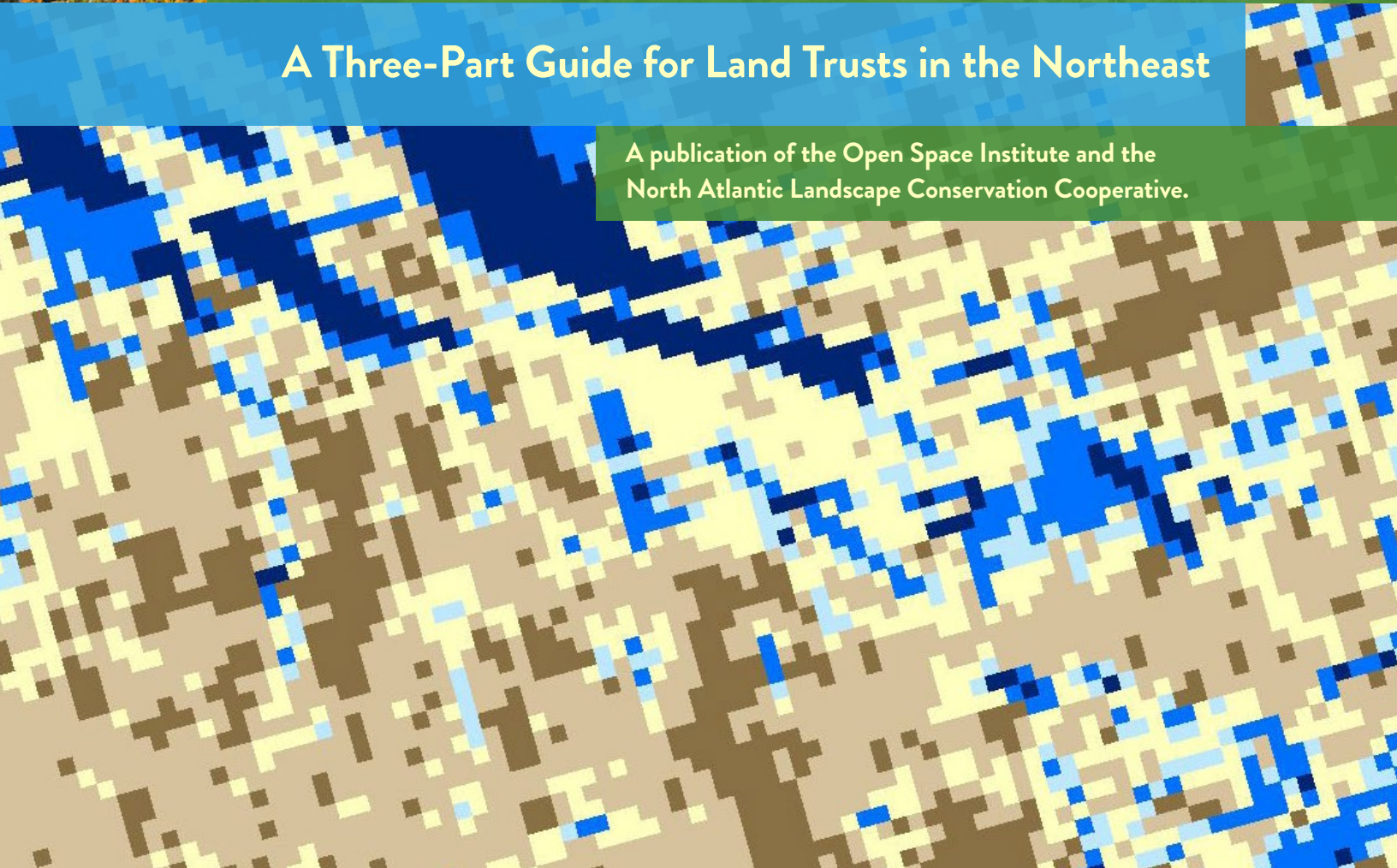


CONSERVING NATURE IN A CHANGING CLIMATE

A Three-Part Guide for Land Trusts in the Northeast

A publication of the Open Space Institute and the
North Atlantic Landscape Conservation Cooperative.



CONTENTS

PREFACE.....	3	Physical Diversity Datasets	56
INTRODUCTION	5	Connectedness Datasets	64
Planning for Resilience	7	Biological Condition Datasets	69
About This Guide	8	Putting It Together	70
		Key Lesson.....	75
		Anticipated Dataset Updates.....	76
PART 1. IDENTIFYING CHARACTERISTICS OF A RESILIENT NETWORK	11	PART 3. CASE STUDY: STRATEGIC CONSERVATION PLANNING.....	77
Resilience: Between Vulnerability and Resistance ..	13	Planning for Climate-Resilient Conservation	79
Characteristics of Resilient Networks	15	How the North Quabbin Partnership Created a Climate-Inclusive Conservation Plan	84
Geodiversity.....	16	Step 1: Reorienting Their Focus and Voting Their Values	84
Landform Diversity.....	20	Step 2: Refining Choices and Sketching a Model.	88
Connectedness	22	Step 3: Making Final Decisions	91
Intact Biological Condition	26	Step 4: Implementation and Outreach	98
Resilience in Freshwater and Coastal Systems	28	Step 5: Reflecting on Lessons Learned	101
Next Steps.....	32	Following in Their Footsteps: How You Can Take Action	102
PART 2. A STEP-BY-STEP GUIDE TO USING MAP-BASED DATASETS	33	APPENDIX.....	105
About Data Basin	35	Appendix A: Resources.....	106
Using Data Basin to Identify Resilient Areas.....	40	Appendix B: Glossary	110
Composite Datasets.....	46	Appendix C: Advisory Committee	114
Terrestrial Resilience.....	46		
Index of Ecological Integrity	50		
Freshwater Resilience.....	54		
Individual Datasets.....	46		

Partial funding for this program is supported by a grant/cooperative agreement from the U.S. Department of the Interior, Fish and Wildlife Service, provided through the North Atlantic Landscape Conservation Cooperative.





PREFACE

Across the Northeast, biodiversity thrives in the places generations before us had the foresight to conserve. Yet shifts in climate are changing the ground rules. As land protection professionals, how can we be sure that our work today will still be relevant in 50 to 100 years – and beyond?

Conserving Nature in a Changing Climate offers a modular, user-friendly approach to addressing this challenge. It is a practical guide that contains tools and strategies to help land trusts conserve the lands most likely to harbor wildlife, and to protect natural resources under a changing climate.

Insights conveyed through the guide come in part from the Open Space Institute's (OSI's) Resilient Landscapes Initiative, which has mobilized land trusts to develop nearly 20 climate-inclusive conservation plans covering all or part of nine states, and to conserve 37,000 acres of climate-resilient lands across the eastern United States; from the North Atlantic Landscape Conservation Cooperative (LCC), which is using regional data and mapping to coordinate NGO, federal, state, and local governments responses to climate change; and from an advisory committee of practitioners and experts (listed in Appendix C).

OSI wishes to thank the U.S. Department of the Interior, Fish and Wildlife Service, which provided critical funding for the development of this guide. Special thanks also to the Doris Duke Charitable Foundation, lead funder of OSI's Resilient Landscapes Initiative, Jane's Trust, and the New York Conservation Partnership Program for their additional support and their vision to translate climate science for land trusts. Additionally, without the groundbreaking work of Mark Anderson, Ph.D., Eastern Regional Director for Conservation Science at The Nature Conservancy, and Kevin McGarigal, Ph.D., Director and Professor of the Department of Environmental Conservation at the University of Massachusetts Amherst, and their colleagues, these approaches for identifying climate-resilient lands for protection would not be possible. The guide was greatly improved thanks to review by the Steering Committee and land-trust practitioners.



INTRODUCTION

Throughout the Northeast, communities and ecosystems are experiencing climate change and grappling with its unknowns. How much will temperatures rise and how quickly? How will floods and droughts affect our food, our homes, and large-scale infrastructure such as roads and rail lines? Will plants and animals be able to adapt in time?

Despite this upheaval, scientists agree: land protection is, and will remain, a key strategy for ensuring that natural systems, and the species and humans that depend upon them, will continue to thrive. While changing weather patterns, species distributions, and other factors will affect the location of plants, animals, and their habitats, land trusts play an important role by protecting so-called “climate-resilient landscapes” and conserving carbon-storing forests and wetlands.

Conserving Nature in a Changing Climate provides a resource for land trusts and other conservation organizations to fulfill their critical missions, even in the face of so many unknowns. With a basic knowledge of relevant climate science and the tools described in this guide, conservation leaders can both revise their land protection goals if appropriate, and confidently explain to funders, board members, and landowners why their efforts matter now more than ever.

PUTTING A NEW SCIENCE INTO PRACTICE

Consider news footage from the aftermath of a hurricane or other natural disaster. The damage can seem remarkably uneven, with winds ripping up soil and trees in one area, while just a few hundred yards away a grove of trees stands tall and relatively unscathed.

What is the difference between these two places—and with the growing imperative of climate change, how can society harness the characteristics of the more resilient areas?

Over the last decade, ecologists have been working to identify characteristics that make a place more resilient to climate change. Building off this science, the US Fish and Wildlife Service and the North Atlantic Landscape Conservation Cooperative (LCC) have highlighted the critical role of land trusts to protect priority resilient sites for wildlife adaptation to climate change.

Starting in 2012, OSI's Resilient Landscapes Initiative, funded by the Doris Duke Charitable Foundation (DDCF), began to use the cutting-edge science to mobilize land trusts to protect resilient lands across the eastern US. In 2014, President Obama commended the Initiative for its investment in natural infrastructure, citing our nation's "moral obligation" to future generations to protect resilient landscapes.

In 2015, OSI began a partnership with the North Atlantic LCC and the Land Trust Alliance to collaboratively translate and disseminate the science more widely to the land trust community. Using this guide, your land trust, too, is becoming an important part of the solution for helping to mitigate the effects of climate change.

PLANNING FOR RESILIENCE

As a land conservation professional, you are likely familiar with the planning cycle for assessing land acquisition priorities (Figure 1).



Figure 1. Flow chart of traditional land trust planning (adapted from *Strategic Conservation Planning*, by Ole Amundsen III). Planning for resilience takes place in step 2 and helps inform the choices made in step 3.

While these planning best practices have been forged in response to traditional threats such as increasing fragmentation and development, climate change is a critical new stressor on natural systems that needs to be addressed using many of the same tools and approaches. A climate-inclusive strategic conservation plan will identify climate change as an active threat to natural resources in Step 1, and use data to identify a suite of resilient cores and corridors that can provide effective refuge to plants and animals.

Typically after applying a climate lens to their land protection priorities, land trusts have found that one or more of the following occurs:

- existing priority areas are determined to be climate resilient;
- places not identified as existing priorities are determined to be climate resilient and may be important new targets for land protection;
- existing priority sites are vulnerable (less resilient) to climate change effects and may require additional monitoring, management or restoration, or could be abandoned as priorities.

In some cases, a land trust may find it has invested significant resources in places with few resilient characteristics. While such places may be important for other reasons, such as enhancing recreation or conserving viewsheds, their long-term ecological health may be in question. Therefore it may be necessary to consider acquisitions that will connect these parcels of land to more resilient sites, or management interventions that increase their resilience (additional resources to inform climate change management decisions are available in Appendix A).

ABOUT THIS GUIDE

Whether used by individual staff or in group workshops, this guide can help conservationists evaluate the climate resilience of existing land protection targets; understand how a specific area contributes to the network of resilient landscapes across the Northeast; and develop or update a conservation plan that identifies regional priorities for land protection.

In three parts, the guide demonstrates how land protection can strategically increase the chances that natural systems will adapt to climate change.

Part 1 Identifying Characteristics of a Resilient Network, introduces four characteristics underlying climate resilience and why they are relevant for determining which places will sustain biodiversity in the face of climate change.

Part 2 A Step-by-Step Guide to Using Mapping Tools, introduces easy-to-use online mapping tools and spatial datasets that incorporate the concepts learned in Part 1. Through screen shots and hands-on exercises, it walks readers through the steps of assessing a property's climate resilience in a regional context.

Part 3 Case Study, provides a detailed look at how a consortium of land conservation groups in North Central Massachusetts, used the four characteristics of climate resilience (Part 1), and deployed mapping tools and datasets (Part 2), to develop a climate-inclusive land acquisition plan.

A common theme throughout the guide is the importance of outreach and communication to the success of conserving resilient landscapes. Effective communication—with landowners, land trust boards of directors, scientists and the general public—about climate change will be vital to success. The desire to address the effects of climate change may vary widely from place to place, so finding ways to adapt communication strategies to each region will be important for success as well.

For reference, the Appendix lists helpful resources on best practices for outreach and communication; conservation planning; web-based tools; funding sources; and other information gleaned from organizations including OSI, LTA, the North Atlantic LCC and others.

Finally, there are a few important considerations as you use this guide:

- ① While the guide does not directly address land protection for human communities, protecting land benefits both biological and human community resilience. Natural infrastructure is one of the most cost-efficient ways to protect against increased severity of storms. Wetlands and floodplains have proved to be the most effective way to temper flood damage.
- ② The guide is designed for land trusts and other groups involved in protecting land within the 13 Northeast states and the Northern Appalachian ecoregion of Canada. However, many of the concepts described are relevant throughout North America, and many similar datasets are available for other regions.
- ③ This guide focuses on protection of terrestrial ecosystems and freshwater wetlands; information on how to apply these concepts to freshwater and coastal systems can be found at the end of section 1.
- ④ The concepts of resilience described in this guide cannot be achieved by any single organization. Resilience requires conservation organizations, from the federal government to state agencies to conservation scientists and local land trusts, working together to create a network of resilient protected lands across the Northeast. As you read, keep in mind that every organization has an important role to play but that no single organization can do it alone.

THE NORTH ATLANTIC LANDSCAPE CONSERVATION COOPERATIVE

Landscape Conservation Cooperatives (LCCs), a network of scientists and practitioners initially organized by the U.S. Department of the Interior, are experts in using the best available science to help public and private conservation groups work together to address climate and land-use change. The North Atlantic LCC was formed in 2009 as a partnership of federal agencies, states, tribes, universities, and private organizations working collaboratively to develop the science and tools needed to prioritize and guide conservation actions in the North Atlantic region, from southeastern Virginia to Atlantic Canada and southern Quebec.

The partnership's services include coordination and organization, ecological planning, conservation design, conservation adoption and delivery, monitoring and evaluation, research, communication and outreach, and information management. Its online Conservation Planning Atlas, which includes maps and data related to climate change in the Northeast, is featured in Part 2. For more information, visit <http://northatlanticlcc.org>

OPEN SPACE INSTITUTE

The Open Space Institute protects scenic, natural, and historic landscapes to provide public enjoyment, conserve habitat and working lands, and sustain communities.

Founded in 1974 to protect significant landscapes in New York State, the Open Space Institute is a leader in environmental conservation. OSI has partnered in the protection of 2.2 million acres in North America, from Alabama to southeastern Canada. All of OSI's work is directed by a consistent strategy emphasizing permanent protection on a landscape-level scale. OSI protects diverse landscapes including parks, preserves, working farms and forests, and utilizes climate science to identify critical landscapes for protection. OSI administers grant funds to preserve habitat for rare and endangered species, protect water resources, enhance recreational access, and support sustainably managed lands.

Generously supported by the Doris Duke Charitable Foundation, OSI launched the Resilient Landscapes Initiative in 2013 to help land trusts and public agencies across the eastern United States respond to climate change. The Initiative seeks to increase conservation of resilient landscapes and to focus land trusts on critical climate priorities. OSI achieves its goals through two capital grant funds in the Northeast and Southeast, and through a Catalyst Grant fund for outreach and education grants.



PART 1

IDENTIFYING CHARACTERISTICS OF A RESILIENT NETWORK

CONTENTS

Resilience: Between Vulnerability and Resistance

Characteristics of Resilient Networks

- Geodiversity

- Landform Diversity

- Connectedness

- Intact Biological Condition

Resilience in Freshwater and Coastal Systems

Next Steps

WHAT IS RESILIENCE?

Ecological resilience is a term ecologists have used for decades to refer to the ability of plants, animals, and natural processes to persist in the face of change. Building on this concept, *climate resilience* is the specific set of conditions that makes systems better able to cope with the changes caused by a warming planet. Specifically, climate resilience demonstrates how the land's specific characteristics can mitigate the effects of changing climate and weather patterns, such as gradual increases in temperature, changes in precipitation (both wetter and drier weather), sea level rise, and more severe and frequent storms.

By definition, resilient sites are better able to tolerate these disruptions, and will require fewer interventions to restore species diversity and support natural processes.

RESILIENCE: BETWEEN VULNERABILITY AND RESISTANCE

Resilience sits in the middle of a continuum from vulnerability to resistance.

Vulnerable places are more likely to require significant and ongoing intervention to protect them from gradual, ongoing, or sudden changes; resistant places, on the other hand, can weather all but the most extreme changes.

As an example, think about three mature forests: one on a steep, exposed mountain slope whose shallow soils are crisscrossed by unpaved roads (a vulnerable site); a second on rolling hills with diverse topography, deep soils, and few or no roads or human infrastructure (a resilient site); and a third forest in a protected valley in a region unlikely to experience much change in climate (a resistant site) (Figure 2).



Figure 2. Conceptual response of resistant, resilient, and vulnerable sites to severe disruption (adapted with permission from a graphic developed by Steven Fuller, North Atlantic LCC)

With moderate disturbances, all three sites may continue to support diverse life and natural processes. However, with more extreme and frequent disturbances (e.g., major storms, wider temperature ranges, additional or reduced snowpack):

- the **vulnerable site** would experience more downed trees and greater loss of soil. Such a site may take decades, even a century or more, to recover; many species that were originally present may not find a tolerable environment locally and will migrate or die off.

- the **resilient site** will have an uneven response to the disturbance, with more trees falling on the hilltops but with plenty of seeds remaining on protected side slopes. Any soil loss on these gentle slopes would be quickly captured by flatter areas. Here, species will find a wide diversity of environments, and likely adapt and persist locally.
- finally, **the resistant site** will avoid significant damage.

In reality, resistant sites are quite rare. However, we can identify sites with greater resilience. While both the resilient and the vulnerable sites experience some destructive effects, the difference is that the resilient site retains or regains its original plants and animals quicker, whereas the vulnerable site may never recover these populations without intervention. This example illustrates an important point: a resilient site is not invincible, but it is able to recover from disturbances. This innate strength comes from two factors: the land's physical features, such as geology and landforms, and biological features, such as its existing diversity of plant and animal species.

*This example illustrates an important point:
A resilient site is not invincible, but it is able to recover
from disturbances. This innate strength comes from two
factors: the land's physical features, such as geology
and landforms, and biological features, such as its existing
diversity of plant and animal species.*

Climate change is impacting sites through increased frequency and intensity of stressors, not simply through one-time events. In this example, we looked at the impact of a discrete storm events on three different sites. Whether we're looking at one event or a series of increased stressors, the point is that certain sites have characteristics that make them better able to cope with stressors, including those caused by climate change. By viewing conservation through this lens of resilience, land trust practitioners can help plants and animals survive without worrying about making exact predictions regarding where habitats or species will shift over time. If we can identify a network of sites with diverse physical and biological characteristics, we can help to increase the chances that plants and animals will adapt to climate change.

CHARACTERISTICS OF RESILIENT NETWORKS

In preparation for developing this guide, a broad group of conservation organizations, including the U.S. Fish and Wildlife Service and the Land Trust Alliance, have formulated the following goal to guide land protection for biological diversity as the climate changes:

“To permanently conserve a network of connected and biologically intact habitats representing the diversity of physical landscape features.”

The goal statement introduces critical characteristics of a resilient network of protected lands:

- Physical Diversity, which is made up of Geodiversity and Landform Diversity
- Connectedness
- Biological Condition

Together, these characteristics are important drivers of land resilience in the face of short- and long-term change.

HOW DO WE PROTECT DIVERSITY IN A CHANGING CLIMATE?

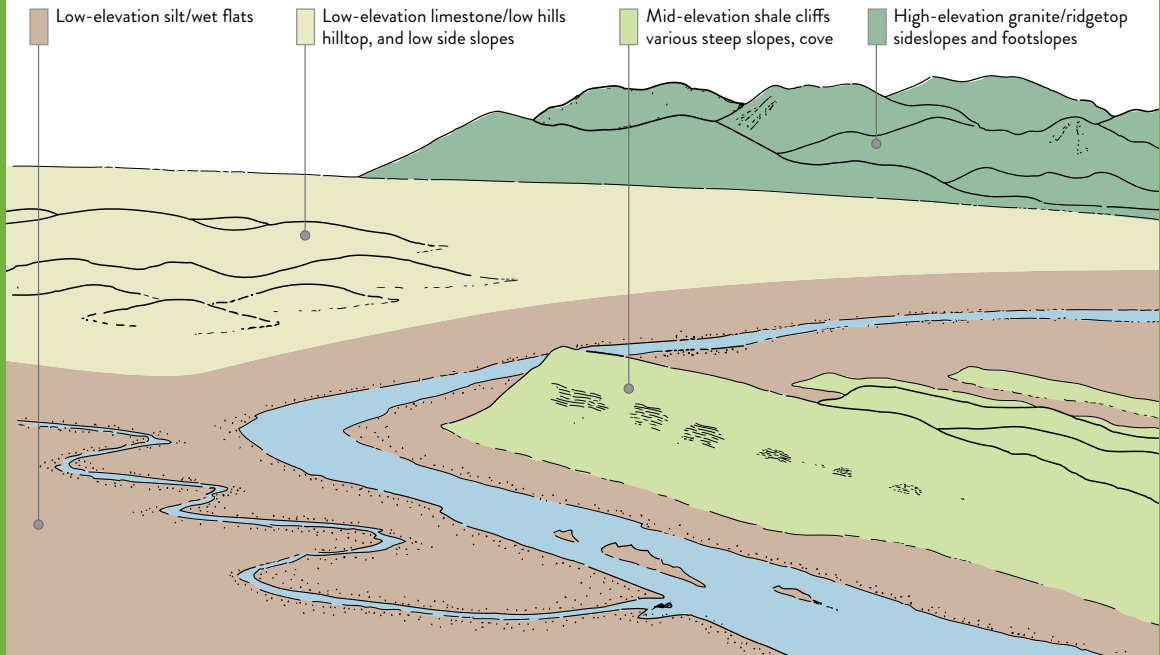
As species and natural communities shift in response to climate change, how do we protect lands that will support diverse plants and animals?

The answer lies in the unique combinations of elevation, geology and landforms that help to foster the rich diversity of habitats. For example, a low-elevation limestone site might sustain rich wetlands known as limestone fens; a mid-elevation shale cliff face fosters a shale glade.

In this way, protection of these physical characteristics helps ensure protection of the full range of plants and animals.

This approach to conservation, also known as a “coarse-filter approach,” allows land conservationists to capture most of the needs of most species rather than tracking thousands of species. It also allows us to conserve diversity without having to predict how species will migrate.

A coarse-filter approach to protecting biodiversity does not replace the need for restoration, relocation, and other species-focused efforts. However, by protecting the full range of geology, elevation, and landforms, we can ensure that the land we conserve protects the broad set of habitats that support diversity.



Physical Features of a Landscape: Physical features include geology, soils, elevation and landform types as well as water features. This imagined landscape pictures a wide diversity of geology and landform types.

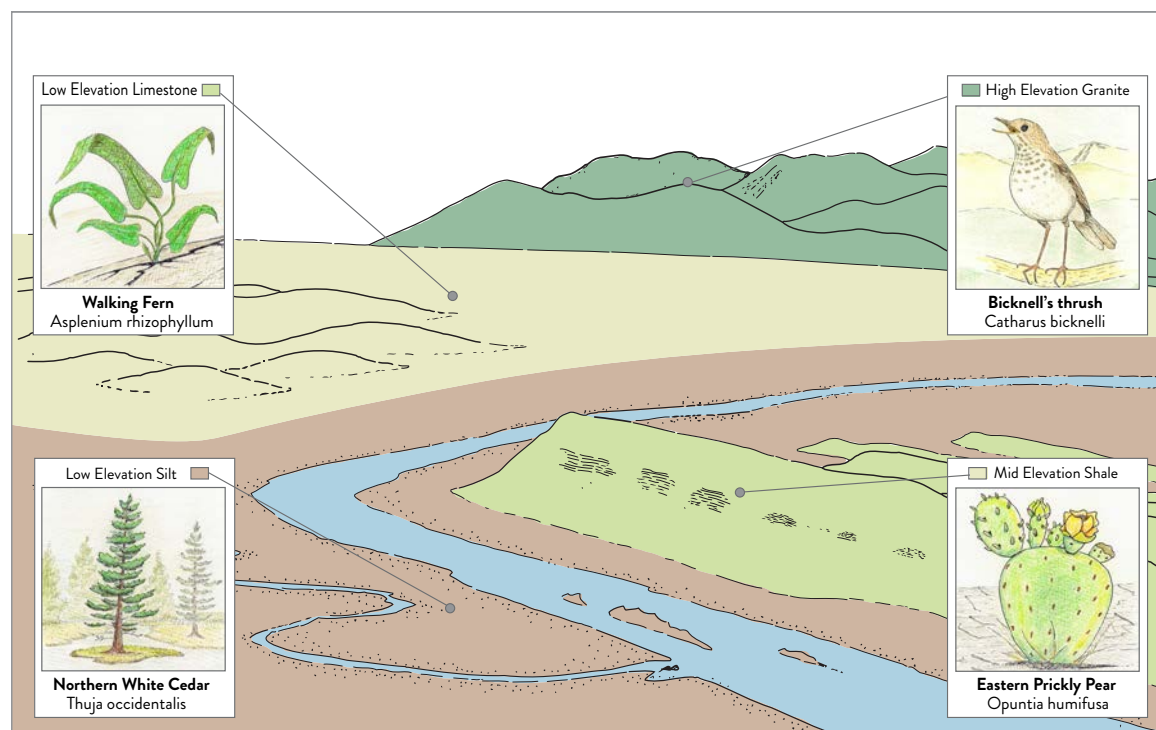
Geodiversity

Geodiversity is the range of geology and elevation gradients that foster habitat and species diversity across a broad network of conserved lands. Recent research has shown that geodiversity is a proxy for biological diversity: In the northeastern United States and Canada, of 23 physical and climatic factors, the strongest predictors of biological diversity were geologic diversity, elevation range, limestone (calcareous) bedrock and latitudinal range. This implies that conservation organizations can achieve climate resilience by working together to conserve geodiversity across latitudinal ranges.

Geology and elevation, together with landforms described below, create the conditions that foster ecosystem, habitat and species diversity. Consider northern white cedar (*Thuja occidentalis*), which thrives on wet sites, including floodplains, fens, seeps and springs. This plant will thrive in silt low lands where water accumulates. It cannot survive on granitic

bedrock where spruce thrives. Or consider the prickly pear cactus, which grows on flaky shale slopes that create the arid conditions that support this plant. The prickly pear does not exist in other geologies or even on flat shale beds at low elevations.

How to Recognize Geodiversity



Geodiversity Fosters Biological Diversity. **Geodiversity:** Geology and elevation create the conditions that foster ecosystem, habitat and species diversity. The range of geologies and elevations on this landscape create the conditions that support the plants and animals depicted.

The range of geology types existing at high elevation, middle elevation and low elevation are the “geophysical settings” that constitute geodiversity. Geophysical settings, sometimes referred to simply as “settings,” can be mapped using elevation models and geology datasets.

As land conservation practitioners, we can assess our progress at conserving geodiversity by looking at the range of geophysical settings represented in protected land. For example, although low-elevation calcareous geology constitutes 10 percent of a focus area for protection, it makes up only 2 percent of the protected land in that area. Meanwhile, one might find that 30 percent of the region is composed of high-elevation granite, yet 60 percent of the protected land is located on that setting.

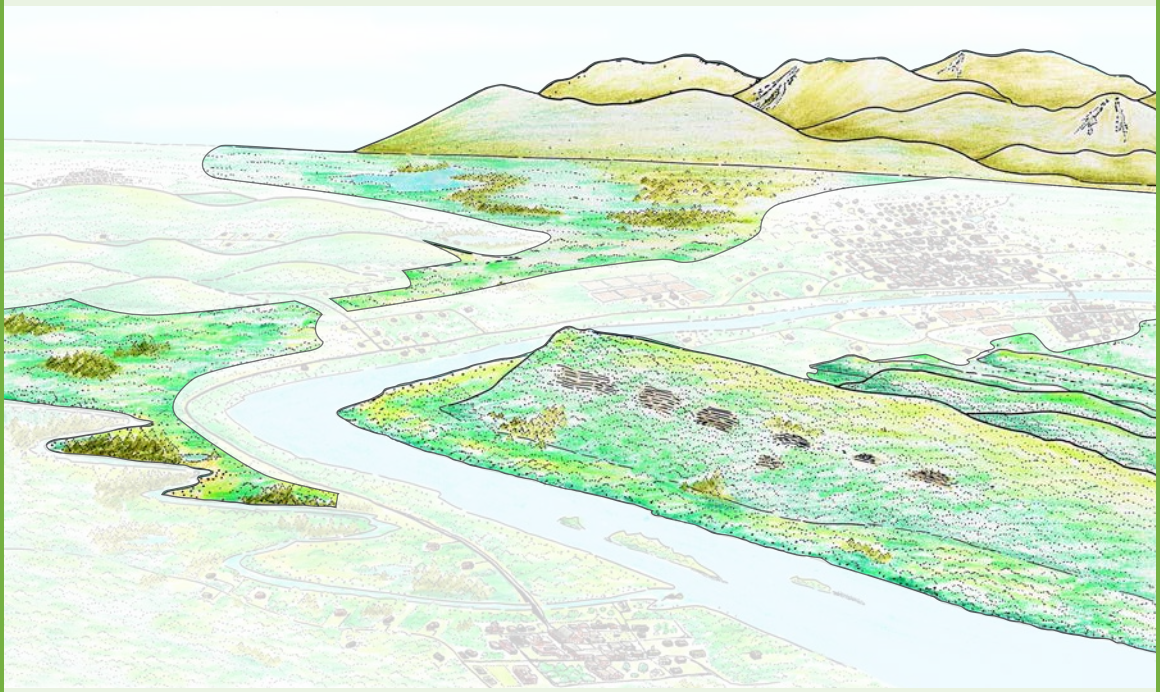
Underrepresented geophysical settings can then be targeted for further protection. This helps ensure that land and easement acquisitions are made with an eye to increasing the geodiversity of protected areas. Latitudinal range, one of the factors driving biological diversity, can be factored in by ensuring protection of each geophysical setting within each state or across larger ecoregions.

Geodiversity must ultimately be protected regionally. It would be challenging to conserve the full range of geologies and elevations even at a statewide scale. While geodiversity protection requires regional planning, land protection occurs locally. Professionals will need to verify the mapped results for specific sites.

Questions to ask as you work:

- Which geophysical settings are found within my geographic service region?
- How well does the protected land there or nearby represent the full range of geologies and elevation types?
- Which settings require additional protection to increase the geodiversity of protected lands?

BALANCING THE LAND PROTECTION PORTFOLIO



Protected Lands: Protected lands, highlighted here, tend to be wet flats or mid- or high-elevation areas with steep slopes. Human settlements have historically been concentrated on rich limestone and dry silt soils along rivers and streams and in valleys.

If we look at the amount of protected land of each geologic type at different elevation ranges, we see that the conservation community has excelled at permanently protecting high-elevation acidic geologies in the northeastern United States. In the Northeast, more than 40 percent of high-elevation granite area is permanently protected; these protected lands are found in large, relatively wild landscapes like the Adirondacks, the Western Maine Mountains and the Allegheny Plateau. In contrast, most low-elevation fertile sites, such as fine silt along rivers or rich calcareous soils, are poorly protected, with less than 3 percent of the area in conservation and more than 52 percent already converted to agriculture or development. These low-elevation sites' high fertility, level topography and capacity to drain water make them desirable for growing food crops and for building.

As roads, housing and commerce increasingly dominate fertile low-elevation sites, ownership patterns tend to become fragmented and the cost of the real estate increases, making land protection increasingly challenging. Notably, protected land in such sites has been conserved largely by private, not-for-profit land trusts and municipalities that often work on smaller (e.g., municipal) scales and collaborate with local communities. In contrast, state and federal agencies have mostly protected large swaths of land at high elevations along with some networks of wetlands, beaches and uplands along the coast.

More work is needed to rebalance the conservation portfolio. In addition to conserving higher-elevation areas, we must also conserve the remaining intact areas of fertile, low-elevation geologies to ensure that the network of protected lands supports the full range of species. This work will require further engaging with communities and employing a broad range of strategies, including land-use planning and conservation easements that integrate needs for working farms and forests alongside protections for biological diversity.

Landform Diversity

Landform diversity or complexity describes the range of landforms and variations in temperature and moisture that foster habitat and species diversity across a broad network of conserved lands. Variation in landform creates a diversity of environments with a range of temperatures and moisture levels, called microclimates.

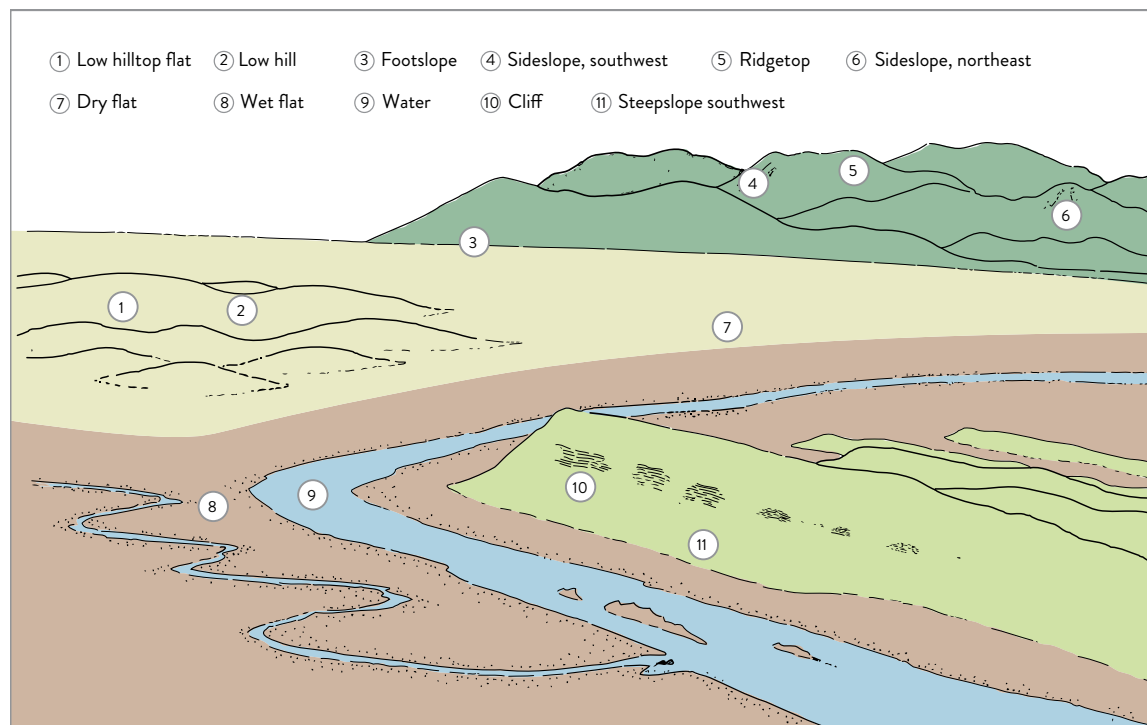
Temperature and moisture can vary dramatically at relatively small scales. Think of a north-facing ravine on a hillside, protected from the sun. A few hundred feet away, there may be a steep, dry, southern-facing slope. The temperature difference between these sites might vary as much as 20 degrees Fahrenheit (11 degrees Celsius) or more. Microclimates can be caused by structure, and the presence or absence of streams, seeps and springs.

Plants and animals experience temperature and moisture locally. The presence of microclimates makes it more likely that an individual organism can find a suitable environment by shifting to the cooler north side of its mountain home or a nearby sheltered ravine. Depending on the species, these shifts might take just moments (mammals) or involve seed dispersal over several years (plants).

Landform diversity can also support resilience during disturbances: hills often provide shelter from the prevailing winds and can protect plants that will ultimately provide seed sources to revegetate areas damaged in a storm. Sites with greater landform diversity may also recover faster because the area's uneven topography provides refuge for seed sources.

Whereas geodiversity is most relevant at a broad regional scale, landform diversity is assessed at the site level but relevant when making regional decisions. By protecting landform diversity and geodiversity, we can come close to protecting the full range of habitat and ecosystem types needed to protect biological diversity.

How to Recognize Landform Diversity



Landform Diversity: Landform diversity describes the range of landforms and the range of variations in temperature and moisture that foster habitat and species diversity. Landforms include features such as cliffs, summits, low hills and dry flats. The image below indicates the variety of landforms pictured in this landscape.

Landforms include features such as cliffs, summits, low hills, wetlands and dry flats. Scientists have identified more than 15 ecologically distinct landforms in the Northeast. Map-based datasets have been created to measure landform diversity across the United States and parts of Canada.

Practitioners with a trained eye can often identify landform diversity by walking the land, which tends to be visually appealing, with topographic changes—wetlands, cliffs, changes in elevation — that make it more interesting. A topographic map, which shows landform diversity by a variation of shades and spacing between contour lines, can be a valuable tool for identifying landform diversity and verifying modeled datasets.

Although important, elevation changes alone don't determine landform diversity; a tall mountain with a consistent slope contains fewer landform types than small hills and valleys that create diverse microclimates within a relatively small area. In flatter low-elevation areas, such as grasslands and coastal plain systems, river channels or small depressions that foster wetlands or wet flats mark the greatest landform variation.

The potential for landform diversity is strongly determined by the underlying geology. Granite will retain more dramatic forms than coarse sand or limestone, which is highly erodible. The relative amount of landform diversity is specific to each geology type and needs to be evaluated relative to each geophysical setting.

Questions to ask as you work:

- Which places in my geographic service area have the most landform diversity?
- Are they protected?
- Which of the land protection projects on our wish list would add the most landform diversity to this service area?

Connectedness

Connectedness creates options for species movement within and between areas in the absence of major human and natural barriers. Scientists differentiate between two types of connectedness: local connectedness, (or connectedness within an area), and regional connectivity, or connectedness between areas and across regions.

Land trusts have been strengthening connectedness for more than a decade by piecing together parcels with intact natural cover, and protecting riparian buffers and other corridors. Climate change, coupled with increasing fragmentation, requires being strategic about increasing connectivity.

Local connectedness reflects the continuity of intact natural cover in the local landscape. It helps determine how well a species can access diverse landforms for food and shelter, and whether there is space to support natural processes, such as a functioning food web, soil formation and regeneration. In the absence of fragmentation from human infrastructure, locally connected sites tend to be better able to tolerate hurricanes, flooding, fire and other disturbances.

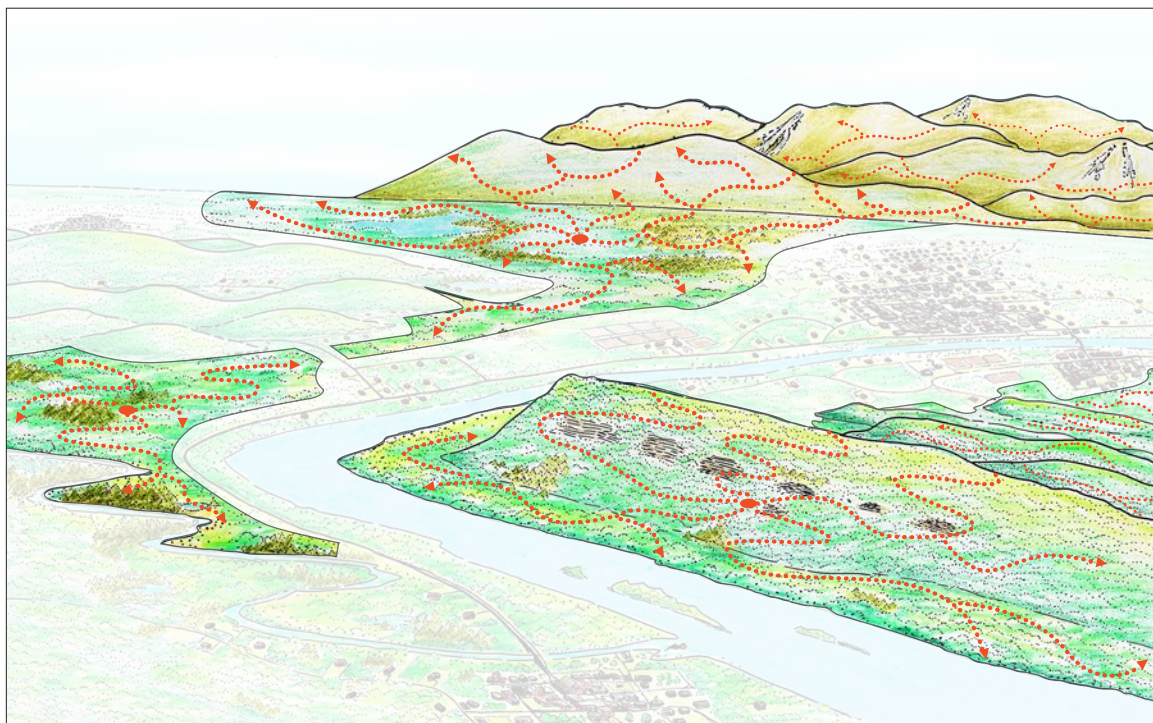
Local connectedness is limited by roads and development as well as by natural barriers, such as divergent habitat types and large water bodies that are challenging to cross. Local connectedness can be species specific: different species may view the same landscape in different ways. For instance, the New England cottontail, a threatened species, requires the thick cover of early successional forest and may not enter a mature woods habitat; for other species, the opposite holds.

Regional connectivity refers to the optimal pathways or “pinch points” between two or more sites or habitat blocks. Regional connectivity ensures we have a functional network and not just isolated resilient sites.

Regional connectivity will become increasingly important as the distribution of many species continues to shift in response to climate change. At the regional scale, it may be particularly important for species to move across latitudes from south to north, upslope or along intact riparian corridors. Regional connectivity links resilient sites, creating a network that has the potential for genetic exchange and facilitating range shifts when the local options no longer support a species’ needs.

How to Recognize Connectedness

Local Connectedness



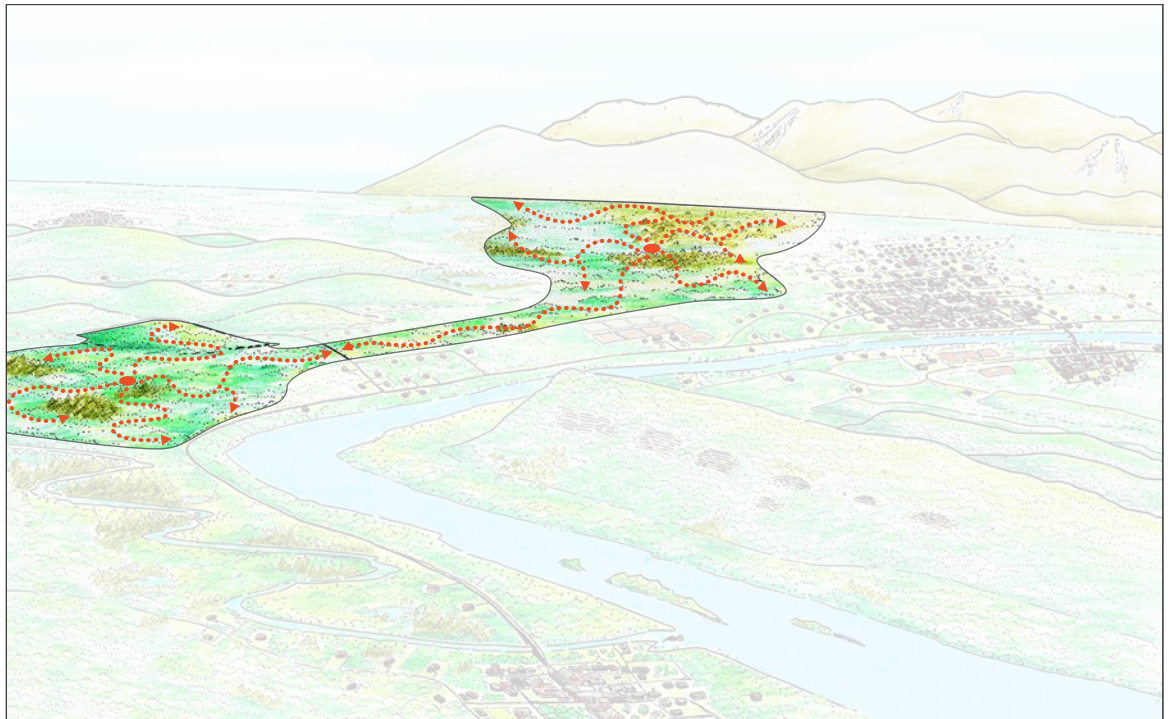
Local Connectedness: Local connectedness reflects the continuity of intact, natural cover in the local landscape. It helps determine how well a species can access diverse landforms for food and shelter and whether there is space to support natural processes, such as a functioning food web, soil formation and regeneration. If a species were located at either of the three red dots shown in the illustration, they would be able to access the portions of the landscape highlighted here. The local connectedness of each of the dots would be assessed based on how much of the landscape could be accessed from that point. Keep in mind that in reality, locally connected sites may or may not correspond with protected lands.

Land trusts typically review how a potential acquisition connects to existing protected land and what types of barriers lie between parcels. In thinking about climate, a second step is to determine how the land uses on a parcel will restrict local movement or limit the types of natural processes that can occur. Even if a site is protected, woodland roads and structures may limit local connectedness.

For local connectedness, one way to evaluate a site and its surroundings is by mapping habitat blocks—areas with contiguous forest or other natural cover free from paved roads or other development. Habitat blocks have become a popular conservation-planning framework in the northeast United States and remain effective tools for planning for climate change.

Satellite imagery and land-cover data are just two of the familiar tools that may also be employed to map habitat blocks. Another approach is to assess the extent that barriers limit movement out from a point. This approach was developed by the University of Massachusetts Amherst and is used in a variety of map-based datasets that evaluate connectedness (see Part 2 for more).

Regional Connectivity



Regional Connectivity: Regional connectivity refers to the optimal pathways and “pinch points” that are necessary to allow for movement between two or more sites. In the previous images the highlighted area does not include the road crossing between the two arrows left of middle in the image. However, when moving from one red dot to the other, this pathway offers the best possible option, emphasizing the importance of conservation and road crossings at that site.

For regional connectivity, land trusts may find it is possible to identify pathways for connecting two or three places. At scales of 1,000 acres or less, examining satellite images can help identify the likely barriers to movement through a corridor: development (buildings, logging roads), changes in land use (from forest to farm, from natural forest to plantation forest), and natural barriers (rivers). At scales of 1,000 acres or more, regional datasets are useful and described in Part 2.

Land trusts play a critical role in protecting pinch points that are critical to connecting resilient sites. Staying Connected, an international collaboration working to increase connectivity, has identified priority sites to maintain or restore regional connectivity in the Northern Appalachian and Acadian region of the United States and Canada. Similar initiatives exist elsewhere in the Northeast and beyond.

Some regional connectivity models indicate the general potential for movement for all species across latitudes and elevations. One challenge, however, is that landscape features can impede movement to different degrees depending on the species: birds can fly across many human barriers, whereas a salamander will not cross a small road. Some scientists are developing regional connectivity assessments for particular species with unique needs.

Questions to ask as you work:

- What parts of my geography are the most locally connected based on the absence of human barriers and could serve as core habitat blocks?
- What parts of my geography are critical for maintaining connections between areas?
- How well protected are these areas?
- How well do these blocks also capture geodiversity and landform diversity?
- Which areas will allow for regional connectivity between blocks of habitat?

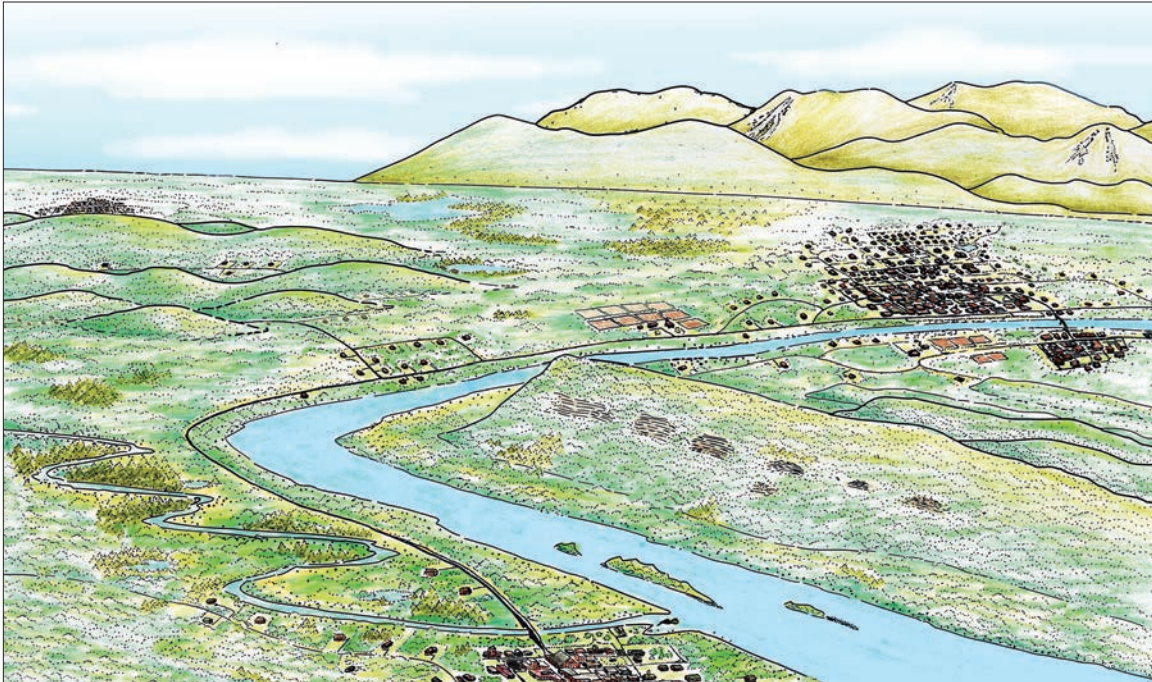
Biological Condition

Biological condition describes the level of stress or degradation to the habitat at a given site. Freedom from stress or degradation makes a site more intact and resilient to climate impacts. The site will be better prepared to adapt to future climate stress and therefore maintain the capacity to support species diversity.

Current and historic patterns of agriculture, development, pollution and forest cover inform the biological condition of a site. Intact biological condition is often indicated, among other factors, by the freedom from human disturbance, diversity of plant and animal life, the availability of seed sources, the presence of decaying matter, and the availability of nutrients.

Understanding the biological condition of a site is critical to understanding its capacity to support biological diversity. Even a site that appears connected and has geologic and landform diversity may be biologically degraded. For example, a monoculture of non-native plants may dominate a limestone glade that, judging by its physical features, we would expect to be biologically diverse. Some sites may again support biodiversity over time if the soil chemistry and structure are allowed to recover, but others may not achieve their full potential without extensive restoration. The biological condition of a site helps indicate whether biological diversity is currently present and can be sustained.

How to Recognize Biological Condition



Biological features include living organisms such as plants and animals, microorganisms and humans. The biological condition of the site is determined by the impact of stressors such as current development, historic human use and climate change.

The clearing of first-growth forests for agriculture, development and mining has altered the biology of much of the eastern United States and eastern Canada. Although the current extent of forest cover in the Northeast is greater than it has been since the 18th century, much of our forested land is biologically degraded. The recovery of these lands will take centuries, and has been further delayed by factors such as acid deposition and the introduction of non-native pests and pathogens. Climate change is anticipated to exacerbate the situation by stressing native plants and favoring generalist invasive plants.

The *Index of Ecological Integrity*, described in Part 2, uses a set of metrics to evaluate the intactness of habitat types including roads, traffic, development, intensity of agriculture, invasive species and other factors. The Index can be used at regional, state, watershed and ecoregion scales to assess the most ecologically intact sites for each habitat type.

In addition to the coarse filter resilience and biological condition, there is a lot of information on the distribution of fish, wildlife and plant species that can be factored into assessing a site's current biological condition. This information includes locations of known occurrences of species, as well as models of where the most suitable habitats for species are across the region. For many of these species models, there is information on where these species are most likely to persist in the face of climate change that can be used for conservation planning and site assessment.

Although biological condition can be assessed at larger scales using the *Index*, it ultimately needs to be evaluated at the site level as well. This requires looking beyond the amount of forest cover or surrounding land uses to examine how human activities have affected the site historically. The simplest technique is to look for telltale signs of past clearing, such as remnants of old rock walls and other human-made infrastructure.

A professional biological assessment will provide the most thorough review of a site's biological condition. During an assessment, a biologist will consider the health of the understory, the diversity of age classes of trees, the availability of seed sources, soil health and other factors.

Questions to ask as you work:

- Are there sites containing habitat types with intact biological condition in my area, as compared with other sites in my state or watershed?
- To what extent have historical human uses—forest clearing, tilling of the soil, compaction—affected the site?
- How many species of shrubs and herbaceous plants are in the understory?
- Is there a diversity of age classes of trees?
- Are there viable seed sources?
- What is the current diversity of plants and animals?

RESILIENCE IN FRESHWATER AND COASTAL SYSTEMS

This guide focuses on terrestrial and wetland resilience. However, land protection can play a vital role in supporting freshwater and coastal resilience as well. The characteristics that support ecological resilience across freshwater and coastal systems are similar to those supporting terrestrial resilience.

Freshwater Resilience

Freshwater resilience is the capacity of a river, stream, lake or pond system to recover after a disturbance and remain functional and biodiverse. A freshwater system is a network of connected streams and/or lakes bounded by either headwaters or, too frequently, dams. As with terrestrial species, freshwater species and habitats will shift across stream systems to adapt to climate change. Connected and diverse aquatic habitats will be essential to supporting resilience.

Fish region diversity.

Geology exerts a large influence on water temperature and pH and, together with evolutionary history and latitude, has created different freshwater habitat types. The

distinct characteristics of these habitat types form “fish regions.” Each fish region is a unit of land and its lake, stream and river systems with distinct characteristics influenced by its geology, history, and latitude—analogueous to terrestrial geodiversity. The northeastern United States has 14 fish regions, and protection of freshwater biological diversity will require the conservation of intact freshwater systems across all 14 fish regions.

Microclimates and aquatic habitat classes.

Just as landforms and elevation ranges create microclimates on land, a variety of stream system lengths, temperatures, and inclines (gradients) form a range of microclimates and habitats across a stretch of connected streams. For example, a warm, low-gradient stretch of stream connected to a cooler, steeper section provides temperature and nutrient diversity. Even if the entire system gets warmer—as may well happen in summer—the spectrum of temperatures can help organisms thrive. Like terrestrial microclimates, aquatic microclimates offer a range of accessible options.

Connectedness.

The ability of organisms to access different parts of a stream and/or lake system is described as linear connectivity. Barriers such as dams, undersized culverts or sediment buildup disrupt linear connectivity by artificially regulating water flow and stopping certain species from migrating or using different environments within a stream system. In a similar way, roads and development interfere with terrestrial local connectedness.

Connectivity across the width of a stream, including the stream’s floodplain and instream wetlands, is referred to as *lateral connectivity*. This is the relationship between the stream and its floodplain. Floodplains provide a place for aquatic organisms to feed and spawn, but only if the stream and floodplain are connected. Channelized streams interfere with lateral connectivity. Therefore, it is important to protect places where the streams run in natural courses with few hard-edged artificial structures impeding the floodplain.

Intact condition.

In addition to linear and lateral connectivity within a stream, assessment of freshwater resilience needs to consider the condition of the watershed, including the amount and type of artificial impervious surfaces, which increase runoff during storms and degrade water quality by increasing pollutant loads. Another consideration is hydrologic flow, or the typical frequency, duration and seasonality of the precipitation that flows into the stream. The effects of land uses on runoff and hydrology vary depending on their location in the watershed. Land uses in headwaters, wetlands and riparian areas have a larger effect on a stream than in other areas. Farms, backyards and roads each contribute different quantities and types of pollutants to streams.

Intact watershed condition corresponds closely with terrestrial connectedness because both are a measure of natural patterns. Riparian and floodplain areas support both terrestrial and freshwater habitat and connectivity, as well as flood mitigation and water quality. It is highly effective for land trusts to concentrate their work at the intersection of terrestrial and freshwater resilience.

Coastal Resilience

Coastal resilience here refers to the capacity of coastal ecosystems and species to persist and adapt in the face of climate change, particularly accelerating rates of sea level rise and more intense coastal storms. Coastal areas also house a disproportionate percentage of the Northeast's human population, resulting in significant habitat loss, fragmentation and disruption of ecological processes.

A rich diversity of fish, wildlife and plant species depends on these threatened coastal ecosystems. Coastal habitats also provide such ecosystem services as flood abatement, recreation and carbon storage.

Scientists are working to identify areas that are likely to best withstand climate change impacts including sea level rise and more intense storms. As with terrestrial systems, elevation, geology, landforms and barriers affect coastal resilience. Other factors are critical as well, including tidal range, estuary type and availability of sediment. Connectedness and freedom from anthropogenic barriers are particularly important for allowing these systems to adapt.

Coastal sites that offer a combination of physical and biological characteristics provide a diversity of habitat types, which will in turn support native species by offering them more microclimates and buffering them from some effects of the changing climate.

Protection of adjacent upland areas allows beach, tidal marsh and other coastal systems to migrate inland where the elevation, slope and lack of hardened shoreline are suitable for migration. These adjacent areas will likely need to be managed to increase the likelihood of migration and creation of new habitats. As with terrestrial and freshwater systems, management will play an integral role in protecting the resilience of coastal systems. Management of existing protected habitat includes water and sediment management, filling or manipulation of ditches, restoration of buffers, species introduction, invasive species control, living shorelines and mitigation of past human activities.

RESILIENCE CHARACTERISTICS OF TERRESTRIAL, FRESHWATER, AND COASTAL SYSTEMS

SYSTEM	BROADSCALE DIVERSITY	LOCAL DIVERSITY	CONNECTEDNESS	INTACT BIOLOGICAL CONDITION
Terrestrial	Geologic diversity	Landform diversity	Local connectedness, regional connectivity	Absence of human impairment, soil structure, plant age-class diversity
Freshwater	Fish region diversity	Microclimates (gradient, stream temperature)	Linear (instream) connectivity, lateral (floodplain) connectivity	Absence of human impairment, instream condition, floodplain condition, watershed condition
Coastal	Shoreline and estuary diversity	Landform diversity	Local connectedness between patches and for tidal flows, migration space for sea-level rise	Absence of human impairment, tidal cycle, natural sedimentation

NEXT STEPS

In this first section of the guide we described how to identify the diverse physical and biological features that will provide resilience. As you consider applying this information to project selection or conservation planning, consider the following three issues.

Balancing the conservation portfolio. As discussed above, land protection has historically been concentrated largely in high elevation, acidic geophysical settings. Land protection has occurred in some of the areas with the best connectedness and biological condition but has stayed away from low elevation fertile valleys where humans tend to settle. Connectedness and biological condition remain critical factors in a changing climate, but decision makers should consider giving increased attention to the relatively new concepts of geodiversity and landform diversity.

Scaling the data up and scaling the data down. Characteristics of resilience will need to be evaluated at regional and site-level scales. Geodiversity is useful in developing a conservation plan at a broad scale. However, it can also be applied at the individual parcel scale to evaluate whether a project captures a previously identified set of underprotected geophysical settings. Landform diversity and local connectedness are evaluated locally, but broad patterns of these resources should be considered when selecting sites for protection. In contrast, regional connectivity is evaluated at the broad regional scale to identify corridors for broad movement. Those broad priority areas can then be honed down to local acquisition targets.

Fostering a human network. The characteristics of resilience reviewed here are critical, to *permanently conserve a network of connected and biologically intact habitats representing the diversity of physical landscape features*; however, success will require connecting across organizational boundaries. At a broad scale it is important to maintain a network of scientists and conservation professionals that develop datasets and regional priorities that will provide movement corridors across the eastern United States. At local scales, practitioners are needed on the ground to refine regional priorities, add local knowledge and protect the land. Feedback and conversation between these scales is critical to success. Scientists working at large scales need feedback about how well their map-based data matches reality, and professionals working on the ground need to know when new information is available.



PART 2

A STEP-BY-STEP GUIDE TO USING MAP-BASED DATASETS

CONTENTS

About Data Basin

Using Data Basin to Identify Resilient Areas

Composite Datasets

- Terrestrial Resilience

- Index of Ecological Integrity

- Freshwater Resilience

Individual Datasets

- Physical Diversity Datasets

- Connectedness Datasets

- Biological Condition Datasets

Putting It Together

Key Lesson

Anticipated Dataset Updates

A STEP-BY-STEP GUIDE TO USING MAP-BASED TOOLS

Part 1 examined the physical and biological characteristics that help sustain ecological resilience and recommended that conservation practitioners permanently protect *networks of connected and biologically intact habitats representing a diversity of physical landscape features*.

To put this science into play, a series of map-based datasets allows practitioners to evaluate resilience remotely at both site and landscape scales. These datasets have been funded in part and made available by the North Atlantic LCC through an online platform developed by Data Basin. This section of the guide provides an introduction to the Data Basin platform and step-by-step instructions on using the datasets to evaluate geodiversity, secured status (level of protection), habitat representation, terrestrial resilience, landform diversity, connectedness, biological condition and freshwater resilience.

Each step interprets the data and explains how the information aids in understanding the landscape's overall resilience. We use Hogencamp Mountain in Tuxedo, New York, and the surrounding area as our example for illustrating the data. While this section focuses on examining the resilience of a relatively small area, keep in mind that all of these datasets put this site in a northeast or broader regional context by comparing the resources at the site to the quality and types of resources across the Northeast or eastern region. Section 3 will review how to use these datasets in the context of developing a conservation plan for an entire land protection service area.

Although we recommend following the steps in order, it is possible to skip to topics of interest. If you are new to Data Basin, we recommend first reading the "About Data Basin" section below before turning to the step-by-step instructions.

ABOUT DATA BASIN

The North Atlantic LCC's Conservation Planning Atlas, hosted by Data Basin, is a free mapping tool that provides access to data and maps related to climate and land-use change. For this guide, the Open Space Institute partnered with the North Atlantic LCC staff who manage the Conservation Planning Atlas to develop Land Protection in a Changing Climate, using a gallery, or collection, of datasets specifically suited to mapping ecological resilience in the Northeast for land trusts. These datasets were created with North Atlantic LCC, state and private foundation funding for the purpose of informing the conservation of resilient landscapes. This set of data is not intended to be comprehensive with respect to how the concepts of resilience from Part 1 can be evaluated; rather, they represent a curated selection of some of the most up-to-date and quality information needed to assess resilience in the context of permanent protection. Most of these datasets were last updated in late summer of 2016. Other datasets available on the Data Basin site may be useful for managing for specific species. Here, we use only the datasets for Land Protection in a Changing Climate gallery.

Many of these datasets are also available on other platforms. For example, The Nature Conservancy has developed a web-based platform for use of its Terrestrial Resilience datasets that is also useful.

DEFINITIONS

Galleries, datasets and maps are helpful ways of curating large amounts of information so that it is meaningful and easy to manage.

A **gallery** is a collection of datasets and maps organized around a topic. We will be working with the Land Protection in a Changing Climate gallery, developed specifically for users of this guide.

A **dataset** is the spatial visualization of a specific collection of data. Layered on top of a map, it appears as highlighted areas or points of various colors. For example, the Terrestrial Habitat, Northeast dataset plots different types of habitat in pixels 30-meters square across the Northeast. Each habitat type is associated with a specific color. This dataset is included in our gallery because it shows how geodiversity leads to habitat diversity.

A **map** is created whenever a dataset is added and projected onto a land area. It can include one or more datasets, including base maps.

Although you can use the Conservation Planning Atlas on the Data Basin site without an account, you cannot save any maps you create until you register. If you have an account with another portal on Data Basin, you can use it here. If you do not have an account, register at <https://nalcc.databasin.org> by clicking Sign Up.

Once you are logged in, go to the Gallery page or type “land protection in a changing climate” into the search bar and look for the gallery in the results. Click the title (not the image) of the gallery to view its contents. Select a dataset (in this case, choose *Terrestrial and Aquatic Habitat Map (DSLland), Version 3.0 Northeast U.S.*) and click on its name to add it. Then click Open in Map. You will see a map of the Northeast overlaid by the dataset of habitat types. Across the top is a toolbar. Tools 1–9 are those you will use most often when manipulating and interpreting what you see. Below is an overview of the functionality of these tools:

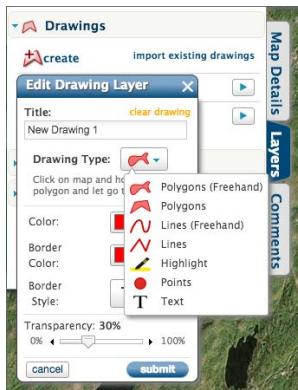


1. “Enable Pan Mode” allows you to move the map by clicking on it and dragging the cursor.
2. “Enable Zoom Mode” allows you to zoom in on an area by drawing a rectangle around it. (Click back to Pan Mode after zooming.)
3. Zoom in.
4. Zoom out.
5. “Full Extent” automatically zooms out to show the entire dataset.
6. “Locate” allows you to enter a location’s name (or its latitude and longitude) to find a specific place. Once you locate the place, you have the option to add a point or zoom to it.
7. “Identify” allows you to click any point on the map and see a description of the data at that point.
8. “Measure” allows you to measure the distance between two points on the map.
9. “Swiper” sets up a divided screen with the dataset on one side and either another dataset or a base map (Street Names, Terrain, etc.) on the other. You can move the divider back and forth to compare the two ways of looking at a single area. First, click on the swiper tool to bring the swiper bar into the Datasets menu (see below), then drag the swiper bar up or down between the datasets you are interested in comparing.

Data Basin also has a Layers tab (on the left) and a Legend window (on the right). The Layers tab (depicted below) includes Drawings, Datasets and Basemaps, each of which appears as a drop-down menu. To see the menus, click on the Layers tab. To hide the menus, click on the Layers tab again.



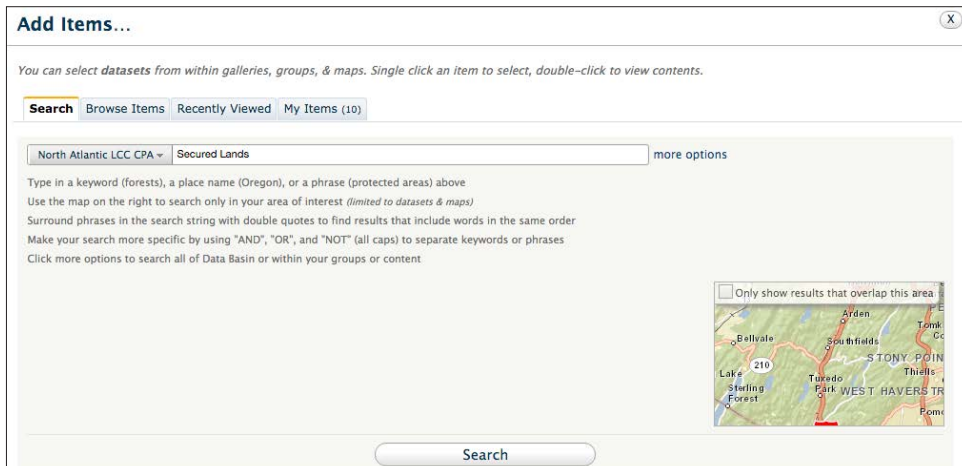
The Drawings menu contains tools to create a polygon, line, highlight, point or textbox directly on the dataset. This can be useful for marking, highlighting and communicating information about focal areas of interest, whether for future reference or for use with collaborators.



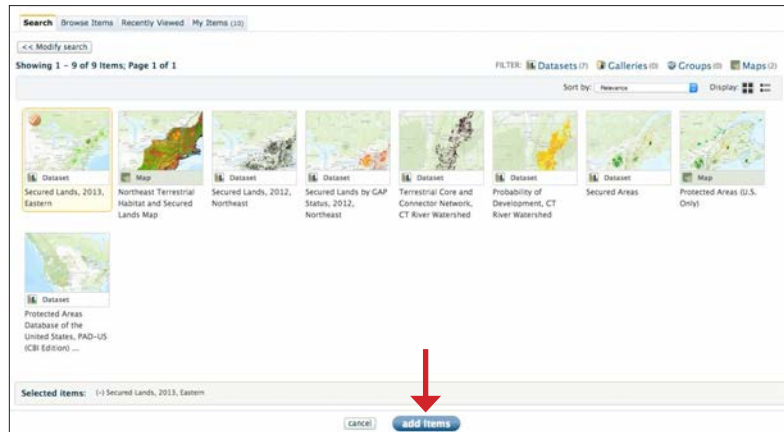
The Datasets menu allows you to add and manage multiple datasets. You can turn them on and off by checking and unchecking the box next to their names. This lets you manage which datasets appear at any time and visualize how changing datasets affect your map results. You can also click on the blue arrow next to each dataset to turn the dataset into a filter, change its transparency or remove the data. A filter screens the dataset so that only select data appear.



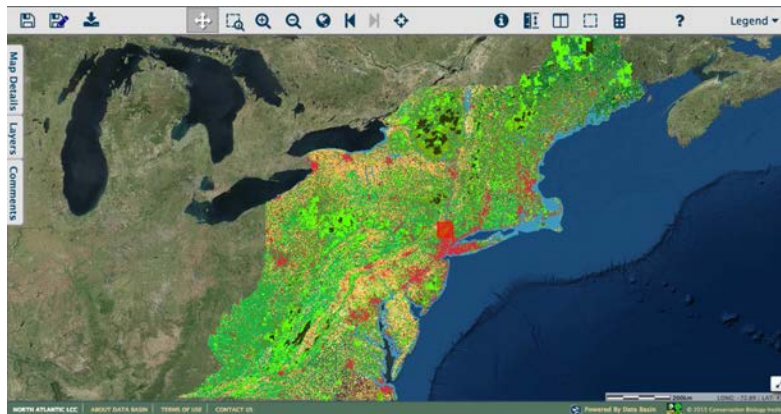
To add a dataset to the *Terrestrial and Aquatic Habitat Map (DSLland), Version 3.0 Northeast U.S.*, click Add Datasets. You can then search for datasets in the search window. In this example, we want to add *Secured Lands, 2014, Eastern U.S.*



If your search returns more than one dataset, select the one you want by clicking its image and then Add Items at the bottom of the screen. You may need to scroll down to the Add Items button. The file may take time to load.

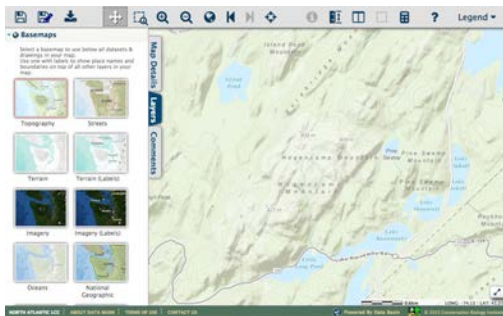


The data from both datasets—the original Habitat map and the Secured Lands that were added—will now appear on one map.

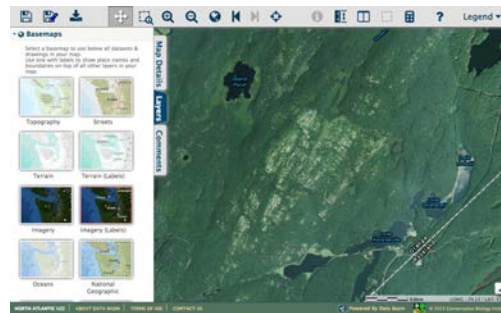


The Basemaps menu provides options for the type of standard map that appears under the datasets, such as Topography or Imagery. Each type offers different information about the places you are viewing. Basemaps can be used strategically to help you interpret and ground-truth the datasets. For example, it is often helpful to use a satellite imagery basemap with the connectedness datasets and a topography map with the landform diversity.

Terrain (Labels)



Imagery (Labels)



Although Data Basin has many additional features, a familiarity with just the above tools will allow you to learn about the resilience of a particular location or simply understand more about these datasets to assess their utility in conservation planning.

DATA UPDATES AND REVISIONS

Map-based datasets are continually evolving and being updated as land uses change and more data become available. Datasets currently being developed will eventually replace those included in this section of the guide, but the North Atlantic LCC will use the same naming conventions. Some data developers are adding a number to the end of each dataset name so that users can easily identify the latest versions. A list of anticipated dataset updates appears at the end of this section.

USING DATA BASIN TO IDENTIFY RESILIENT AREAS

The four characteristics of terrestrial resilience discussed in Part 1 have been translated into map-based datasets by scientists at universities, government agencies and conservation organizations. The datasets identify patterns of resilience characteristics across the Northeast. The full set of datasets reviewed in this guide are summarized and briefly explained in Table 1 below.

Table 1. At-a-glance guide to datasets in *Land Protection in a Changing Climate* gallery. All raster datasets are at a 30-meter resolution unless otherwise noted.

DATASET	SUMMARY
<i>Geophysical Setting, 2016 Eastern U.S. and Canada</i>	Maps bedrock and surficial geology classes across the Northeast and combines geologic information with five elevation classes to identify 62 geophysical settings.
<i>Secured Lands, 2014, Eastern U.S.</i>	Shows which lands have legal protections from development, and their GAP status or the type of restrictions.
<i>Terrestrial and Aquatic Habitat Map (DSLland), Version 3.0 Northeast U.S.</i>	Terrestrial, fresh water stream and wetland ecological systems (lake and pond classifications to be added soon after publication) of the Northeast based on NatureServe's Ecological Systems Classifications combined with human-modified land types such as roads and agriculture.
<i>Resilience Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada</i>	Assesses overall physical resilience of sites, combining geodiversity, landform diversity, and local connectedness. Resilience is evaluated separately for each geophysical setting and ecoregion, and then combined into a continuous dataset. The Regional Override feature overrides the ecoregion scores where they are the region's highest scoring values.

DATASET	SUMMARY
<i>Landscape Diversity Stratified by Geophysical Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada</i>	Evaluates landform types within 100-acre circles and assigns score to the 30 meter30-meter pixel at the center of each circle. Landform diversity is evaluated separately for each geophysical setting and ecoregion.
<i>Local Connectedness Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada</i>	Evaluates the possibility of dispersal from a starting point throughout a circle with 33-km diameter. It is a measure of dispersal and a landscape's capacity to support natural ecological processes.
<i>Regional Flow 2016 , Eastern U.S. and Canada</i>	Provides generalized model of movement potential in north-south and east-west directions. This newest dataset incorporates a preference for movement upslope and northward, and was confirmed with observed patterns of species migration.
<i>Index of Ecological Integrity, Stratified by Ecosystem, Region-wide, Version 3.1, Northeast U.S.</i>	Evaluates a site's freedom from human impairment and capacity to recover from stress for terrestrial and freshwater systems. The dataset is stratified by habitat type (using an updated version of the <i>Terrestrial and Aquatic Habitat</i> data).
<i>Freshwater Resilience, All Streams, Stratified by Fish Region and Freshwater Ecoregion, 2013 Northeast</i>	Scores resilience of streams at least two miles long based on condition, connectivity, diversity, resilience, and complexity. The dataset only scores stream complexes with a threshold amount of connectivity. The dataset is being updated and may be released in 2017.

These datasets have been developed with the express purpose of directing conservation projects to climate-resilient sites. They can be used for both conservation planning at a broad scale and project evaluation at a local scale. Even when evaluating resilience characteristics at a site, remember that the data incorporates the assessment of how the site compares to other similar sites across the entire northeast United States or eastern United States and Canada, depending on the dataset.

We will now learn what the datasets in the North Atlantic LCC Data Basin gallery can teach us about the resilient characteristics of the landscape surrounding Hogencamp Mountain in Tuxedo, New York. First, we will review using the composite datasets for this purpose. Next, we will walk through each of the three characteristics of resilient sites—physical diversity, connectedness and biological condition—and how to use the datasets that correspond to these concepts.

COMPOSITE DATASETS

Most of the datasets reviewed in this guide contain information about a single resilience factor. However, two datasets, *Terrestrial Resilience* and the *Index of Ecological Integrity*, combine three or four of the characteristics of resilience into single datasets measuring overall resilience. These datasets can be particularly useful to practitioners looking for a single dataset that can help identify resilient characteristics.

Table 1 compares the two datasets and describes how they incorporate the resilience characteristics. Another composite dataset, *Freshwater Resilience*, complements *Terrestrial Resilience*, while the *Index of Ecological Integrity* incorporates freshwater and terrestrial scores into a single dataset.

Table 2

	TERRESTRIAL RESILIENCE	INDEX OF ECOLOGICAL INTEGRITY
Dataset name and source	<i>Resilience Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada</i> (called <i>Terrestrial Resilience</i> throughout). Project of The Nature Conservancy (TNC) Eastern Regional Program, led by Mark Anderson.	<i>Index of Ecological Integrity, Stratified by Ecosystem, Region-wide, Version 3.1, Northeast U.S.</i> (Index of Ecological Integrity or IEI). Project of Designing Sustainable Landscapes (DSL), led by Kevin McGarigal of UMass Amherst.
Summary	Measures diversity of options available from a site, including options for movement and microclimates for 62 geophysical settings at 30-meter resolution. Includes only terrestrial and wetland systems. Measures ability of living systems to adjust to climate change, to moderate potential damages, take advantage of opportunities, or cope with consequences.	Measures relative freedom from human impairment for more than 150 habitat types at 30-meter resolution. Includes terrestrial, freshwater and coastal systems in one seamless dataset. Final dataset identifies examples of each habitat most likely to sustain important ecological functions over long term.
Physical Diversity: Geodiversity	Diversity of geology and elevations is captured by stratifying data by geophysical settings. Final dataset implicitly incorporates the need for protection of all geology types at all elevations.	Diversity is captured through stratifying data by habitat types. Habitat types incorporate diversity of geology, elevation and landforms. Identifies priorities for all terrestrial, fresh water and coastal marsh systems.

	TERRESTRIAL RESILIENCE	INDEX OF ECOLOGICAL INTEGRITY
Physical Diversity: Landforms	Measures landforms for 100-acre region surrounding each site and combines with other statistics to provide score for “landscape diversity.” Landscape diversity is treated as one of two components of resilience, along with local connectivity.	The diversity of habitats captures significant landform diversity.
Connectedness	Local connectedness is measured by assessing type and spatial arrangement of barriers that would be encountered when moving out from a site and measures ability to access resources on landscape. Regional Connectivity is not measured as part of this dataset.	Measures freedom from human impairment through two metrics: “intactness” and “resiliency.” Metrics include a wide range of measures for terrestrial and fresh water connectedness, including road traffic, road salt, dams and edge predators. Here “resiliency” measures similarity of surrounding habitat to facilitate movement through landscape. Regional Connectivity is not measured as part of this dataset.
Intact Biological Condition	The dataset does not attempt to incorporate biological condition. It is recommended that priorities be checked against current species distributions or other measures of the quality of the site’s ecological condition.	Incorporates elements of ecological condition that can be mapped at a broad scale. The dataset includes invasive plant distributions, pollution from road salt and road traffic, and impacts of intensive agriculture on pollinators and soil biotic diversity.

The North Atlantic LCC and TNC staff have gone one step further. Using these composite datasets as a jumping off point, they have each worked with steering committees to map a comprehensive network of resilient sites for conservation. These maps of conservation priorities incorporate regional connectivity and measures of current biological diversity.

For the North Atlantic LCC, these sites are called Regional Conservation Opportunity Areas (RCOA). They combine the Index of Ecological Integrity, the Terrestrial Resilience data, and species-specific datasets to identify priority conservation areas most likely to support species diversity in the face of climate change. The project includes a place-based pilot in the Connecticut River watershed (<http://connecttheconnecticut.org/>).

The Nature Conservancy has separately combined data on terrestrial resilience, corridors and species diversity to develop a resilient and connected network of sites that represents the full suite of geophysical settings across the eastern United States and Canada. This network includes a new measure of riparian climate corridors and current records of biological diversity.

COMPOSITE DATASETS

Terrestrial Resilience Dataset

THE DATASET: *The Resilience Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada (Terrestrial Resilience)* dataset was developed by The Nature Conservancy (TNC) to assess the overall physical resilience of a terrestrial or wetland site or landscape. It combines information about geodiversity, landform diversity and local connectedness but does not incorporate regional connectivity, biological condition, freshwater resilience or coastal resilience. The landscape complexity and local connectedness scores were summed and then stratified (see “Stratification” note on page 49.) by geophysical setting to identify the places with the greatest landform diversity and local connectedness.

Terrestrial Resilience may be used alone to assess the physical resilience of a site. There are also datasets that allow you to examine geodiversity, landform diversity and connectedness separately, as demonstrated below.

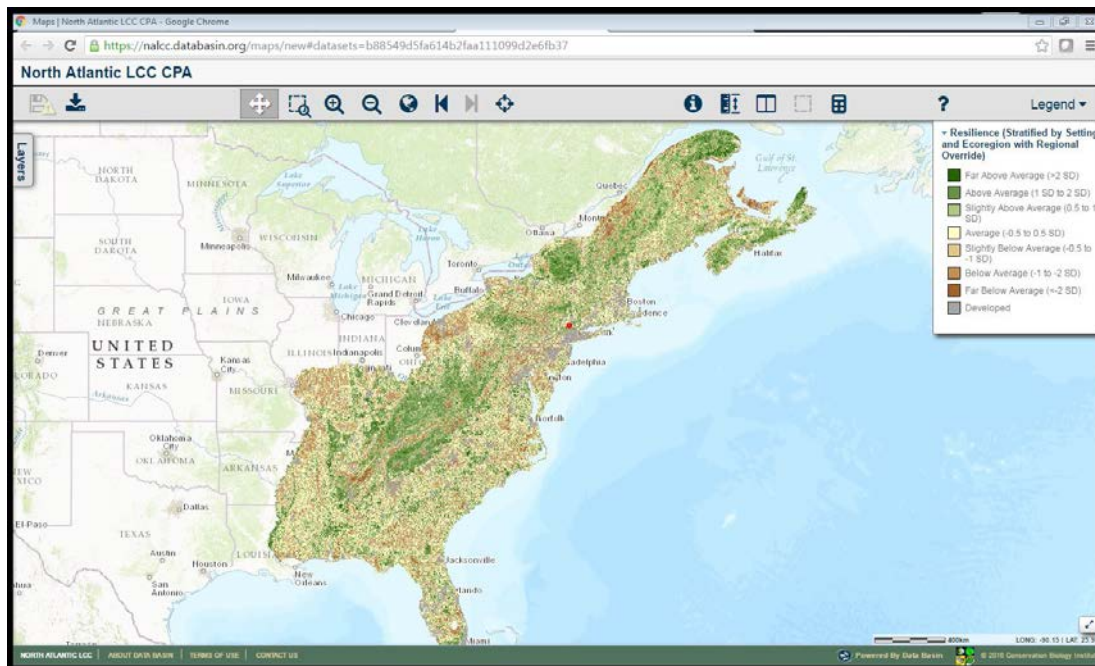
In *Terrestrial Resilience*, the darker shades of green indicate high resilience scores and the darker shades of brown indicate low scores. Tan indicates average scores.

Questions to ask as you work:

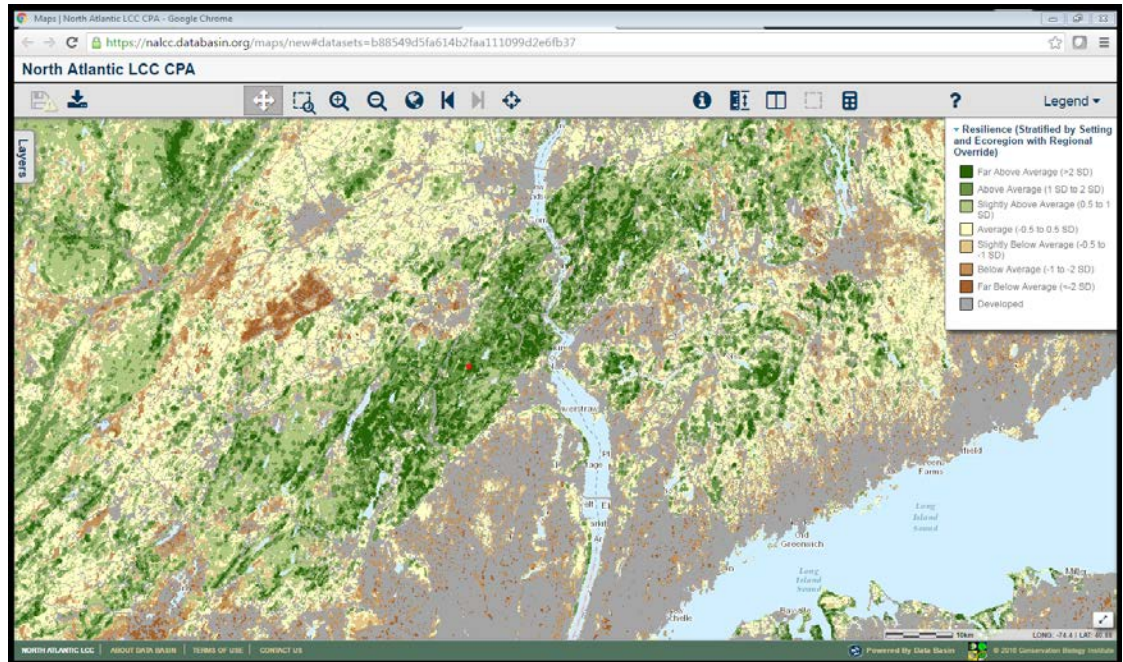
- How resilient is my geography?
- Which areas scoring above average for resilience are not yet protected?

How-to:

- 1 Go to the Land Protection in a Changing Climate gallery on Data Basin and add the Resilience Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada dataset. Zoom in to the region of interest or use the Locate tool to enter the site's name. As mentioned above, we will use Hogencamp Mountain in Tuxedo, New York (see red dot) throughout the examples. You may use other sites to follow along.

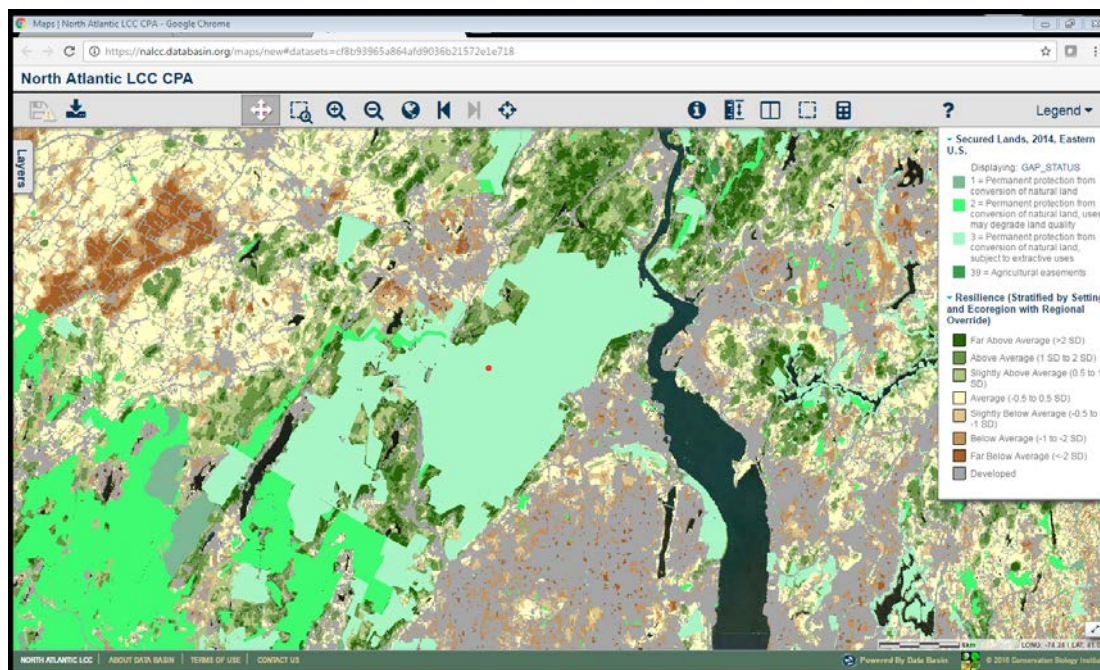


- ② **Zoom in further to the region of interest.** To orient yourself to the geography, increase the transparency by clicking on the arrow to the right of the dataset.



Here we can see that the New York and New Jersey Highlands are a resilient belt running southwest through this geography. As we'll explore below in the discussion of individual datasets, these areas score well because of their high levels of landform diversity and local connectedness compared with other, similar geophysical settings. The grey areas, where development has been taken out of the dataset, are often surrounded by low resilience (brown), because the development creates a barrier to local connectivity. The areas to the southwest and northwest are more heavily developed but have pockets of high landform diversity.

③ Add the *Secured Lands, 2014, Eastern U.S.* dataset on top of the *Resilience* dataset.



As you can see, the protected land is highly resilient. To the southwest and north of the red area are some highly resilient sites that are not yet protected. These may be appropriate targets for future land protection.

STRATIFICATION

To make sure we're protecting the best example of each habitat type or the most connected example of each geophysical setting, we can sort the data by these categories and then see the rankings within each one. This process, called stratification, allows us to identify the areas that are "best in class" rather than best overall. In other words, we compare like with like: one hemlock forest with other hemlock forests, or one limestone valley with other limestone valleys. Identifying the top example of each type or class helps ensure that the conservation plan captures sites that will support a full diversity of plant and animal life, rather than always pointing towards the high elevation acidic types that tend to be the most connected and intact. Other ways to stratify data are by ecoregion, state or watershed, to provide a regional comparison of sites. Datasets can be stratified by more than one factor at a time.

Index of Ecological Integrity

THE DATASET: *The Index of Ecological Integrity, Stratified by Ecosystem, Region-wide, Version 3.1 Northeast* (Index of Ecological Integrity) dataset, developed by the University of Massachusetts Amherst, evaluates terrestrial, freshwater and coastal intactness and connectedness in a single dataset. Because it is stratified by habitat type, it represents resilient examples of all habitats plants and animals need. Rather than comparing the relative integrity of all sites against one another, it compares the relative integrity within each habitat type, including freshwater and coastal habitats. It uses habitat diversity to capture geodiversity and landform diversity. The final product identifies the highest-scoring examples of each habitat type.

This dataset differs from *Terrestrial Resilience* in that it considers the suitability of surrounding habitats. It assumes that a site's resilience is stronger if the neighboring habitat types are similar, since similarity of habitat facilitates movement.

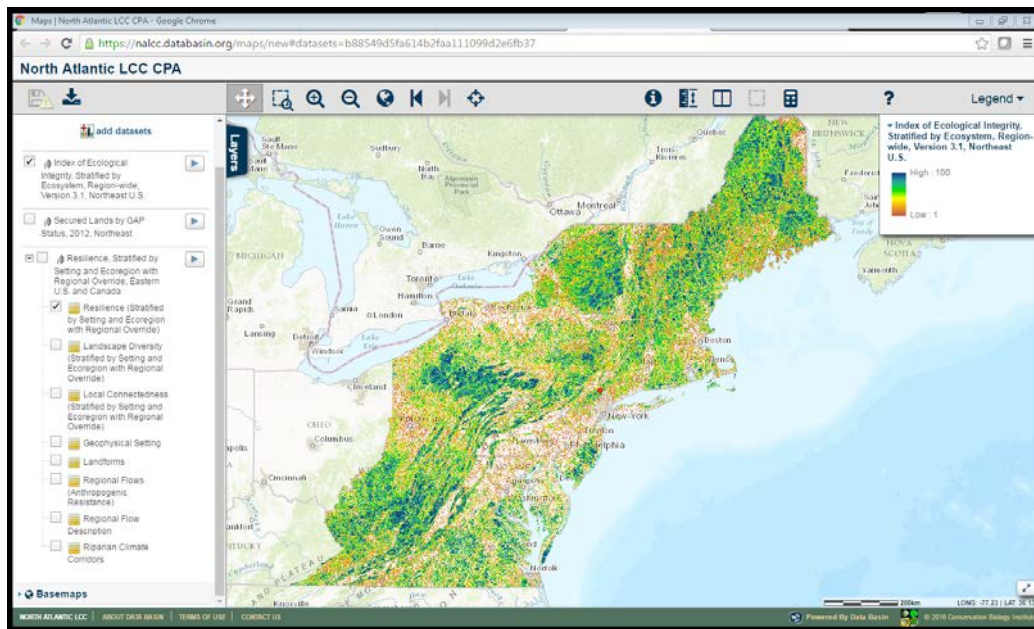
The *Index of Ecological Integrity's* freshwater component is analogous to terrestrial integrity but looks at the intactness (freedom from human impairment) in the watershed of a river, stream, lake or pond and the linear connectivity (absence of dams and barriers) in the stream. Aquatic data assesses the relative integrity of each aquatic habitat type across the region, state, watershed or ecoregion.

Questions to ask as you work:

- How does land use in the area affect integrity scores?
- How do the Index of Ecological Integrity scores compare with the Resilience scores?

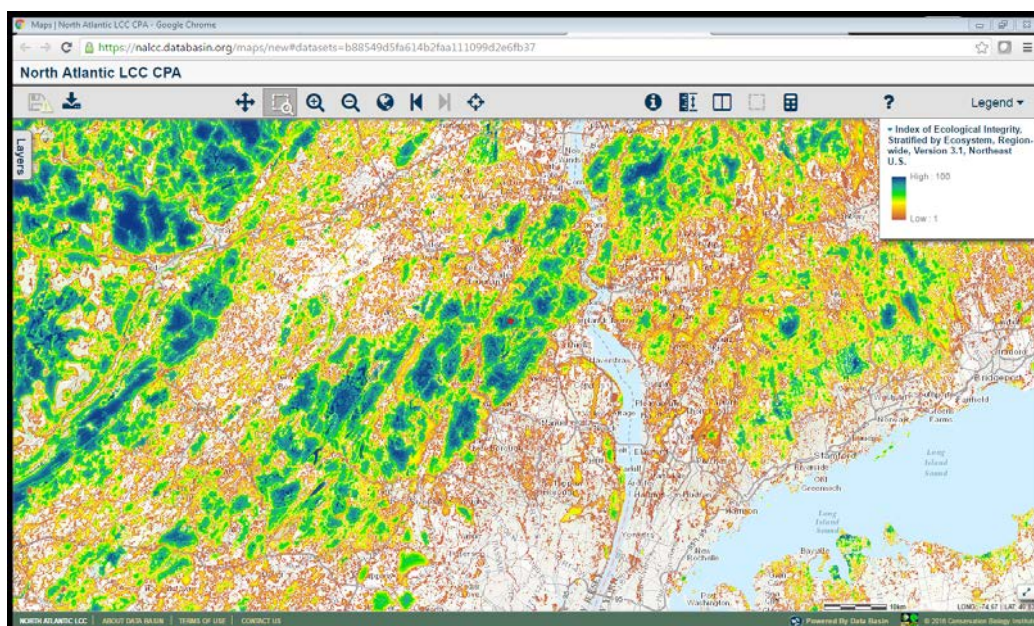
How-to:

- ① Using the same map as in the previous steps, add the **Index of Ecological Integrity Stratified by Ecosystem, Region-wide, Version 3.1 Northeast dataset**. Uncheck any other datasets in the Datasets menu on the Layers tab.



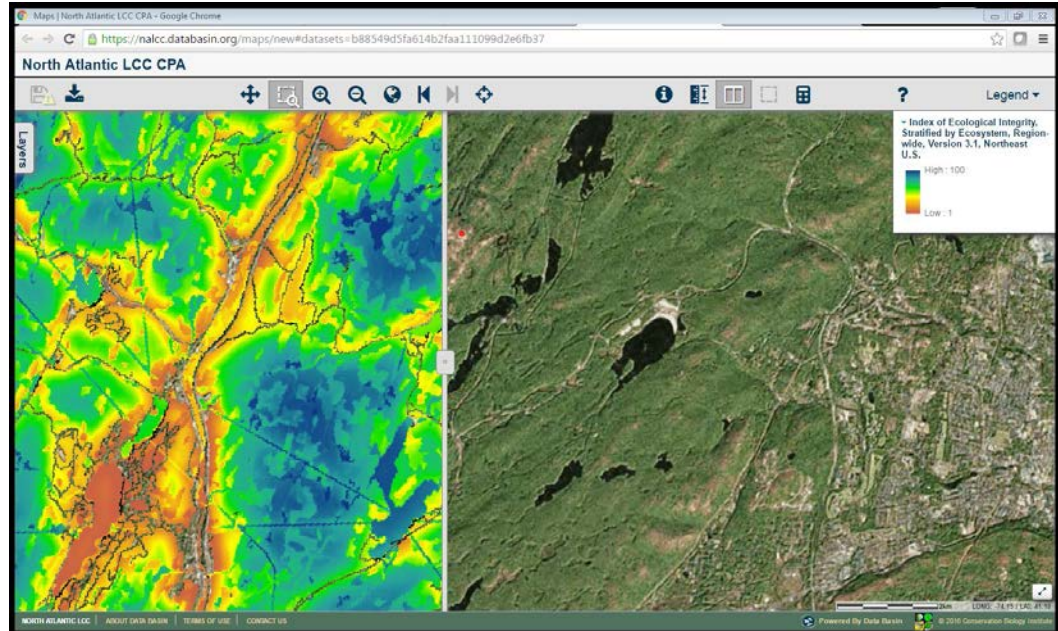
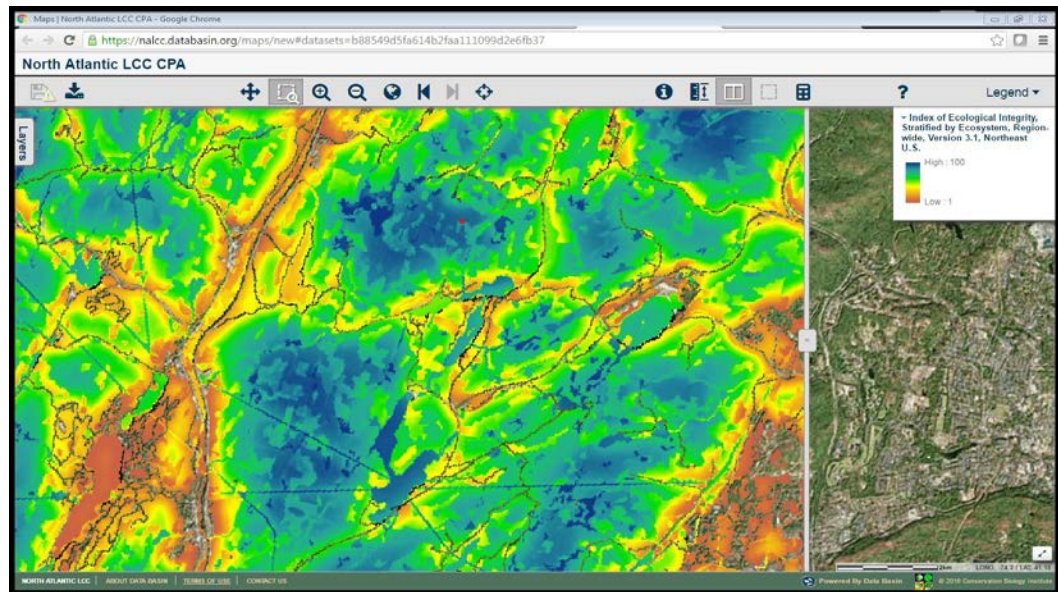
Note: the white areas represent developed areas that have been taken out of the dataset.

- ② Zoom in to the region of interest.



Cooler colors (green and blue) represent higher integrity, and warmer colors (red and orange) indicate lower integrity.

- 3 Set the base map to Imagery. Use the swiper tool to compare integrity with aerial views of the land.

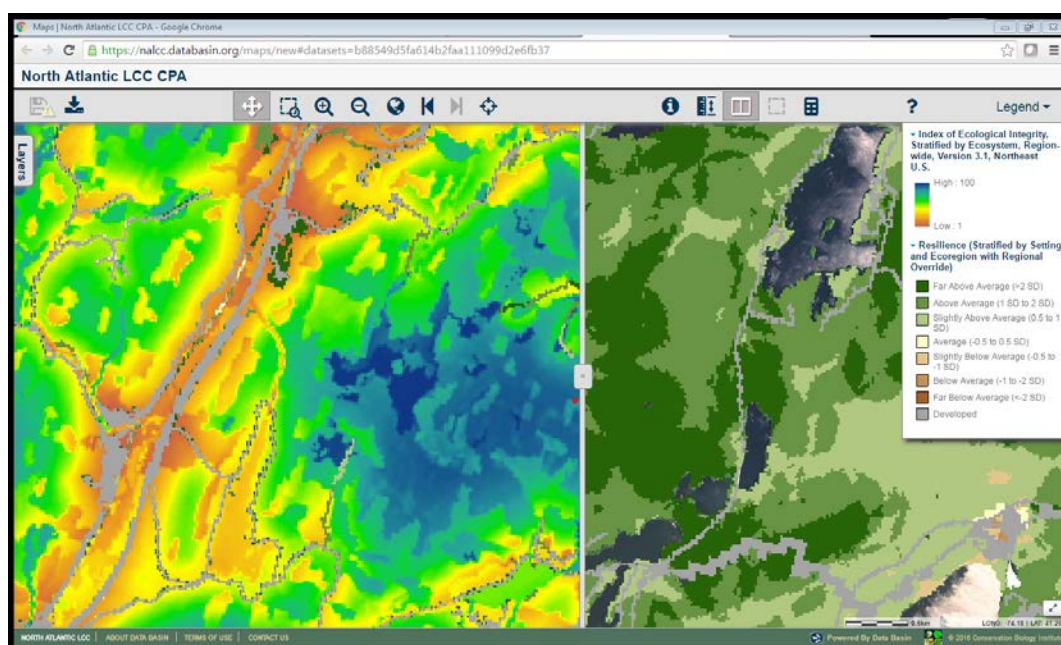


Look at the region with and without the *Index of Ecological Integrity*, using the swiper tool to shift between the data and the base map.

Areas near the high-scoring rocky summit (in blue) have no roads or clearings and score high. The blue indicates that these sites are the most intact examples of their habitat type across the northeast. Surrounding this central area are more roads and some farms, and the scores go down. Note that abrupt changes in score often indicate a change in habitat type.

④ Use the swiper tool to compare the Index of Ecological Integrity with another dataset.

This time, use the swiper tool to compare the *Terrestrial Resilience* with the *Index for Ecological Integrity*. Turn back on the *Terrestrial Resilience* layer and select the swiper tool.



In this example, the area with the highest *Index of Ecological Integrity* score also generally scores well under *Terrestrial Resilience*. The two datasets use different methods to evaluate resilience: The former stratifies data by habitat type and the latter stratifies it by geophysical setting and ecoregion, yet they largely identify similar sites as important.

The dataset confirms what we learned from *Resilience*: summit forests are generally connected, but floodplain forests can be highly affected by development. Note that the best example of a low-elevation, fertile habitat type could be located in what we might consider a relatively fragmented landscape.

Freshwater Resilience Datasets

CONCEPT REFRESHER: Freshwater resilience is a stream system's capacity to recover after a disturbance while remaining functional and biodiverse.

DATASETS: The *Index of Ecological Integrity, Stratified by Ecosystem, Region-wide, Version 3.1, Northeast* dataset measures watershed intactness and connectedness, including connectedness with a stream's floodplain, watershed impervious surface, and instream barriers for each type of aquatic habitat. The final integrity scores are stratified: stream, river, lake and pond types are compared only with similar types. For example, cool and steep streams are compared with other cool and steep streams, and lakes with other lakes. Higher integrity scores are good indicators of current and future biodiversity.

Freshwater Resilience, All Streams, Stratified by Fish Region and Freshwater Ecoregion, Northeast scores the resilience of streams that are at least second order and at least two miles long. The streams are evaluated based on their condition, diversity, resilience and complexity:

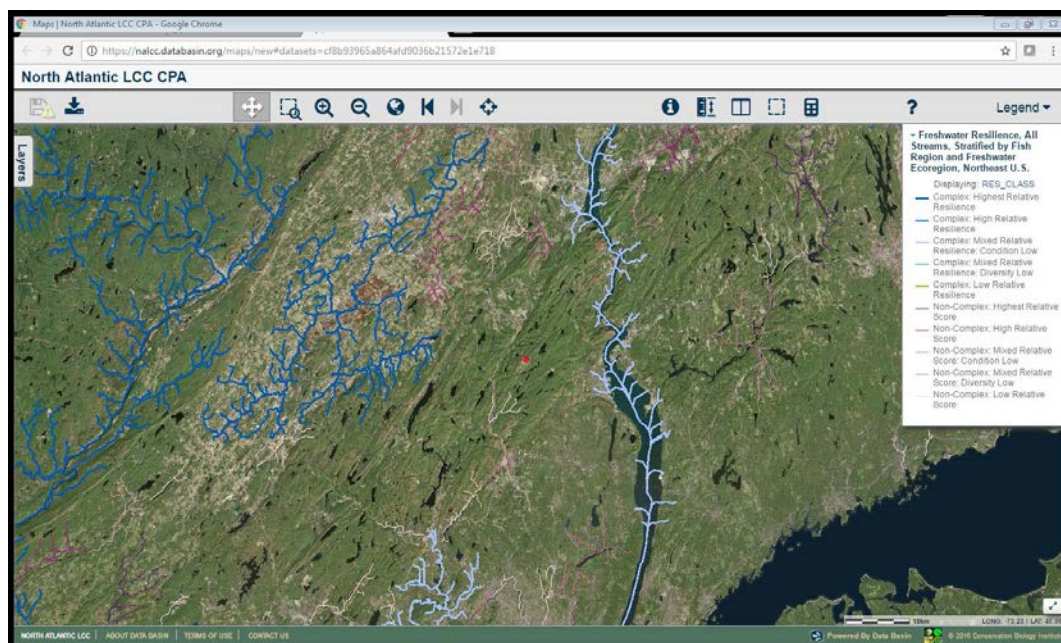
Condition is a measure of the hydrologic alterations, natural land cover in the floodplain, and amount of impervious surface in the watershed. Diversity is a measure of the number of gradients and temperatures in the stream segment.

Questions to ask as you work:

- Where are resilient streams with good condition values that might benefit from land protection in their watersheds?
- What are Index of Ecological Integrity values near above average resilient streams?

How-to:

- 1 Click **Add Datasets** and add the **Freshwater Resilience, All Streams, Stratified by Fish Region and Freshwater Ecoregion, Northeast** dataset. Uncheck any other open datasets, and then zoom in to the region of interest.



- 2 Identify the streams in your area and note how resilient they are.

Within complex and non-complex streams, relative resilience ranges from high to mixed to low. Some categories have additional details indicating whether the stream's condition is low or diversity is low.

- 3 Compare freshwater resilience with an aerial base map and look for connections between the water and the land use.

The area depicted above contains complex, non-complex, high-scoring, low-scoring, low-condition, and low-diversity streams and rivers. Many of the low-scoring, low-condition streams can be improved by reducing runoff from nearby or upstream sources (especially in headwaters). Places with impervious surfaces are more prone to flooding, regardless of the stream's score.

INDIVIDUAL DATASETS

Physical Diversity Datasets

Geodiversity

CONCEPT REFRESHER: Geologies and elevation classes (e.g., high, medium and low) are two drivers of biological diversity. If we can protect the full range of geologies across the full range of elevations, we are off to a good start protecting the full range of environments that support plants and animals. To date land protection has been concentrated in high elevation acidic rock types.

THE DATASET: *The Geophysical Setting, 2016 Eastern U.S. and Canada* dataset maps out the basic bedrock and surficial geology classes across the Northeast and combines them with five classes of elevation data to define 62 geophysical settings.

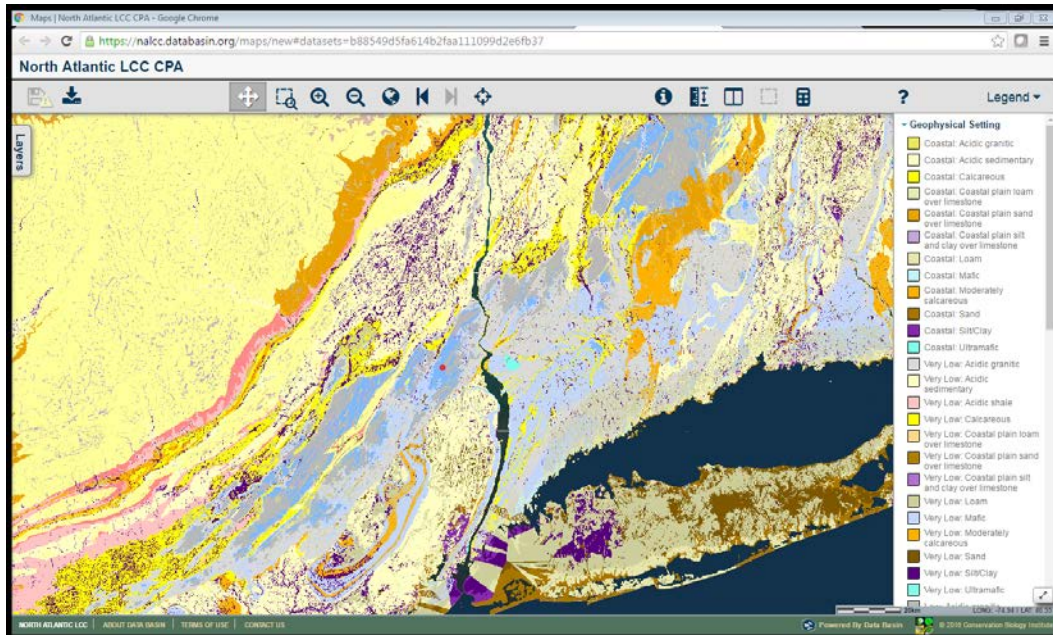
This dataset can help ensure that our land protection priorities cover the full range of geologies and elevations in areas of interest. If we work in an area with only one or two types of geology, knowing this can still help us understand its regional contribution to geodiversity. We can then focus on protecting the most resilient and intact examples of these geologies.

Question to ask as you work:

- How geologically diverse is the geography in which I work?

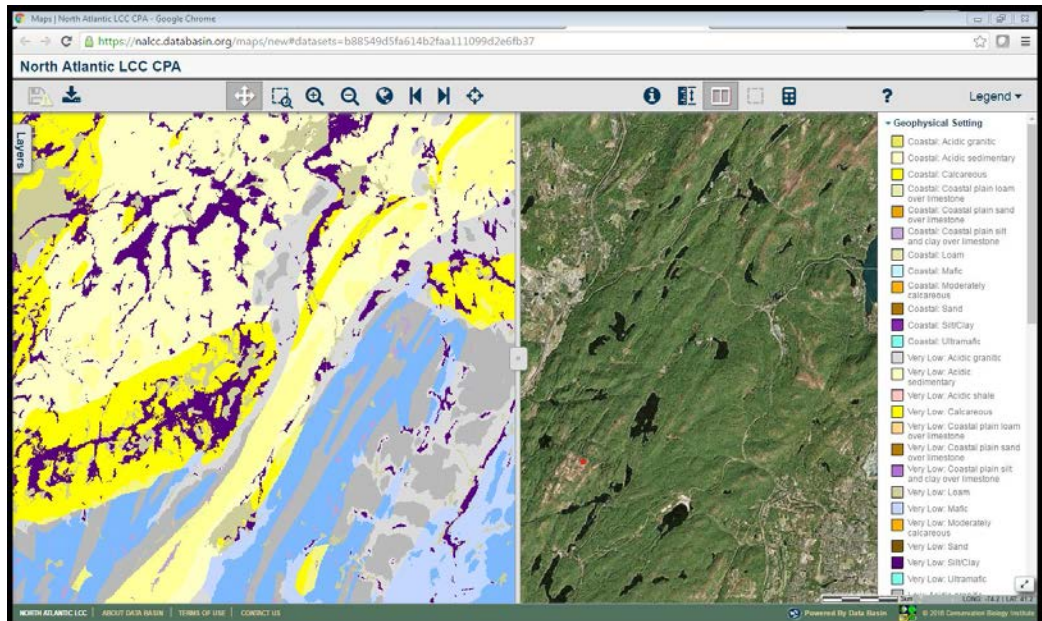
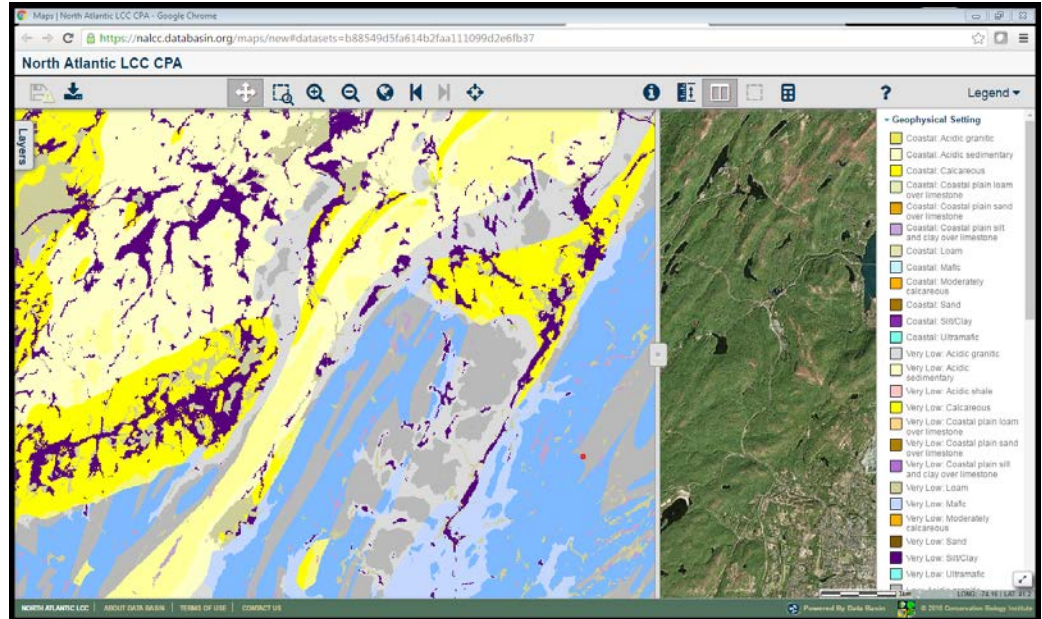
How-to:

- 1 Add the *Geophysical Setting, 2016 Eastern U.S. and Canada* dataset to the current map. Zoom in to the region of interest or use the Locate tool to enter the name of the site.



The yellow surrounding the region is largely sedimentary rock with bright yellow and orange showing where calcareous (i.e. limestone) or moderate calcareous deposits were exposed when the Appalachians were formed. The Highlands are largely composed of granite (grey) and mafic (blues) rocks.

② Use the swiper tool to compare geology with land use.



On the Layers tab, set Basemaps to Imagery. Now look at the region with and without the geophysical settings dataset. Use the swiper tool to shift between the data and the base map. Hogencamp Mountain is mostly granitic and mafic, with limestone deposits surrounding it. We see more development associated with those rich, low elevation valleys. Note how in the above illustration the bright yellow (calcareous) triangle to the north of Hogencamp Mountain is largely developed.

Underrepresentation and Secured Status

CONCEPT REFRESHER: If we examine the pattern of land use across the Northeast, we find human communities concentrated in low-elevation fertile settings and habitats: river valleys, coastal regions, and places with limestone (prime) soils. Meanwhile, conservation lands tend to be concentrated on steep, acidic rock types. Balancing the conservation portfolio to make more rich, fertile low elevation settings for species will be essential for providing a spectrum of environments to support species diversity.

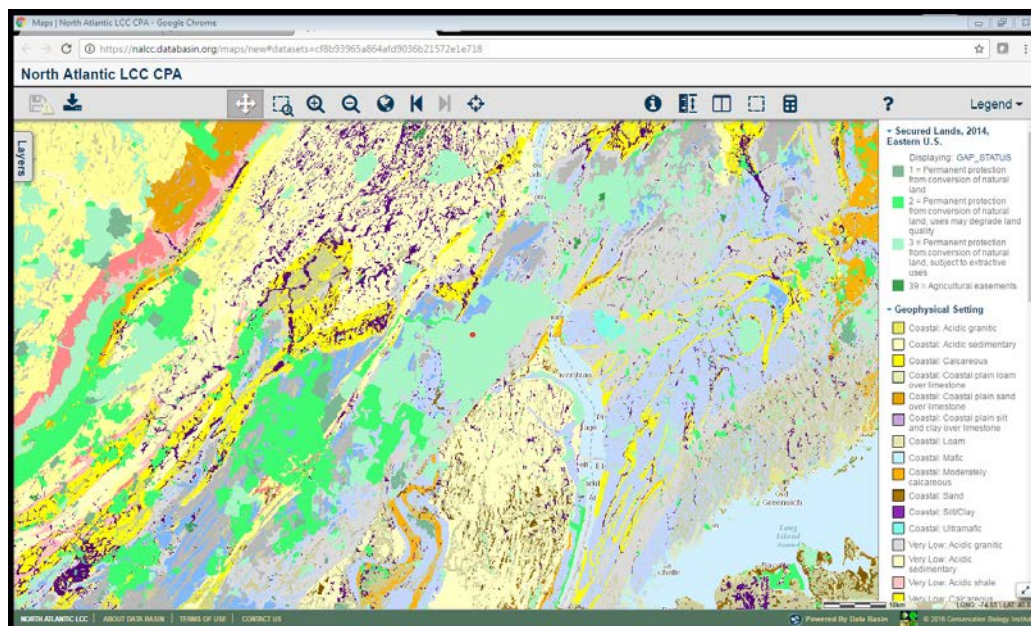
THE DATASETS: We can quantify the relative protection of different geophysical settings and habitat types, thereby identifying types that are underrepresented in conservation. Here we will combine geophysical data with protected-areas data to identify bias in our protected lands. *The Secured Lands, 2014, Eastern U.S.* dataset identifies which lands have legal protections from development and also their GAP status—the type of restrictions currently in place. GAP status is measured on a scale of 1 to 3 and color-coded on the dataset. GAP 1 lands have management plans developed for the express purpose of protecting wildlife and do not allow extractive uses. GAP 3 lands are protected but allow for multiple uses. Even protected land is not necessarily free from barriers to movement, however, and protected status alone does not guarantee that the land will remain unchanged.

Question to ask as you work:

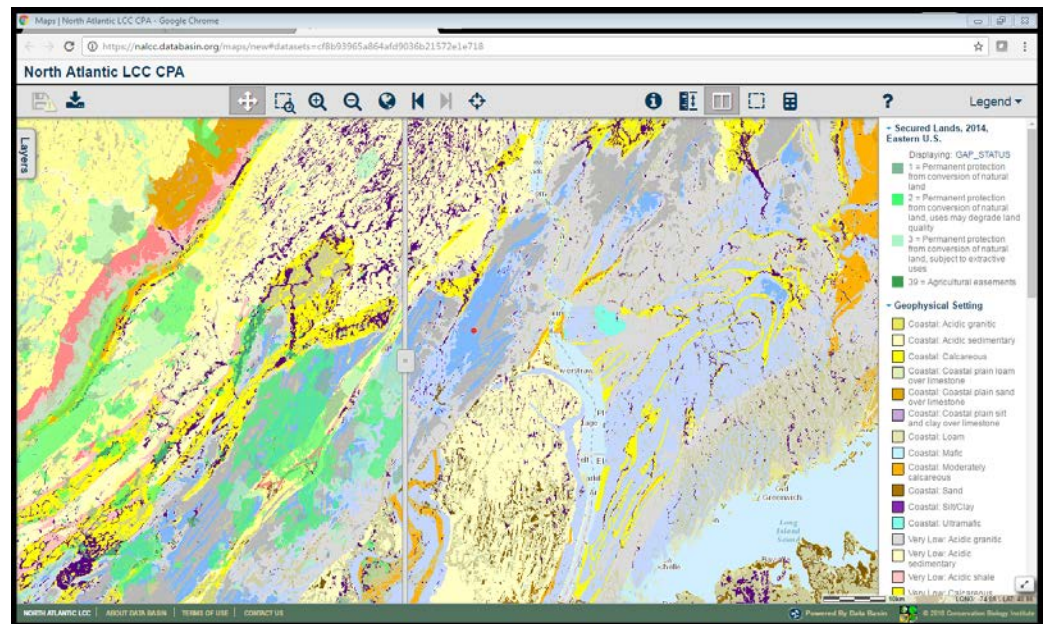
- How well protected are low-elevation geophysical settings in my service area?

How-to:

- ① Turn on the **Geophysical Settings** and the **Secured Lands, 2014** datasets together.



- ② Use the swiper tool and transparency to explore which settings are well protected and which settings have very little protection.



You'll quickly notice that the greys (granite) and blues (mafic) are well protected, especially those types concentrated in mid- and high-elevation settings. By zooming in, you can also begin to explore where low-elevation geologies are protected and what types of settings require more protection. Additional analysis of underrepresented settings can be conducted in GIS.

Diversity of Habitat Types

Geodiversity is a major driver of habitat type. Our evaluation of diversity can be further refined through consideration of how well land protection conserves the full range of habitat types. Note that this data layer adds a biological component to our assessment of diversity and that the *Index of Ecological Integrity* provides an efficient way to evaluate the examples of each habitat type that are most connected and intact.

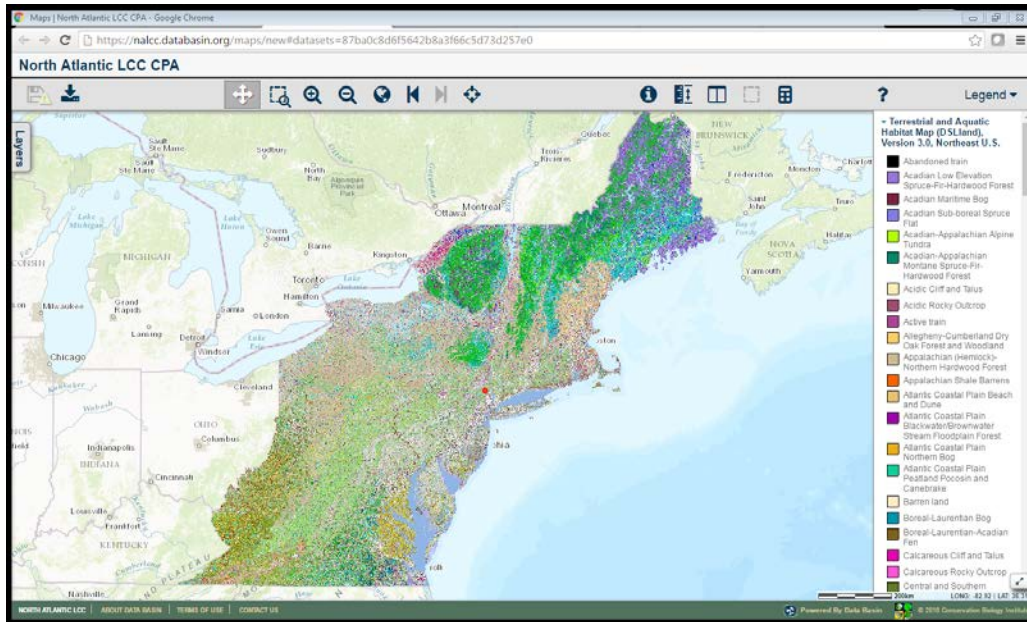
Question to ask as you work:

- What habitats are present in my service area?

How-to:

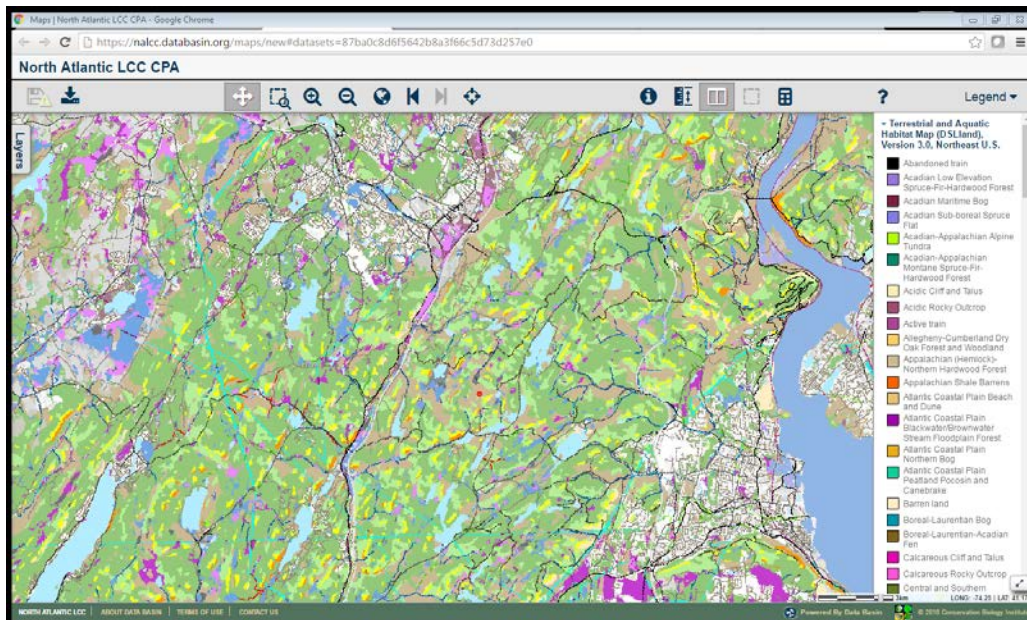
① Add the *Terrestrial and Aquatic Habitat Map (DSLland), Version 3.0 Northeast* dataset.

Uncheck any other open dataset in the Datasets menu on the Layers tab so that only the *Terrestrial Habitat* dataset appears.



This dataset includes the 150 ecosystems present in the Northeast.

② Now enter the location or zoom in to the area of interest.



By zooming in, we can identify the diversity of habitats at Hogencamp Mountain. Development (grey, white and black) occurs primarily in this area's valleys, away from the red point that represents Hogencamp Mountain. The bright pinks represent calcareous (limestone) rocky outcrops and you can see them lining the developed areas. Hogencamp Mountain itself is composed largely of central oak-pine, northern hardwood and conifer habitat types.

Landform Diversity

CONCEPT REFRESHER: The more landforms—slopes, valleys, cliffs and so on—the more options resident species have to adapt their temperature and moisture levels locally. Think of a landscape whose north-facing slope still retains snow in April and whose south-facing slope loses snow in early March. These microclimates buffer species from the direct effects of climate-related changes by providing a variety of local habitat options. A landscape with microclimates is expected to retain plants and animals longer because they don't need to move far to find their optimal climate, even when that habitat has shifted location.

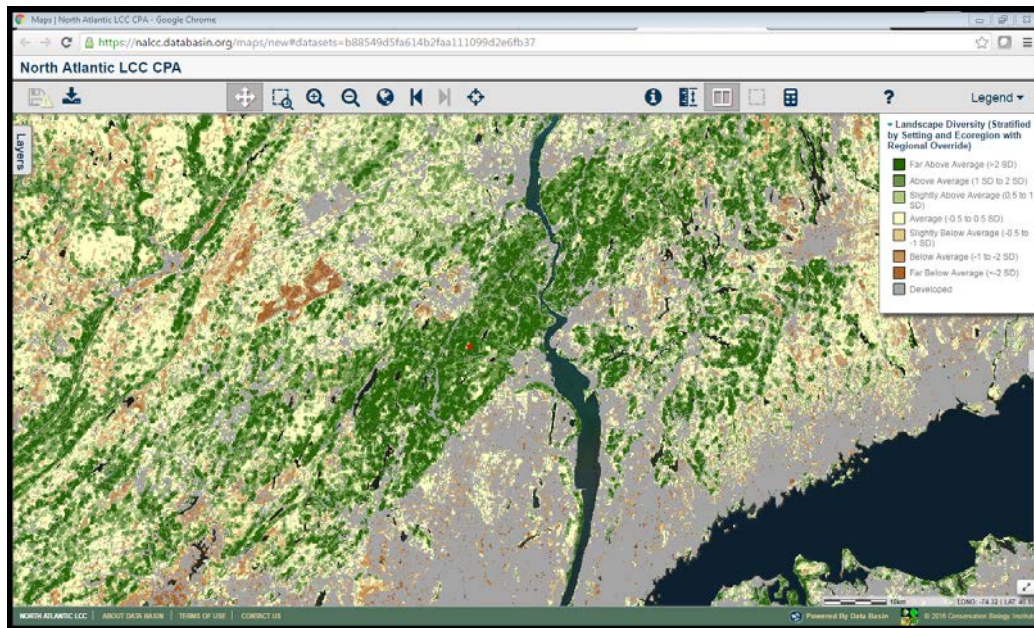
THE DATASET: TNC has developed the *Landscape Diversity Stratified by Geophysical Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada* dataset to evaluate distinct landform types within the circumference of a 100-acre area from the site being evaluated. Landform diversity is evaluated separately for each geophysical setting. For example, areas with a low-elevation calcareous (limestone) geology within each ecoregion across the entire Northeast are compared and ranked accordingly. This dataset identifies the areas of highest landform diversity for each setting.

Question to ask as you work:

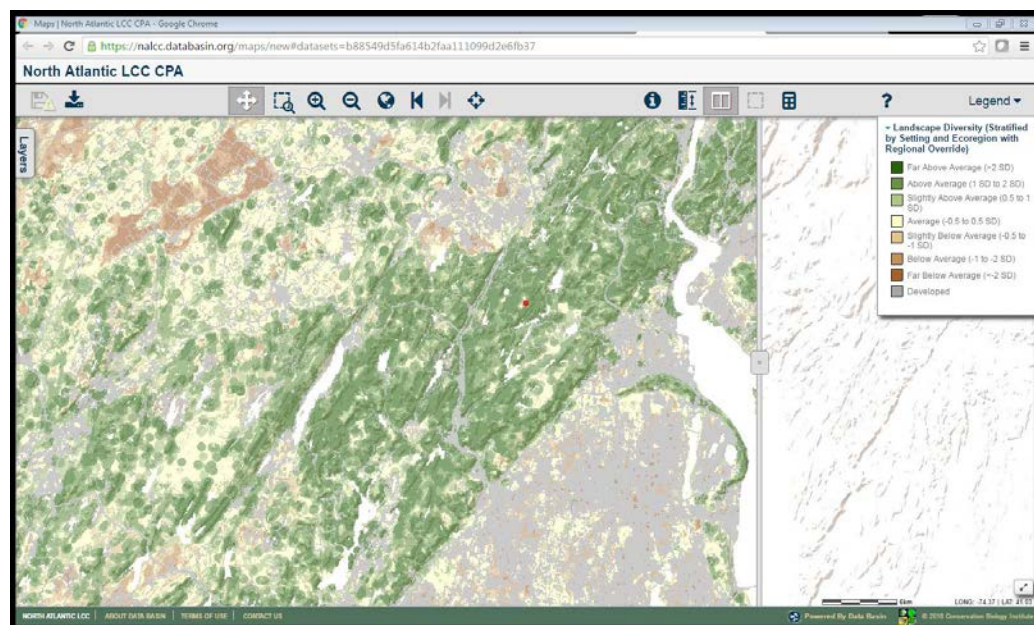
- Are there some places with a greater concentration of diverse landforms than others?

How-to:

- 1 Click **Add Dataset** and add the **Landscape Complexity Stratified by Geophysical Setting and Ecoregion, Northern Appalachians** dataset. Switch to the **Terrain** base map so that you can confirm the presence of landforms. Uncheck any other datasets using the **Datasets** menu on the **Layers** tab. Zoom in to the region of interest.



- 2 Use transparency and the swiper tool to ground-truth the landform diversity scores.



Remember that landform diversity looks different for different geophysical settings. Granite and silt, for example, each create very different landforms. Generally, areas with the highest density of shadowing have high landform diversity. Around Hogencamp Mountain, landscape diversity is concentrated in the Highlands, but the flat areas also have some variety of landforms due to subtle depressions in wet flats. Other areas in the south-central part of this map do not have much landscape diversity.

Connectedness Dataset

CONCEPT REFRESHER: Connectedness is important for protecting biodiversity as the climate changes because it facilitates movement, provides access to local microclimates and nutrients, and enables ecosystem processes to continue. We will review three map-based tools developed to assess connectedness at a variety of scales: an index of ecological integrity, a local connectedness dataset, and a regional connectivity dataset.

Local Connectedness

CONCEPT REFRESHER: Local connectedness creates options for species movement within areas free of human and natural barriers.

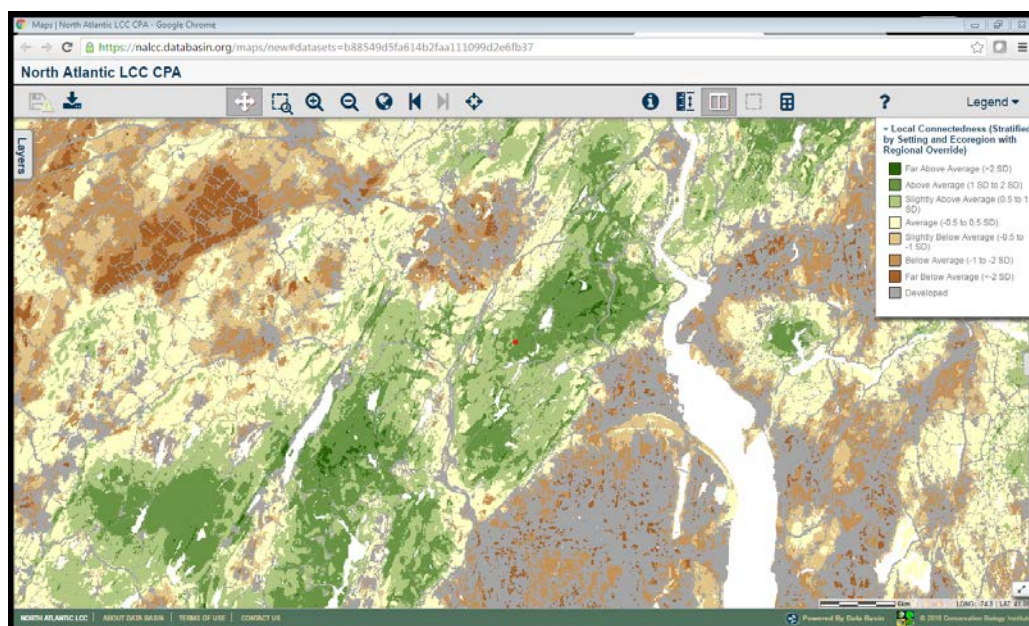
THE DATASET: We will use the *Local Connectedness Stratified by Setting and Ecoregion with Regional Override, 2016 Eastern U.S. and Canada* dataset, which is a component of the TNC Resilience dataset. It provides general guidance on the possibility of plant and animal dispersal across the landscape and evaluates a landscape's capacity to support natural ecological processes. It does not consider the habitats' similarity or even geologies in the surrounding area, only human-created barriers (such as roads, farms and development) and natural barriers to movement (such as rivers).

Questions to ask as you work:

- What barriers exist that may reduce connectedness?
- How does secured status relate to local connectedness scores?

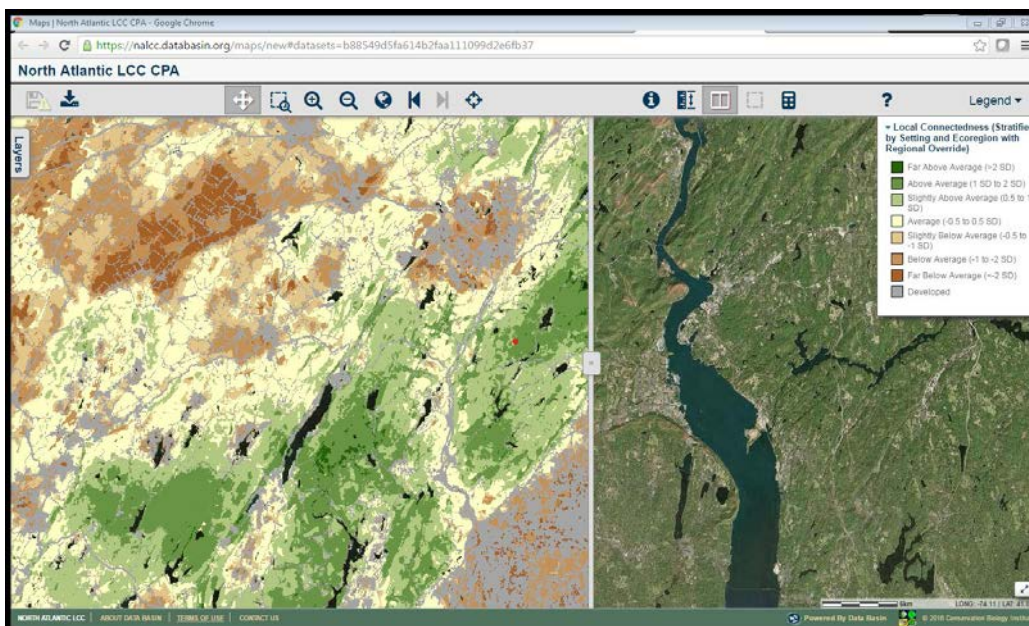
How-to:

- 1 Add the **Local Connectedness Stratified by Setting and Ecoregion, Northern Appalachians dataset**. Hide any other datasets using the Datasets menu on the Layers tab. Enter the location or zoom in to the region of interest.



Here, the data shows development (grey) surrounded by low local connectivity (browns) with the Highlands as a band of more connected (green) running through the center.

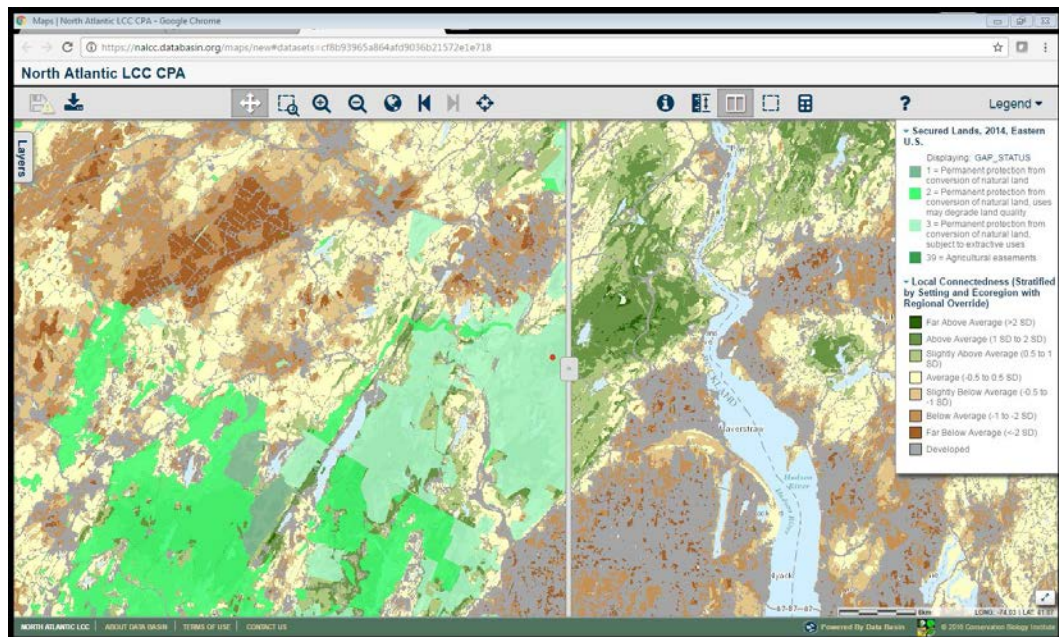
- 2 Use the swiper tool to compare connectedness with land cover.



First, set the base map to Imagery. Look at the region with and without the dataset, using the swiper tool to shift between the data and the base map. Switch the base map to see new aspects of the land and continue to view the area with the different base maps.

This comparison is helpful for identifying barriers to connectedness. The cluster of roads—apparent only on the base map—prevents species movement. However, as the development gives way to Bear Mountain State Forest, there are fewer obstacles, leading to greater local connectedness.

- ③ Add or turn on the *Secured Lands, 2013, Eastern* dataset and use the swiper tool to compare local connectedness in the area with the secured lands in the same area.



Click and drag the swiper between the two datasets in the Datasets tab. By comparing secured status and local connectedness, you can see that protected areas tend to have above-average connectedness, but sometimes protected land is compromised by roads and visitor centers, as on the left. This information is also helpful for identifying connected areas that are not yet protected. In this case, the area just northeast of the center is connected but not yet permanently protected.

Regional Connectivity

CONCEPT REFRESHER: Regional connectivity is a measure of the ability to move through a region from point A to point B. Regionally connected places will support range shifts and broad-scale movement as the climate changes.

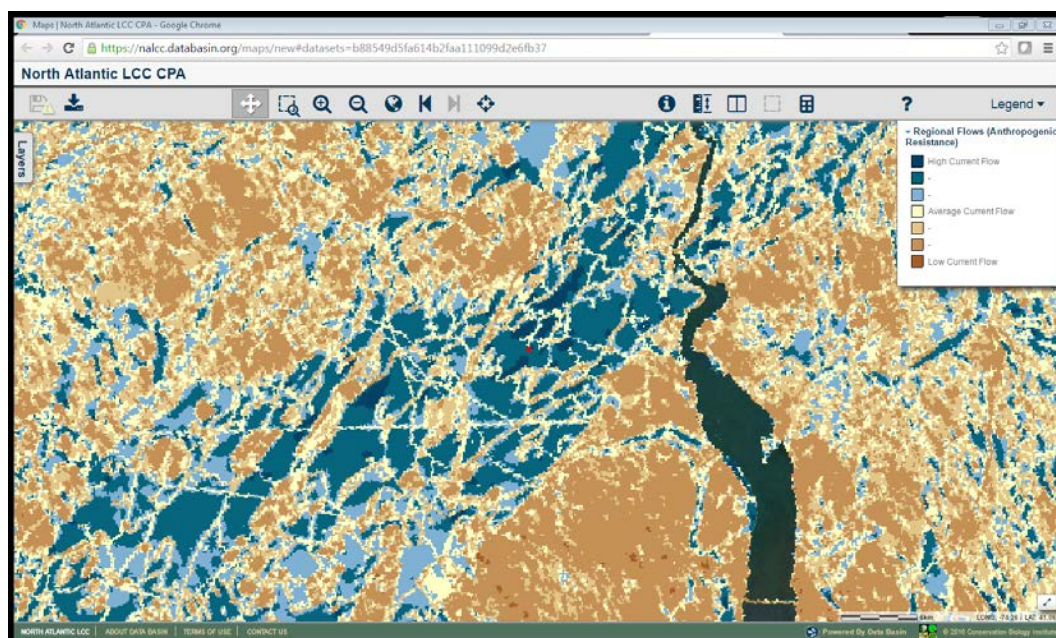
THE DATASET: The *Regional Flow 2016, Eastern U.S. and Canada* dataset, developed by TNC, provides a generalized model of movement potential in north-south and east-west directions. When considering regional flow, keep in mind that different species have different abilities to circumvent barriers. Based on tracking and other techniques, The Nature Conservancy recently conducted a review of how well the regional flow dataset corresponded to observed species movement; the correspondence across the eastern United States was very high.

Questions to ask as you work:

- Are there significant barriers to movement in this area?
- What lands would need to be protected to enhance regional connectivity in this area?

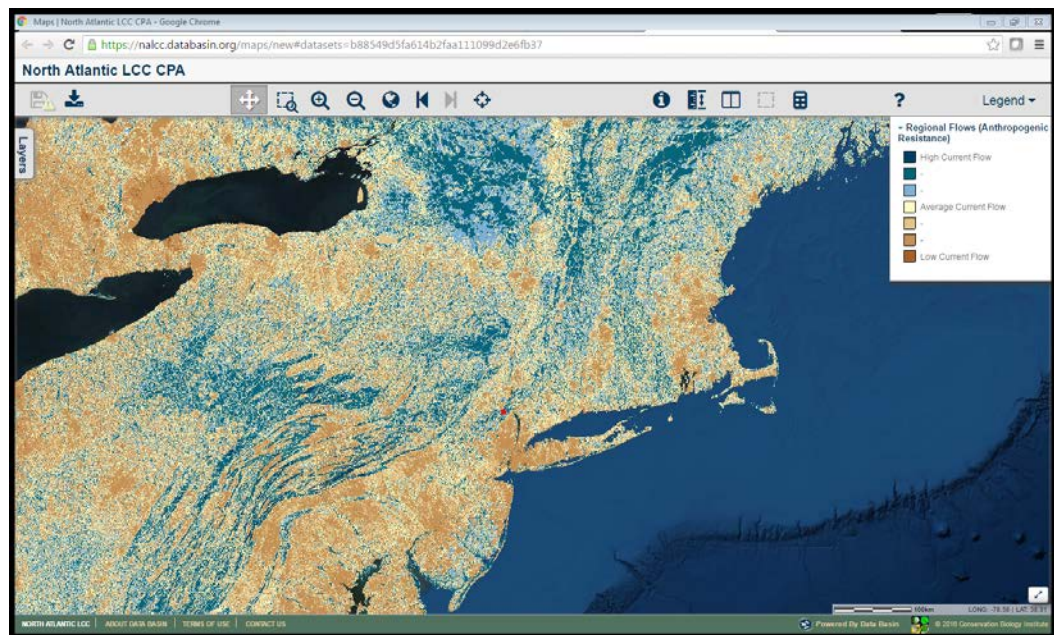
How-to:

- ① Using the same map as in the previous steps, add the **Regional Flow Patterns, Northern Appalachians dataset**. Uncheck any other datasets in the Datasets menu on the Layers tab. Zoom in to the region of interest.



Dark blue areas indicate the highest levels of connectivity; light blue, yellow and brown indicate increasingly lower connectivity. Barriers to regional connectivity are often the same as for local connectivity: Roads, development, agriculture and water bodies can all create barriers.

- ② **Zoom out to view region-wide options for movement.** When you zoom out, the data provides a region-wide view of options for movement. From that view it is evident that the Highlands (locate the red dot) are one of the only options for species to migrate from the Central Appalachians to the Northern Appalachians. By zooming in it is possible to identify specific land protection targets to augment regional connectivity.



BIOLOGICAL CONDITION

CONCEPT REFRESHER: Biological condition describes the potential for a site to support biological diversity today and into the future as a result of the absence of stress, and the availability and quality of natural resources at that site.

Biological condition can be assessed regionally using the *Index of Ecological Integrity*. In addition, the current species diversity can be assessed using regional or statewide datasets on rare and endangered species. The state wildlife action plans developed by each state's wildlife or game department often include map-based datasets on biological diversity and species rarity. (These datasets often require data-sharing agreements because of the sensitive nature of the information.) It is important to assess the biological condition of an individual site before protecting it as a resilient site. Biological inventories or other site-based evaluations are valuable if there is time.

PUTTING IT TOGETHER

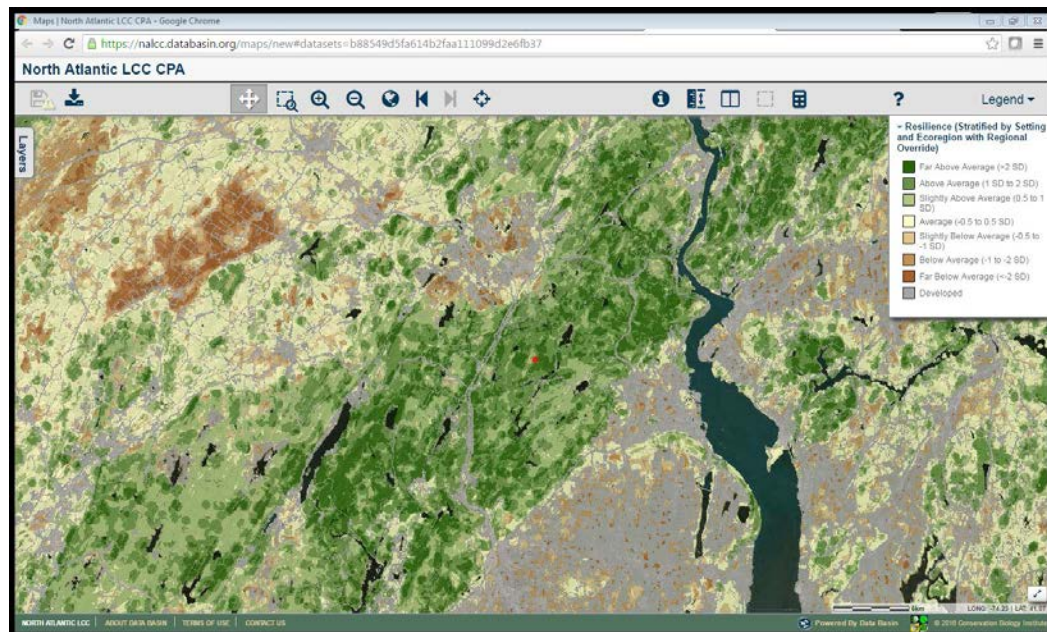
Combining the datasets described above and summarized in Table Y allows a conservation practitioner to learn a great deal about the landscape.

Questions to ask as you work:

- Are there any geophysical settings or habitat types that have no protection?
- Is the land likely to be resilient and continue to host plants and animals as the climate changes?
- Are there microclimates in the area?
- Would species be able to move within and through the area? Why or why not?

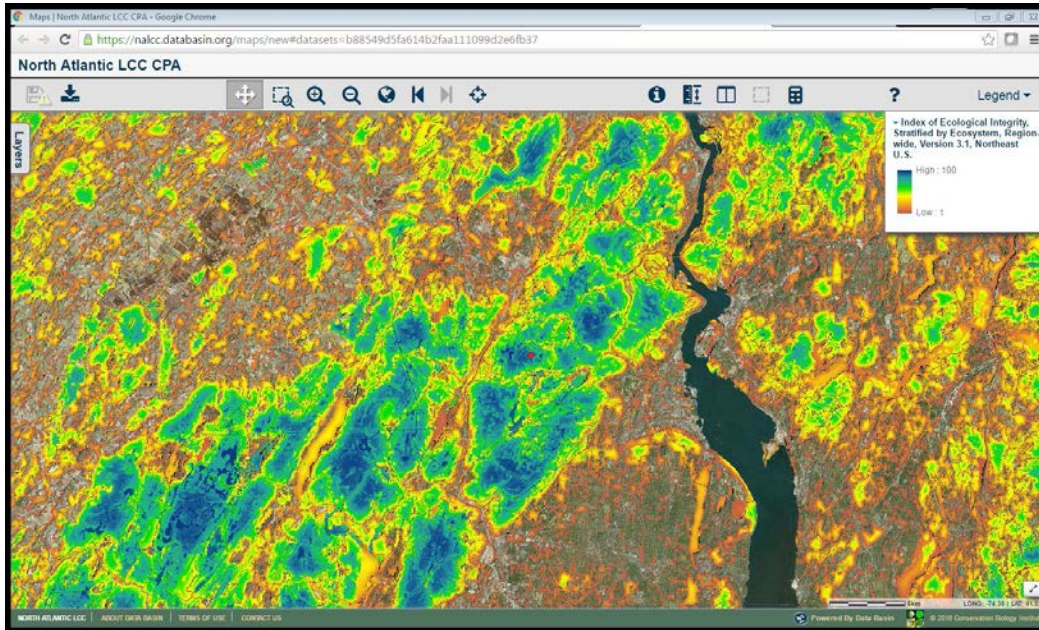
Hogencamp Mountain exemplifies many individual characteristics of resilience. We will now look at the region as a whole and see how these characteristics work together.

1. Resilience



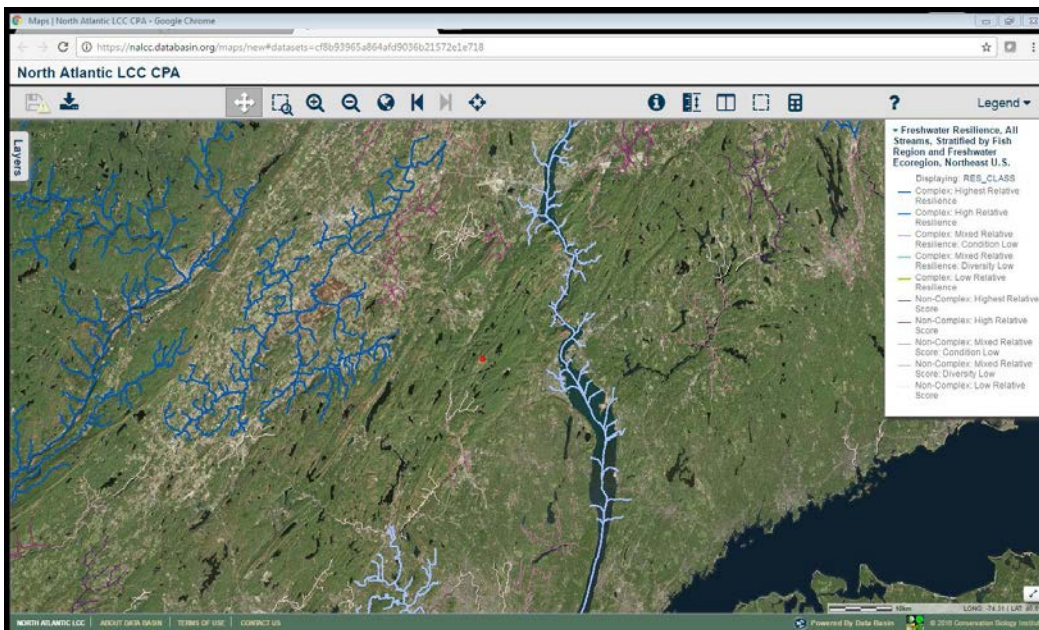
The area has above-average (light green) and far above-average (dark green) resilience at the center, transitioning to less resilient areas (tan) on each side.

2. Ecological Integrity



According to the *Index of Ecological Integrity*, the center of this region (blue) is largely intact. However, Hogencamp Mountain is surrounded by roads and fragmented habitats.

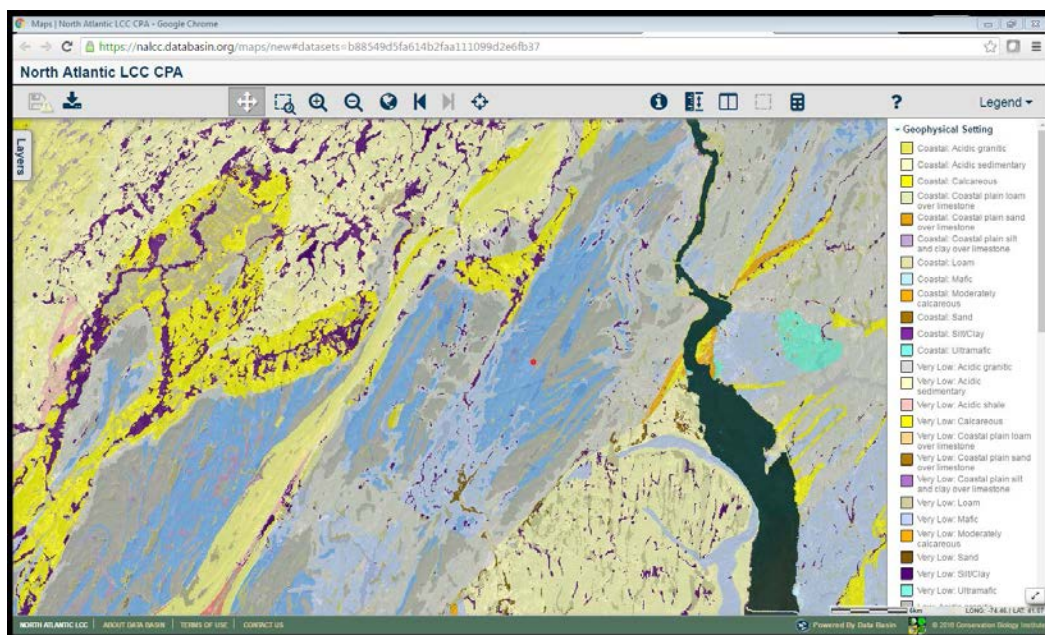
3. Freshwater Resilience



The regional streams shown here are affected by the surrounding land uses. Scores for the streams in this region range from non-complex and low-resilience to complex and high-resilience in more intact areas.

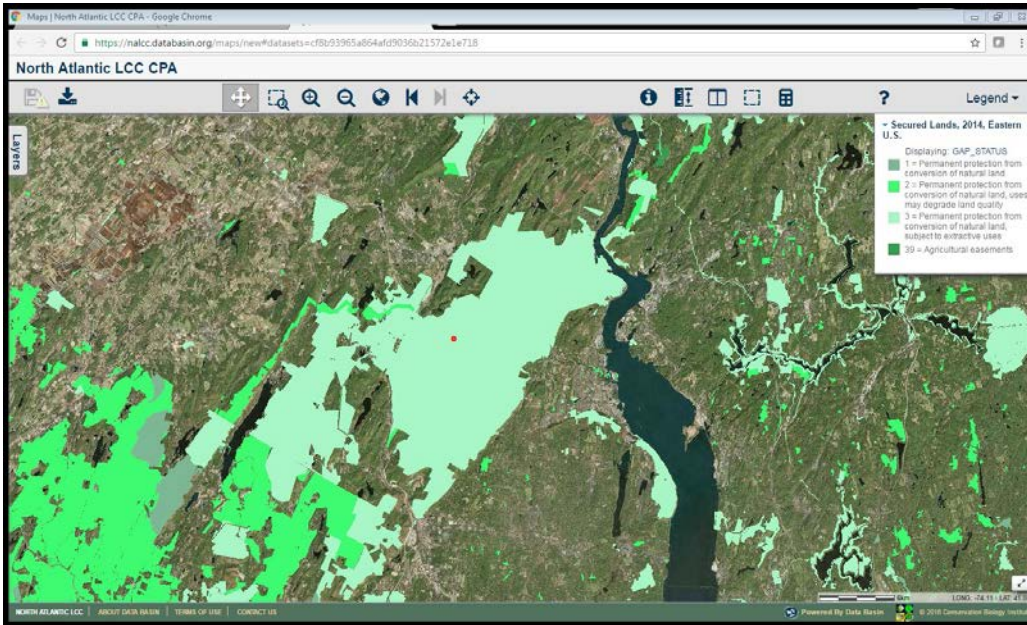
The freshwater scores for the *Index of Ecological Integrity* can also be assessed by reviewing the scores that dataset gave to stream corridors.

4. Geodiversity



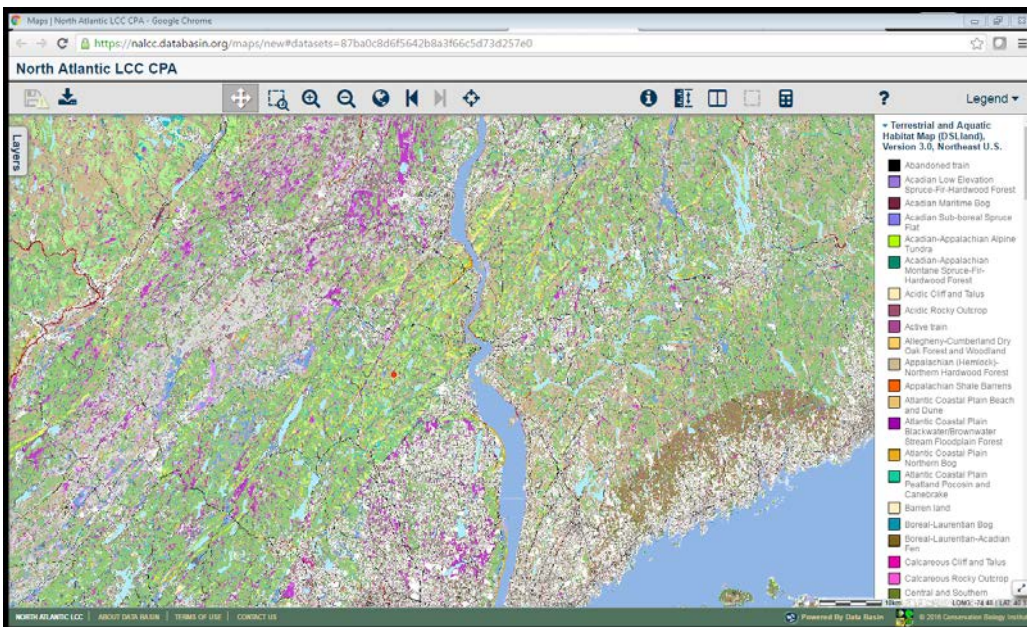
Protected areas consist of mafic (blue) and granitic (gray) geologies, and agricultural and developed uses are in limestone (bright yellow) geologies.

5. Secured Status



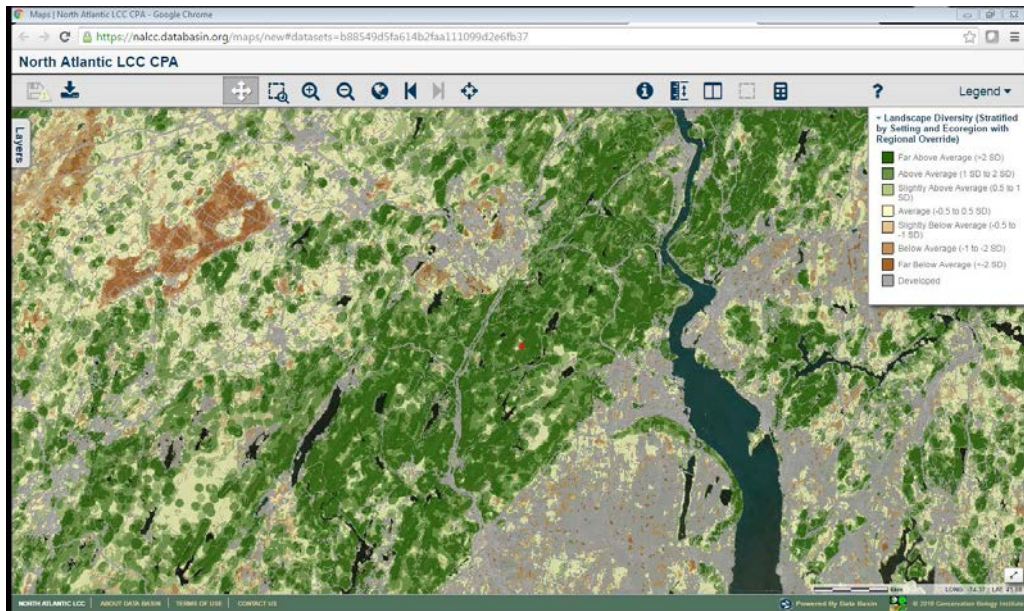
Much of the land is secured as State Park. Future priorities can be identified.

6. Representation of Habitats



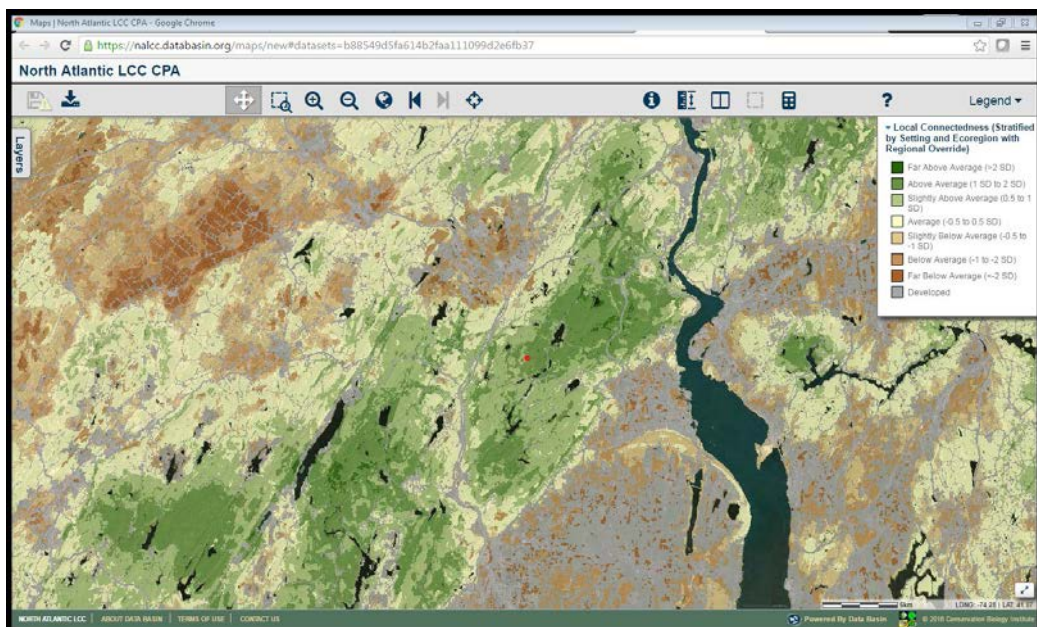
The area has a range of habitats.

7. Landform Diversity



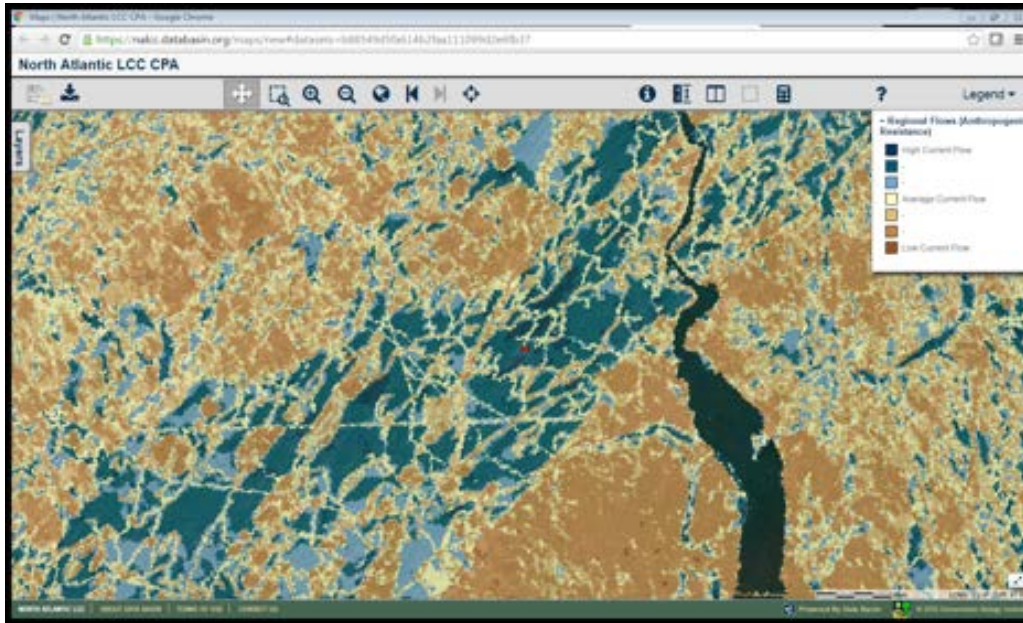
The landscape scores high for landscape complexity. Areas with above-average complexity (green) are likely to have more microclimates. The areas with high levels of complexity enhance the land's pre-existing resilience.

8. Local Connectedness



The state park has above-average scores for local connectedness, but the land uses surrounding the region disrupt the connectedness.

9. Regional Connectivity



Looking at regional movement, we can identify the pinch points where species need to move across barriers.

10. Biological Condition

This characteristic can be assessed using the *Index of Ecological Integrity*, local datasets and field-based assessments.

KEY LESSON:

Many factors combine to determine the resilience of this area. Despite some barriers to connectedness, the landscape is a good example of integrity and complexity. The abundance of microclimates—its most remarkable feature—argues for improving the connectivity of this landscape. Protection is needed to ensure remaining resilient sites are not developed and to augment regional connectivity through the region.

Depending on a land trust's conservation planning goals (wildlife, water quality, etc.), you will need other datasets to complement the climate screen provided by the resilience-related datasets. By combining climate-related data with existing priorities, you can conserve land not only for its value today, but also for its value into the future.

ANTICIPATED DATA UPDATES

Coastal Resilience

The North Atlantic LCC, using the Interior Department's Hurricane Sandy disaster mitigation funds, is working with the University of Massachusetts to improve the relevance of the *Index of Ecological Integrity* for coastal ecosystems. A new version should be available in late 2016 or 2017.

The LCC is also working with The Nature Conservancy to improve the *Resilience* products for coastal systems, also due in late 2016 or 2017.

Predicting Future Change

The authors of the *Index of Ecological Integrity* at the University of Massachusetts Amherst are working on tools that predict future development and impact of climate change on the integrity of habitat types.

Freshwater Resilience

Finally, The Nature Conservancy is developing an updated version of the *Freshwater Resilience* dataset that will be more user-friendly and include scores for all stream segments. The dataset will be available in late 2017.



PART 3

CASE STUDY: STRATEGIC CONSERVATION PLANNING

CONTENTS

Planning for Climate-Resilient Conservation

How the North Quabbin Partnership Created a Climate-Inclusive Conservation Plan

Step 1: Reorienting Their Focus and Voting Their Values

Step 2: Refining Choices and Sketching a Model

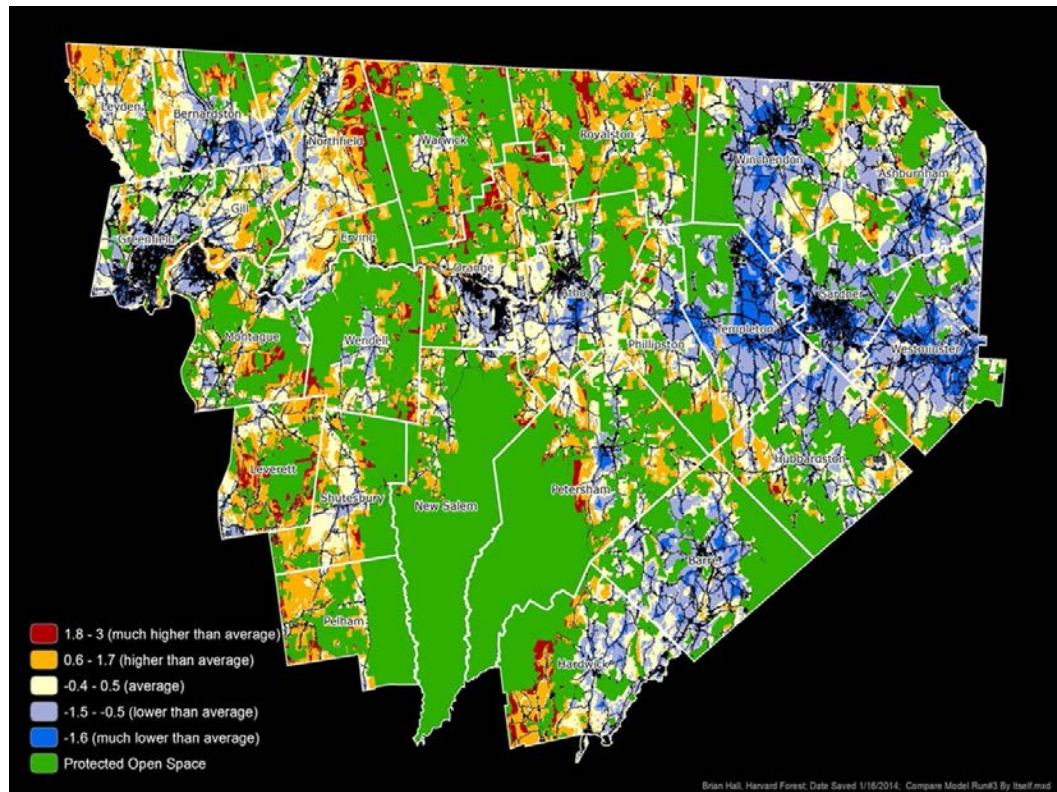
Step 3: Making Final Decisions

Step 4: Implementation and Outreach

Step 5: Reflecting on Lessons Learned

Following in Their Footsteps: How You Can Take Action

CASE STUDY: STRATEGIC CONSERVATION PLANNING



Final map of the North Quabbin Regional Landscape Partnership conservation priorities, completed in early 2014 with a planning grant from Open Space Institute.

Looking at a color-coded map of north-central Massachusetts in early 2014, members of the North Quabbin Regional Landscape Partnership saw areas of their region that appeared to have been spattered with red and orange paint. These color spatters were figurative red flags, alerting the partners to places whose characteristics made them potential strongholds for plants and animals in the face of climate change. One such oasis was the town of Hardwick, just 20 miles from Worcester, on the eastern side of the Quabbin Reservoir.



View from Mount Watatic on the New Hampshire-Massachusetts border looking across the North Quabbin region.”

PLANNING FOR CLIMATE-RESILIENT CONSERVATION

Hardwick is in the service area of the East Quabbin Land Trust, a member of the partnership. Previously, East Quabbin had not done much work in western Hardwick, but as executive director Cynthia Henshaw explained, “Having the town show up in the mapping exercise gave us reason to rethink our prioritization.” So when East Quabbin was approached by a landowner from western Hardwick who wanted to conserve his property, “The map increased our interest in working with that landowner and other neighbors over time,” according to Henshaw. East Quabbin also incorporated the mapping results into grant applications to help fund transaction costs for a conservation restriction on two parcels totaling 20 acres in the middle of the new high-priority area. “We expect other landowners to follow suit with permanent conservation in the years to come,” said Henshaw.

East Quabbin Land Trust’s shift in focus is one of several results of a significant, collaborative planning effort to integrate climate into conservation planning. The effort is the subject of the third and final part of this guide, which recounts how the North Quabbin Regional Landscape Partnership applied the characteristics of climate-resilient sites to developing a strategic conservation plan. It shows each step of a tested path that other land conservation organizations can follow to harness new climate science for their work on the ground, ensuring a more secure future for plants, animals and the human communities that rely on nature.

As you read, it may be useful to ask yourself the following questions:

- What specific climate risks does my area face?
- How well will the existing protected lands support plants and animals as the climate changes?
- What additional physical and biological characteristics need protection to better support plants and animals?

CHALLENGES AND OBJECTIVES

In the past, when selecting conservation priority areas, the North Quabbin Regional Landscape Partnership “focused on areas where individual partner organizations were already working,” said Sarah Wells, North Quabbin’s coordinator and also a conservation specialist with the Mount Grace Land Conservation Trust. She would hand out paper maps at a quarterly meeting and ask partners to circle their priority areas. She then digitized the polygons drawn on the twenty-something maps to show where interests overlapped (Figure 3).

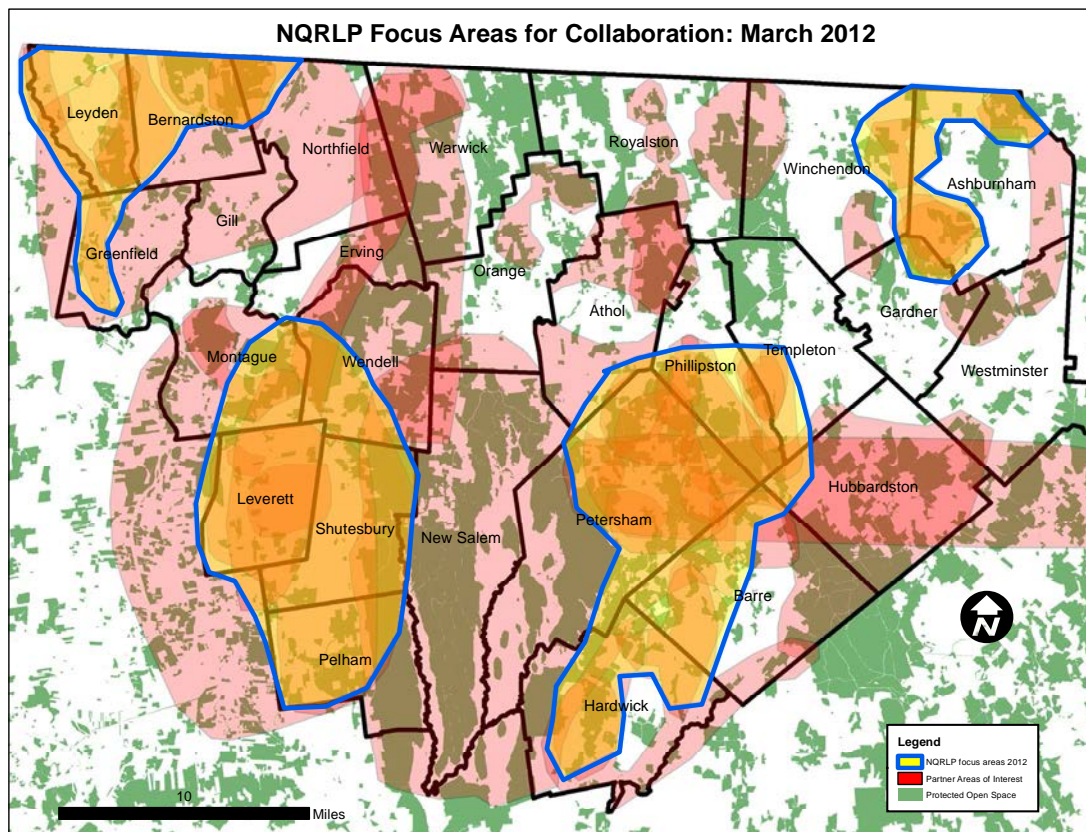


Figure 3. North Quabbin’s focus areas for 2012, circled in blue, were based mainly on partners’s preferences and opportunities for collaboration. Note that western Hardwick had been identified as a local priority but had not risen to the level of a regional priority in this analysis.

But 2012 had been one of the hottest years on record, and with the devastating floods of Hurricane Irene still fresh in everyone’s mind, the group sensed that the approach that had served it well in the past might be outdated. “The topic of climate change began to pop up regularly at our meetings,” Wells said.

Climate change could complicate or even undo years of Wells' and her colleagues' work, but the precise effects were hard to predict. Among other things, people wondered how the area's unique places—including temperature-sensitive natural communities such as kettle bogs and spruce-tamarack wetlands—would fare over time. But there was little sense of what might be most important to consider, or even how to start. They suspected that to plan for climate change, they would have to shift away from their previous informal, low-tech approach.

So they were eager to participate when the Highstead Foundation, a regional conservation organization known for ecological research, invited them to be guinea pigs for a pilot project funded by the Open Space Institute's Resilient Landscapes Initiative. The project's goal was to see whether new climate science could be integrated into a land conservation plan.

MAPPING A NEW APPROACH

On a crisp October day in 2013, more than 30 people hunkered down in a conference room with computers and plenty of coffee. This meeting was the first of three half-day workshops at the Millers River Environmental Center in Athol, Massachusetts. In attendance were representatives from six land trusts, five towns, two state agencies (including the Massachusetts Department of Fish and Game), one planning commission, one academic institution and a conservation group—16 of North Quabbin's 23 partner organizations.

The task: to create a digital map that identified places in their 26-town service area most likely to protect natural resources as the climate changes. This map would be more than a locator of conservation targets. It would also serve as the foundation for a strategic, long-term conservation plan and as a springboard for community engagement on climate concerns.

As one of the first land conservation collaboratives to attempt a climate-inclusive regional conservation blueprint, North Quabbin was exploring literally uncharted territory. Though no strangers to collaboration, each of the member organizations had its own perspectives and values. The series of workshops set up to advance the planning process created an opportunity to put differences on the table and chart a path forward.

About the North Quabbin Partnership



Figure 5. Ashburnham, Massachusetts, as viewed from Mount Watatic.

The [North Quabbin Regional Landscape Partnership](#) is a regional conservation partnership (RCP) comprising 23 organizations. New England and eastern New York State have nearly 40 RCPs—multistakeholder collaboratives involving land trusts, conservation organizations, public agencies and landowners who work across geographic and political boundaries. North Quabbin was one of the first RCPs in its region. Although it has a single mission, the day-to-day work of North Quabbin's members takes place in 26 towns. Because they work simultaneously at the municipal and regional levels, their experiences developing a strategic plan to respond to climate change are transferable to land trusts working at a variety of geographic scales.

Formed in 1997, North Quabbin serves a 560,000-acre area in heavily forested North-central Massachusetts (Figures 5, 6). Its service area is a tapestry of rolling hills, farmland, wetlands, rivers, lakes and the Quabbin Reservoir, the largest inland body of water in the state and a source of drinking water for two million people.

The region includes some of the largest remaining roadless areas in the state and provides habitat for mammals including moose, bobcat and bear, which depend on its large, unfragmented habitat blocks. Places like the Tully Trail and Mount Watatic provide exceptional recreational opportunities within two hours of Boston. All of these resources are experiencing intensive development pressure—and some effects of climate change.

Wells characterized the area around the reservoir as an “accidental wilderness”: some 35 percent of the region is already in some form of preservation, largely because the state exercised eminent domain to develop the Quabbin Reservoir as a drinking water source for Boston. Years of work by state agencies and land trusts have added conservation lands to this site. Historically, the group’s members have focused on filling gaps and linking protected natural areas.

In addition to its mission of conserving rural heritage and workinglands, the group also works in a broader context. North Quabbin participates in several initiatives to protect forests and watersheds, including the [Quabbin Reservoir to Wachusett Mountain Forest Legacy Project](#) (Q2W), [Quabbin to Cardigan Initiative](#) (Q2C), and [Wildlands and Woodlands](#).

THE PROJECT LEADS

The workshops were led by the Highstead Foundation, a Connecticut-based non-profit conservation and research organization that promotes RCPs to accelerate land conservation. To expand its ability to assist RCPs and member land trusts in incorporating climate resilience into conservation planning, Highstead initiated the workshops under a 2013 Catalyst Program grant from the Open Space Institute’s Resilient Landscapes Initiative. Bill Labich, Highstead’s senior conservationist and North Quabbin’s former co-chair, coordinated this effort. He pegged North Quabbin as an ideal test case because of the organization’s capacity and history of innovation. For example, North Quabbin aggregated multiple land ownerships to get Forest

Legacy Fund grants for what would otherwise be considered local conservation projects.

One member of North Quabbin is Harvard Forest, an ecological research center where students and staff study the interactions of biological, physical and human systems. Its “laboratories” include 3,500-plus acres of forested land in Petersham, one of the towns that anchor the partnership’s region. Brian Hall, a research assistant at Harvard Forest and a geographic information system (GIS) expert, served as a technical trainer and map-building lead for the workshop series.

HOW THE NORTH QUABBIN PARTNERSHIP CREATED A CLIMATE-INCLUSIVE CONSERVATION PLAN



Figure 10. North Quabbin members learned about new climate resilience data at one of three workshops.

Step 1: Reorienting the Partners' Focus and Voting Their Values

Although the partners had discussed climate change and had a breadth of knowledge and intimate understanding of the landscape, few members knew how they could factor climate change into their planning efforts. A post-workshop survey revealed that most participants had limited understanding of resilience science, despite their strong belief in the importance of engaging on climate change.

Understanding Resilience

The first meeting, held in October 2013 and facilitated by North Quabbin coordinator Jay Rasku, was devoted to coming to a shared understanding of the characteristics of a resilient network, as defined by The Nature Conservancy (TNC). Geographic information system expert Brian Hall presented the conceptual background on geodiversity landform complexity, and local connectedness and explained that datasets had recently been developed specifically to help steer land protection to ecologically resilient sites.

The group had concerns about the definition of resilience, because it set aside the value of working lands and human resilience. Looking more closely at the data, the group was specifically concerned that farming and active forest management decrease the connectedness values of these land uses. Some participants also felt the need to directly address human resilience.

Hurricane Irene had left 700,000 people in Massachusetts without electricity and turned roads into rivers. Would this science sufficiently address the damage of such storms?

Through this conversation, climate change emerged as a vast issue, and participants knew they needed to start somewhere. They agreed to focus their planning process on ecological resilience. Many were convinced that more resilient natural systems would ultimately support more resilient human systems. Others could see the value of focusing a planning process on biological resources, and coming back to add human systems and working lands at another time.

“What Do You Care About?”

Led by Brian Hall, the participants proceeded to their primary task: deliberating on the natural features and data elements that would drive the mapmaking. They knew they'd focus on biological priorities, but which ones? How would these priorities be combined with the physical features represented in the climate data? And how should the different climate-resilience data layers be weighted? “We asked them, what do you care about? We'll choose datasets to reflect those values,” Hall recalled. This sparked an informal brainstorming session using a flipchart, which generated an unwieldy list of ideas. To evaluate the ideas more systematically, the group decided to take a vote.

*“We asked them, what do you care about?
We’ll choose datasets to reflect those values.”*

Each member was asked to rank items on a list of nearly 40 datasets and GIS layers. Each participant had 100 points to assign as desired to the listed conservation values. When tallied, the votes showed areas of agreement. Buffering protected land and making more connections to the “accidental wilderness” received many points. Species populations and other traditional conservation values also held sway, in part because they reflected the funding priorities of grants from the Commonwealth of Massachusetts on which the partners have relied to underwrite their projects. The climate resilience data were also favored. Despite concerns about the details, the group was excited to have a way to incorporate climate science into their planning. The participants recognized that none of the other datasets identified their region’s unique geology and landforms; they were interested in highlighting these traits.

CO-OCCURRENCE MODELING

During the first workshop, David Graham Wolf, deputy director of Mount Grace Land Conservation Trust (North Quabbin's fiscal sponsor), introduced and led a discussion on building a co-occurrence model, a type of analysis that would help locate places that met the criteria the group had selected. Co-occurrence analysis is a GIS-based method for ranking areas on a landscape according to their value, determined in this exercise by how many important conservation features overlap, or "co-occur," in each area. North Quabbin used the layers of information visualized in the chosen datasets to find these overlaps. In the simplest co-occurrence models, each feature is ranked "one", such that land with one desired conservation feature has a score of one, land with two desired conservation features has a score of two, and so forth. Each value is given the same weight to simplify the modeling exercise. The greater the number of valued features in a place, the higher its score and the more likely it is to be a prime candidate for protection. This technique is most effective for prioritizing one aspect of conservation at a time, such as biodiversity or agriculture, but not both, since they are unlikely to co-occur.

Resolving Conflicts

Parsing these issues also led to the first of several spirited debates reflecting the partners' varying interests—and remaining skepticism about TNC's resilience criteria. Wells recalled, "Water features were very important to most of us. Climate resilience science is based on terrestrial features, and it perceives water as a barrier to species movement. For other reasons, we view water as an asset!" (In fact, partly as a result of feedback from this group, subsequent versions of the *Resilience* dataset no longer consider water bodies as significant barriers.) Working lands were still a sore point. As one participant noted, important species can thrive on agricultural lands. Wells recalled, "Some didn't see a place where farms could plug into the map."

Afterward, Hall and four other GIS-savvy individuals, including Rasku and Matthias Nevins, North Quabbin's AmeriCorps member, held the first of several separate meetings. They planned to compile, analyze and tweak draft versions of the map based on feedback from the larger group. But when they made the first draft using the datasets that scored highest in the values-ranking exercise, they noticed that the results were skewed.

Several of the selected datasets reflected similar conservation values, so people had, in effect, chosen to do one thing—emphasize contiguous forest cover—in several different ways. So Hall made an executive decision: Basing the choice of datasets to use on overall trends, he selected the newest and highest-quality set of data for represented blocks for connected forestland. Using all the datasets would overload the co-occurrence model and make it difficult to understand. Also, for the sake of simplicity, he awarded equal weight to each conservation value selected.

Step 2: Refining Choices and Sketching a Model

At the second meeting, in November 2013, Hall showed the participants the results of their conservation feature rankings and unveiled the draft map based on their overall preferences. The map was a window showing where they were headed, but the vision was still too general to drive their conservation plan. So their next task was to refine their choices. How best to combine familiar measures of biological diversity with physical measures focused on landform characteristics? Equally, or favoring one over the other?

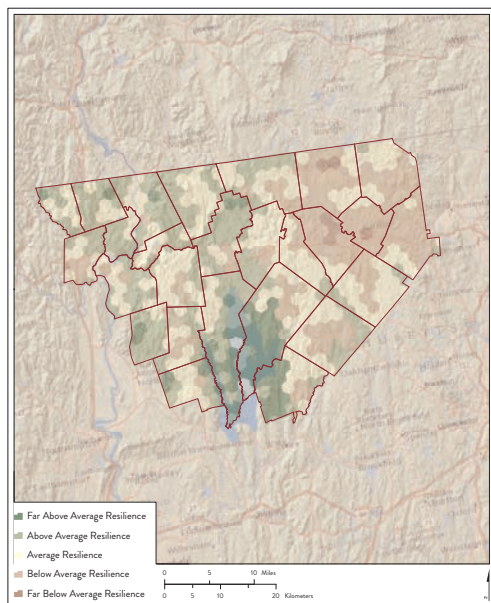
To help answer these questions, the GIS team presented map models in which various sites “popped out” as ecologically significant depending on how data layers were combined and weighted. The models reflected different feature rankings, depending on whether TNC resilience data were used, and depending on different scales.

As Hall zoomed in to selected sites, people evaluated how the different approaches to combining the data matched their on-the-ground knowledge of these sites.

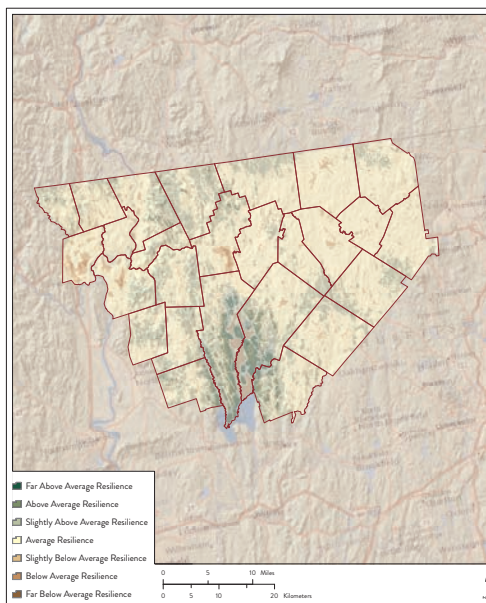
Balance, Trade-Offs and Scale

One critical decision was how to incorporate the familiar BioMap2 dataset, which informs the state’s Wildlife Action Plan. Component layers of BioMap2 can be isolated to reveal core forest areas, display wetland features, show the presence of rare species and so on—and the North Quabbin partners valued this information. Moreover, many natural features that BioMap2 identifies are also signs of biological condition, one of the criteria used to assess a landscape’s resilience.

Participants asked themselves, Shall we use broader or finer data? The data were originally available at the 1,000-acre hexagon and 30-meter cell scales. Although the 30-meter scale was preferable, they had used the 1,000-acre hexagon data to assess geology, so results were not strictly accurate.

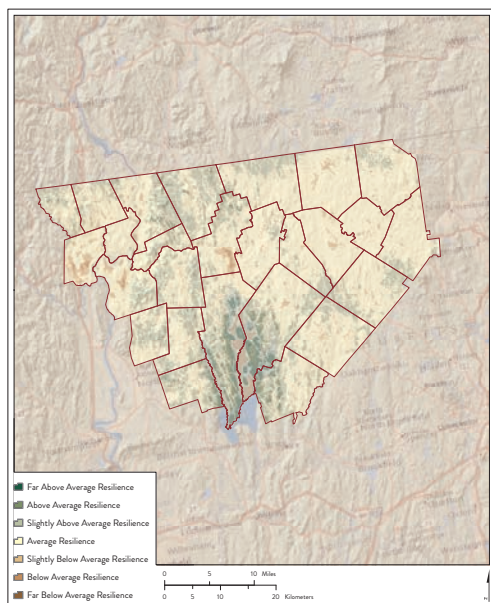


1. TNC Resilience scores, resolution to the 1000 acre hexagon

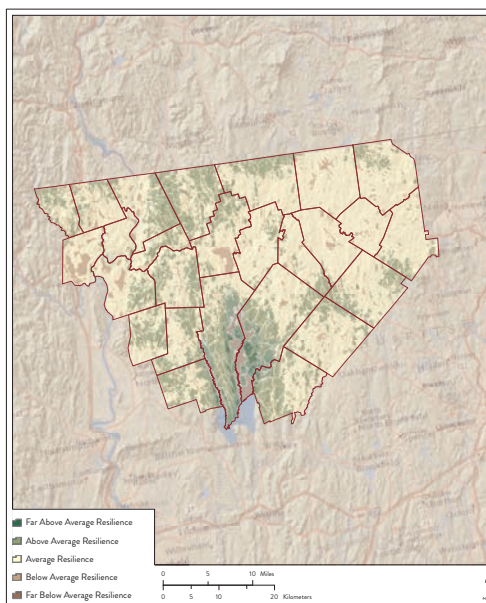


2. TNC Resilience scores, resolution to the 90 meter pixel

The question of context was also important for the partners: If the map-based datasets of resilience are relative, against which context shall we compare our region—the whole ecoregion, the state or our service area?



3. TNC Resilience scores compared within to the North Quabbin region, created by Brian Hall



4. TNC Resilience scores compared across the northeast and the Lower New England / Northern Piedmont ecoregion.

The issue of context and regional priorities came up again in relation to geodiversity. Participants were surprised and proud to learn that their region was home to one of the largest protected areas of low-elevation mafic geology in the Northeast. The Open Space Institute had highlighted this geology as a priority for protection because of its low level of regional conservation. But locally, North Quabbin had already protected 80 percent of this setting. Should the land trusts continue to protect this geology type, or diversify?

Ultimately, the partners would vote on data scale, context and which datasets to use—this time, from a highly informed position. Their choices:

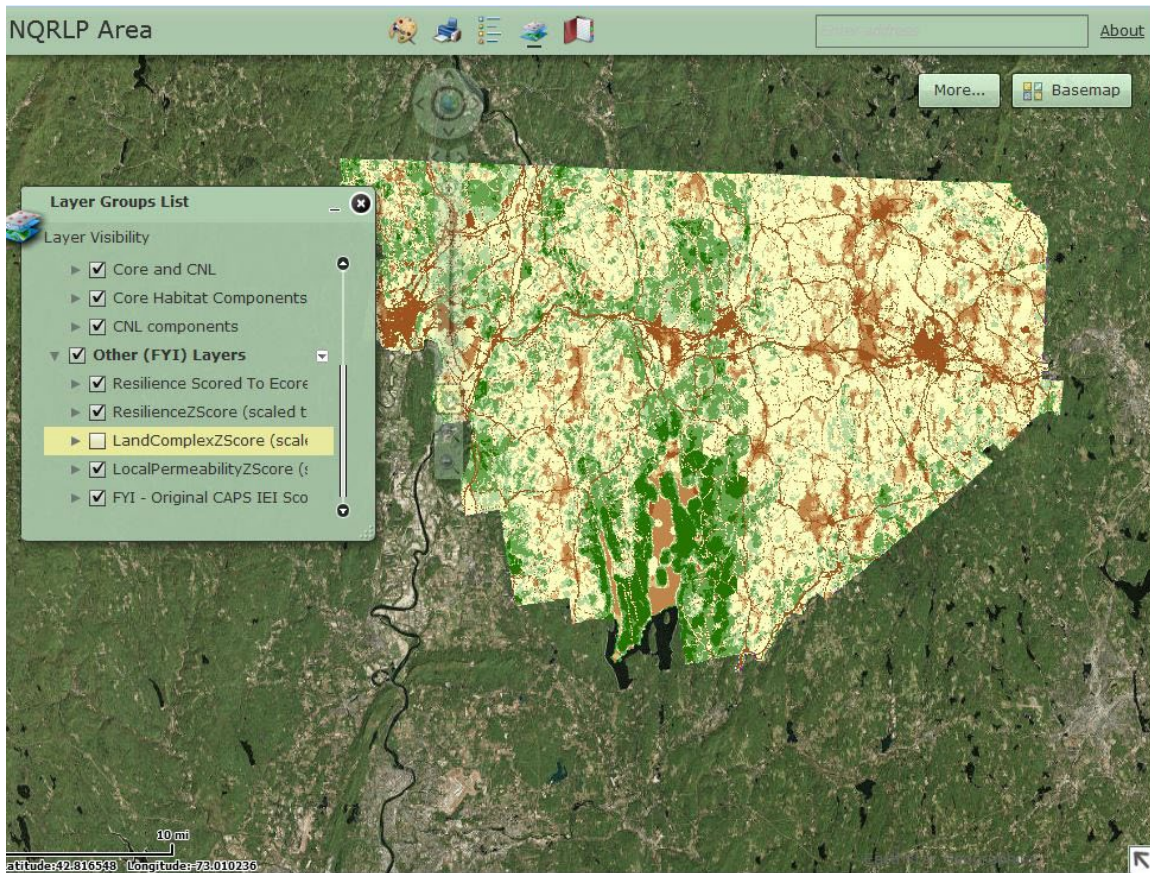
- use the finer-scale data, because properties in the region are often much smaller than 1,000 acres;
- evaluate resilience at both regional and local scales;
- continue to protect local low-elevation mafic geology and thus contribute to regional representation; and
- allot 40 percent of the data inputs “budget” to mapping climate-resilient physical features and 60 percent to biological data—animals, forest and water-related features.

Visualizing Priorities

Hall was now tasked with producing a working map reflecting those decisions and other feedback from the second session. He soon realized that even these narrowed-down options could not all be easily represented on a single map.

“If we included everything, nobody would understand what it showed,” he said. “It had to be explainable to someone in less than three minutes.”

So he came up with an interactive website to help people understand what the data showed. On their own time, participants could play with the layers they’d selected, turning features on and off to see how their choices affected each of four “straw man” models Hall had created.



18. Screen shot of an interactive website developed by the North Quabbin Partnership to allow members to explore data layers prior to assigning final ‘weights’.

Step 3: Making Final Decisions

By December 2013, when the third session began, the participants had engaged enough with the possibilities that they felt more confident making choices and could understand the implications of what the map showed. Now, Hall had them discuss the pros and cons of the four finalist maps again, using the same web application but reviewing them as a group. In many cases, said Nevins, it seemed that the maps “confirmed the work that has been done over the years. Areas that were highlighted for prioritization were areas where the partnership has been focusing their collaborative energy.” But the final choice of datasets revealed potential new priorities.

SNAPSHOT: NORTH QUABBIN'S FINAL CHOICES

It was time for the North Quabbin partners to vote on the weights they would assign to each of their preferred data layers, thereby deciding which features represented their top conservation values. The “winners” are listed below.

DATASETS

The question: *What information is most relevant for us?*

- TNC Resilience
 - scaled to Geophysical Setting in Ecoregion
 - scaled to North Quabbin service area
- TNC/OSI Underrepresented Geophysical Settings Tier 1 (at risk and biologically rich)
- TNC/OSI Underrepresented Geophysical Settings Tier 2 (moderately underrepresented, at risk)
- TNC Regional Flow
- Protected Open Space Within 400m
- BioMap2 Critical Natural Landscape CNL (CNL data tracks intact landscapes)
 - Aquatic Buffer
 - Landscape Blocks
 - Wetland Buffer
- BioMap2 Core Habitat CH (CH data tracks endangered species)
 - Aquatic Core
 - Forest Core
 - Priority Natural Communities
 - Species of Conservation Concern
 - Vernal Pool Core
 - BioMap2 Wetlands

DATA TAILORING

The question: *At how fine a “grain” do we need to understand these landscapes?*

- Use only overall resilience data (no component layers)
- Use individual component data layers of BioMap2 (each one got one point)
- Use 30-meter cells (rather than 1,000-acre hexagons)

RESILIENCE SCORE SCALING

The question: *At what scale do we want to use this information in order to make decisions?*

- Geophysical setting in ecoregion (one point)
- North Quabbin’s service area (one point)

As these final dataset choices show, the participants incorporated the four terrestrial resilience characteristics (discussed in Part 1) into their map and plan, and did it in a way that assessed what was relevant to their historical priorities. By choosing TNC’s Resilience dataset, for example, they accessed combined information about geodiversity, landform diversity and local connectedness. The two underrepresented settings datasets provided them with additional information about geodiversity, and the regional flow dataset offered new details about their area’s connectivity.

The partners were able to infer landscape condition in two ways. They were personally familiar with the state of the land, having long worked in the area. Also, the data layers in BioMap2 provided information about the current status of important plant and animal communities.

Sarah Wells explained the thinking behind their choices: because the partners were familiar with BioMap2, they felt confident examining its individual component layers and including these in their final map. Moreover, the Commonwealth requires its use for recipients of conservation funding. But they decided not to “parse out” TNC’s Resilience data and accepted it as a whole. “We trusted TNC’s expertise and said, ‘Let’s not mess with this,’” she said.

However, the group did tinker with the scaling, looking at resilience from the perspective of both the 26-town region that constitutes North Quabbin’s service area and the entire multistate ecoregion. Also, participants wanted to ensure that more of the geophysical settings important for biodiversity were conserved. “We’ve already protected a large area of mafic lands more locally,” Wells noted, “but ecoregion-wide, these areas are not well protected.” The group decided to continue focusing on protecting this geology type.

Last Steps

The last step in creating the map was for Hall to clip out roads, developed lands and water, leaving visible only the land available for conservation.

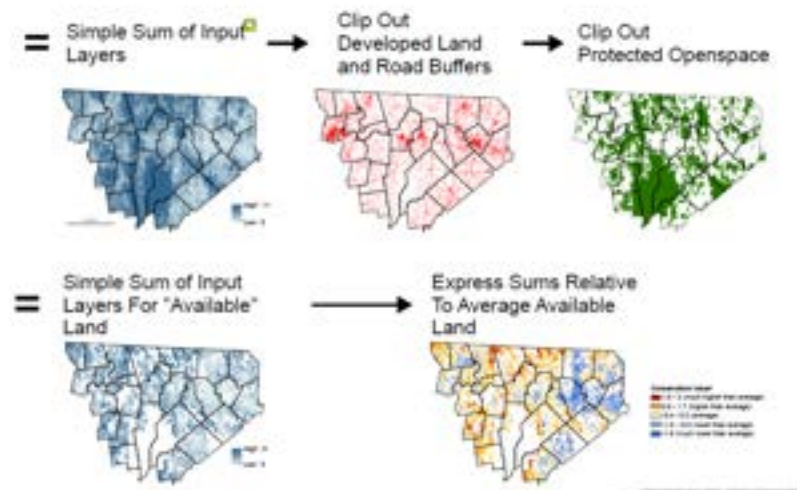


Figure 20. GIS expert Brian Hall “clipped out” certain land features so that only available conservation land was visible on the map.

Then he rescaled the combined data layers relative to the remaining cells so that the group could focus on the features of interest and to “make the action needed clearer,” he said. The result: the completed Strategic Conservation Priorities Map (Figure 21).

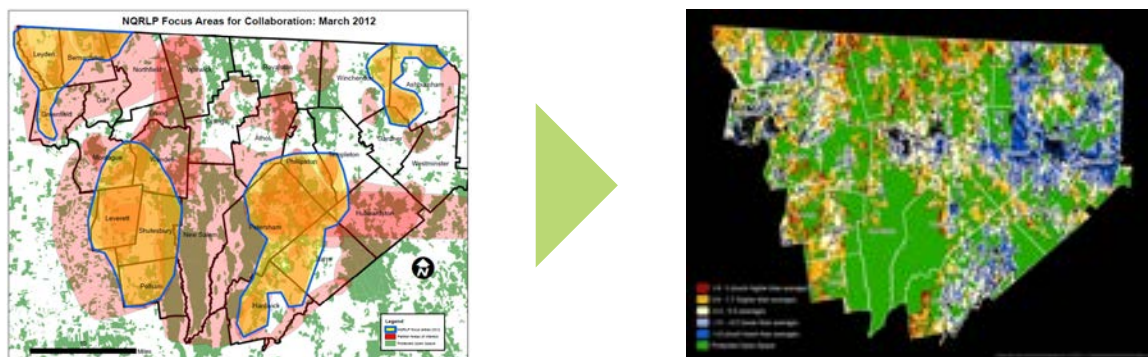


Figure 21. Left: North Quabbin’s previous hand-annotated map. Right: The final “hot/cold” map, built using datasets visualizing both physical traits supporting climate resilience and biological traits. Areas in red and orange flag the highest levels of relative resilience, cool blues have lower relative resilience, and green areas represent already protected land. The partners had already selected general areas (blue outlines on previous map) with highly resilient sections, but they also missed resilient areas that the second map reveals.

What the Map Showed

North Quabbin’s final map shows resilience “hot spots” in crimson and minimally-resilient lands in pale blue. The colors highlighted three heavily-wooded places, two of them new to the partners, which had multiple resilience traits:

- the town of Leyden, which is very hilly with varied terrain and was the site of an OSI-supported neighborhood conservation project in 2013;
- the corridor heading north from the Quabbin Reservoir into the town of Royalston; and
- land just east of the Quabbin, especially the town of Hardwick.



The area south of Royalston was “a little surprising,” observed Wells. “It also corresponds with an area that’s relatively developed compared with other parts of our region.” Route 2 bisects it, as do the town centers of two larger communities, Athol and Orange. However, the complexity and diversity of geologies in this area brought it to the top.

To bring home the import of what they had created, Hall showed the participants the new map side by side with the same map without TNC’s Resilience data (Figure 22).

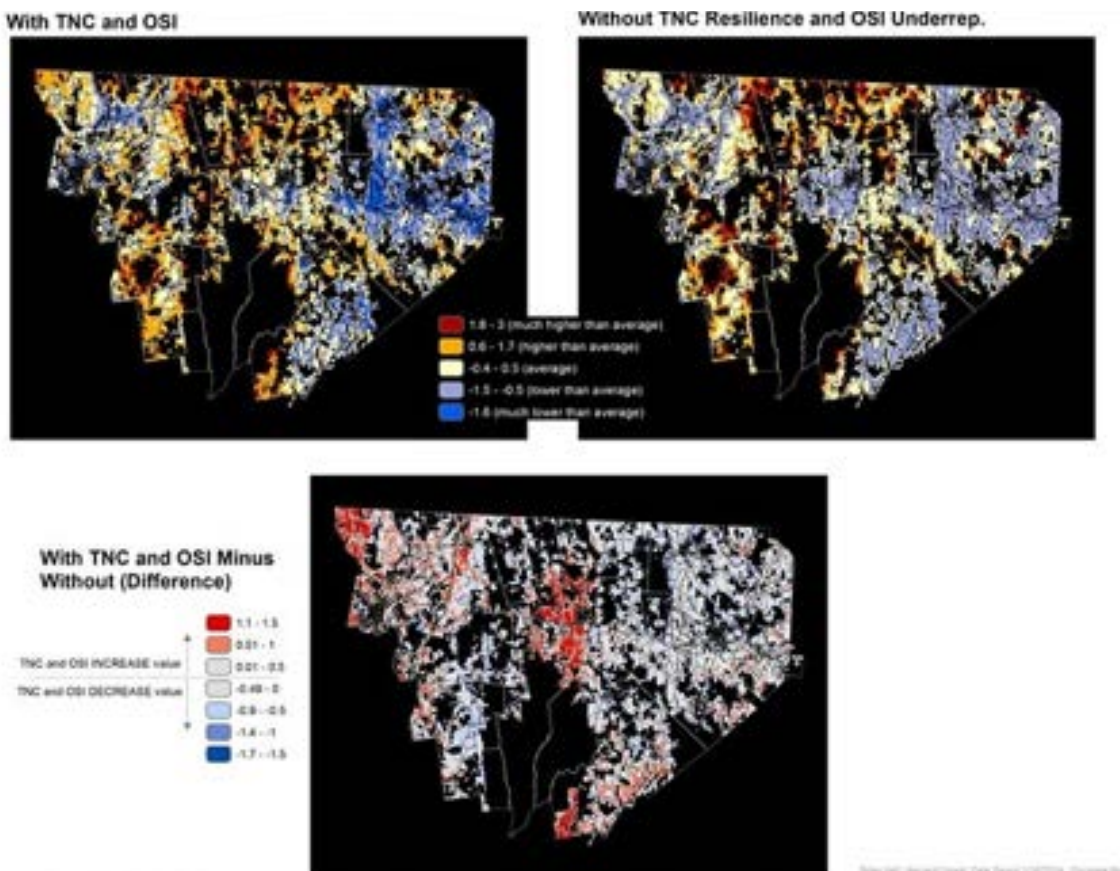


Figure 11. The North Quabbin service area, as visualized with and without the climate resilience data (top images), and a final map illustrating in red which places become more important when the climate resilient data layers are added (bottom).

Step 4: Implementation and Outreach

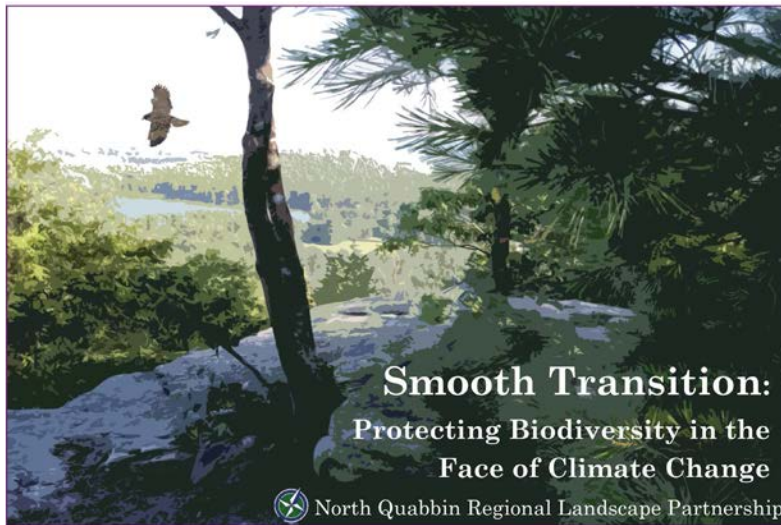
As the Hardwick example that opened this case study illustrates, the mapmaking process equipped the North Quabbin partners with the knowledge and skills to be proactive about climate change. They learned how to translate the science, develop a climate-inclusive conservation plan, and bring that knowledge to their work with landowners. Moreover, the organization views its new climate-inclusive plan as a living tool for advancing the conversation on climate change.

Wells said, “In the past, our maps were more for internal use. This one’s especially significant because of its potential to bring public engagement around an important topic.” The map also stands as a replicable model, so practitioners can use the resilience concepts and related datasets in their future work.

“In the past, our maps were more for internal use. This one’s especially significant because of its potential to bring public engagement around an important topic.”

The partnership has begun outreach to multiple audiences at the regional level.

- **Town boards.** Town boards, like conservation and open-space committees, are important liaisons with the local community, helping to bring the partnership’s work to fruition. Maggie Owens, North Quabbin’s AmeriCorps member, drafted a user-friendly illustrated booklet about the map and how towns can use it, such as by partnering with a land trust or considering climate resilience when designing infrastructure projects. Ultimately, North Quabbin plans to package the brochure and map as a set and bring it to meetings with each of the 26 towns in its service area.



Other partners. North Quabbin identified several resilient places where multiple partners have already expressed interested in working and submitted grant applications to the U.S. Forest Legacy Program and the Commonwealth of Massachusetts. Nevins observed, “One of the major advantages of doing a large-scale regional mapping process is that we can look across boundaries, and see where we can improve collaboration and potentially spark new projects.”

- **Landowners.** North Quabbin often sponsors events on land-related topics in neighborhoods throughout the region. The climate map provides both targeted locations in which to hold them and an additional reason to engage local landowners in protecting their property.

The partnership recently staged a well-attended meeting in Royalston, one of its new priority conservation areas.

- **Local residents.** North Quabbin’s public outreach strategy has continued to evolve. In January 2015, it hosted a hike so that other partners could see what resilience looks like on the ground (Figure 24). Despite the deep winter chill, a small group of people came out to explore a protection-worthy landscape in Royalston. They also brainstormed about how best to get climate into the local conversation. After the hike, they decided their outreach would emphasize doable actions tailored to specific audiences. They plan to piggyback messages about resilience and “conserving the stage” onto popular programs North Quabbin already sponsors, such as animal-tracking trips and invasive-weed pulls.



Figure 24. North Quabbin members led a hike to show partners an area found to be highly resilient because of its rolling landscape, among other traits.

North Quabbin is also having an effect beyond the Bay State. The Northeast office of the U.S. Fish and Wildlife Service published an article about the many uses of North Quabbin's map on its website. The partnership has been making presentations to hundreds of people at gatherings of other RCPs and recently shared its mapmaking story at an OSI-led session at the Land Trust Association's Rally 2015 in California. There, the audience included many western and a few international land trusts.

Step 5: Reflecting on Lessons Learned

Both North Quabbin and Highstead viewed the mapmaking process as a success, with some qualifications. A post-workshop survey and interviews identified factors that helped or hindered the exercise.

- **Trust.** The partners enjoyed a high pre-existing level of trust because they were accustomed to working together and were already comfortable thinking regionally.
- **Active participation.** The members had a keen interest in tackling climate “beyond the handwringing,” as one member put it, and showed great interest in “getting it right”—so much so that some points they raised during the training are being incorporated into revisions of TNC’s Resilience dataset.
- **Highly-skilled tech leads.** Several of North Quabbin’s members had GIS experience or scientific backgrounds, but participants agreed that without the expertise and flexibility of Harvard Forest’s Brian Hall to “lay out decision paths in the form of if/then,” as Bill Labich put it, mastering the concepts and tools would have been more difficult.
- **Clearly-defined roles.** Hall observed that each participant assumed one of three roles: “big thinkers, practitioners and champions.” The thinkers consider, “What biological and geologic things do we really care about?” The practitioners “put time and effort in to understanding the different data layers and how they fit together.” And the champions “take up the cause to use the map.”
- **Insufficient time.** Most participants felt they had barely enough time to understand the mapmaking process and achieve consensus. People suggested there should have been from one to as many as nine additional meetings.

Perhaps the most resounding lesson of all, though, was that “it let us see that we can do something about climate change,” Wells said. “Now we have a resource to guide us, and it will lead to conservation on the ground over the coming years.”

FOLLOWING IN THEIR FOOTSTEPS: HOW TO TAKE ACTION

For some land trusts, following the steps outlined in Part 2 will be sufficient for their work. However, North Quabbin's experience is instructive for understanding the learning curve of planning for climate change, the need to clarify values first, the trade-offs that may be required, and the wide range of planning possibilities that resilience science and cutting-edge tools can offer.

Questions to Consider

- How are my organization's challenges and objectives similar to or different from North Quabbin's, and what might that mean for planning?
- How can North Quabbin's approach inform how my organization engages partners with diverse backgrounds?
- Could some of the datasets that North Quabbin used help us to reach our goals?
- Are any of the datasets redundant with others we already use or are thinking of adopting?
- Would using a co-occurrence model like North Quabbin's be the best method for planning for climate resilience, or is it more complex than what we need?
- Which of the outreach strategies might work in our service area?
- How might we benefit from the lessons North Quabbin learned?

North Quabbin's plan is ambitious, and the group had the benefit of OSI funding for Highstead and Harvard Forest to support its process with data mapping and science education. As the science is applied more widely and as guidebooks help introduce the concepts to a broader audience, more organizations may be able to use climate science in conservation work with only limited technical assistance.

Land trusts that want to follow in North Quabbin’s footsteps have several options.

- Highstead has since conducted climate-planning workshops to several other RCPs and plans to offer additional sessions in the future. Contact Bill Labich at blabich@highstead.net to inquire about participating.
- If you are an individual organization, use Part 2 of this guide to evaluate the resilient characteristics of your service area or a specific conservation project.
- If you are interested in finding partners for collaborative work, visit the Land Trust Alliance’s website, <http://www.landtrustalliance.org>. This website also offers case studies on climate-inclusive conservation planning on its “Conservation in a Changing Climate” page.
- North Quabbin welcomes inquiries from groups with questions and has taken its story on the road. Representatives of the partners have presented their case study at various conferences. To reach them, contact Sarah Wells at wells@mountgrace.org.
- It may be useful to review the projects completed by other recipients of OSI climate funding on the OSI website here, and then contact the organizations involved for more information.



NEXT STEPS

Now that you've worked through all three parts of *Conserving Nature in a Changing Climate: A Guide For Land Trusts in the Northeast*, you should possess a basic understanding of climate resilience science (Part 1) and proficiency in using digital mapping tools to identify the best places to protect by assessing characteristics of individual landscapes (Part 2). With this knowledge in hand, you should now feel confident in taking the steps to create a climate-inclusive conservation plan (Part 3). Additionally, a list of resources follows in Appendix A.

In years ahead, the ecological concepts discussed below are likely to remain relevant, but science and practice are not static. This is a living document. As our knowledge of climate change grows, so will the tools to plan for it and the community of conservation organizations incorporating them into their work. We plan to update and revise this guide and online resources, and we encourage land trusts to share their lessons and experience to help us continually improve.

If you have further questions or are interested in scheduling an OSI-led orientation or workshop, please contact: Abigail Weinberg at aweinberg@osiny.org.



APPENDIX

[Appendix A: Resources](#)

[Appendix B: Glossary](#)

[Appendix C: Advisory Committee](#)

APPENDIX A: RESOURCES

Practical Information for Land Trusts

Land Trust Alliance, Climate Toolkit. A special section of the LTA website offers extensive resources for land trusts to learn how climate change may affect their work, including a self-assessment and case studies describing how colleagues are responding to this challenge. <http://climatechange.lta.org/>

Strategic Conservation Planning, by Ole Amundsen III. This book provides conservation professionals with the process and tools to identify, prioritize, pursue and protect the land that will most effectively and efficiently achieve an organization's mission. Available for purchase at the LTA website. https://iweb.lta.org/Purchase/ProductDetail.aspx?Product_code=CURR_STRATEGIC

The Nature Conservancy, Conservation Gateway/Climate Change. This web portal provides data, results and reports from TNC's efforts to map the locations of climate-resilient sites in the Northeast, Southeast, and Pacific Northwest. There are also links to articles, web tools and other resources. <http://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/edc/reportsdata/climate/Pages/default.aspx>

North Atlantic Landscape Conservation Cooperative, Conservation Planning Atlas. An online map portal hosted by Data Basin provides access to hundreds of datasets on climate and biodiversity. The site enables the user to create maps and evaluate project sites or landscapes for any location in the Northeast. <http://nalcc.databasin.org/>

Web Tools

Coastal Resilience Mapping Portal. This global network of science and conservation practitioners features an interactive tool designed to help communities understand their vulnerability from coastal hazards such as sea level rise and storms, reduce their risk, and assess nature-based solutions. <http://www.coastalresilience.org>

The Nature Conservancy, Climate Wizard. A user-friendly tool for exploring projections for temperature and precipitation in North America, using several different emissions scenarios and mathematical climate models. <http://www.climatewizard.org/>

NatureServe, Climate Change Vulnerability Index. This downloadable software program ranks the vulnerability to climate change of individual plant and animal species and some communities throughout North and South America, based on expert opinion. <http://www.natureserve.org/conservation-tools/climate-change-vulnerability-index>

Resilient Land Mapping Tool. Users can zoom in anywhere on a map of the eastern United States and Canada to see scores for resilience, connectedness and landscape diversity, and then overlay them on satellite images, landform models or topographic maps. The tool also allows users to import datasets or draw tracts of land and calculate their scores. <http://maps.tnc.org/resilientland/>

Communications and Outreach Techniques

“Connecting on Climate: A Guide to Effective Climate Change Communication,” by EcoAmerica, a nonprofit that grows the base of support for climate solutions in America, and Columbia University’s Center for Research on Environmental Decisions. <http://ecoamerica.org/wp-content/uploads/2014/12/ecoAmerica-CRED-2014-Connecting-on-Climate.pdf>

“Let’s Talk Climate: Messages to Motivate Americans,” by EcoAmerica. This report and accompanying webinar deliver the results from message research on climate change designed to engage Americans on solutions across political and demographic groups. <http://climateforhealth.org/talk-climate>

Yale Project on Climate Change Communication. The project conducts research on public climate knowledge, risk perceptions, decision-making and behavior; designs and tests new strategies to engage the public in climate science and solutions; and empowers educators and communicators with the knowledge and tools to more effectively engage their audiences. The site offers opinion maps, research reports, peer-reviewed articles and webinars. <http://environment.yale.edu/climate-communication/>

Funding Sources

The Open Space Institute, Resilient Landscapes Initiative. This conservation organization offers \$12 million in grants for protection of resilient land in select areas in the eastern United States. http://www.osiny.org/site/PageServer?pagename=Issues_Habitat

The Open Space Institute has also provided planning grants to support integration of climate change considerations into strategic conservation plans. These projects, summarized in the link below, offer ideas for how land trusts can get started. http://www.osiny.org/site/DocServer/Catalyst_GranteesToDate_All.pdf?docID=14401

Wildlife Conservation Society, Climate Adaptation Fund. This conservation organization has funded grants for testing or applying creative approaches to climate adaptation. Findings are summarized at <http://www.wcsnorthamerica.org/Climate-Adaptation-Fund.aspx>.

Climate Science and Environmental Stewardship

National Wildlife Federation, Climate-Smart Conservation. This section of the National Wildlife Federation's website contains resources for designing and carrying out natural resources management planning in the face of a rapidly changing climate, including the report "Climate-Smart Conservation: Putting Adaptation Principles into Practice."

Northern Institute of Applied Climate Science (NIACS), Climate Change Response Framework. This organization, a collaborative of scientists, managers and landowners focused on incorporating climate change into natural resources management, provides an excellent integrated set of tools, partnerships and actions to support climate-informed conservation and forest management. <http://www.forestadaptation.org/>. An NIACS document, "Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers," offers practical suggestions for forest managers. http://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs87.pdf

U.S. Climate Resilience Toolkit. This extensive website, compiled by the federal Office of Science and Technology Policy and the Council on Environmental Quality, offers a wide range of resources, workbooks and climate-related case studies. One feature is a "Climate Explorer" that allows users to visualize climate data in maps and graphs. <https://toolkit.climate.gov/>

U.S. Geological Survey, National Climate Change and Wildlife Center. This site collects all the projects and tools generated by the nation's regional climate science centers, providing updates on recent projects organized by region. <https://nccwsc.usgs.gov/>

Articles

“Conserving Nature’s Stage” is a special section of the peer-reviewed journal *Conservation Biology* (June 11, 2015; volume 29, issue 3, pp. 611–701). An editorial and nine articles address various aspects of the effect of climate change on biodiversity and conservation, with an emphasis on geodiversity. <http://onlinelibrary.wiley.com/doi/10.1111/cobi.2015.29.issue-3/issuetoc>

“How Climate Change Is Spawning a New View of Conservation,” by Pete Spotts (*Christian Science Monitor*, August 20, 2015). <http://www.csmonitor.com/Environment/2015/0820/How-climate-change-is-spawning-a-new-view-of-conservation>

“Resilience: A New Conservation Strategy for a Warming World,” by Jim Robbins (*Yale Climate Change 360*, July 13, 2015). http://e360.yale.edu/feature/resilience_a_new_conservation_strategy_for_a_warming_world/2893/

“Blue Ridge Mountains in Conservation Spotlight,” by Karen Chávez (*Ashville Citizen-Times*, May 22, 2015). http://images.burrellesluce.com/image/23053A/23053A_101

APPENDIX B: GLOSSARY

adaptation the capacity of natural or human systems to reduce harm or take advantage of benefits in a new or changing environment. See mitigation.

barrier a natural or human-made impediment to species movement, such as a water body, road, building or other development

base map a map depicting background reference information about a location (such as landforms roads, and political boundaries) onto which other information is placed

biological diversity the variety and variability among living organisms and the ecological settings in which they occur. Synonym: biodiversity.

calcareous made of or referring to limestone geology

climate change alteration in global or regional climate patterns. The change apparent since the mid- to late 20th century is attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.

coastal resilience the capacity of a coastal ecosystem to respond to increased disturbance caused by climate change

connectedness the quality of being free of human and natural barriers that prevent species movement within and through local areas; the continuity of the local landscape that allows species to access resources and supports natural processes. Connectedness is a local characteristic. See connectivity.

connectivity connectedness through a region; the pathways between two or more forest cores. Connectivity is a regional characteristic. See connectedness.

conserving nature's stage the strategy of permanently protecting physical features, such as geology and landform types, that both engender and support biological diversity. Research shows that if protected lands capture the full diversity of such physical characteristics in a connected network, those lands will continue to protect representative environments and host the broadest range of plants and animals even as the climate changes.

co-occurrence modeling a GIS-based method for ranking areas on a landscape according to their value. The value is based on how many important conservation features "co-occur," or overlap, in each area.

Data Basin a free, science-driven mapping tool created by the Conservation Biology Institute that provides data, maps and galleries of environmental information

dataset a collection of related information stored, retrieved and manipulated as a unit (common usage). In Data Basin, dataset refers to the spatial visualization of a specific collection of data.

ecological resilience the ability of plants, animals and natural processes to persist in the face of change; specifically, the capacity of land for renewal during and after disturbances exacerbated by changes in climate

ecoregion a unit of land and water containing a geographically distinct assemblage of species, natural communities and environmental conditions

elevation gradient the steepness (low, middle or high) of the slope of a landform

elevation range the span or scale of heights to which landforms rise in a given area

fish region a unit of land and its lake, stream and river systems with distinct characteristics influenced by its geology, history and latitude

freshwater resilience the capacity of a river, stream, lake or pond system to recover after a disturbance such that it remains functional and biodiverse

gallery a collection of information organized around a topic in Data Basin

GAP the Gap Analysis Program of the U.S. Geological Survey, setting out guidelines and restrictions on how protected land is managed for conservation.

geodiversity the range of geology and elevation gradients that foster habitat and species diversity across a broad network of conserved lands

geophysical setting a distinct combination of geology and elevation. Collectively, settings constitute geodiversity.

habitat block an area with contiguous forest (or other natural cover) free from barriers, such as paved roads or other development

hydrologic flow the typical frequency, duration and seasonality of precipitation that flows into a stream

biological condition the fitness of a site to support biological diversity today and into the future due to the availability and quality of its natural resources

landform a specific geologic feature on the surface of the earth, ranging from large-scale areas such as plains, plateaus and mountains to relatively minor features such as hills and small valleys

landform diversity the variety of geologic features in an area. Landform diversity creates a variety of environments, or microhabitats, that allow species to find suitable temperature and moisture levels locally

landscape conservation collaborative (LCC) a self-directed partnership involving federal agencies, states, tribes, nongovernmental organizations, universities and other entities that collaboratively define science needs and jointly address broad-scale conservation issues in a defined geographic area

latitudinal range the span or scale of latitudes at which species are found in a given area

lateral connectivity the relationship between a stream and its floodplain

linear connectivity the relationship between different parts of a stream or lake. Linear connectivity allows organisms to access different parts of a hydrologic system.

map in Data Basin, a user-created visualization compiled from one or more datasets, several of which can be overlaid to create a single image

microclimate the climate of a distinct area whose temperature and moisture levels differ from those of the surrounding area. Microclimates are created by landform diversity.

mitigation in the context of climate change, efforts to reduce or prevent emissions of greenhouse gases by reducing sources of these gases (e.g., the burning of fossil fuels) or enhancing the “sinks” that accumulate and store these gases (e.g., oceans, forests and soil). See adaptation.

North Atlantic LCC Conservation Planning Atlas a science-based mapping platform that allows conservation managers and LCC members to view, retrieve and analyze spatial information for specific conservation goals

network in land protection, a series of interconnected protected lands that functionally support the survival of plants and animals and their movements from place to place

regional conservation partnership (RCP) a multistakeholder collaborative involving land trusts, conservation organizations, public agencies and landowners who work collectively across geographic and political boundaries to protect land across a broad region. New England and eastern New York State have nearly 40 RCPs.

resilience the ability of a living system to adjust to an environmental disturbance by moderating potential damages, taking advantage of opportunities, or coping with consequences; the capacity to adapt. See resistance, vulnerability.

resistance the ability of a living system to recover from an environmental disturbance. Because of its inherent traits, a resistant area can avoid any significant harm from disturbances. Resistance is on the opposite end of the continuum from vulnerability. See resilience, vulnerability.

stratification a comparison of the traits of one habitat or geology with those of the same type elsewhere (e.g., comparing one hemlock forest with other hemlock forests, or one granite geology with other granite geologies)

underrepresentation the lack of protected areas in a particular geophysical setting in proportion to the distribution of such settings across a landscape

vulnerability the inability of a living system to adjust to an environmental disturbance. Vulnerable places are likely to be severely affected by disturbances and to require intervention to protect them from gradual or sudden changes. See resilience, resistance.

APPENDIX C: ADVISORY COMMITTEE

Ole Amundsen III

Executive Director, Maine Audubon Society

Kevin Case

Northeast Director, Land Trust Alliance

Steven Fuller

Science Delivery Coordinator, North Atlantic Landscape
Conservation Cooperative, U.S. Fish and Wildlife Service

Michale Glennon

Adirondack Landscape Science Coordinator,
Wildlife Conservation Society North America

Erin Heskett

National Services Director, Land Trust Alliance

Bill Labich

Regional Conservationist, Highstead/Regional Conservation
Partnership Network Coordinator

Andrew Milliken

Coordinator, North Atlantic Landscape Conservation Cooperative,
U.S. Fish and Wildlife Service

Margo Morrison

Manager, Conservation Science, Nature Conservancy of Canada,
Atlantic Region

Joanna Ogburn

Senior Advisor, Chesapeake Conservancy

