutrient cycling. Harvest timber when ground is frozen to avoid soil disturbance, compaction, and erosion. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Sustain fundamental ecological functions • Reduce competition for moisture, nutrients, and light	**Benefits:** Retention of woody debris is already part of business as usual, but could be increased. This tactic also improves habitat structure for various wildlife species (e.g., salamanders, invertebrates). **Drawbacks and Barriers:** Potential drawback is if restricting harvests to frozen conditions either causes a lack of bids on the sale, or if mild winters prevent adequate duration of frozen conditions to accomplish the sale within the contract timeframe (3 to 5 years).	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)*

Tactic: Emulate aspects of natural disturbances through forest management techniques to encourage the development of multiple age cohorts.

Using silvicultural treatments to promote and enhance diverse regeneration of native species. Transitioning plantations to more complex systems by underplanting or promoting regeneration of a variety of native species expected to do well under future conditions. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Promote diverse age classes • Maintain and restore diversity of native species	**Benefits:** Creating young forest improves overall age diversity of forest on the WMA. Regenerating oak stands and plantations not only creates young forest habitats, but also establishes diverse, vigorous stands that should be more resilience to climate impacts. **Drawbacks and Barriers:** None.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)*

Tactic: Retaining the oldest and largest trees with good vigor during forest management activities. Retaining survivors of pest or disease outbreaks, droughts, windthrow events, or other disturbances. Retaining individual trees of a variety of uncommon species to maintain their presence on the landscape.

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Retain biological legacies	**Benefits:** Retaining large, old trees and survivors of past disturbances will provide beneficial genes to the young forest, while retaining valuable habitat structure to add diversity to the future forest. Retaining legacy trees is already a management practices we use during harvests. **Drawbacks and Barriers:** The primary conflict is that some seemingly healthy trees will need to be removed to provide the appropriate conditions for young forest establishment, especially of shade-intolerant species. In some cases, the treatment of invasive vegetation may require a broadcast application of the understory, potentially impacting uncommon native species present.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

Tactic: Plant seeds and seedlings of native species from more southern locations, and also southern species forecast have more northern future ranges. Retain individuals at northern extent of range and attempt to regenerate these species. *(20 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance genetic diversity • Use seeds, germplasm, and other genetic material from across a greater geographic range • Favor existing genotypes that are better adapted to future conditions	**Benefits:** This will improve species composition of young forests, adding potential resiliency to climate impacts. **Drawbacks and Barriers:** This was ranked medium because availability of appropriate seed and seedling species may be hard to find or purchase.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

Tactic: Control invasive vegetation and interfering native vegetation before and after regeneration harvest. Perform follow-up TSI to favor and promote growth of desirable growing stock. *(25 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Facilitate community adjustments through species transitions. • Guide changes in species composition at early stages of stand development • Protect future-adapted seedlings and saplings • Introduce species that are expected to be adapted to future conditions	**Benefits:** This improves the value of young forest while growing a valuable, more resilient future forest. **Drawbacks and Barriers:** Follow-up treatments of young forest stands to control interfering vegetation and perform TSI work could lack priority as limited staff become overwhelmed with multiple timber projects, or could be entirely forgotten as staff turnover over time (retirement or promotion, sometimes big lags before new hires).	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

Tactic: Increase monitoring for known or potential invasive species to ensure early detection, and control existing populations or seed sources. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Prevent the introduction and establishment of invasive plant species and remove existing invasive species	**Benefits:** This tactic would benefit all Objectives of this project. This is currently part of management activities but needs to be increased. **Drawbacks and Barriers:** Eradication is unlikely, but reduction and control is feasible. The biggest barrier would be scenarios where there is a large infestation of an invasive plant. Small populations can reasonably be treated by program staff, and even large populations within a stand planned for harvest can be incorporated in that sale contract, but, large populations in other locations (seed sources) on the property would require a service contract, which is time consuming and funding approval is not guaranteed.	• Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

4b. Non-native Invasive Vegetation: Adaptation Tactics

Tactic: Increase monitoring for known or potential invasive species to ensure early detection, and control existing populations or seed sources. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Prevent the introduction and establishment of invasive plant species and remove existing invasive species	**Benefits:** This tactic would benefit all Objectives of this project. This is currently part of management activities but needs to be increased. **Drawbacks and Barriers:** Eradication is unlikely, but reduction and control is feasible. The biggest barrier would be scenarios where there is a large infestation of an invasive plant. Small populations can reasonably be treated by program staff, and even large populations within a stand planned for harvest can be incorporated in that sale contract, but, large populations in other locations (seed sources) on the property would require a service contract, which is time consuming and funding approval is not guaranteed.	• Reduce understory invasive plant cover to 5% or less in project area *(5 years)* • Maintain 5% or less invasive plant cover in young forest stands *(15 years)*

4c. Oak Regeneration: Adaptation Tactics

Tactic: Creating a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Maintain or improve the ability of forests to resist pests and pathogens	**Benefits:** By creating young forest and regenerating stands, it will establish young trees with improved vigor, and will improve structural diversity of the greater mature forest that is not part of this project. In some cases these young forests will have increased tree species diversity. **Drawbacks and Barriers:** None that I can think of. The only concern is that if we do not implement this tactic soon enough that oak stands may decline and have reduced oak regeneration potential.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Promoting abundant regeneration of multiple species in order to supply more browse than herbivores are expected to consume. Using tree tops from forest harvest or plantings of nonpalatable tree species as locations for “hiding” desirable species from herbivores to reduce browse pressure. *(10 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Manage herbivory to promote regeneration of desired species	**Benefits:** This is already a technique incorporated in our timber harvests and will benefit several objectives. **Drawbacks and Barriers:** The practicability of this is rated medium just because in some smaller cuts it may be hard to supply enough browse to overwhelm deer. If invasive vegetation is not adequately controlled prior to establishing young forest, it can reduce available browse favored by deer, causing them to seek out desired seedlings.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Retain coarse woody debris to maintain moisture, soil quality, and nutrient cycling. Harvest timber when ground is frozen to avoid soil disturbance, compaction, and erosion. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Sustain fundamental ecological functions • Reduce competition for moisture, nutrients, and light	**Benefits:** Retention of woody debris is already part of business as usual, but could be increased. This tactic also improves habitat structure for various wildlife species (e.g., salamanders, invertebrates). **Drawbacks and Barriers:** Potential drawback is if restricting harvests to frozen conditions either causes a lack of bids on the sale, or if mild winters prevent adequate duration of frozen conditions to accomplish the sale within the contract timeframe (3 to 5 years).	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Emulate aspects of natural disturbances through forest management techniques to encourage the development of multiple age cohorts.

Using silvicultural treatments to promote and enhance diverse regeneration of native species. Transitioning plantations to more complex systems by underplanting or promoting regeneration of a variety of native species expected to do well under future conditions. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Promote diverse age classes • Maintain and restore diversity of native species	**Benefits:** Creating young forest improves overall age diversity of forest on the WMA. Regenerating oak stands and plantations not only creates young forest habitats, but also establishes diverse, vigorous stands that should be more resilience to climate impacts. **Drawbacks and Barriers:** None.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Retaining the oldest and largest trees with good vigor during forest management activities. Retaining survivors of pest or disease outbreaks, droughts, windthrow events, or other disturbances. Retaining individual trees of a variety of uncommon species to maintain their presence on the landscape.

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Retain biological legacies	**Benefits:** Retaining large, old trees and survivors of past disturbances will provide beneficial genes to the young forest, while retaining valuable habitat structure to add diversity to the future forest. Retaining legacy trees is already a management practices we use during harvests. **Drawbacks and Barriers:** The primary conflict is that some seemingly healthy trees will need to be removed to provide the appropriate conditions for young forest establishment, especially of shade-intolerant species. In some cases, the treatment of invasive vegetation may require a broadcast application of the understory, potentially impacting uncommon native species present.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Plant seeds and seedlings of native species from more southern locations, and also southern species forecast have more northern future ranges. Retain individuals at northern extent of range and attempt to regenerate these species. *(20 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance genetic diversity • Use seeds, germplasm, and other genetic material from across a greater geographic range • Favor existing genotypes that are better adapted to future conditions	**Benefits:** This will improve species composition of young forests, adding potential resiliency to climate impacts. **Drawbacks and Barriers:** This was ranked medium because availability of appropriate seed and seedling species may be hard to find or purchase.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

Tactic: Control invasive vegetation and interfering native vegetation before and after regeneration harvest. Perform follow-up TSI to favor and promote growth of desirable growing stock. *(25 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Facilitate community adjustments through species transitions. • Guide changes in species composition at early stages of stand development • Protect future-adapted seedlings and saplings • Introduce species that are expected to be adapted to future conditions	**Benefits:** This improves the value of young forest while growing a valuable, more resilient future forest. **Drawbacks and Barriers:** Follow-up treatments of young forest stands to control interfering vegetation and perform TSI work could lack priority as limited staff become overwhelmed with multiple timber projects, or could be entirely forgotten as staff turnover over time (retirement or promotion, sometimes big lags before new hires).	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

4d. Red Pine Plantations: Adaptation Tactics

Tactic: Creating a diverse mix of forest or community types, age classes, and stand structures to reduce the availability of host species for pests and pathogens. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Maintain or improve the ability of forests to resist pests and pathogens	**Benefits:** By creating young forest and regenerating stands, it will establish young trees with improved vigor, and will improve structural diversity of the greater mature forest that is not part of this project. In some cases these young forests will have increased tree species diversity. **Drawbacks and Barriers:** None that I can think of. The only concern is that if we do not implement this tactic soon enough that oak stands may decline and have reduced oak regeneration potential.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Promoting abundant regeneration of multiple species in order to supply more browse than herbivores are expected to consume. Using tree tops from forest harvest or plantings of nonpalatable tree species as locations for "hiding" desirable species from herbivores to reduce browse pressure. *(10 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Reduce the impact of biological stressors • Manage herbivory to promote regeneration of desired species	**Benefits:** This is already a technique incorporated in our timber harvests and will benefit several objectives. **Drawbacks and Barriers:** The practicability of this is rated medium just because in some smaller cuts it may be hard to supply enough browse to overwhelm deer. If invasive vegetation is not adequately controlled prior to establishing young forest, it can reduce available browse favored by deer, causing them to seek out desired seedlings.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Retain coarse woody debris to maintain moisture, soil quality, and nutrient cycling. Harvest timber when ground is frozen to avoid soil disturbance, compaction, and erosion. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Sustain fundamental ecological functions • Reduce competition for moisture, nutrients, and light	**Benefits:** Retention of woody debris is already part of business as usual, but could be increased. This tactic also improves habitat structure for various wildlife species (e.g., salamanders, invertebrates). **Drawbacks and Barriers:** Potential drawback is if restricting harvests to frozen conditions either causes a lack of bids on the sale, or if mild winters prevent adequate duration of frozen conditions to accomplish the sale within the contract timeframe (3 to 5 years).	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Emulate aspects of natural disturbances through forest management techniques to encourage the development of multiple age cohorts.

Using silvicultural treatments to promote and enhance diverse regeneration of native species. Transitioning plantations to more complex systems by underplanting or promoting regeneration of a variety of native species expected to do well under future conditions. *(10 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Promote diverse age classes • Maintain and restore diversity of native species	**Benefits:** Creating young forest improves overall age diversity of forest on the WMA. Regenerating oak stands and plantations not only creates young forest habitats, but also establishes diverse, vigorous stands that should be more resilience to climate impacts. **Drawbacks and Barriers:** None.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Retaining the oldest and largest trees with good vigor during forest management activities. Retaining survivors of pest or disease outbreaks, droughts, windthrow events, or other disturbances. Retaining individual trees of a variety of uncommon species to maintain their presence on the landscape.

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance species and structural diversity • Retain biological legacies	**Benefits:** Retaining large, old trees and survivors of past disturbances will provide beneficial genes to the young forest, while retaining valuable habitat structure to add diversity to the future forest. Retaining legacy trees is already a management practices we use during harvests. **Drawbacks and Barriers:** The primary conflict is that some seemingly healthy trees will need to be removed to provide the appropriate conditions for young forest establishment, especially of shade-intolerant species. In some cases, the treatment of invasive vegetation may require a broadcast application of the understory, potentially impacting uncommon native species present.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Plant seeds and seedlings of native species from more southern locations, and also southern species forecast have more northern future ranges. Retain individuals at northern extent of range and attempt to regenerate these species. *(20 years)*

Practicability: Medium

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Maintain and enhance genetic diversity • Use seeds, germplasm, and other genetic material from across a greater geographic range • Favor existing genotypes that are better adapted to future conditions	**Benefits:** This will improve species composition of young forests, adding potential resiliency to climate impacts. **Drawbacks and Barriers:** This was ranked medium because availability of appropriate seed and seedling species may be hard to find or purchase.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

Tactic: Control invasive vegetation and interfering native vegetation before and after regeneration harvest. Perform follow-up TSI to favor and promote growth of desirable growing stock. *(25 years)*

Practicability: High

Adaptation Strategies and Approaches	Benefits, Drawbacks and Barriers	Associated Management Objectives
Facilitate community adjustments through species transitions. • Guide changes in species composition at early stages of stand development • Protect future-adapted seedlings and saplings • Introduce species that are expected to be adapted to future conditions	**Benefits:** This improves the value of young forest while growing a valuable, more resilient future forest. **Drawbacks and Barriers:** Follow-up treatments of young forest stands to control interfering vegetation and perform TSI work could lack priority as limited staff become overwhelmed with multiple timber projects, or could be entirely forgotten as staff turnover over time (retirement or promotion, sometimes big lags before new hires).	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

5. Monitoring Plan

Monitoring is critical for understanding if management actions are e·ective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

5a. Young Forest Habitat: Monitoring Plan

Monitoring Variable: Adaptability of young forest

Criteria for Evaluation	Plans for Implementation	Associated Management Objectives
At least 50% of saplings in young forest are forecast to experience either no change or an increase under future climate projections (Tree Atlas - e.g., bigtooth aspen, hickories, black cherry, oaks, black walnut, cucumbertree, pitch pine, tulip tree, black birch)	Around 10 to 15 years following the timber harvest, these stands will be re-inventoried and if 50% of expected dominant trees are not "climate adapted" then a thinning or crop tree release will be planned to promote the % that is present.	• Create 362 acres of young forest, to bring the young forest component on the WMA to 10% of total forested acreage. *(10 years)* • Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

Monitoring Variable: Desirable regeneration in young forest.

Criteria for Evaluation	Plans for Implementation	Associated Management Objectives
At least 80% of seedling/saplings are desirable species (not invasives and not Ostrya virginiana, Fagus grandifolia, or Acer pensylvanicum), and regeneration establishment is adequate to ensure a fully stocked future forest stand (in 6' radius plots, at least 70% of plots contain at least 25 stems, with 5 stems over 3' tall).	Surveys will occur 3 and 5 years after harvest and may require re-treatment if criteria is not met at 5 years (e.g., soil scarification, seeding, planting, installation of deer browse protection).	• Ensure that young forest stands are composed of at least 80% desirable tree species (e.g., oaks, red and sugar maple, hickory, aspen, spruce, pine, hemlock) *(15 years)*

5b. Non-native Invasive Vegetation: Monitoring Plan

Monitoring Variable: Invasive species abundance.

Criteria for Evaluation	Plans for Implementation	Associated Management Objectives
5% or less component of non-native, invasive vegetation.	This will be assessed in May/June of the first, third, fifth, and fifteenth years following the harvest. At each monitoring interval, invasives encountered may be re-treated with herbicide, even if deemed less than 5% of the stand.	• Reduce understory invasive plant cover to 5% or less in project area *(5 years)* • Maintain 5% or less invasive plant cover in young forest stands *(15 years)*

5c. Oak Regeneration: Monitoring Plan

Monitoring Variable: Oak regeneration.

Criteria for Evaluation	Plans for Implementation	Associated Management Objectives
At least 50% of seedlings/saplings present in former mature oak stands are an oak species.	This will be monitored at the end of the growing season 1 and 3 years following timber harvest completion. If an adequate oak component is not present, direct planting or seeding may occur, followed again by monitoring at 1 and 3 years after. The stand will be assessed again after 10-15 years to determine oak status and if a thinning or crop tree release is required.	• Establish 191 acres of seedling/sapling stands with at least a 50% oak component. *(15 years)*

5d. Red Pine Plantations: Monitoring Plan

Monitoring Variable: Mixed hardwood/conifer regeneration.

Criteria for Evaluation	Plans for Implementation	Associated Management Objectives
At least 30% of the seedlings/saplings present in the former conifer plantations is composed of evergreen conifer species. Species composition contains at least 5 tree species, including three different genera.	This will be assessed at the end of the first and third growing seasons following timber harvest completion. If the conifer component is not at least 30% of the stand, then direct seeding or planting will be considered.	• Establish 171 acres of seedling/sapling mixed hardwood/conifer stands where current pine plantation stands occur *(10 years)*

6. References

This adaptation plan was developed using the Adaptation Workbook (www.adaptationworkbook.org (https://www.adaptationworkbook.org)) and Adaptation Strategies and Approaches developed by the Northern Institute of Applied Climate Science. View the Adaptation Strategies and Approaches at: www.adaptationworkbook.org/strategies (https://www.adaptationworkbook.org/strategies).

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