The Hudson Valley Conservation Strategy

Conservation in a Changing Climate

SCENIC HUDSON

land ■ parks ■ advocacy

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The Doris Duke Charitable Foundation has generously supported Scenic Hudson's development of the HVCS, in both its initial conception and its current implementation.

EXECUTIVE SUMMARY

Worldwide, the conservation community is grappling with the challenge of ensuring that species and habitats have the ability to adapt to climate change, which is essential for their—and our—long-term survival. The biological richness and ecological function of the Hudson River Valley face unprecedented challenges due to climate change, sea level rise, habitat fragmentation, and the loss of productive farmland to development. To address these threats, and to safeguard the region's resilience in the face of climate change, Scenic Hudson designed the Hudson Valley Conservation Strategy (HVCS) to complement and build upon our existing conservation strategies—the *Saving the Land That Matters Most* campaign, the *Hudson Valley/New York City Foodshed Conservation Plan*, and the *Tidal Wetland Adaptation Framework*. In addition, it incorporates the most current and rigorous regional climate-resilience and natural resource datasets generated by non-profit, state agency, and academic partners.

Using Marxan, a leading systematic conservation planning tool, Scenic Hudson's scientists and geographic information systems experts used an array of datasets to identify and prioritize the most efficient combinations of potential land conservation projects that will achieve explicit targets in three categories. The categories are: **biodiversity** (the variety and variability of life on earth); **climate resilience** (the capacity of a site to adapt to climate change while still maintaining biodiversity); and **landscape connectivity** (the degree to which landscape conditions facilitate or impede the movement of organisms and resources between large habitat blocks). Additionally, data from Scenic Hudson's *Hudson Valley/NYC Foodshed Plan* was incorporated to identify and prioritize productive farmland, while simultaneously ensuring climate resilience, landscape connectivity, and ecological complexity and function. The HVCS represents a significant advance in integrating The Nature Conservancy's *Resilient Sites for Terrestrial Conservation* data with other data sources to create actionable goals for conservation investments in the Hudson River Valley. In all, the strategy points to approximately **760,000 acres** in the **11 counties** of the Hudson Valley region that represent the best potential conservation investments for achieving a resilient, functional, and productive landscape. The HVCS represents a durable and dynamic planning framework: it builds on existing protected areas, and is easily updated to incorporate newly conserved lands, new data on natural resources, shifting priorities, or other revisions to the strategy.

The resulting HVCS can be implemented by Scenic Hudson and its conservation partners in the region, and supports efficient, coordinated action across the landscape. It promises to optimize the conservation value of open space investments, and creates a strategic framework for Hudson Valley conservation that supports the diverse missions of individual land trusts and land protection agencies while aligning the investments of these multiple actors for the greatest collective impact.

The HVCS is a tool for guiding landscape-scale conservation planning, aligning partner efforts, and informing decisions about conservation transactions. As such, appropriate applications of the HVCS include:

- **Prioritizing sub-regions of high conservation importance within the larger region**
- **Prioritizing available properties for conservation**
- **Informing land use planning and natural resource management decisions**
- **Promoting an ongoing dialogue about conservation goals and targets in the Hudson Valley**

The Hudson Valley Conservation Strategy

Conservation in a Changing Climate

The Hudson Valley Conservation Strategy (HVCS) is a rigorous framework for landscape-scale conservation in the region that meets multiple ecological objectives. It is a tool that transforms land protection efforts by identifying the most efficient and synergistic network of properties for conserving long-term climate resilience, biodiversity, and landscape connectivity across the Hudson Valley, including productive and scenic working farmland.

Worldwide, the conservation community is grappling with the challenge of ensuring that species and habitats can adapt to climate change, which is essential for their—and our—long-term survival. The Doris Duke Charitable Foundation has led efforts to help the land trust community adjust to this new reality and shift away from narrow, species-specific solutions to more comprehensive strategies that protect habitats and ensure their ability to adapt to changing conditions over time. Scenic Hudson designed the HVCS analysis to complement and build upon our existing conservation strategies—the *Saving the Land That Matters Most* campaign, *Hudson Valley/New York City Foodshed Conservation Plan*, and *Tidal Wetland Adaptation Framework*. In addition, it incorporates the most current and rigorous regional climate resilience and natural resource datasets generated by non-profit, state agency, and academic partners. The HVCS represents a significant advance in integrating The Nature Conservancy's *Resilient Sites for Terrestrial Conservation* data with other data sources to create actionable goals for conservation investments.

The Components of a Climate-Resilient Conservation Strategy

Scenic Hudson has created a strategic framework for land conservation in the Hudson Valley to achieve the multiple conservation goals of climate resilience, landscape connectivity, and biodiversity while ensuring the preservation of productive working farmland. The HVCS achieves these four goals in an efficient and dynamic way that minimizes costs and maximizes impact.

Biodiversity—Biological diversity, or biodiversity, generally refers to the variety and variability of life on Earth. It spans all levels of biological organization, including organisms, communities, and ecosystems. Maintaining biodiversity is essential for the long-term stability of ecosystem functions. In addition, it provides many critical ecosystem services and economic benefits, including safeguarding our food supply and providing vital aesthetic and recreational opportunities for a growing population.

Climate Resilience—The term "resilience" describes the capacity of a site to adapt to climate change while still maintaining biodiversity, regardless of whether current species composition remains the same in the future. The basic concept is that by conserving representatives of all the Ecological Land Units (ELUs)—the *types of places* (different geologies, elevations, slopes, etc.)—and targeting areas that contain especially high varieties of ELUs, we will be conserving the full range of conditions to which organisms respond. We may not know which species will come to live there under future conditions, but by conserving enough of each type of place and connecting them to each other we will ensure that biodiversity will have a place to persist. A helpful analogy is "conserving the stage, but not necessarily the actors, in order to conserve the play."

Landscape connectivity—Landscape connectivity can be described as the degree to which landscape conditions facilitate or impede the movement of organisms and resources between large habitat blocks. A crucial component of climate resilience, it allows species to respond to changing conditions by moving northward or to higher elevations. Habitat fragmentation, the inverse of connectivity, is one of the most commonly cited threats to species persistence.

Productive farmlands—Nearly 18 percent of the Hudson Valley land base is farmland, a backbone of the valley's economic output that provides fresh, local food to farmers markets, restaurants, groceries, and other outlets throughout the region.[1] Hudson Valley farms also maintain our scenic working landscapes, rural heritage, and quality of life, all of which help drive a multibillion-dollar tourism industry and fuel greener economic growth. In addition, conserved farms safeguard rare species and wildlife habitat and environmentally sensitive areas such as meadows, woodlands, wetlands, and streams. Overall, more than 50% of Hudson Valley farmland supports biodiversity and habitat values. Farms also protect local aquifers and other drinking-water supplies, and keep a lid on local property taxes by requiring just 37 cents in municipal services for each $1 of taxes they pay. Successful agricultural conservation requires keeping individual farms in production as well as maintaining high-priority clusters of these agricultural operations. This reflects the reality that it takes a "critical mass" of farm operations to keep farming economically viable in a region, while also ensuring that agricultural acreage isn't lost at a macro level.

How to Use the Hudson Valley Conservation Strategy

The primary purpose of the HVCS is to provide a strategic framework for the land protection efforts of Scenic Hudson and our conservation partners to build long-term climate resiliency across the Hudson Valley landscape. Recognizing the diverse missions of our individual partners, the strategy can serve to align our collective land conservation investments, maximizing efficiency and promoting meaningful progress in conserving a climate-resilient and biodiverse landscape. We defined our focal area to include 11 counties in New York State: Albany, Columbia, Dutchess, Greene, Orange, Putnam, Rensselaer, Rockland, Sullivan, Ulster, and Westchester.

The HVCS also provides valuable information about the distribution of its components (climate resilience, biodiversity, and landscape connectivity), which can be used in natural resource management and land use planning. For instance, lands with high climate-resilience value but low biodiversity or connectivity values could be prioritized for habitat restoration. Simultaneously, the conservation value of properties that cannot be protected by fee acquisition can still be safeguarded with conservation easements or effective land use policy and planning that mitigates impacts to the land's sensitive or high-value features.

The HVCS is a dynamic decision-support tool, not a static solution or plan. Its identification of networks of land units (i.e., tax parcels or hexagon grid cells) that most efficiently contribute to achieving conservation targets across the region is based on the best available data, but it does not incorporate all of the considerations affecting conservation decisions, such as the availability of lands for acquisition. It is also important to note that the "irreplaceability" values (see inset on page 14) assigned to a particular area of land in the HVCS do not represent absolute conservation values. Rather, they are metrics of a parcel's contribution to networks of land units that, in aggregate, achieve the multiple conservation goals and targets with the minimum land area across the entire Hudson Valley region. The HVCS irreplaceability values are the result of a dynamic optimization and balancing process, which will change over time with new conservation successes and losses as well as updates to data sets, goals, and targets. In this way, the HVCS is meant to support the conservation decisions of land trusts and government agencies over time.

Conservation Priorities in the Hudson Valley

Promoting Resilience in the Face of a Changing Climate

Now is the time to start planning for climate change and building resilience considerations into conservation. In 2014, the U.S. Global Change Research Program released its *National Climate Assessment* summarizing the impacts of climate change on the United States.[2] The report, compiled by an interagency team of more than 300 experts, guided by a 60-member Federal Advisory Committee, and extensively reviewed by the scientific community and the public, concluded that human-induced climate change is already happening, and the impacts are increasing across the country. Regional findings of the assessment for the Northeast show:

- *Heat waves, coastal flooding, and river flooding will pose a growing challenge to the region's environmental, social, and economic systems. This will increase the vulnerability of the region's residents, especially its most disadvantaged populations.*
- *Infrastructure will be increasingly compromised by climate-related hazards, including sea level rise, coastal flooding, and intense precipitation events.*
- *Agriculture, fisheries, and ecosystems will be increasingly compromised over the next century by climate change impacts. Farmers can explore new crop options, but these adaptations are not cost- or risk-free. Moreover, inequities exist in adaptive capacity, which could be overwhelmed by changing climate.*
- *While a majority of states and a rapidly growing number of municipalities have begun to incorporate the risk of climate change into their planning activities, implementation of adaptation measures is still at early stages.*

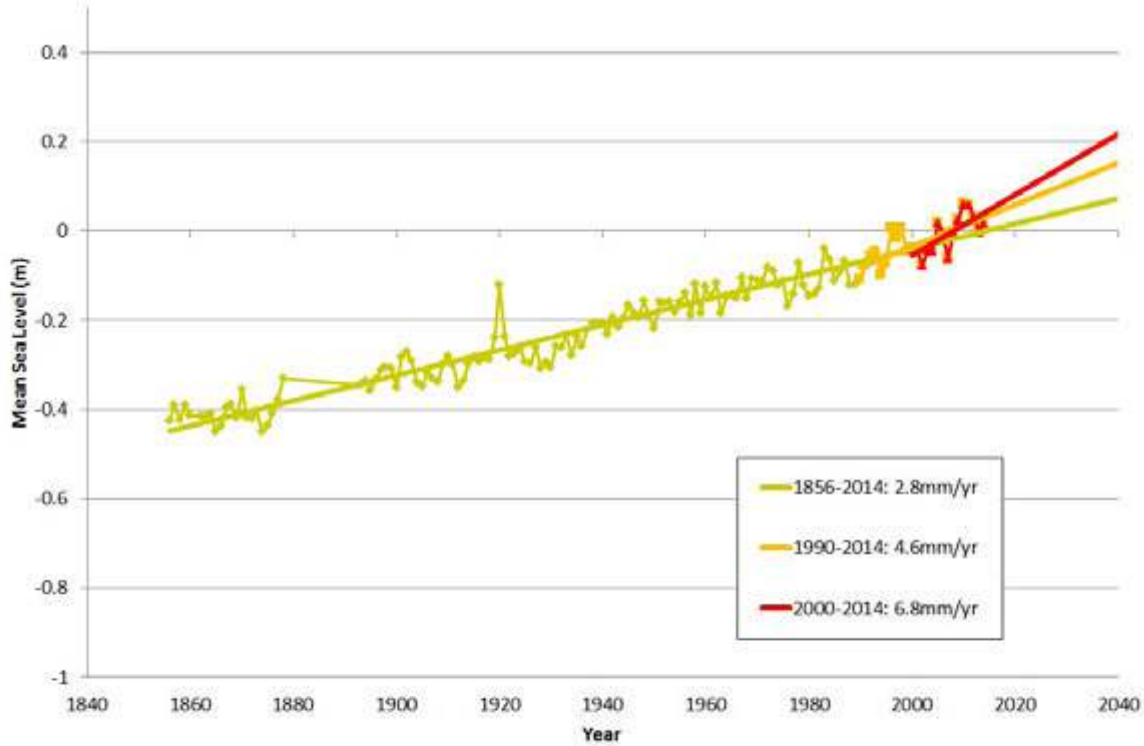


Figure 1. Mean sea level trends at The Battery, New York

Figure 2. Future Climate Scenarios

Temperature is rising in New York State at about a half degree per decade.[2] Sea level rise along the Hudson has accelerated from 2.8 mm per year in the 20th century to nearly 7 mm per year in this century.[3] And climate extremes—which often define the limits of species ranges and the impacts to people and nature better than averages—are widening. Trending flood magnitude in the Eastern U.S. since the middle of the 20th century has grown by around 10% per year.[2] This mirrors increases in extreme precipitation, heat waves, and storm surges.

The result of continued warming will be dramatic in New York. Even if, as a global community, we aggressively reduce our greenhouse emissions, we can still expect that New York's climate will resemble Virginia's by the end of this century (see Figure 2). However, based on our current emissions pathway, we may experience something more like the climate of Georgia by 2100. Consider the ecological disruption of moving an ecosystem 1,000 miles or more in just a century.[4]

We have every reason to expect that the Hudson Valley will be one of the most dynamic and rapidly changing ecosystems in America. Shown in Figure 3 is a map of the ecoregions of the lower 48 states—broad areas with similar sets of habitats and other natural resources.[5] Crossing from the Coastal Plain through the Appalachians and the Allegheny Plateau, the Hudson Valley may well be the most eco-regionally complex area of its size in the United States.

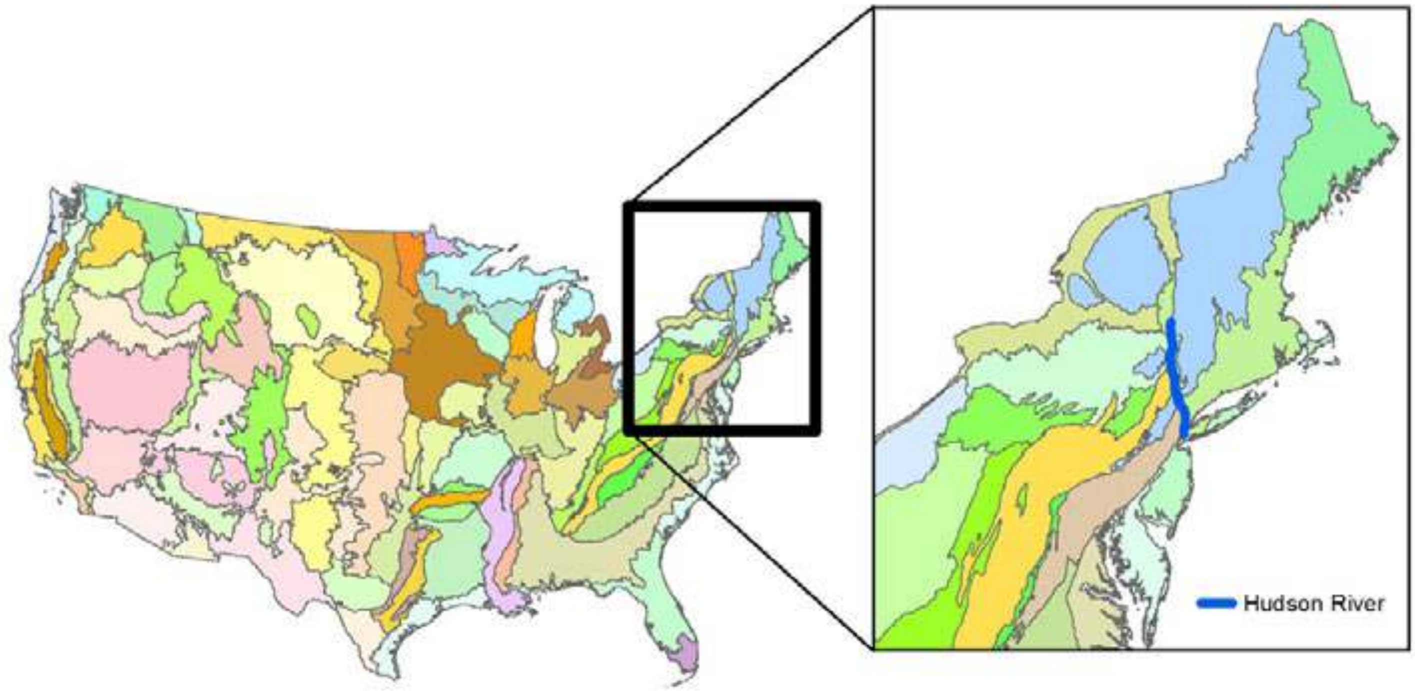


Figure 3. Ecoregion complexity of the Hudson Valley

Safeguarding the Region's Rich Biodiversity

As one of the most species-rich regions in the entire Northeast, the Hudson Valley contains a remarkably broad gradient of habitats, including globally significant "hot spots" of turtle, salamander, and dragonfly diversity, and over a dozen critically important breeding areas for both resident and migrant bird species. The Hudson River itself is home to nearly 200 species of fish, including the largest remaining populations of federally endangered Atlantic and shortnose sturgeon, and 7,000 acres of intertidal wetlands that sustain the resident and migratory birds and fish of the estuary.

As this rich community of habitats and species is increasingly impacted by climate change, the Hudson Valley region needs a conservation strategy that helps ensure the long-term resilience of this ecosystem.

Ensuring a Connected Landscape

Landscape connectivity may be described as the degree to which the landscape facilitates or impedes the movement of organisms among areas of intact habitat.[6] Connectivity includes both structural connectivity (the physical characteristics of a landscape that allow for movement, including topography, hydrology, vegetative cover, and human land use patterns) and functional connectivity (the movement of genes, propagules, individuals, or populations through the landscape).[8] The degree to which a landscape is connected determines the amount of dispersal among areas of intact habitat, which influences gene flow, local adaptation, extinction risk, colonization probability, and the potential for organisms to move as they cope with climate change.

Fragmentation and habitat loss threaten to degrade landscape connectivity in the Hudson Valley and can reduce the size and quality of available habitat, impede and disrupt movement of organisms to new habitats, and affect seasonal migration patterns. In turn, these changes can lead to detrimental effects for populations and species, including decreased carrying capacity, population declines, loss of genetic variation, and ultimately species extinction.[9] Many conservation efforts focus on protecting and enhancing connectivity to offset the impacts of habitat loss and fragmentation on biodiversity conservation, and to increase the resilience of reserve networks to potential threats associated with climate change.

Preventing Fragmentation in the Hudson Valley/ New York City Foodshed

Although the essential character of the landscape remains intact, the agricultural productivity and biological richness of the Hudson Valley face unprecedented challenges.[1] To begin with, it is one of the most highly "parcelized" of any geographic region in the U.S. Sitting on the back doorstep of New York City, it has been one of the fastest growing areas in the Northeast over the past two decades. Sprawling development has fragmented parts of the landscape, spreading a network of new roads and subdivisions that has segmented forest blocks, separated wetlands from upland habitats, and decimated critical habitats. Additionally, according to the American Farmland Trust, New York State has been losing farmland at an alarming rate–the equivalent of one farm every 3½ days. These trends make the protection, restoration, and enhancement of habitat vital to the persistence of biodiversity in the region, and protecting farmland is an important contributor to the overall resilience of the Hudson Valley.

Scenic Hudson's 2013 *Hudson Valley/New York City Foodshed Conservation Plan* presents a strategic approach to identify and conserve the most important agricultural land that can supply fresh, local food to the people of New York City and the Hudson Valley. The plan identifies important farms to consider for conservation, prioritizes farms based on their agricultural values, and delineates nine regional areas of importance with the highest density of high-value farmland. The HVCS builds on the Foodshed Plan by identifying the contribution of conserved farms to safeguarding wildlife habitat, environmentally sensitive areas, and a resilient landscape while also maintaining scenic working landscapes, rural heritage, and quality of life.

Planning for Multiple Goals

Up to this point, broad conservation strategies in the Hudson Valley have focused primarily on priority habitats and agricultural landscapes, and have historically treated these objectives as distinct. Now, the realities of climate change have added an additional context to consider in conservation planning: *resilience*.

In a preliminary study funded by the Doris Duke Charitable Foundation, Scenic Hudson examined the intersection of these conservation objectives, seeking to detect areas within a "sweet spot" where multiple goals can be met with targeted conservation investments. Scenic Hudson found places within the Hudson Valley landscape, often on or near conserved farmland, that can contribute to achieving all three conservation objectives. More than half of the farm parcels identified in the *Hudson Valley/NYC Foodshed Conservation Plan* also support high-quality habitat. In addition, 45% contribute to regional climate resilience.

A conservation strategy is needed that defines how much conservation is sufficient to achieve all three objectives efficiently and simultaneously. It should be a strategy that builds on prior investments and earlier conservation successes, so that we move away from a patchwork of priorities toward a regional network of conservation areas that add up to more than the sum of their parts—building regional climate resilience and landscape connectivity through coordinated conservation investments.

The HVCS builds upon the network of approximately 890,000 acres of already-protected public and private lands in the Hudson Valley (see Figure 4). As new lands are conserved, the HVCS dynamically incorporates data updates to guide future land-protection activities and build an efficient and cohesive conservation network.

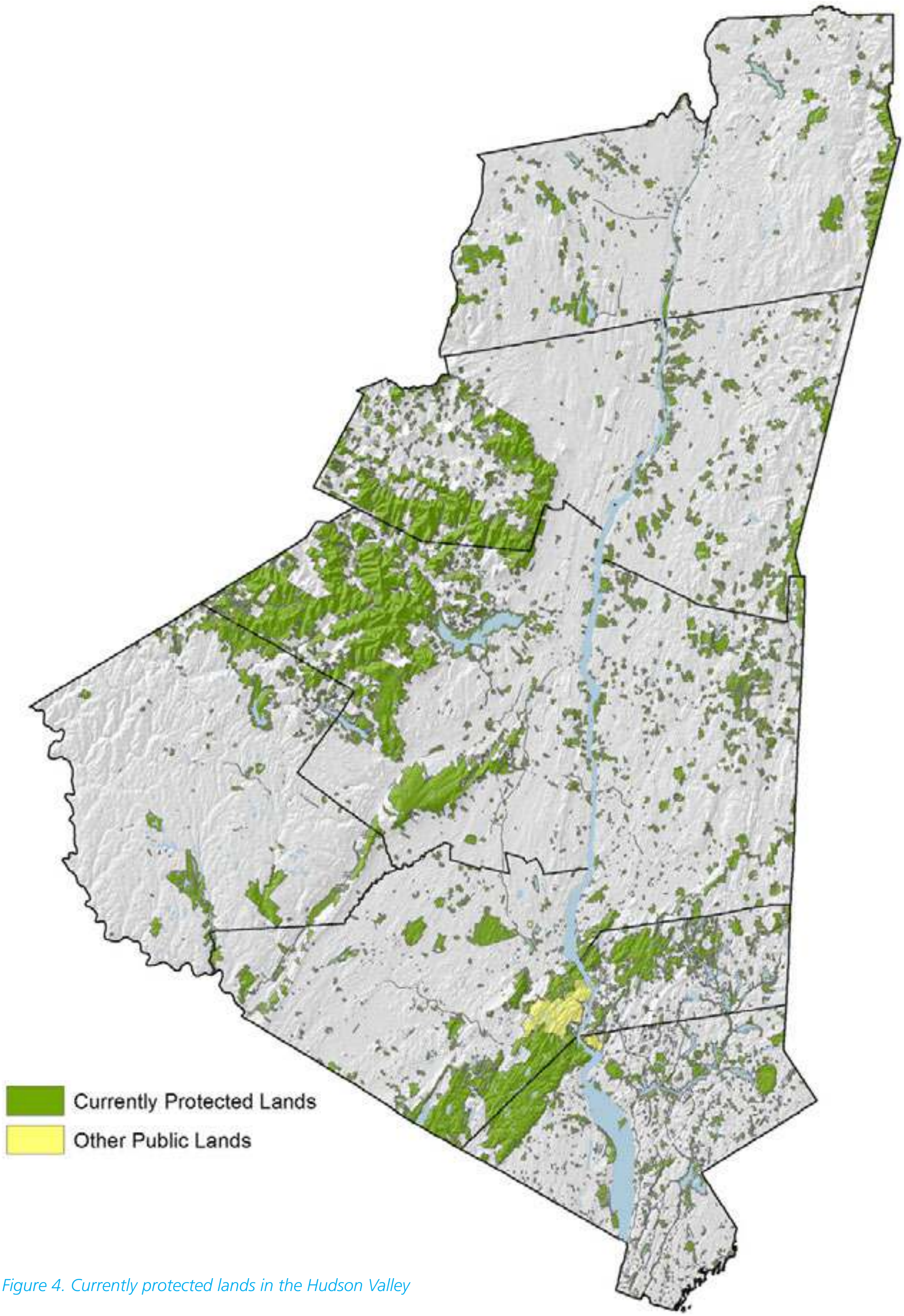


Figure 4. Currently protected lands in the Hudson Valley

However, farmlands and fertile lowland areas are under-represented in the current network of conserved lands in the Hudson Valley. This mosaic of existing land protection shows great progress by our conservation community, but does not represent all of the different types of places required in a robust and resilient conservation network. As shown in Figure 5, of the 18 ELUs that make up the Hudson Valley, six are less than 12% conserved and occur in the fertile lowlands. That means we need a strategy that integrates climate resilience with our other conservation goals—conserving underrepresented ELUs, supporting the rich biodiversity of the region, and ensuring landscape connectivity so species can move across the landscape.

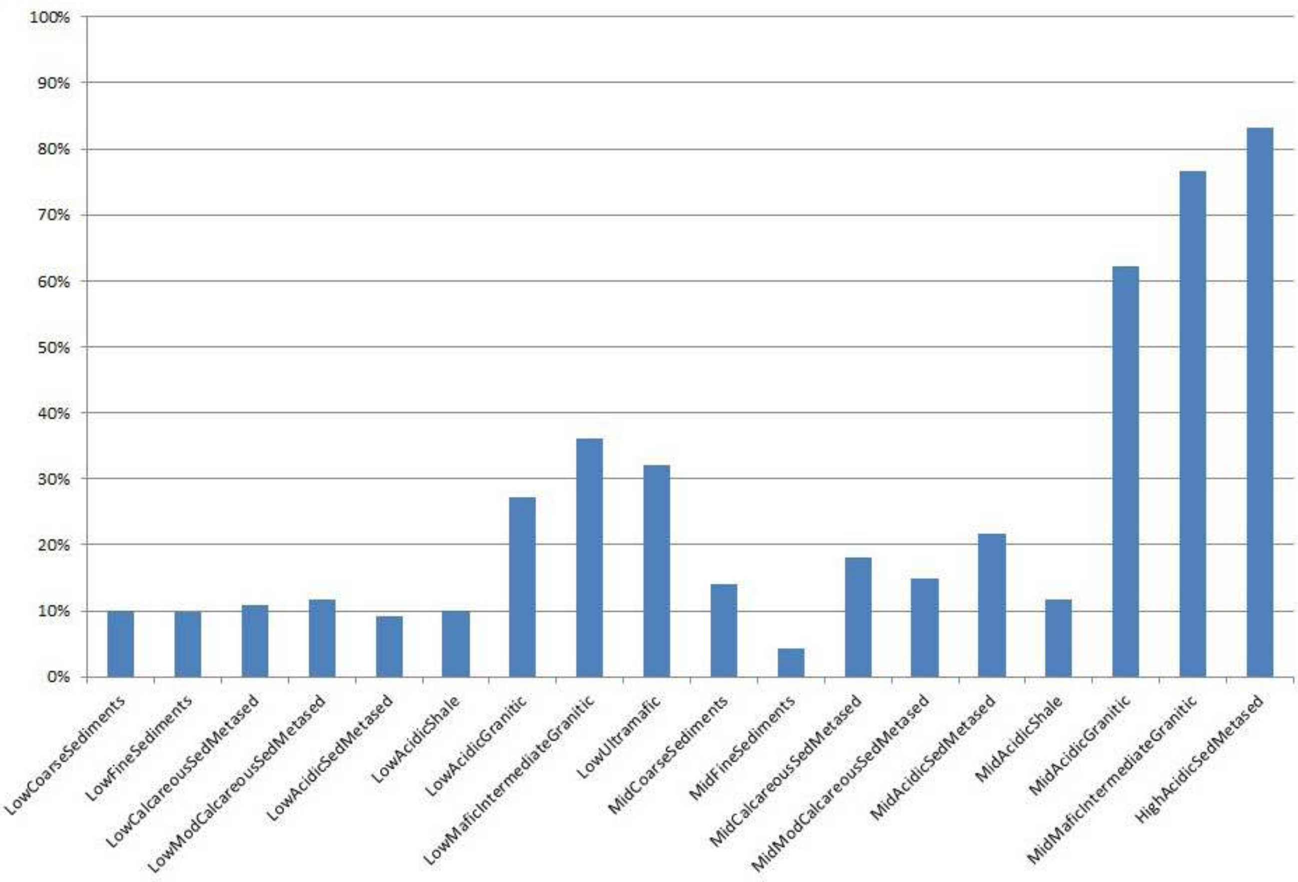


Figure 5. Percent protected land by ELU

Systematic Conservation Planning

"Systematic conservation planning" is a structured, step-wise approach to mapping conservation area networks that allows feedback, revision, and reiteration (where needed) at any stage, making it ideal for regional multi-objective planning.[10,11] We used a systematic conservation planning approach to develop the HVCS because it is:

- **Efficient**: By including and building upon already protected lands, the solutions produced by the tool represent the minimum acreage required to meet conservation targets and goals;
- **Complete**: Conserving all of the defined conservation targets can be achieved through solutions identified by the analysis;
- **Rigorous**: The tool uses the best available data to represent and quantify conservation targets and weighting factors;
- **Dynamic**: The tool can be easily updated with new or revised data or additional conservation goals, as needed; and
- **Participatory**: By incorporating the best available knowledge and guidance from scientific and technical experts and soliciting feedback from managers and land protection practitioners, Scenic Hudson was able to design a robust and practical tool to meet the needs of the conservation community. The ability to update the results will allow us to incorporate feedback from stakeholders to refine the strategy, ensuring it remains relevant for future conservation efforts.

By using this approach, Scenic Hudson seeks to establish a conservation prioritization framework that our regional community of partners can use for guiding conservation investments across the valley. We don't suggest that the HVCS should supplant individual missions and strategic initiatives, but we believe it can help drive our collective efforts toward conserving places that, in addition to providing local benefits, will contribute to a more effective and resilient regional conservation network that achieves multiple conservation goals.

Prioritizing by Determining Irreplaceablility

The HVCS uses a *spatially explicit* systematic conservation planning software to define and aggregate the individual land units (i.e., tax parcels or hexagon grid cells) to develop **conservation network solutions**. The tool starts with the existing network of protected lands and randomly adds and removes land units, evaluating the criteria to decide whether to keep or discard each change. This process iterates 100 million times, swapping land units in and out, and eventually identifying a near-optimal conservation network solution that efficiently achieves our targeted goal.

However, in this approach each land unit is either selected or discarded as part of our protection network; it's either "in" or "out." This provides us with only one possible "good" solution out of the large number of possible combinations of planning units that also would meet all of our goals.

Therefore, we re-run the program 100 times and stack up each unique good solution. Then we can drill down through the stack to determine how many times out of 100 a particular unit is selected as part of a good solution. This gives us an indication of the **irreplaceability** of that land unit in contributing to *any* good solution for that conservation goal. We can represent the data with a gradient from light to dark green with increasing irreplaceability, based on how often each unit is part of a good solution.

You can see this in the two magnified areas below. In the map at left, which represents a single run, each land unit is either in or out, green or white. In the right-hand map, each unit is scored on a gradient of irreplaceability indicating how many times out of 100 runs it was part of a good solution.

A single "good" conservation network solution

Irreplaceability aggregates 100 "good" solutions

A land unit with an irreplaceability value of 100 means that the unit is *always* selected as part of a good conservation solution. This indicates there is a high confidence that conserving this land will contribute significantly to achieving regional goals efficiently and will complement previously conserved lands. However, a land unit with an irreplaceability value of 50 may indicate that the land could still contribute to achieving regional goals, but it might be less efficient or more disjointed from existing conserved lands. A unit with a lower score may indicate that this land area is low in its contribution to regional goals, but still could be an important component of a local conservation strategy. Thus, every land unit identified in the HVCS has a degree of irreplaceability, with higher scores indicating greater conservation worthiness in its contribution to building regional landscape resiliency and ecological function.

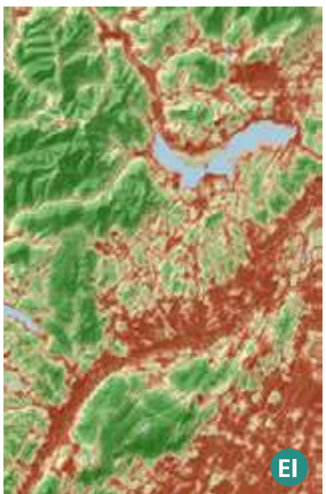
Conservation Goals and Network Solutions

For our primary goals of conserving climate resilience, biodiversity, and habitat connectivity, individually and in combinations, we developed conservation network solutions using our systematic planning tool.

Quantitative spatial *data layers* allow specific numeric *targets* to be defined for each objective (see Table 1 on Page 27 in the Methods section for criteria and values). Ecological *weighting factors* steer the tool to the selection of higher-quality land units for efficient solutions that achieve the conservation targets in areas of high ecological quality.

Ecological Integrity

Across all of the conservation networks described in the following sections, **ecological integrity** is used as a weighting factor to guide conservation outcomes toward lands that provide higher ecological values and reduced habitat fragmentation.



Green areas show high ecological integrity

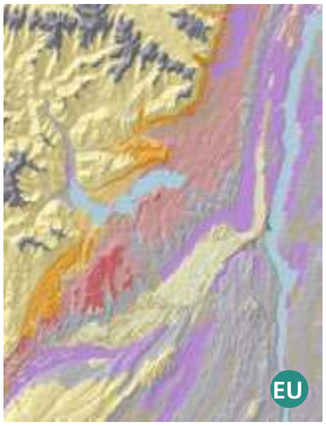
Data Layers:

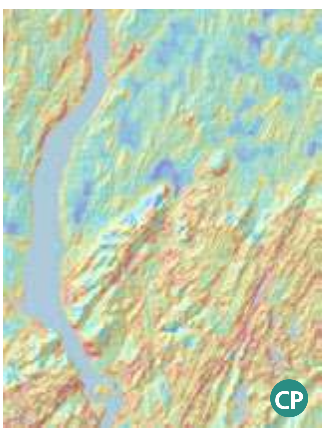
EI *Ecological Integrity (Weighting Factor)*
Ecological integrity is the ability of an area to support biodiversity and those ecosystem processes necessary to sustain biodiversity over the long term.[12] This includes two categories of landscape metrics: **landscape intactness** and **disturbance resiliency**.

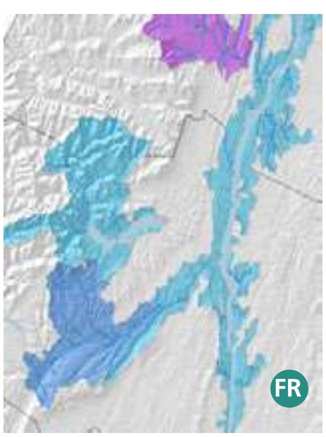
Landscape intactness is defined as the freedom from recent human impairment (anthropogenic stressors), measured as a combination of a number of stressor metrics.

Disturbance resiliency is the capacity of the landscape to recover from disturbance and stress, measured as a combination of the connectedness and similarity to neighboring natural areas.

An ecosystem-based approach to the conservation of biodiversity is based on the premise that maintaining the integrity of ecosystems and the landscape will ensure that important ecological functions persist, to the benefit of humans and nature, and that focusing conservation activities on ecosystems is an efficient and practical strategy for protecting the majority of biodiversity, including species that may generally be overlooked or difficult to assess. As this definition of ecological integrity is based on ecological functions rather than static composition and structure, it accommodates the adaptation of systems over time to changing environmental factors driven by climate change.







Climate Resilience Conservation Network

Goal: Ensure the climate resilience of the Hudson Valley

Objectives:

- Conserve representative examples of Ecological Land Units
- Conserve wetland pathways
- Conserve landscape complexity
- Conserve resilient freshwater stream catchments

Data Layers:

EU *Ecological Land Units (Target)*
Ecological Land Units (ELUs) are based on elevation zones, geology, and landforms, and describe the "ecological potential" of the landscape.[13] Decisions on where to focus conservation efforts require an understanding of patterns of environmental variation and biological diversity. This dataset assesses the biophysical character of landscapes and maps the distribution and composition of natural community assemblages across those landscapes.

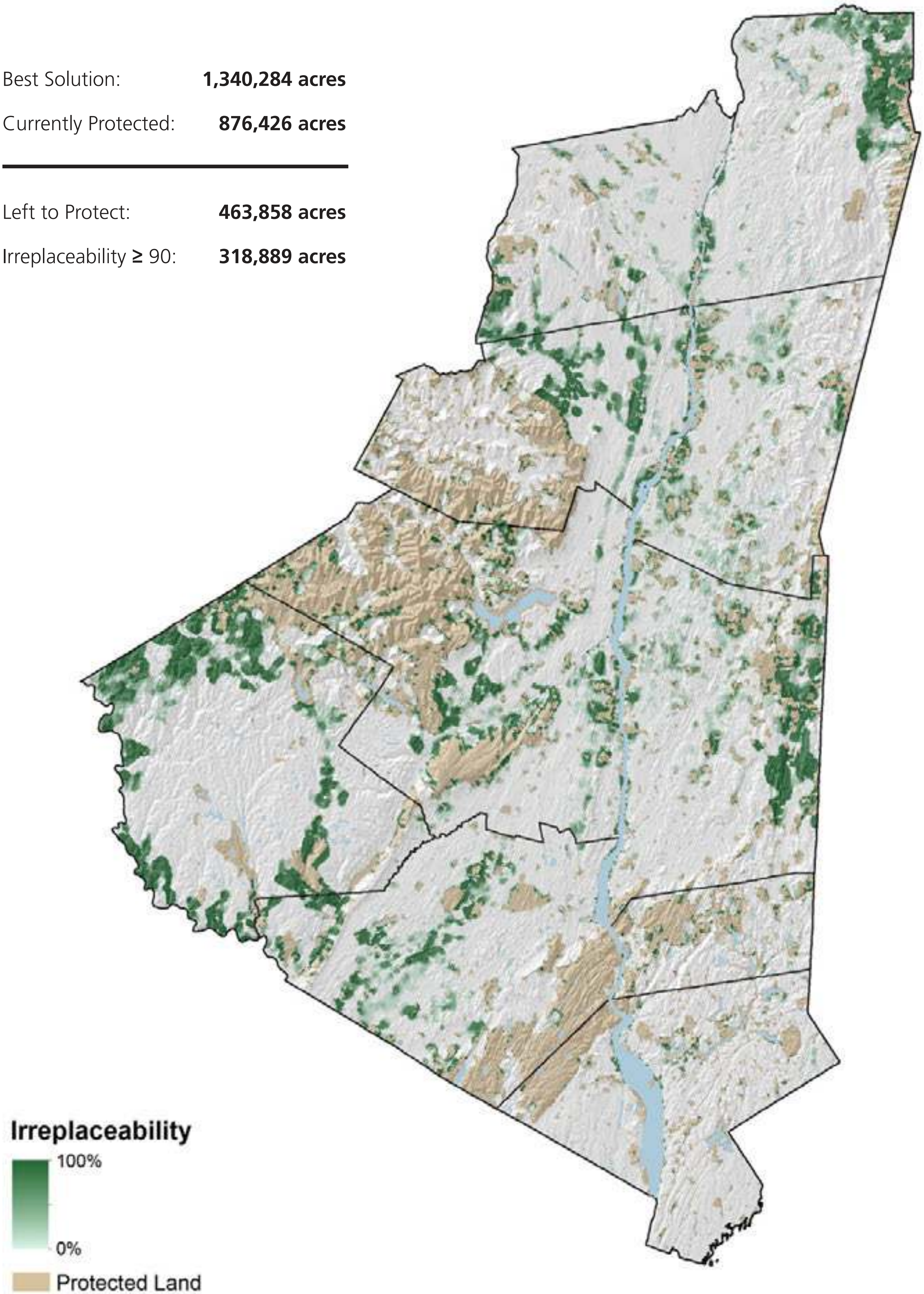
WP *Wetland Pathways (Target)*
Wetland pathways ensure that wetlands have the physical room to adapt to rising sea levels, which is essential to the long-term health of the Hudson River estuary ecosystem as well as human communities.[14] A wetland pathway is the combined area of tidal wetland projected in this century under the full possible ranges of sea level rise and accretion rates examined in Scenic Hudson's Tidal Wetland Adaptation Framework Study.

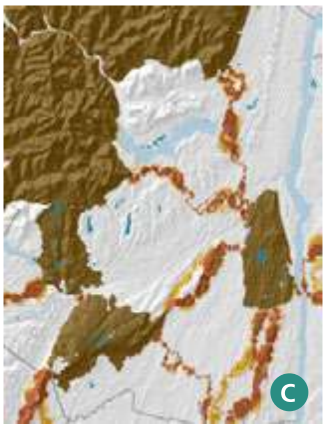
CP *Landscape Complexity (Weighting Factor)*
Landscape complexity represents the variety of microclimates present in the landscape and can be used to estimate the capacity of the site to maintain species and ecological functions.[15] Landscape complexity is based on landform variety, elevation range, and (in flatter regions) wetland density.

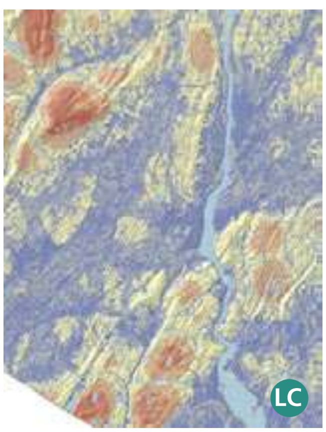
FR *Freshwater Resilience (Weighting Factor)*
Resilient freshwater stream systems are those that will maintain ecological functions and support biodiversity even as species composition and hydrologic properties change in response to shifts in environmental conditions due to climate change.[16] Identifying and conserving streams and catchments with the capacity to adapt to these climatic changes is critical for protecting healthy freshwater systems. The Nature Conservancy evaluated freshwater systems based on seven characteristics correlated with resilience, including four physical properties (stream network length, number of size classes, number of gradient classes, and number of temperature classes) and three condition characteristics (risk of hydrologic alterations, natural cover in the floodplain, and amount of impervious surface in the watershed). We used this weighting factor to prioritize land units for conservation in the catchments of resilient freshwater systems.

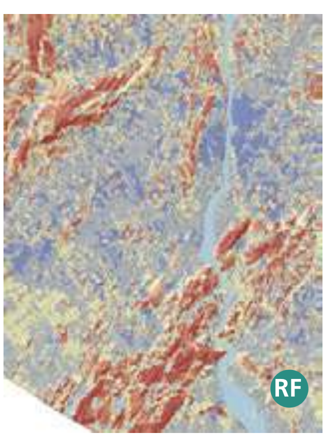
HVCS Network Solution: Climate Resilience

Best Solution:	**1,340,284 acres**
Currently Protected:	**876,426 acres**
Left to Protect:	**463,858 acres**
Irreplaceability ≥ 90:	**318,889 acres**









Landscape Connectivity Conservation Network

Goal: Maintain present landscape connectivity for ecological function and resilience of the Hudson Valley

Objectives:

- Conserve forest and wetland habitat cores
- Maintain core-to-core corridors
- Maintain local and regional connectivity

Data Layers:

HC *Habitat Cores (Target)*
Forest and wetland cover types are considered essential for supporting biodiversity in the Hudson Valley and will likely dictate the movement of species to more suitable sites under the stressors of climate change.[17] Forest Habitat Cores are large, contiguous areas whose size and natural condition allow for the maintenance of ecological processes, viable forest communities, and species populations. The NYSDEC Hudson River Estuary Program used wetland size, biodiversity representation, and ecological integrity to identify the most intact wetland cores in each elevation-geologic zone, assuming these would be the most climate-resilient.

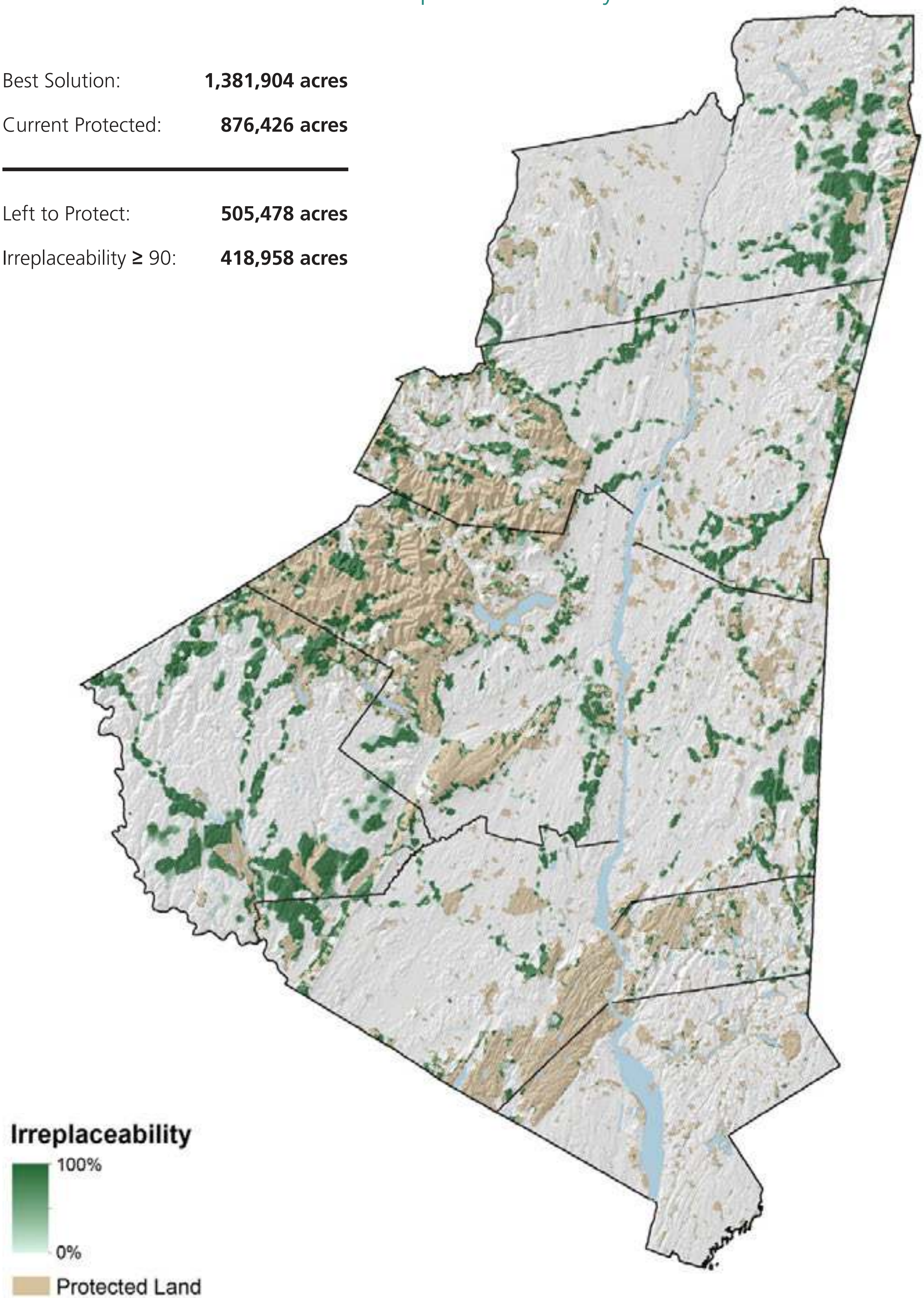
C *Connective Corridors (Target)*
Connective corridors are components of the landscape that facilitate the movement of organisms and processes between habitat cores.[17] The Hudson River Estuary Program developed a baseline map of corridors to help sustain native biodiversity, using broad scale models to connect core areas of forest and wetland cover types.

LC *Local Connectivity (Weighting Factor)*
Maintaining a connected landscape is the most widely cited strategy in scientific literature for ensuring climate resilience.[15] A landscape with low fragmentation and few barriers to movement facilitates the range shifts and ecological community reorganization expected under current climate change scenarios. The local connectedness raster data estimates the degree of connectedness of each 90-meter cell with its surroundings within a three-kilometer radius of that cell.

RF *Regional Flow (Weighting Factor)*
The Nature Conservancy modeled regional flow patterns to identify potential larger-scale directional movements of organisms, such as directional range shifts, north-south migrations, and upslope dispersal patterns, and to pinpoint the areas where flow patterns are likely to become concentrated, diffused, or rerouted due to the structure of the landscape.[15]

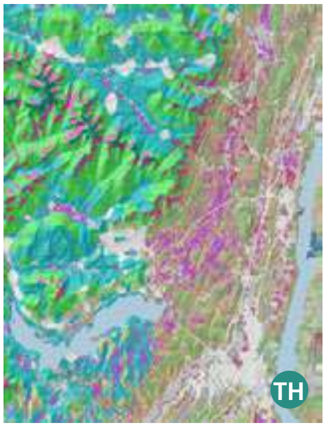
HVCS Network Solution: Landscape Connectivity

Best Solution:	**1,381,904 acres**
Current Protected:	**876,426 acres**
Left to Protect:	**505,478 acres**
Irreplaceability ≥ 90:	**418,958 acres**



Biodiversity Conservation Network

Goal: Maintain ecological complexity and function of the Hudson Valley

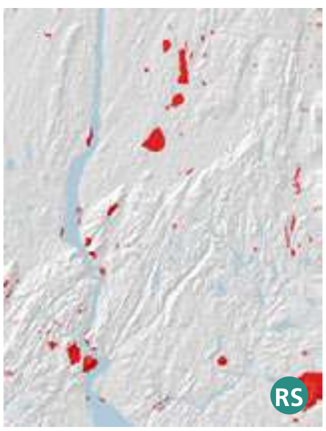


Objectives:

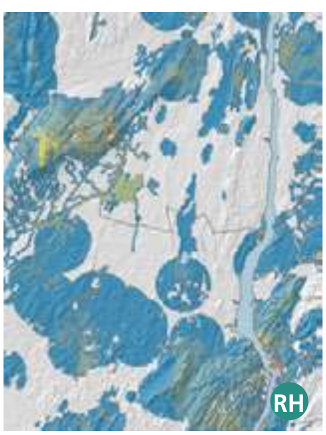
- Conserve representatives of all current terrestrial habitats
- Conserve rare and vulnerable species occurrences
- Conserve rare and vulnerable species habitats

Data Layers:

TH *Terrestrial Habitats (Target)*
The Nature Conservancy's terrestrial habitats map provides a common, consistent map of habitats for the Northeast region. It guides conservation efforts by allowing users to assess the distribution and condition of habitats.[18] Data is assembled from spatially comprehensive datasets of 71 ecological variables and the compilation of over 70,000 ecological community samples.



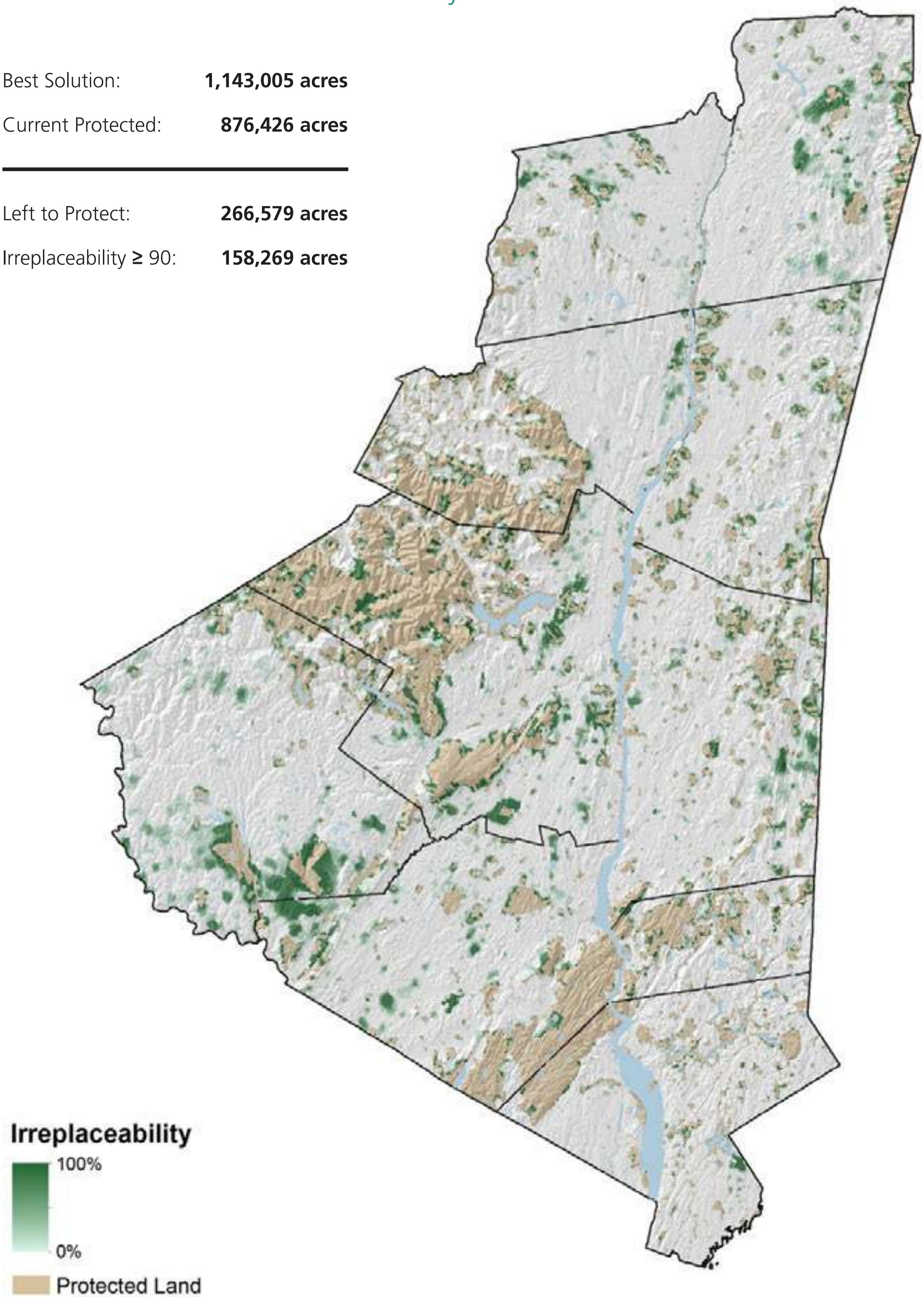
RS *Rare and Vulnerable Species (Target)*
New York Natural Heritage Program (NYNHP) maintains New York's most comprehensive database on the status and location of rare species and natural communities.[19] NYNHP presently monitors 181 natural community types, 803 rare plant species, and 476 rare animal species across the state, keeping track of more than 13,700 locations where these species and communities are found. NYNHP data is essential for prioritizing those species and communities in need of protection and for guiding land use and management decisions where these species and communities exist.



RH *Rare and Vulnerable Species Habitats (Weighting Factor)*
NYNHP Important Areas are lands and waters that support the continued presence and quality of known populations of rare animals and plants, and documented examples of rare or high-quality ecological communities.[20]

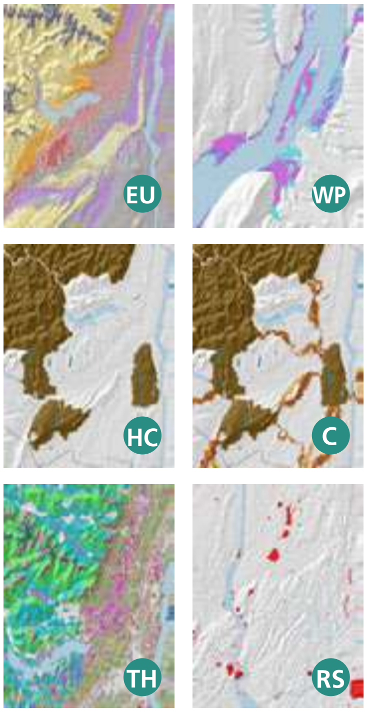
HVCS Network Solution: Biodiversity

Best Solution:	**1,143,005 acres**
Current Protected:	**876,426 acres**
Left to Protect:	**266,579 acres**
Irreplaceability ≥ 90:	**158,269 acres**



Multiple Objectives Conservation Network

TARGETS

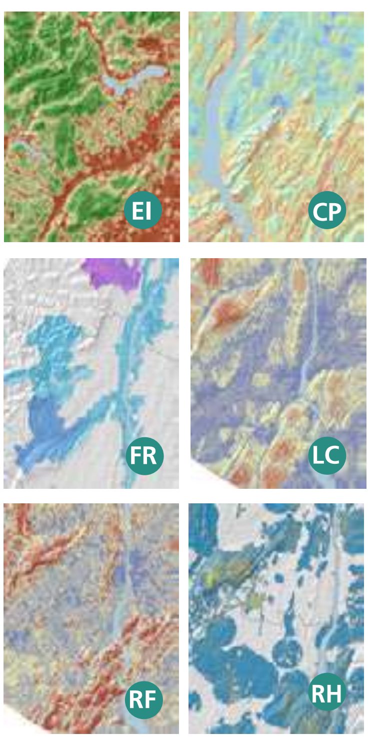


Goal: Ensure the climate resilience, landscape connectivity, and ecological complexity and function of the Hudson Valley.

Objectives:

- Conserve representative examples of Ecological Land Units
- Conserve wetland pathways
- Conserve landscape complexity
- Conserve resilient freshwater areas
- Conserve forest and wetland habitat cores
- Maintain core-to-core corridors
- Maintain local and regional connectivity
- Conserve representatives of all current terrestrial habitats
- Conserve rare and vulnerable species occurrences and habitats

WEIGHTING FACTORS



Data Layers:

Targets:

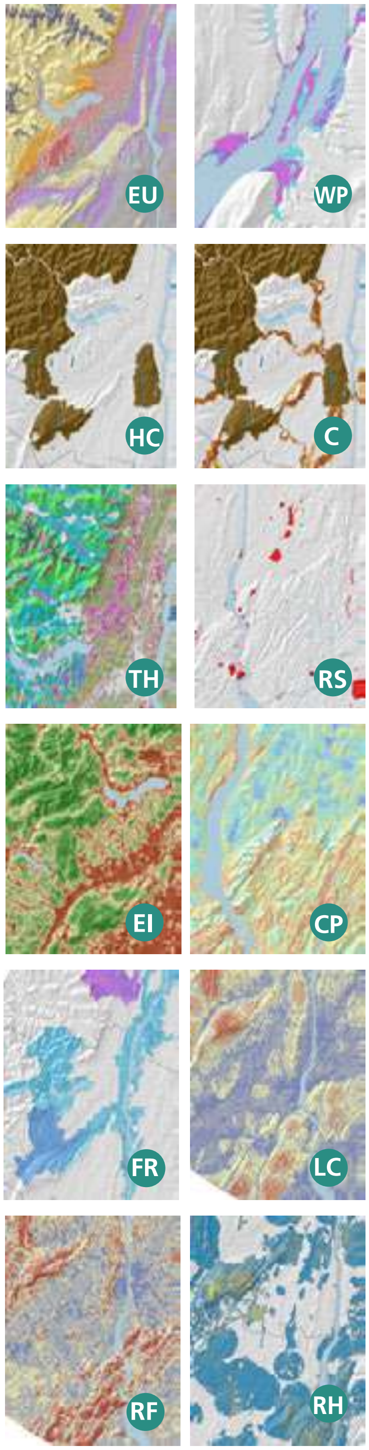
- EU *Ecological Land Units*
- WP *Wetland Pathways*
- HC *Habitat Cores*
- C *Corridors*
- TH *Terrestrial Habitats*
- RS *Rare and Vulnerable Species*

Weighting Factors:

- EI *Ecological Integrity*
- CP *Landscape Complexity*
- FR *Freshwater Resilience*
- LC *Local Connectivity*
- RF *Regional Flow*
- RH *Rare and Vulnerable Species Habitats*

HVCS Network Solution: Multiple Objectives

Best Solution:	**1,610,983 acres**
Current Protected:	**876,426 acres**
Left to Protect:	**734,557 acres**
Irreplaceability ≥ 90:	**611,017 acres**



Multiple Objectives with Agriculture Conservation Network

Goal: Safeguard viable and productive farmland in the Hudson Valley, while simultaneously ensuring climate resilience, landscape connectivity, and ecological complexity and function.

Objectives:

- Conserve high-priority farmland
- Maintain "critical masses" of farms
- All objectives of the Multiple Objectives Conservation Network

Data Layers:

All Targets and Weighting Factors of the Multiple Objectives Conservation Network, and additionally:

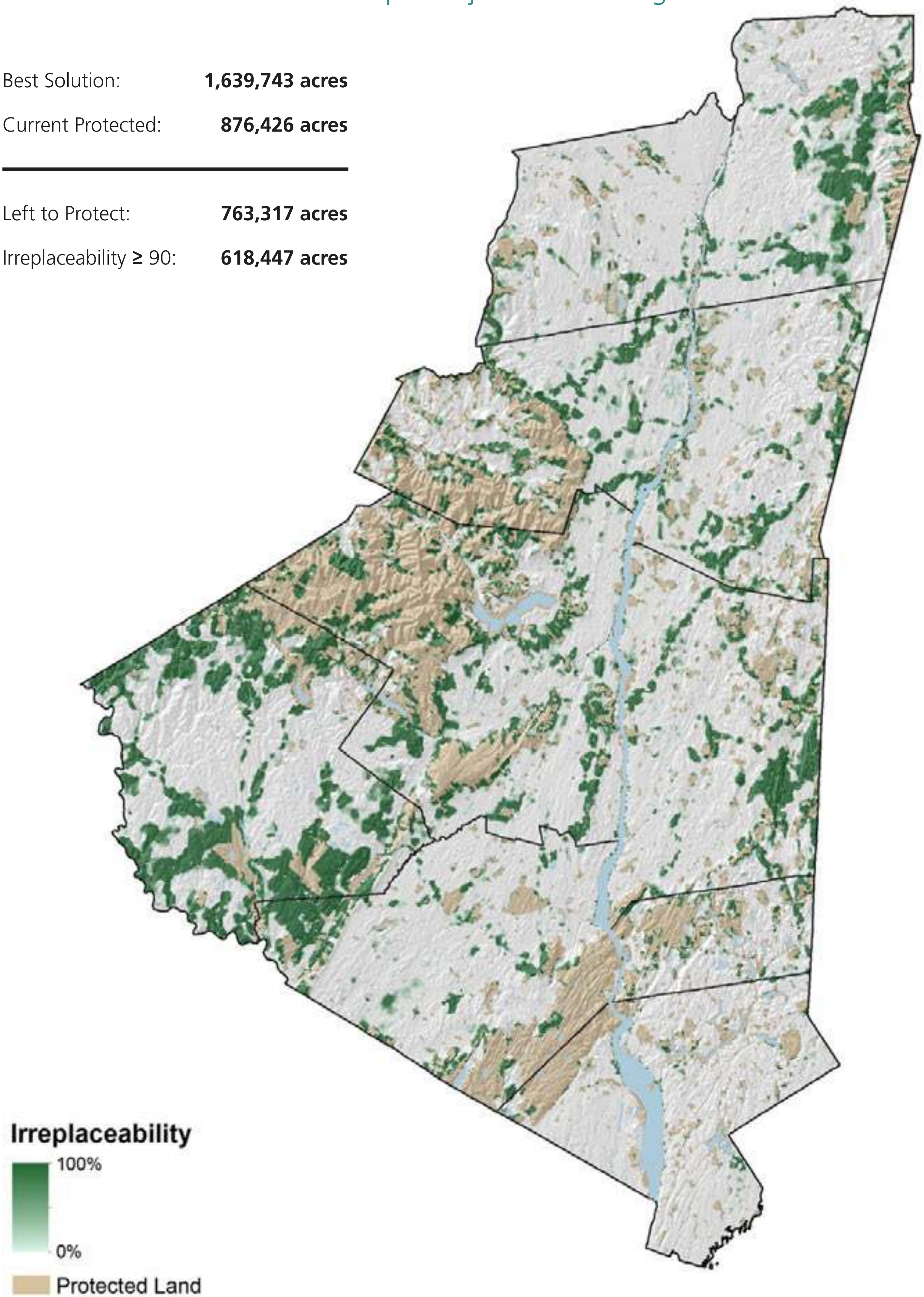
FC *HV/NYC Foodshed Conservation Plan Farms and Clusters (Targets)*
Scenic Hudson's *Hudson Valley/NYC Foodshed Conservation Plan* identified 5,387 farms of 45 acres or larger, comprising a total of 730,390 acres, in the Hudson Valley by combining data including agricultural districts, agricultural land use designations, and agricultural tax exemptions, which were further verified by aerial photography.[1]

Regional Areas of Importance are identified using mean soil productive capacity, relative concentration of farms, and the average size of farms, combined to yield a cumulative farmland index by town. Collectively, all of the information is analyzed at both local and regional scales to identify nine priority conservation clusters with the highest density of high-value farmland.

HVCS Network Solution: Multiple Objectives with Agriculture

Best Solution:	**1,639,743 acres**
Current Protected:	**876,426 acres**

Left to Protect:	**763,317 acres**
Irreplaceability ≥ 90:	**618,447 acres**



Methods

Scenic Hudson used Marxan, the most widely-used systematic conservation planning tool, to identify efficient landscape conservation solutions that simultaneously achieve our multiple goals. Marxan generated these conservation scenarios by identifying and prioritizing the most efficient sets of potential land conservation projects that achieve explicit targets for the array of climate resilience, habitat connectivity, biodiversity, and agricultural conservation objectives.

Our strategy employed this "spatially explicit" systematic planning tool, where we defined the individual land units that the tool aggregated to develop networks of recommended conservation lands. We developed two independent products: one using tax parcels as explicit units of land ownership, another using a regular hexagon grid independent of land ownership.

Tax parcels provide "actionable" information for land conservation—most useful in planning a specific acquisition strategy. Tax parcel polygon data were acquired for each county in the study area and processed in a Geographic Information System (GIS). Parcels of less than five acres were removed from the analysis to reduce the data processing load, remove highly developed and fragmented areas, and eliminate parcels that were unfeasible and of low consequence for land protection transactions.

Hexagons provide a "pure" representation of the distribution of resources and values across the region. The hexagon-based planning unit data layer was generated for a similar extent and coverage as the parcel-based layer. Hexagons were created with a side length of 125 meters, resulting in 10-acre planning units. The 10-acre grid size was determined as an appropriate scale for conservation planning in the study area, as it produced a reasonable number of units for analysis and provided a feasible unit of land to inform decision-making.

The foundation of our tool is the current network of protected lands. This base provides the starting point for the tool to build conservation network solutions, leverage previous investments, and build an efficient and cohesive network of conserved lands.

Importantly, the easily updated HVCS creates a durable and dynamic framework that supports conservation investments responsive to both prior investments (existing or newly added conservation areas) and new data on natural resources, connectivity routes, conservation transaction opportunities, or other changing conditions. Metadata detailing the GIS and Marxan analysis methods are available from Scenic Hudson upon request.

Targeting and Weighting

A key element of this planning tool is that it allows us to explicitly define the *conservation goals, objectives, targets,* and *weighting factors* to be achieved. Quantitative data allow specific numeric targets to be defined and achieved for each objective. Ecological weighting factors steer the tool to the selection of higher-quality parcels for efficient solutions. Source data for all targets and weighting factors were assembled and processed using GIS. Quantitative target criteria, target values, and weighting factors for the data layers that went into each conservation network solution are provided in Table 1.

Conservation Network(s)	Data Layer	Criteria	Target Value	Weighting Factor
Climate Resilience, Landscape Connectivity, Biodiversity, Multiple Objectives, Multiple Objectives with Agriculture	Ecological Integrity	average index value		+/-10%
Climate Resilience, Multiple Objectives, Multiple Objectives with Agriculture	Ecological Land Units (ELUs)	ELU less than 1000 ac	80% of acreage	
		ELU between 1000 and 5000 ac	50% of acreage	
		ELU greater than 5000 ac	25% of acreage	
	Wetland Pathways	high-confidence areas	100% of acreage	
		medium-confidence areas	75% of acreage	
	Landscape Complexity	average index value		+/-10%
	Freshwater Resilience	within resilient catchment		+10%
Landscape Connectivity, Multiple Objectives, Multiple Objectives with Agriculture	Habitat Cores	each forest core	50% of acreage	
		each wetland core	100% of acre-age	
	Corridors	all corridors	85% of acreage	
	Corridor Buffers	all corridor buffers	50% of acreage	
	Local Connectivity	average index value		+/-10%
	Regional Flow	average index value		+/-10%
Biodiversity, Multiple Objectives, Multiple Objectives with Agriculture	Terrestrial Habitats	habitat type less than 1000 ac	80% of acreage	
		habitat type between 1000 and 5000 ac	50% of acreage	
		habitat type greater than 5000 ac	25% of acreage	
	Rare and Vulnerable Species	S1 occurrences*	100% of occurrences	
		S2 & S3 occurrences*	75% of occurrences	
	Rare and Vulnerable Species Habitats	number of overlapping habitats		0 to 10%
Multiple Objectives with Agriculture	Foodshed Cluster	total farm acreage within cluster	33% of acreage	
	Foodshed Farms	each farmland cluster's farm parcels	25% of parcels	

Table 1. Quantitative Targets and Weighting Factors

*NY State Protected Status Ranking

What the Hudson Valley Conservation Strategy is Useful For:

Land Protection

The HVCS is broadly implementable by Scenic Hudson and our partner land conservation organizations to support efficient, coordinated decision making and action across a highly biodiverse and resilient landscape. It can optimize the conservation value of open space and farmland protection investments by all stakeholders. Further, it creates a strategic conservation framework that supports the diverse missions of individual land trusts and land protection agencies while aligning the investments of these multiple actors.

Land Use Planning

While direct land protection through fee acquisition and conservation easements is a critical component of an overall strategy for conserving natural resources and ecosystem services, it isn’t feasible or desirable to purchase all the areas necessary to achieve success. For land use planning and policy efforts, the HVCS can provide crucial information on the distribution of resilience and ecological values across the landscape and efficient scenarios for guiding development activities away from sensitive or unique areas.

Habitat Restoration

Some areas may have degraded habitats or limited landscape connectivity but play important roles in fostering climate resilience. In such instances, forest management or habitat restoration measures could improve these other values, thereby increasing a property’s value as part of a multi-objective conservation project. Habitat restoration activities could include riparian tree planting, invasive species control and removal, hydrologic restoration, etc.

What the Hudson Valley Conservation Strategy is Not:

Decision Support Tool, not the Decision Itself

The HVCS is a dynamic, long-term vision and framework for how to conserve lands to achieve conservation goals across the Hudson Valley. The tool helps identify networks of land units that most efficiently contribute to achieving conservation objectives and targets across the region, but it does not incorporate several important considerations for making conservation decisions. One obvious example is that the tool does not incorporate the availability of lands for conservation. Land trusts have long understood the importance of opportunity in carrying out land conservation projects, and while careful planning and outreach can certainly guide activities, often the market availability of individual properties is uncertain. While this tool can help guide activities and reinforce the justification for conservation activities within a regional context, it should not be assumed that properties that have low irreplaceability values cannot make important contributions to local conservation strategies. Hence, although a property with a higher irreplaceability value may be a more efficient conservation solution, it may not be available, while one with a lower irreplaceability value may contribute substantially to achieving conservation targets. Therefore, the HVCS is an important tool that can contribute valuable information to guide the conservation decision-making process, but it should not be considered the final "answer."

Regional Efficiency, not Absolute Conservation Value

The HVCS attempts to identify efficient conservation solutions that span the Hudson Valley. It does this by identifying networks of land units that, in aggregate, achieve multiple conservation goals and targets with the necessary minimum land area, the smallest "footprint." However, this is a balancing act that defines a land unit's irreplaceability based on its total contribution to those goals across the entire Hudson Valley region. It is not a measure of the intrinsic conservation value of any one unit, but rather an evaluation of how the unit fits into a larger conservation vision. Due to this dynamic and pragmatic regional balancing act, the irreplaceability of individual units will change over time, as land protection successes and land use changes redefine where compact solutions can be built to achieve our conservation goals.

Climate-Resilient Conservation in Action

In implementing HVCS in our conservation work, Scenic Hudson has set minimum irreplaceability thresholds, which identify properties we consider to possess compelling resilience and other HVCS priorities. We set these irreplaceability value thresholds for hexagon- and parcel-based conservation network solutions: Climate Resilience (Hexagon) = **30**, Multiple Objectives (Hexagon) = **40**, Climate Resilience (Parcel) = **50**, Multiple Objectives (Parcel) = **40**. We mapped the HVCS results showing the climate-resilience irreplaceability threshold in blue, the multiple-objective irreplaceability threshold in red, and the areas where these two values overlap in purple (see Figure 6a). Representing the results in this way allowed Scenic Hudson to identify areas of high climate resilience that also meet additional HVCS goals (see Figures 6b,c,d), achieving a highly efficient conservation outcome.

A 132-acre property located just south of the Village of Catskill is contiguous with RamsHorn-Livingston Sanctuary, which is cooperatively owned and managed by Scenic Hudson and Audubon New York. The property encompasses approximately 3,400 feet of estuary shoreline, and includes a significant portion of the Ramshorn Marsh wetlands complex, containing a substantial swath of freshwater tidal swamp in essentially natural condition. It is one of the largest and best examples of this globally rare habitat type in all of New York State. The Ramshorn Marsh property scored very highly in this evaluation, with 100% of the hexagons and parcels having irreplaceability of 100, well above the threshold values.

The property has a geophysical setting of low elevation and coastal flats with gentle slopes and fine sediment deposits, resulting in a landscape that is a complex mosaic of dry lowlands and wetlands with many microclimates and high connectivity. This allows organisms to find suitable conditions in response to climate change. Ramshorn Marsh is home to numerous species classified by the NY Natural Heritage Program as endangered, threatened, rare, and of greatest concern. Dry lowland portions of the property are wetland pathways considered well-suited to accommodating the inland migration of this wetlands complex, which is projected to become increasingly inundated due to sea level rise. In addition, the property is part of a habitat corridor connecting the Hudson River estuary, RamsHorn-Livingston Sanctuary, Catskill Creek, and the Catskill Mountains, offering a path for species to migrate in response to a changing climate.

With capital grant funding from the Doris Duke Charitable Foundation, Scenic Hudson acquired the property in May 2017. The land will be added to the 480-acre sanctuary, significantly expanding the protection of the Ramshorn Marsh freshwater tidal wetlands complex.

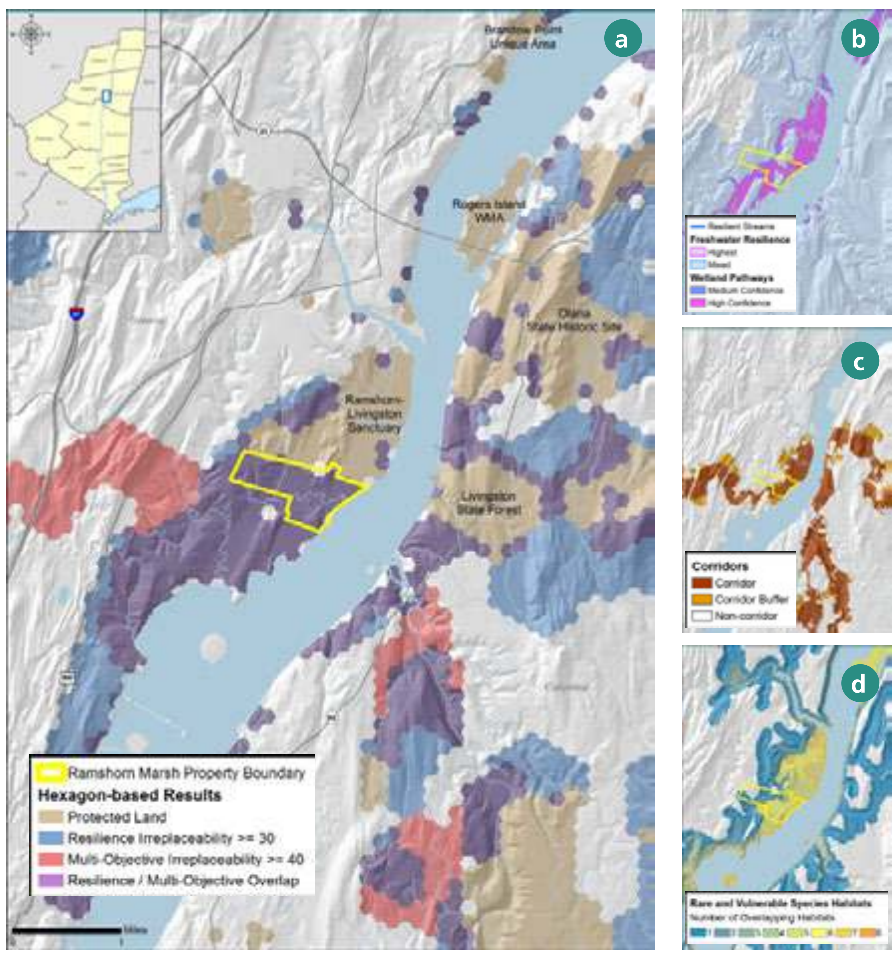


Figure 6. Ramshorn Marsh Property HVCS evaluation

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