Forest Resilience Report

Restoration Priorities for the central Appalachians

APPALACHIANS GLOBAL FOCAL PLACE

ON THE COVER: Aerial photograph of the Cumberland Forest Project, KY © Cameron Davidson; THIS PAGE Tank Hollow Falls in Cleveland, Virginia. © Steven David Johnson

Executive Summary

This report highlights significant opportunities to improve forest climate resilience through strategic management and restoration approaches across 20 million acres of The Nature Conservancy's Focal Landscapes in the central Appalachians (Fig 1).

Our Focal Landscapes were informed by the terrestrial Resilient and Connected Network (RCN) which represents places with greater potential for climate resilience as they have maintained biodiversity, productivity, and ecosystem functions in the face of past climate changes. The RCN can guide how we prioritize places with greater resilience potential. As a next step we assessed current ecosystem resilience of our Focal Landscapes to help land managers plan strategic actions to build resilient forests now.

We assessed and ranked the key ecological attributes of resilient ecosystems (KEAs--biodiversity, climate adaptive capacity and ecosystem function) across the major forest community types of the central Appalachian Focal Landscapes (see results on p. 8). We found a wide range in the current condition of these attributes, with each community type possessing strengths and weaknesses. Based on these findings we suggest a set of priorities to build ecosystem resilience and provide examples of using the assessment to guide local action mapping.

Overall, this assessment delivers a broad picture of how the attributes of ecosystem resilience varies across this region and illustrates the need for forest community-specific management and restoration approaches to achieve improved climate resilience outcomes. We believe it also provides a common language and framework for consistently assessing forest condition for climate resilience across the Appalachians, and can serve as a guide to develop regional and local priorities for resilience-building forest management.

Introduction & Background

Climate change will continue to impact Appalachian forested ecosystems, forcing many species to adapt or migrate at an unprecedented rate. Conservation of our forests' biodiversity now requires us to reassess our ecological goals and forest management strategies using a climate resilience and adaptation lens. Some existing strategies become more urgent (e.g., restoring fire-adapted forests), while new strategies are required for other climate threats (e.g., assisted gene flow for red spruce).

The Nature Conservancy's shift in conservation strategy to prioritize climate resilience has been informed by the North American Terrestrial and Freshwater Resilient and Connected Networks (RCN) led by Mark Anderson's team at TNC's Center for Resilient Conservation Science in collaboration with hundreds of scientists (Anderson et al., 2016; Anderson et al., 2024).

The Terrestrial RCN used landscape-scale natural cover and landform diversity to map resilient sites and highlight connectivity flow zones and corridors. This map guides the places where we prioritize lands and waters for protection and improved management – our Focal Landscapes of the Appalachians (FLs). However, the RCN does not describe the current condition of those places, information which natural resource managers need to prioritize and plan to build ecosystem resilience now.

This assessment is the next step; it provides a closer look at the forests within the Focal Landscapes to reveal their current capacity for climate resilience. The assessment is designed to help conservation planners and land managers 1) understand current landscape-level resilience so they can 2) prioritize management actions to further improve resilience, in service of our Appalachians Improved Lands Management 2030 Goals – and beyond.

- Connectivity across natural ecosystems will be increasingly important for resilience in place and range shifts for plants and animals.
- Forest biodiversity, such as species composition and canopy structural diversity, provide habitat options for wildlife and buffer against impacts of pests and pathogens.
- The adaptive capacity of species and ecosystems in the face of climate change matters as the rate of environmental change is accelerating.
- Basic ecosystem functions (e.g. soil chemistry, hydrology) enable and support biodiversity over time. If these functions have been altered, then the ecosystem is fundamentally less capable of fully supporting all manner of life (e.g. acidic deposition eliminates plant species that need non-acidic soils).

Our approach has its roots in the science behind "conserving nature's stage" (for example, Anderson and Ferree, 2010) prompting land managers to 'manage the stage', or the ecosystem functions in place, as new 'actors', or species, may migrate with changing climates. The RCN points to the places and this assessment can guide management and restoration planning to make progress on the KEAs. The next sections detail the indicators we developed to assess the status of the KEAs, then present the results of the assessment and the implications for conservation action.

Methodology

We limited our analysis to the RCN Focal Landscapes (~20 million acres) that were identified as a priority for the central Appalachians ecoregion. The units of analysis, six landscapes, were based on physiographic boundaries and major forest communities (e.g. Interior Mesophytic, Figure 1) as mapped by LANDFIRE.

To assess forest resilience, we developed a series of indicators for key ecological attributes (KEAs) of resilience: biodiversity, ecological function and adaptive capacity. We consulted the RCN analysis (Anderson et al, 2016), TNC's guidance document for "Managing for Resilience" (Lombard et al, 2021) and current scientific literature during this process. There are 6 indicators related to biodiversity, 3 for adaptive capacity and 3 for ecological function. See pages 5-7 for details on each indicator and its metric, which are grouped by the attribute they describe.

We assessed each indicator at the scale of the forest community landscape, or in some cases, by the major productivity class (dry, dry-mesic, or mesic forest) within the community type. The latter allowed for some examination of variability, where appropriate, since an individual community type covered 1-4 million acres.

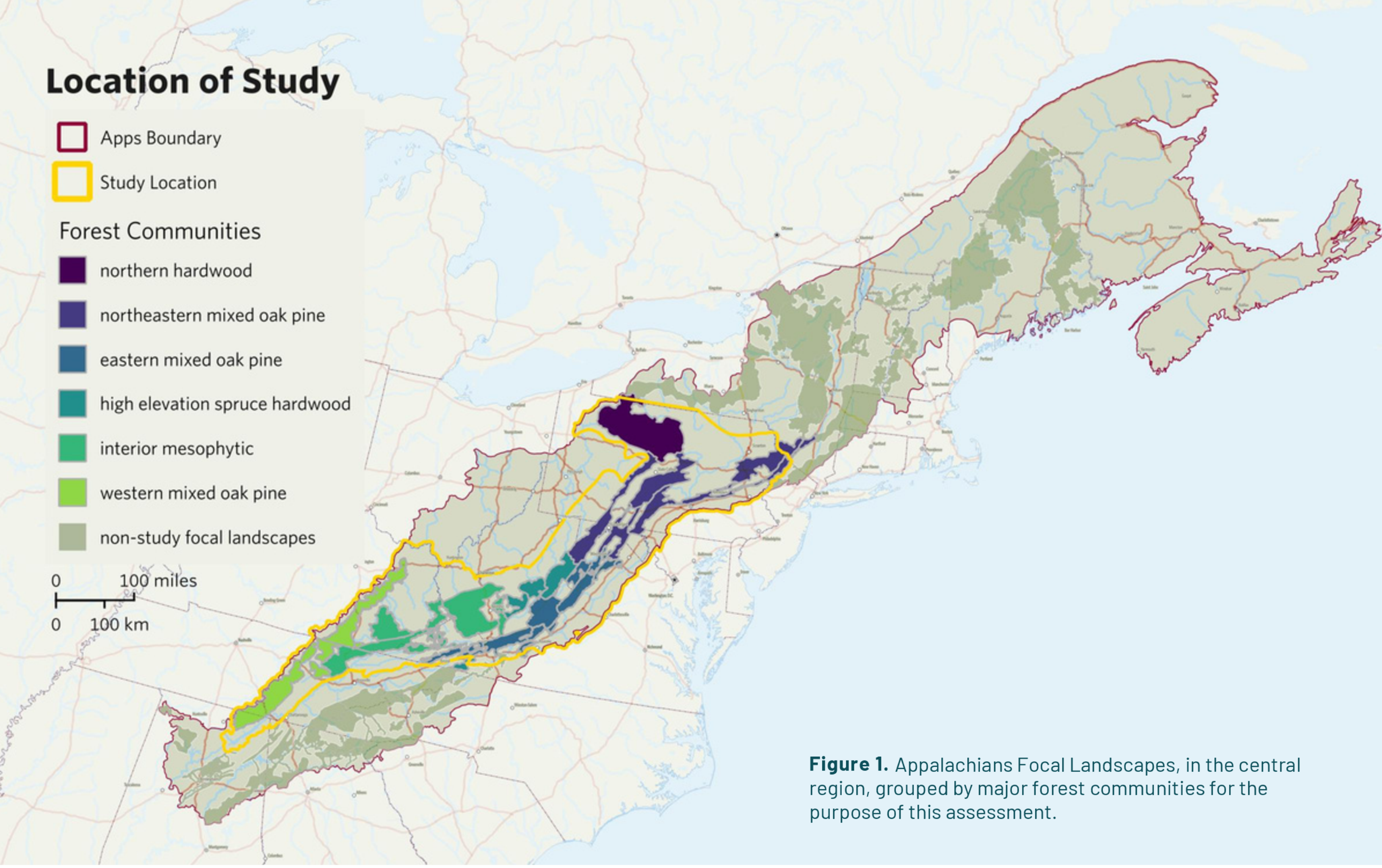

Figure 1. Appalachians Focal Landscapes, in the central region, grouped by major forest communities for the purpose of this assessment.

We used several sources of data, representing empirical field data from national databases (e.g. USFS's Forest Inventory and Analysis program) as well as modeled outputs from other scientific publications (e.g. USFS's Central Appalachian climate vulnerability assessment). The data sources represent a wide range of resolutions; one pixel of LANDFIRE's Canopy Cover layer is 0.22 acres, whereas one FIA plot represents 6,000 acres. For reliable comparison, each indicator's data was aggregated to the larger scale described above.

Indicators were designed such that higher values of its metric represent a more resilient condition. For example, 'canopy tree richness' assessed how many tree species are present in each major forest community landscape; a higher number of species was considered to be more resilient.

We ranked each community type's indicator as high, moderate or low based on the values. We chose these relative descriptors as resilience is likely more along a continuum than having a defined threshold between "resilient" and "not resilient". We then ranked each resilience KEA by considering the combined rankings of its' indicators; Adaptive Capacity was given an overall ranking based on the combined rankings of 'Tree Species Turnover', 'Adaptability' and 'Suitable Habitat Trend'.

IMAGE CREDIT: TNC and partners convene in western Maryland for a late successional forest management workshop © Matt Kane

We did not further synthesize the three KEA rankings to create a single "resilience" score for each forest community landscape. We felt that doing so would be too reductive, obscuring important and specific information about forest condition. We wanted to showcase the status of each KEA to enable more precise planning of actions which address specific deficiencies of forest condition. However, we do qualitatively sum up overall system resilience for each community landscape based on the KEA rankings. The full results of the analysis are presented in Table 1.

Forest Resilience Indicators

Biodiversity

1 Canopy tree richness

The number of tree species that make up the current forest canopy. Higher species richness in the forest canopy indicates greater forest resilience; the ecosystem possesses more ecological niches to house diversity and more "building blocks" for adapting to climate change.

- **Metric 1a:** The number of tree species that are > 0.5% of total forest volume (FIA, >5"DBH).
- **Metric 1b:** Number of all tree species inventoried as part of total forest volume (FIA).

2 Canopy tree diversity

The diversity (species richness and evenness) of the current forest canopy. Higher canopy tree diversity indicates higher forest resilience; less dominance by any one species means that more species are competitive and likely more stable over time. Additionally, the loss of any one species (e.g. due to a novel pest) is less of a disruption in a high-diversity setting.

Metric: Shannon-Weiner index of the current forest canopy (FIA) and future forest canopy (LANDIS modelling in NIACS). A Focal Landscape will be labeled as high, medium or low for this metric using relative ranking.

3 Keystone species abundance

The relative amount of keystone tree species in the current forest canopy. Higher levels of keystone species abundance indicates higher forest resilience; ecosystem-wide biodiversity is elevated when keystone species are more abundant. In most central Appalachian landscapes (i.e. not high-elevation spruce), oak species enable higher levels of diversity in the surrounding forest (e.g. birds, moths) through various mechanisms, serving a keystone function.

Metric: Oak species proportion of current canopy tree volume (FIA, >5"DBH).

4 Keystone species sustainability

The projected change in keystone species abundance over the next century. Greater sustainability of keystone species indicates higher forest resilience; keystone functions are more likely to continue into the future, enabling greater biodiversity.

Metric: Change in oak species' proportion of total basal area, from current (FIA) to future (2100, as per LANDIS modelling in NIACS).

5 Age class diversity

Age class diversity describes the range and scale of variability in forest stand ages. Generally, greater diversity of stand ages in the forest landscape indicates a greater capacity for resilience; different ages represent different habitat niches for plants and animals and respond differently to stressors, increasing the likelihood of sustaining greater biodiversity over time.

Metric: The "departure" (0-100%) of the current distribution of age (based on USFS FIA data) as compared to the desired distribution which is defined using the Historic Range of Variability of the dominant forest community (as per its LANDFIRE Bio-physical Setting description). The use of historic reference data is justified as past conditions gave rise to the historic or current biodiversity that we seek to sustain and is likely still a foundation for biodiversity with rapid climate change.

6 Canopy structure diversity

Canopy structure diversity describes the range and scale of variability in forest canopy structures. Generally, greater diversity of structure in the forest canopy indicates greater capacity for forest resilience; different structures represent different habitat niches for plants and animals, increasing the likelihood of sustaining greater biodiversity over time.

Metric: The "departure" (0-100%) of the current distribution of forest canopy structure (LANDFIRE's Canopy Cover) as compared to the desired distribution, defined using the Historic Range of Variability of the dominant forest community (BpS). The use of historical reference data is justified as those conditions gave rise to the historic or current biodiversity that we seek to sustain and is likely still a foundation for biodiversity with rapid climate change.

IMAGE CREDIT: Red spruce-fir forest restoration planting in Canaan Valley, WV © Mark Moody;

Adaptive Capacity

7 Tree species turnover

The projected amount of loss and gain of tree species (aka turnover) within the landscape over the next century. Lower rates of gaining/losing tree species indicates higher forest resilience; more stable ecosystems are more likely to continue to support greater biodiversity.

Metric: The percentage of total tree species in a Landscape that are modeled to be Lost or Gained by 2100 (Iverson et al, 2019). Lost = 'Very Poor' or 'Lost' Capability rating, Gain = 'New Habitat', in either the low or high climate change scenario.

8 Adaptability

The degree to which the tree species that dominate the current forest canopy are adaptable to environmental change, generally speaking. Higher adaptability of dominant tree species indicates higher forest resilience; the next century will be one of rapid environmental change, and species with life history traits that exemplify general adaptability will likely fare better.

Metric: The average of the adaptive capacity index of the top tree species (FIA), weighted by species' current volume. Matthews et al (2011) created this species-specific index of adaptive capacity based on a suite of life history characteristics. This work has been used extensively in climate vulnerability assessments by NIACS.

9 Suitable habitat trend

The degree to which the tree species that dominate the current forest canopy are suited to modeled future climate scenarios. Higher amounts of suitable habitat in the future indicate higher forest resilience; tree species that are better-suited to the future climate will likely fare better.

Metric: Average change in Suitable Habitat for each dominant tree species, weighted by current volume (FIA). Suitable Habitat values from the USDA Climate Change Tree Atlas were used; that program combines a distribution model, migration model, and climate scenarios to generate a spatial map of the future importance value (IV) for a species. The future IV of a species is compared to it's current IV, and the percent change in IV is characterized as the percent change in "suitable habitat". For this exercise, Suitable Habitat values found in NIACS reports are applied to relevant Focal Landscapes.

Ecological Function

As most ecological functions can't be "improved" beyond normal parameters, most of these metrics are measurements of impairment, either current or future.

10 Soil fertility/chemistry

The degree to which current soil fertility and chemistry are currently unimpacted by man-made stresses like acid deposition. Higher levels of unimpacted soil indicate higher forest resilience as it means this ecosystem function is operating close to normal.

Metric: The percent of acreage with a low Acid-Neutralizing Capacity (ANC) value (<50 μmol/L), as modelled by McDonnell et al (2019), and supplemented with Nitrogen and Sulphur deposition data from Lamarque et al (2010). Both data sources are being used by the USFS as part of their national Terrestrial Condition Assessment.

11 Tree regeneration capacity

The degree to which forestland regenerates tree seedlings at a basic level that perpetuates functioning forest cover. A greater ability to successfully regenerate trees indicates greater forest resilience; sustained forest cover continues to provide habitat for forest-associated biodiversity.

Metric: Average '% likelihood of regeneration failure' due to deer browse. The primary driver of failed tree regeneration is deer overbrowse. Region 9 of the Forest Service has developed browse pressure survey and mapped its results across the Region (McWilliams et al 2018). Areas outside of R9 will be assigned a value based on local expert opinion.

12 Woody debris density

Woody debris density is the current amount of downed woody debris (DWD), compared to published values for old-growth forests by forest community type. Snags and DWD, in amounts approximate to those found in old-growth forest, indicates higher forest resilience; dead wood is present and likely supporting biodiversity as it has historically.

Metric: --not used, data still under development--Tons/acre of Coarse and Fine Woody Debris (FIA-FHM) and number of snags/acre (>5"dbh, FIA) compared to values found in old-growth forest communities of a similar type (e.g. Spetich et al 2022 review of dry-mesic oak).

Additional Resilience KEAs

Connectivity

The original Resilient and Connected Network analysis (Anderson et al 2016) extensively modeled connectivity, both local and regional. And because the Focal Landscapes examined in this analysis all ranked highly in that original exercise, we believed there was little utility in further exploring connectivity at this scale.

Ecosystem Services

Ecosystem services are a human-centric attribute that is part of a broader definition of a 'resilient systems'. Ecosystem services are valued for sustaining resilient human communities (e.g., through provision of drinking water, economic and recreational opportunities), particularly critical in the Appalachians. Some of these metrics are already captured in other bodies of work (NCS, climate mitigation, freshwater). A future goal would be to assess indicators of key ecosystem services.

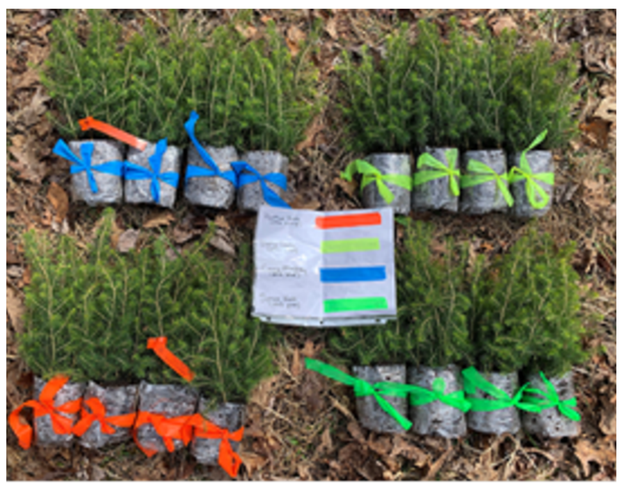

IMAGE CREDIT: A broad and growing movement is enhancing red spruce genetic diversity in restoration plantings across the species' native range. Here, four genetically distinct sources were planted at a western Maryland preserve. © Kathryn Shallows / TNC

Results

Overall, the Eastern Oak-Pine and Western Oak-Pine community types ranked as the most resilient as all three of their resilience KEAs are ranked either High or Moderate (Table 1). Their relatively higher forest resilience is derived from a rich tree species assemblage, high levels of foundational oaks, lower numbers of tree species gain/loss, normal tree regeneration capabilities and less-impacted soil chemistry.

Conversely, the Spruce Highlands and Northern Hardwoods community types have the lowest potential resilience given that their attribute rankings were either Low or Moderate. Their relatively lower resilience is derived from lower tree species richness, lack of dominant foundational tree species, and lower tree regeneration capacity.

The remaining community types, Interior Mesophytic and Northeastern Oak-Pine were in a moderately resilient condition given their attribute rankings were a mixture of Low, Moderate and High. These community types have low tree regeneration capacity and lower tree species richness but also have moderate levels of other attributes like 'suitable habitat trend' or 'foundational species dominance'.

Two indicators are worth pointing out as they show troubling trends across all community types. The 'foundational species sustainability' indicator has only negative values, whether the foundational genus was oak or spruce. Similarly, most community types have a negative 'suitable habitat trend' value, indicating that the current suite of tree species are not well-suited to the future climate. Both of these findings point to a significant shift in the foundational composition of the forest communities that have come to define a large part of the central Appalachians.

Deep Dive into Eastern Oak-Pine Resilience

Here we present a deep dive into the results from the Eastern Oak-Pine forest community type (Fig 1), consisting of 3.1 million acres primarily in Virginia to help guide the reader in interpreting the ranking results presented in Table 1.

The Biodiversity attribute was ranked as High, given that 4 of the 6 related resilience indicators were categorized as High: the forests in this landscape contain the most tree species ('canopy tree richness-dominant' and 'canopy tree richness - all'), house a substantial amount of oak species ('foundational species dominance') and possess an age class distribution that closely matches a desired, natural distribution ('age class diversity'). Two indicators are categorized as low: there is a substantial potential loss of keystone oaks ('keystone sustainability') as well as a lack of diversity of forest canopy structure ('structural diversity').

The Adaptive Capacity attribute was ranked as Moderate, given the mix of rankings for the 3 related indicators. The current composition of trees is slightly less well-suited to specific climate conditions predicted for the future ('suitable habitat trend'). However, the projected loss and gain of tree species ('tree species turnover') is relatively low, and the current group of dominant tree species are relatively adaptable ('adaptability-canopy').

The Ecological Function attribute was ranked as High, given the 2 related indicators are High. The forest soils here have not been impacted as much by acid deposition ('soil chemistry/fertility'), nor does deer over-browsing limit successful tree regeneration ('tree regeneration capacity').

Open-canopied oak forest on TNC's Warm Springs Mountain preserve, a missing and ecologically-valuable part of the Appalachian ecosystem and re-created here using controlled burning. © Jean Lorber/TNC

Table 1. Key ecological attributes of resilience values and ranking by Focal Landscape group

Forest Resilience KEA	Metric	Indicator of Forest Resilience	Eastern Oak-Pine	Spruce Highlands	Interior Mesophytic	Northeastern Oak-Pine	Northern Hardwoods	Western Oak-Pine
biodiversity	1a	canopy tree richness (dominant)	27	21	26	24	20	29
biodiversity	1b	canopy tree richness (all)	79	59	89	79	58	79
biodiversity	2	canopy tree diversity	2.5-2.8 decr 14%	2.0-2.6 decr 14%	2.6-2.8 decr 14%	2.6-2.7 no change	2.4-2.7 no change	2.7-2.9 decr 12%
biodiversity	3	foundational species dominance	30-61%	15-20%	20-49%	38-45%	19-26%	24-53%
biodiversity	4	foundational species sustainability	-41%	-70%	-41%	-4%	-6%	-33%
biodiversity	5	age class diversity	Low Departure (12%)	Moderate Departure (23%)	High Departure (80%)	Low Departure (17%)	Moderate Departure (29%)	Moderate Departure (41%)
biodiversity	6	structural diversity	High Departure (58%)	Low Departure (3%)	Low Departure (3%)	High Departure (52%)	Low Departure (13%)	High Departure (52%)
Biodiversity Attribute Ranking			**High**	**Low**	**Low**	**Medium**	**Low**	**Medium**
adaptive capacity	7	tree species turnover	26%	35%	44%	26%	35%	35%
adaptive capacity	7a	loss of tree species	5 (GW)	7 (MON)	11 (MON + JEFF)	5 (GW)	7 (Allegheny NF)	8 (Boone NF)
adaptive capacity	7b	gain of tree species	7 (GW)	10 (MON)	13 (MON + JEFF)	7 (GW)	10 (Allegheny NF	6 (Boone NF)
adaptive capacity	8	adaptability-canopy	5.1-5.5	4.6-5.4	5.2-5.6	5.3-5.6	4.8-5.4	5.3-5.6
adaptive capacity	9	suitable habitat trend	0.82-0.94	0.78-0.82	0.86-0.9	0.89-0.93	0.97-1.05	0.85-1.05
Adaptive Capacity Attribute Ranking			**Medium**	**Low**	**High**	**High**	**Medium**	**High**
function	10	soil chemistry/fertility	79%	73%	61%	71%	71%	84%
function	11	tree regeneration capacity	High	Moderate	High	Low	Low	High
function	12	downed woody debris	555 +/- 8%	2022 +/- 53%	1038 +/- 29%	626 +/- 10%	595 +/- 9%	776 +/- 16%
Ecological Function Attribute Ranking			**High**	**Medium**	**Medium**	**Low**	**Low**	**High**

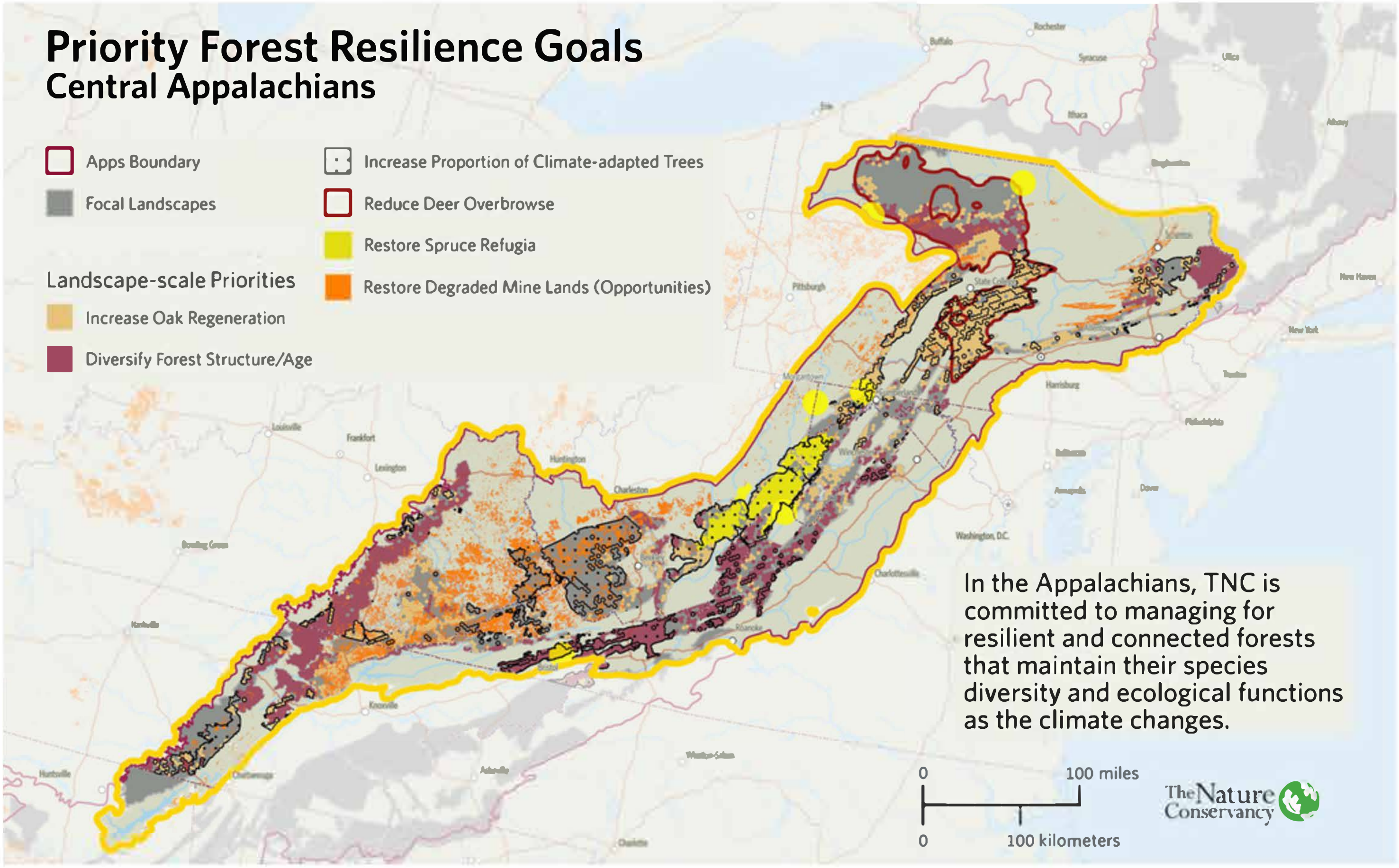

Figure 2. Landscape-scale forest resilience goals informed by the resilience assessment.

Regional Priorities

This assessment revealed which landscape-scale attributes of resilience are most deficient across the region, and therefore may benefit from widespread conservation action. The goals below address some of those deficiencies which can be addressed with common management practices. A coarse-scale spatial prioritization filter is presented for each goal (Fig.2), based on underlying ecological dynamics. Note that a suggested process of action mapping for any attribute is provided on the next page.

- **Increase oak regeneration:** Loss of foundational oak species, and related impacts to forest resilience, is most at threat on dry-mesic sites. Regional priority areas can be established where dry-mesic sites are concentrated to apply forest management treatments to increase oak regeneration (e.g., prescribed burning and mechanical thinning).
- **Restore spruce refugia:** The attributes of forest resilience rank lowest overall for this forest community group. Regional priority areas should be established to protect, manage, expand, and connect red spruce ecosystems with climate-informed plantings to enhance adaptive capacity and canopy release.
- **Diversify forest age/structure:** Less than desirable forest age and structural diversity, and related impacts to forest resilience, are most likely to occur on xeric to dry-mesic sites. Regional priority areas for forest management treatments that diversify age and structure (e.g. thinning) should be established where these sites are concentrated.
- **Increase proportion of climate-adapted trees:** Forest composition is least well-adapted to the future climate in the Spruce Highlands community types as well as on mesic sites in the Interior Mesophytic community type. Regional priority areas for treatments to favor climate-adapted species (e.g. thinning, tree-planting) should be established in these landscapes.
- **Reduce deer overbrowse:** The greatest limitation of tree regeneration due to deer overbrowse is found in the Northern Hardwood and Northeastern Oak-Pine community types, on all site types. Regional priority areas should be established in these community types to increase tree regeneration or decrease browse pressure.

The above goals and related actions build resilience in the existing forest footprint and strategies to increase forest connectivity will also improve regional resilience. One of the greatest fragmenting features are vast areas of degraded former mine lands are concentrated in the coalfields of central Appalachia, in many cases lacking foundational native forest cover which underpin many attributes of a resilient forest. To restore connectivity we need to prioritize restoring degraded mined lands. Regional priority areas should be established where there are opportunities to connect and restore former mined lands to native cover through invasive species removal, soil decompaction, and native plantings where mine lands.

Take Action Using the Forest Resilience Assessment Results

Our teams will continue to review and share the findings of this assessment with colleagues and partners across the Appalachians. The results of this assessment can be used in local and landscape-scale action-mapping exercises aimed to improve forest climate resilience. we will use this and additional local data to develop action areas for new landscape-scale project to advance planning and implementation efforts with partners. The figure below illustrates three examples for action mapping using this assessment's data.

We look forward to exploring how these results can be used to inform conservation investments across the Appalachians, scaling up existing programs that face larger threats or highlighting new conservation priorities.

1. Identify the target resilience KEA and indicator goals for improvement. KEAs and indicators that are ranked 'Low' are a good initial set of priorities, although improving any indicators is important for building resilience.

2. Identify the actions needed to improve the targeted indicator. Describe the goal for the action which should contain environmental site details that help focus the mapping effort (e.g. relevant forest type or elevation threshold). Included in this step are any parameters about the action itself (e.g. must be within 100m of existing roads because of equipment accessibility).

3. The final step is to assemble the relevant data layers, guided by the details provided above. The assessment's broad range of forest condition data can be re-purposed to map sites relevant to most of the indicators; Ecozones can be used to identify optimal oak sites (or spruce sites). For some indicators, several data sources might need to be combined, including other factors like funding opportunities.

Attribute	Adaptive Capacity	Biodiversity	Biodiversity
(Indicator)	(Suitable Habitat trend)	(Structural Diversity)	(Foundational species sustainability)
Goal	Increase dominance of white oak, a climate-adapted species most prevalent on dry-mesic sites	Increase acres of open-canopy woodlands on the most fire-adapted sites	Increase red spruce representation in climate refugia
Map	Areas with the most dry-mesic sites, within 100m of existing roads	Areas with the most pine heath and dry oak types and closed canopy forest	Areas within the historic, and future climate-suitable, red spruce range, currently with understory red spruce
Action	Conduct thinnings to favor climate adapted tree species	Design and conduct prescribed fire to increase structural diversity	Conduct crop-tree release to accelerate the growth of red spruce to the canopy

References

Anderson, M.G., and C.E. Ferree. 2010. Conserving the Stage: climate change and the geophysical underpinnings of species diversity. PLoSONE July (5): 7 e11554.

Anderson, M.G., Barnett, A., Clark, M., Prince, J., Olivero Sheldon, A. and Vickery B. 2016. Resilient and Connected Landscapes for Terrestrial Conservation. The Nature Conservancy, Eastern Conservation Science, Eastern Regional Office. Boston, MA.

Anderson, M.G., Olivero, A.P., Barnett, A.R., Khoury, M.L., and Martin, E.H. 2024. Mapping Freshwater Resilience across the Conterminous U.S. The Nature Conservancy, Center for Resilient Conservation Science. Newburyport, MA.

Butler, P. R. 2015. Central Appalachians forest ecosystem vulnerability assessment and synthesis: a report from the Central Appalachians Climate Change Response Framework project. US Department of Agriculture, Forest Service, Northern Research Station.

Forest Inventory and Analysis database, Evalidator tool. https://apps.fs.usda.gov/fiadb-api/evalidator. Accessed February 15, 2023. USDA Forest Service.

Iverson, L.R., Peters, M.P., Prasad, A.M., and Matthews, S.N. 2019. Analysis of Climate Change Impacts on Tree Species of the Eastern US: Results of DISTRIB-II Modeling. Forests, 10 (302). 28p. Lamarque

LANDFIRE, 2020, BioPhysical settings. LANDFIRE 2.0.0, U.S. Department of the Interior, Geological Survey, and U.S. Department of Agriculture. Accessed January 15, 2023 at http://www.landfire/viewer.

LANDFIRE, 2020, Canopy Cover Layer, LANDFIRE 2.0.0, U.S. Department of the Interior, Geological Survey, and U.S. Department of Agriculture. Accessed January 15, 2023 at http://www.landfire/viewer.

Matthews, S.N., Iverson, L.R., Prasad, A.M., Peters, M.P., and Rodewald, P.G. 2011. Modifying climate change habitat models using tree species-specific assessments of model uncertainty and life history factors. Forest Ecology and Management. 262: 1460-1472.

McDonnell, T.C., W.A. Jackson, B.J. Cosby, and T.J. Sullivan. 2018. Atmospheric Deposition Effects Modeling for Resource Management on Southern Appalachian National Forests. Final Report prepared or USDA Forest Service – Asheville, NC. E&S Environmental Chemistry, Inc., Corvallis, OR.

McWilliams, William H.; Westfall, James A.; Brose, Patrick H.; Dey, Daniel C.; D'Amato, Anthony W.; Dickinson, Yvette L.; Fajvan, Mary Ann; Kenefic, Laura S.; Kern, Christel C.; Laustsen, Kenneth M.; Lehman, Shawn L.; Morin, Randall S.; Ristau, Todd E.; Royo, Alejandro A.; Stoltman, Andrew M.; Stout, Susan L. 2018. Subcontinental-scale patterns of large-ungulate herbivory and synoptic review of restoration management implications for midwestern and northeastern forests. Gen. Tech. Rep. NRS-182. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 24 p. https://doi.org/10.2737/ NRS-GTR-182.

Peters, M.P., Prasad, A.M., Matthews, S.N., & Iverson, L.R. 2020. Climate change tree atlas, Version 4. U.S. Forest Service, Northern Research Station and Northern Institute of Applied Climate Science, Delaware, OH. https://www.fs.usda.gov/nrs/atlas.

Spetich, M.A., Jenkins, M.A., Shifley, S.R., Wittwer, R.F., and Graney, D.L. 2022. Characteristics of Dry-Mesic Old-Growth Oak Forests in the Eastern United States. Earth (3): 975-1009.

Acknowledgements

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