Essex County Greenbelt Association
Land Conservation Prioritization Project

Greenbelt
Essex County's Land Trust

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Introduction

Essex County Greenbelt is a non-profit land trust that works to conserve the farmland, wildlife habitat and scenic landscapes within the 34 cities and towns of Essex County, Massachusetts. Greenbelt acquires and manages land to protect the integrity of our ecological systems, to maintain a base for local farmers growing food, and to protect areas for outdoor recreation and education. A primary focus of our work is the creation of a network of "greenbelts" consisting of natural corridors and visually intact landscapes. Since its founding in 1961, Greenbelt has conserved over 17,900 acres of land, and has been directly involved in protecting 75% of the Essex County acreage conserved in the last decade. Through active land conservation initiatives, as well as multi-platform public outreach, Greenbelt continues to build a community of land conservation and stewardship throughout the region.

Background of the Project

Previous Greenbelt Prioritization

In 2011, Greenbelt completed a GIS-based prioritization that evaluated assessors' parcels for habitat, agriculture, and connectivity value. Each parcel was assigned a rank from 1-4 (or no result) and the highest rank in any given category was assigned as the parcel's overall rank. The results were imported into an outreach database, and were used for landowner outreach and project evaluation. The database housed 6,489 parcel records, which included all parcels five acres or larger in Essex county. The parcel data originated from individual towns, and varied drastically from town to town in terms of format, quality, and accuracy. Additionally, the formatting of the database and GIS parcels wasn't compatible, which made working with the data across platforms extremely difficult.

Improved Database

Starting in 2013, the state of Massachusetts started to standardize parcel data into a Level III format, which sets out guidelines for compiling methods, formatting and quality. The creation of consistent, standardized, high quality parcel data motivated us to build a new database that would: seamlessly connect our GIS system and outreach database, allow us to make use of new fields in the parcel data, and allow us to update the parcels in our database over time. We completed a custom database in early 2017, which holds 9498 parcel records, an increase of 46% over the old one. The new database serves both our conservation and stewardship departments and houses data on parcels, projects, properties, conservation restrictions, and landowners.

As a part of the database effort, we imported the acreage of 28 natural resource data sets for every parcel. Examples included: drinking water, USDA farmland soils, BioMap2, The Nature Conservancy's (TNC) climate resiliency, and types of protected open space data. The Level III parcel data has some parcels categorized as Chapter 61 (a property tax reduction program for parcels whose current use is agriculture, forestry, or recreation). This data is of interest because it accurately identifies land use of the parcel, may indicate a landowner's interest in land conservation planning, and, importantly, gives the municipality the right of first refusal if there is a change of use for the property. We wanted to ensure that data was complete so we contacted each municipality in Essex County and received lists of all of their Chapter 61 parcels. That effort brought the number of Chapter 61 parcels from 874 in the Level III data to 1165, an increase of 33%. At the completion of the database project, we found ourselves with access to new and more complete parcel data, new GIS data such as the climate resiliency work completed by TNC, and new Chapter 61 data, all of which spurred the staff to identify the prioritization project as the next data product.

These land parcels that have been imported into the database also serve as the areas to be analyzed within the prioritization project. Parcels that are already permanently protected were not included in the analysis unless they included 5 acre or larger portions that were unprotected. There were also a number of parcels belonging to municipal watershed lands, or that may not be considered permanently protected by Greenbelt's assessment, which were included into the analysis parcel datalayer.

Funding & Implementation

Greenbelt has had a successful GIS intern program with the Salem State University Geography Department since 2013. In order to complete the prioritization in a timely manner, Greenbelt created a GIS Fellowship. We had hosted a graduate student intern starting in the spring and summer of 2018. His success in that position made it a natural fit to bring him on as the fellow. The fellowship began in the fall of 2018 and concluded the summer of 2019. We received the generous support of the New England BioLabs Foundation, the Towards Sustainability Foundation, and the Land Trust Alliance to fund the fellowship. The GIS fellow has been an integral part of the team and was critical to the success of the project.

Process

The prioritization team consisted of Greenbelt's President, Director of Land Conservation, Assistant Director of Land Conservation, Conservation Project Manager, GIS Manager, and GIS Fellow. We held 20 meetings over ten months in 2018 into 2019. During those meetings we identified the analysis modules to be completed and reviewed draft methods and results. The team identified the following prioritization modules to be completed: Agriculture, Natural Resiliency, Drinking Water, Flood Mitigation, Habitat, and Urban Cooling. These modules were selected for the following reasons:

Core Mission Objective:
- Habitat
- Agriculture
- Natural Resiliency

New Data Availability:
- Natural Resiliency
- Agriculture

New Organizational Focus Areas:
- Natural Resiliency
- Flood Mitigation
- Urban Cooling
- Drinking Water

In the spring of 2019 we had draft results for all six modules. At that point we reached out to an Advisory Panel made up of experts and practitioners in related fields who provided feedback on the methods and results (see panel members below). The comments from the panel led to a number of important changes, such as increasing the importance of farm soils in the agricultural analysis, including cold-water fisheries data in the habitat analysis, and expanding the scope of the drinking water and flooding analyses. Greenbelt is extremely grateful for the contributions of the panel.

Prioritization Advisory Panel:

- Wayne Castonguay, Ipswich River Watershed Association
- Jessica Dyson Deitrich, The Nature Conservancy
- Andy Finton, The Nature Conservancy
- Noah Kellerman, Alprilla Farm
- Nathan L'Etoile, American Farmland Trust
- Dr. Marcos Luna, Salem State University
- Dr. Barbara Parmenter, Tufts University, Retired
- Jae Silverman, Land for Good
- Tim Simmons, NHESP Restoration Ecologist, Retired
- Julie Wood, Charles River Watershed Association
- Dr. Stephen Young, Salem State University

In June of 2019 we applied for and subsequently received a Coastal Resilience Grant from the Massachusetts Office of Coastal Zone Management (CZM). The funding supported a number of climate resiliency projects including outreach with the Town of Essex and the City of Gloucester about the prioritization project. For each municipality we created maps and interactive data viewers and distributed information on the methods and data sources that were used. We met with municipal staff and volunteers to solicit feedback on the results in each town. The comments from the towns led us to make a number of changes such as creating two separate flood modules, one that evaluated inland flooding and one that evaluated coastal flooding. The updates were completed by the spring of 2020 at which point all of the analysis modules were complete.

Meeting with the Town of Essex

Meeting with the City of Gloucester

Future Use & Outreach

Greenbelt is currently using the data to inform project selection and review, grant applications, and landowner outreach. In 2020-2021 we anticipate expanding the municipal outreach portion of the project to make the data available to more towns within Essex County. Currently, we have completed customized map products for the Towns of Amesbury and Georgetown. The maps we are making are intended for open space planning purposes such as to be used in Municipal Vulnerability Plans or Open Space and Recreation Plans. We are also exploring a possible partnership with the Merrimack Valley Planning

Commission (MVPC) to evaluate incorporating this data into participating towns' data viewers.

The analysis modules are intended to be a living prioritization. As new data layers become available they will be incorporated as appropriate. We will also run periodic updates as new parcel data becomes available. Our hope is that the analysis will remain responsive to the needs of the users while utilizing the most up to date data possible.

Natural Resilience Methodology

Purpose

The climate in Essex County is changing, as can be seen and felt by its residents and visitors. Some of the observed changes include increased volume and intensity of precipitation, increased ocean temperatures, and changes to the timing and duration of seasons (Dupigny-Girous, et al, 2018). When Greenbelt completed the previous parcel prioritization in 2011, there was limited data available that specifically addressed climate resilient habitats. The primary source at that time was BioMap2, which was a key layer included in the previous habitat analysis, but there wasn't enough information to create a standalone module. In recent years, there has been significant work completed by The Nature Conservancy (TNC) to identify the most resilient sites for conservation. TNC defines site resilience as "…the capability of a site to adapt to climate change while maintaining diversity and ecological function" (Anderson et al., 2016).

For many years, Greenbelt has incorporated TNC climate data into our acquisition planning. The need for parcel based climate resiliency ranking was a primary driver of the new prioritization project, so completing a natural resiliency module was a given. While the TNC data can serve alone as a resiliency framework, we wanted to combine the numerous TNC data layers, where appropriate. Additionally, we wanted to include inland aquatic habits, which are not currently included in TNC data, so that led us to include the BioMap2 freshwater layers that were identified as climate adaptation strategies (Woolsey, Finton, & DeNormandie, 2010). In addition to these three core layers, we added a bonus for climate corridors (TNC), Flow (TNC), and density of nearby open space (MassGIS); these totals were combined to create a score that can be used to evaluate each parcel with a single climate resiliency metric.

Greenbelt

Reference Layers

Data	Reason for Inclusion	Source	Notes
Assessor's Parcels	Land ownership boundaries to assess conservation project opportunities.	MassGIS Data: Level 3 Standardized Assessors' Parcels	Unprotected portions of parcels were included if over 5 acres. 7,068 in total.
TNC's Coastal Resilience: • **Migration Space**	Scientists from TNC evaluated more than 10,000 coastal sites in the Northeast and Mid-Atlantic to determine their ability to provide a natural buffer to communities from increasing inundation by rising seas, as well as their capacity to sustain biodiversity. Each site received a resilience "score" based on the likelihood that its costal habitats are able to migrate to adjacent lowlands. In addition, they identified migration space areas where conditions are most optimal for marsh migration as the sea level increases.	The Nature Conservancy	
TNC's Terrestrial and Coastal Resilience Merged	Resilience areas are defined by TNC as places buffered from climate change because they contain many connected micro-climates that create climate options for species. TNC has produced resiliency datasets for both terrestrial and coastal ecosystems, and has more recently provided them as a single merged dataset.	The Nature Conservancy	
TNC's Priority and Resilient Connected Landscapes • **Climate Corridors**	The climate corridor data was the only part of this dataset that was used. Climate corridors are defined as a narrow conduit in which the movement of plants and animals becomes highly concentrated, often a riparian channel or linear ridgeline.	The Nature Conservancy	
TNC's Regional Flow Categorized	TNC defines "Flow" as the movement of species populations over time in response to climate. Of four flow types mapped by TNC, "Constrained Flow" and "Concentrated Flow" are present in the study area. Concentrated Flow are areas where large quantities of flow are concentrated through a narrow area. Because of their importance in maintain flow across a larger network, these pinch points are good candidates for land conservation. "Constrained Flow" is defined as areas of low flow that are neither concentrated nor fully blocked but instead move across the landscape in a weak reticulated network. These areas	The Nature Conservancy	Received from TNC

	present large conservation challenges. In some cases restoring a riparian network might end up concentrating the flow and creating a linkage that will be easier to maintain over time.		
BioMap2 Aquatic Layers: • **Aquatic Core** • **Wetlands** • **Vernal Pool Core** • **Coastal Adaptation**	BioMap2 Core Habitat are defined by the BioMap2 report as areas that are critical for the long term persistence of rare species and other species of Conservation Concern, as well as a wide diversity of natural communities and intact ecosystems across the Commonwealth. Critical Natural Landscapes (CNL) are defined as including large natural Landscape Blocks that provide habitat for wide-ranging native species, support intact ecological process, maintain connectivity among habitats, and enhance ecological resilience; and includes buffering uplands around coastal, wetland and aquatic Core Habitats to help ensure their long-term integrity.	BioMap2: produced by the Natural Heritage and Endangered Species Program (NHESP) of the Massachusetts Division of Fisheries, and Wildlife and the Massachusetts Program of The Nature Conservancy (TNC).	These four aquatic layers were merged and treated as one layer in the analysis.
Protected Open Space Heatmap	Used to assess high density areas of protected open space	MassGIS Data: Protected and Recreational OpenSpace	Created by converting the open space layer to points, and using ArcMap's Kernel Density tool to create a density raster. Acres were used as the 'Population Density' field with a search distance of 1609 meters (1 mi)

Parcel Scoring System

Core Layers:
(TNC Resilience or BioMap2 score is applied, whichever is higher – not additive):

TNC Terrestrial and Coastal Resilience (merged):

Far Above Average (FAA):	**3 points**
Above Average (AA):	**2 points**
Slightly Above Average (SAA):	**1 point**
Migration Space FAA:	**3 points**
Migration Space AA:	**2 points**
Migration Space SAA:	**1 points**
Tidal Complex AA:	**2 points**

or

BioMap2 Aquatic Layers:

Aquatic Core/Wetlands/Vernal Pools/Coastal Adaptation:	**2 points**

+

TNC's Regional Flow Categorized (full value added total from above layers):

High Concentrated Flow/Concentrated Flow:	**2 points**
Constrained Flow:	**1 point**

Bonus Layers:
(30% bonus per layer added to core layer):

TNC's Priority Resilient and Connected Landscape:

Climate Corridor with Confirmed diversity/Climate Corridor:	**2 points**

Open Space Heatmap:

Far Above Average:	**2 points**
Above Average:	**1 point**

Greenbelt

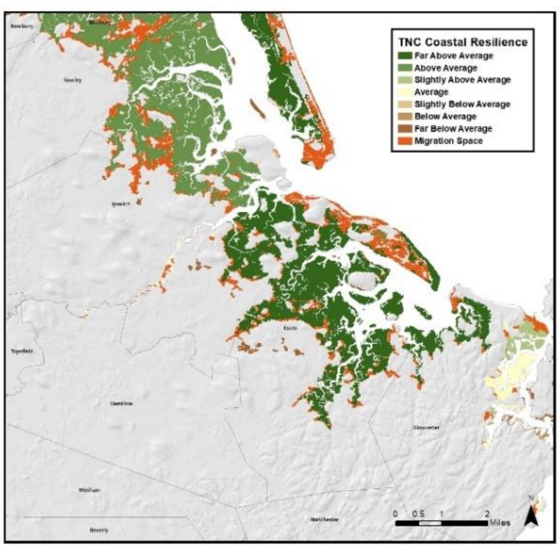
Methods

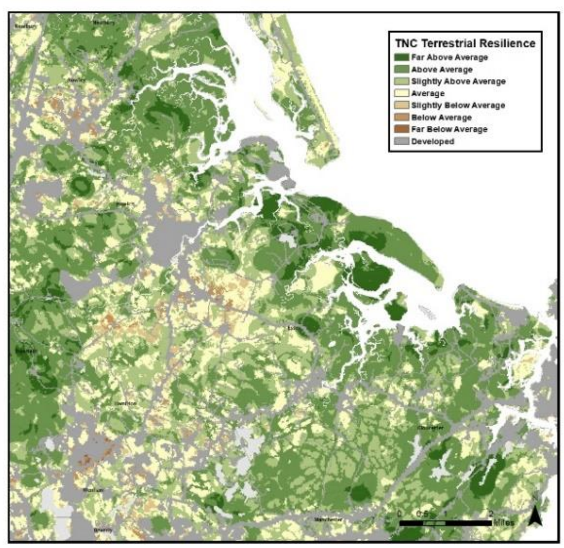
This prioritization assesses the natural resiliency value of unprotected land parcels in Essex County. The analysis calculates the acreage of various climate resilience datasets per parcel, and scores them accordingly.

The analysis first looks at the core datasets of TNC Terrestrial and Coastal Resilience, BioMap2 Aquatic layers, and TNC Regional Flow Categorized, and multiplies the acreage of each category by its associated point value. These layers were selected because of the way they speak to the different types of habitat in the county, as well as the ability for ecosystems and species to migrate in response to climate change. The layers include inland terrestrial, inland aquatic, and coastal ecosystems. Whichever score is the highest of the three core datasets is assigned to the parcel.

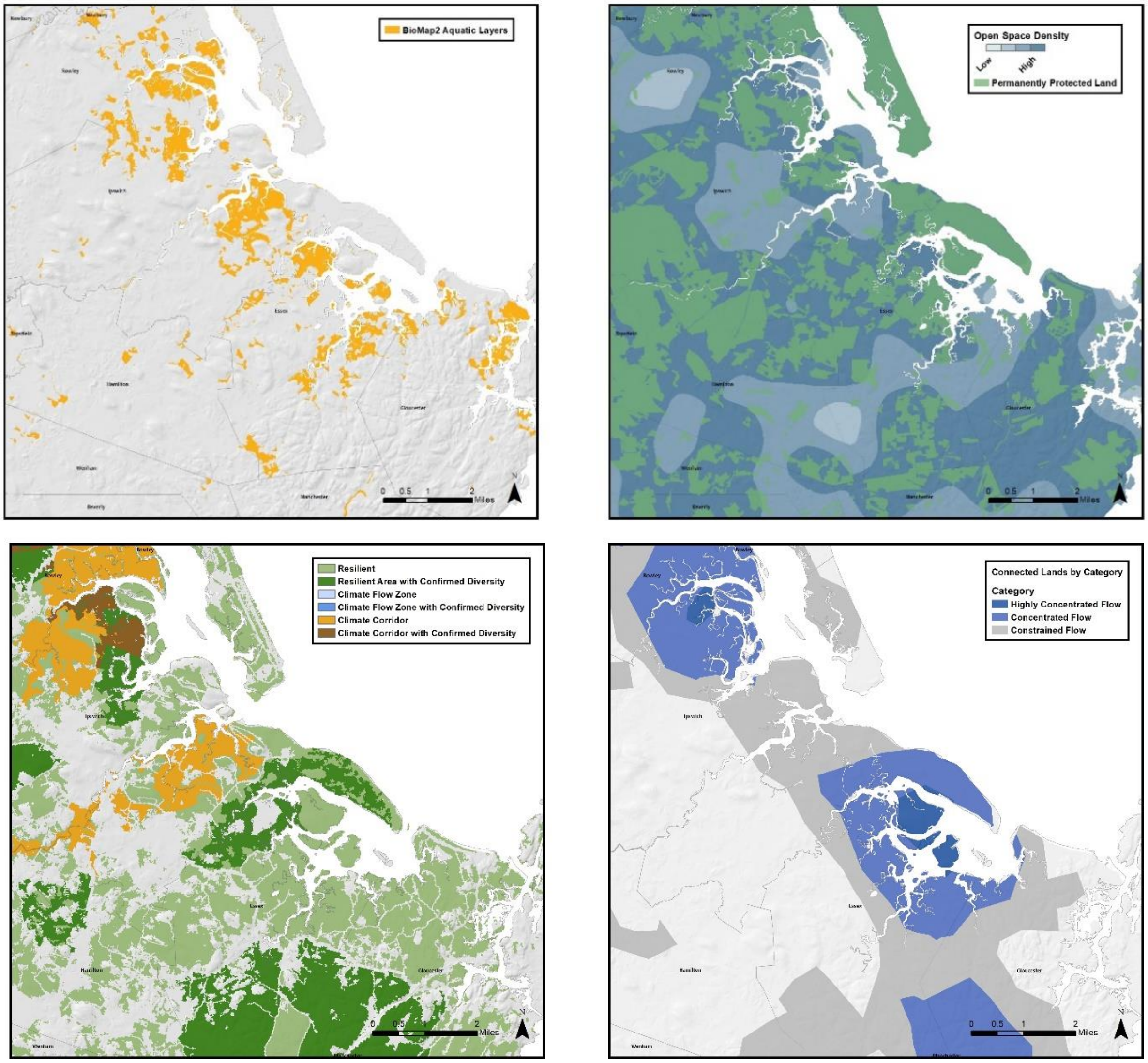
In addition to a parcel's resilience value, we incorporated the density of protected open space surrounding a parcel because conserving larger tracts of land and promoting connectivity is a climate resiliency strategy. Using MassGIS's permanently protected open space as an input, we created an open space "density map" for the county, which identifies areas with the greatest concentrations of protected land. Above average and far above average categories were created using the top two quartiles from the density analysis. These areas are calculated and summed to create an additional 30% bonus for each parcel.

Finally, the analysis assigns bonus scores for TNC Climate Corridors, which identify narrow zones of highly concentrated flow, often riparian corridors or ridgelines. A 30% bonus is awarded for areas included within Climate Corridors.



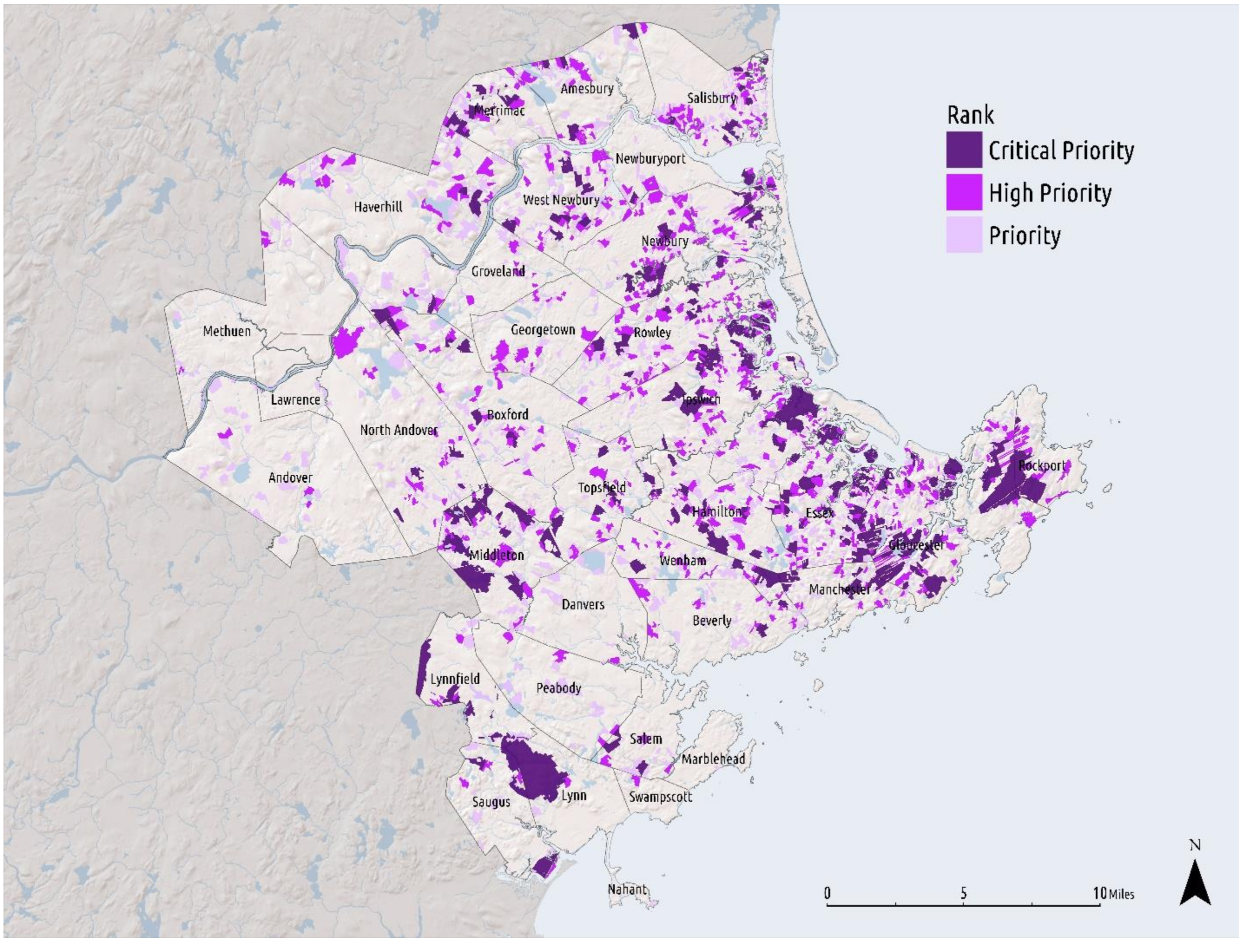


TNC Coastal Resilience (left) and TNC Terrestrial Resilience (right) data layers used in the analysis.



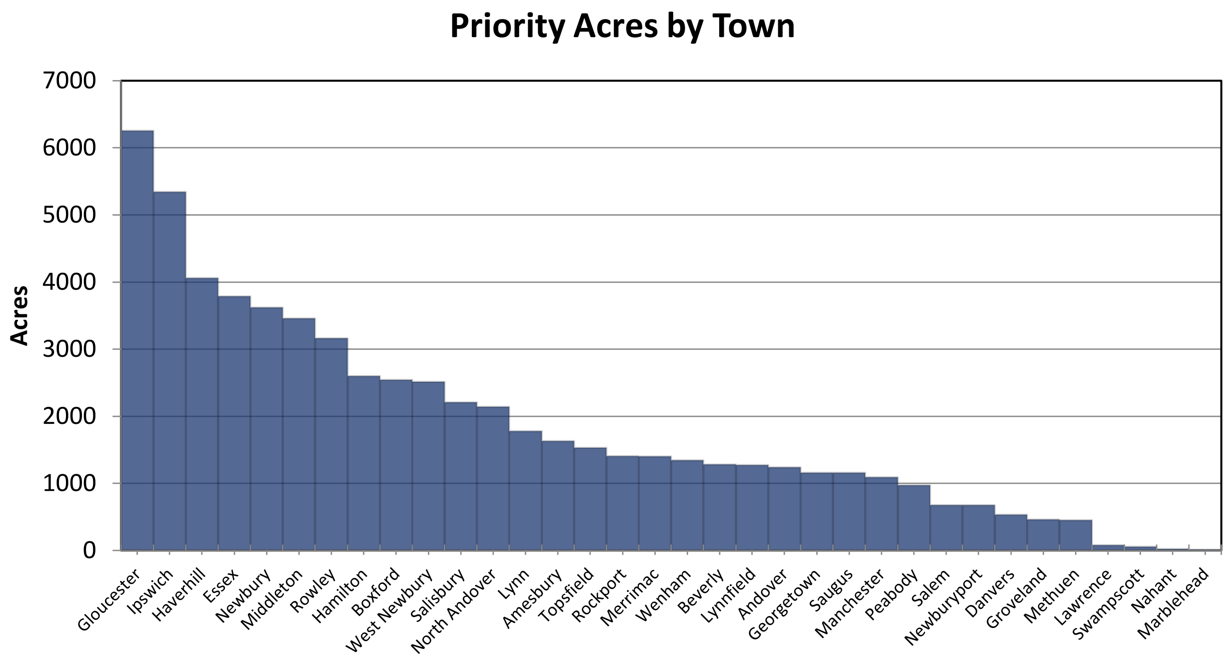
Four of the data additive layers included in the analysis: BioMap2 Aquatic Layers (top left), Open Space Density (top right), Priority Resilient and Connected Landscapes (bottom left), and Regional Flow Categorized (bottom right).

Results



The analysis returned a volume of resilient parcels throughout the county. While these are focus areas familiar to Greenbelt, these results help to assess climate resilience on a parcel basis, which is helpful to the workflow of project managers. This kind of analysis helps to assess which resilient lands in the county have already been protected, and which regions are especially critical to conserve as Essex County continues to be ‘built out’.

These results will assist Greenbelt’s conservation planning process by providing insight into the climate resilience of parcels throughout the county. The analysis incorporates data from a variety of sources, providing a more comprehensive look at climate resilience using one scoring metric. This analysis will also assist Greenbelt in pursuing funding for conservation projects, communicating the importance of climate resilience to municipal decision makers, and monitoring the effects of land cover change over time.


Priority Acres by Town
Acres
7000
6000
5000
4000
3000
2000
1000
0
Gloucester
Ipswich
Haverhill
Essex
Newbury
Middleton
Rowley
Hamilton
Boxford
West Newbury
Salisbury
North Andover
Lynn
Amesbury
Topsfield
Rockport
Merrimac
Wenham
Beverly
Lynnfield
Andover
Georgetown
Saugus
Manchester
Peabody
Salem
Newburyport
Danvers
Groveland
Methuen
Lawrence
Swampscott
Nahant
Marblehead

Habitat Analysis Methodology

Purpose

Greenbelt's mission is to work with landowners and the thirty-four cities and towns of Essex County to conserve open space, farmland, wildlife habitat, and scenic landscapes. As a core mission objective, habitat emerged early on in the planning process as the topic of a dedicated analysis module. Land trusts in Massachusetts are fortunate to have a variety of high quality habitat data available for conservation planning. In this module, we wanted to combine the datasets we determined to be the most critical for defining habitat value and weigh them based on Greenbelt's organizational priorities and values.

In addition to the habitat module, we completed a separate analysis that identifies the most critical parcels for natural resilience. This was done as a part of our commitment to incorporating climate planning into our land acquisition process. These two modules are intended to be used together to allow users to evaluate a parcel's potential habitat value from a variety of perspectives. We determined that including climate resiliency in habitat protection planning was essential, so we also included resiliency data in this analysis so that it could operate as a robust standalone module. In addition to these core layers, we added a bonus for density of nearby open space and parcel size; these totals were combined to create a score that can be used to evaluate each parcel with a single habitat metric.

Reference Layers

Data	Reason for Inclusion	Source	Notes
Assessor's Parcels	Land ownership boundaries to assess conservation project opportunities	MassGIS Data: Level 3 Standardized Assessors' Parcels	Unprotected portions of parcels were included if over 5 acres. 7,068 in total.
BioMap2 Layers: • **Core Habitat** • **Critical Natural Landscape (CNL)**	BioMap2 Core Habitat is defined by the BioMap2 report as areas that are critical for the long term persistence of rare species and other species of Conservation Concern, as well as a wide diversity of natural communities and intact ecosystems across the Commonwealth. CNL are defined as including large natural Landscape Blocks that provide habitat for wide-ranging native species, support intact ecological process, maintain connectivity among habitats, and enhance ecological resilience; and includes buffering uplands around coastal, wetland and aquatic Core Habitats to help ensure their long-term integrity.	BioMap2: produced by the Natural Heritage and Endangered Species Program (NHESP) of the Mass Division of Fisheries, and Wildlife and the Mass Program of The Nature Conservancy (TNC).	
TNC's Terrestrial and Coastal Resilience Merged	Resilience areas are defined by TNC as places buffered from climate change because they contain many connected micro-climates that create climate options for species. TNC has produced resiliency datasets for both terrestrial and coastal ecosystems, and has more recently provided them as a single merged dataset.	The Nature Conservancy (TNC)	
Conservation Prioritization and Assessment System (CAPS)	CAPS is an ecosystem based (coarse-filter) approach for assessing the ecological integrity of lands and waters and subsequently identifying and prioritizing land for habitat and biodiversity conservation. They define ecological integrity as the ability of an area to support biodiversity and the ecosystem processes necessary to sustain biodiversity over the long term.	The Landscape Ecology Lab at the University of Massachusetts Amherst	
Priority Habitats of Rare Species	Priority Habitats of Rare Species represent the geographical extent of habitat for all state-listed rare species, for both plants and animals, based on observations documented within the last 25 years in the Mass Natural Heritage & Endangered Species Program (NHESP).	MassGIS Data: NHESP Priority Habitats of Rare Species	Sites are updated by NHESP every four years. Last updated 8/1/2017.

MA DFW Coldwater Fisheries Resources	Essex County contains relatively few coldwater streams. These serve as critical habitat for a variety of rare species. With some of these resources lacking representation in Priority Habitat and other datasets, and following feedback from our review panel, we included them as a unique dataset.	MassGIS Data: MA DFW Coldwater Fisheries Resources	
Protected Open Space Heatmap	Large habitat areas are generally more conducive to greater biodiversity and improved ecosystem services than small ones. We created this dataset to assess high density areas of protected open space to identify parcels that could increase connectivity.	MassGIS Data: Protected and Recreational OpenSpace	Created by converting the open space layer to points, and using ArcMap's Kernel Density tool create a density raster. Acres were used as the 'Population Density' field with a search distance of 1609 meters (1 mi)

Parcel Scoring System

(TNC Resilience or BioMap2 score is applied, whichever is higher – not additive):

TNC Resilience (merged):

Terrestrial Far Above Average (FAA):	**3 points**
Terrestrial Above Average (AA):	**2 points**
Terrestrial: Slightly Above Average (SAA):	**1 point**
Migration Space FAA:	**3 points**
Migration Space AA:	**2 points**
Migration Space SAA:	**1 points**
Tidal Complex AA:	**2 points**

BioMap2:

Core Habitat:	**2 points**
Critical Natural Landscape:	**1 point**

(Core Habitat and Critical Natural Landscapes overlap so the total possible point value for BioMap2 is 3)

CAPS:

Far Above Average (76 – 100 raster value)	**3 points**
Above Average (50 – 75 raster value)	**1.5 points**

Priority Habitat: **3 points**

Open Space Heatmap:

Far Above Average:	**2 points**
Above Average:	**1 point**

DFW Coldwater Fisheries (200' either side of stream) **2 points**

Bonus Layers:

Open Space Adjacency (within 100 feet): **1 point**

Parcel Size:

100 acres or larger:	**3 points**
50 acres or larger:	**2 points**
10 acres or larger:	**1 point**

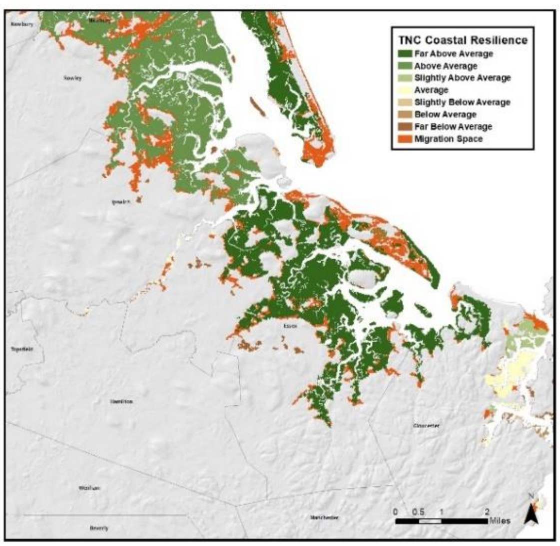
Greenbelt

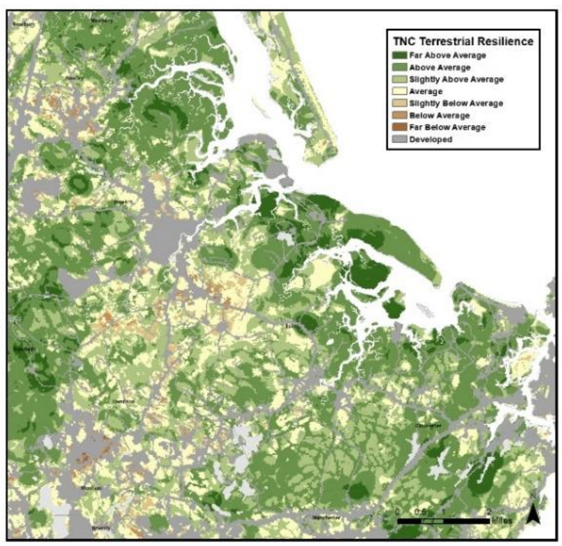
Methods

This prioritization assesses the habitat value of land parcels in Essex County. The analysis calculates the acreage of various habitat value and climate resiliency datasets per parcel, and scores them accordingly. The analysis is additive within each dataset. The layers included are: BioMap2 Core Habitat and Critical Natural Landscapes, the Conservation and Prioritization System (CAPS) Priority Habitat, Department of Fisheries & Wildlife (DFW) Coldwater Fisheries Resources, and TNC's Coastal and Terrestrial Resiliency.

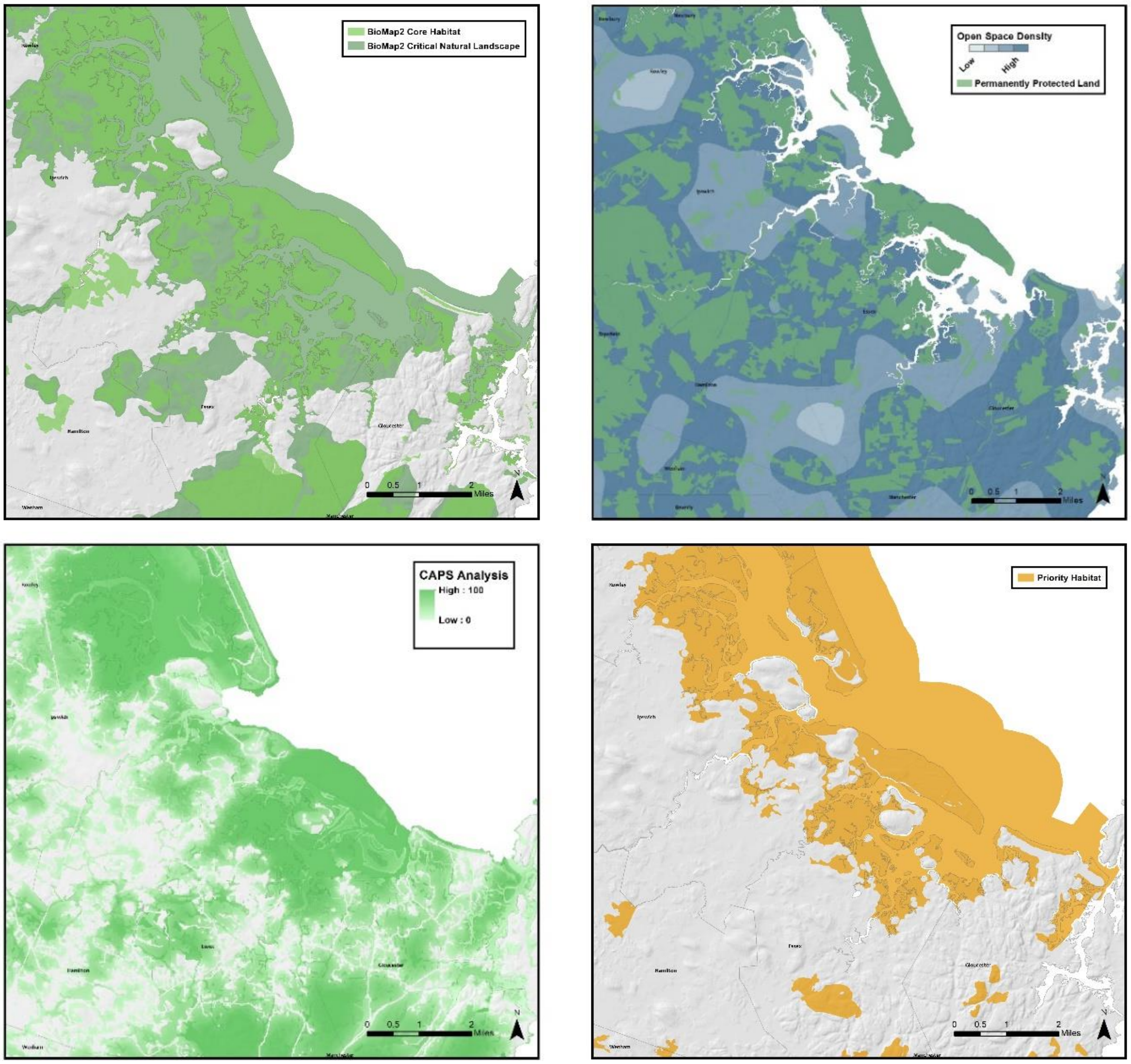
In addition to a parcel's resilience value, we wanted to incorporate the density of protected open space surrounding a parcel, as larger tracts of land generally support greater biodiversity and provide better long-term viability of its habitat. Using permanently protected open space as an input, we created a density map for the county. Above average and far above average categories were created using the top two quartiles from the density analysis. These areas are calculated and summed to create an additional bonus for each parcel. With coldwater fisheries resources as a rare feature in Essex County and critical habitat for many species, we included these streams and buffered them 200 feet to value adjacent parcels.

Next, the analysis assigns bonus scores if a parcel is within a 100-foot proximity to existing protected open space parcels and if the analysis parcel acreage is ten, fifty, or hundred acres or larger. As larger tracts are better able to support diverse habitats, these characteristics speak to the contiguity of habitat on an analysis parcel to existing protected land.



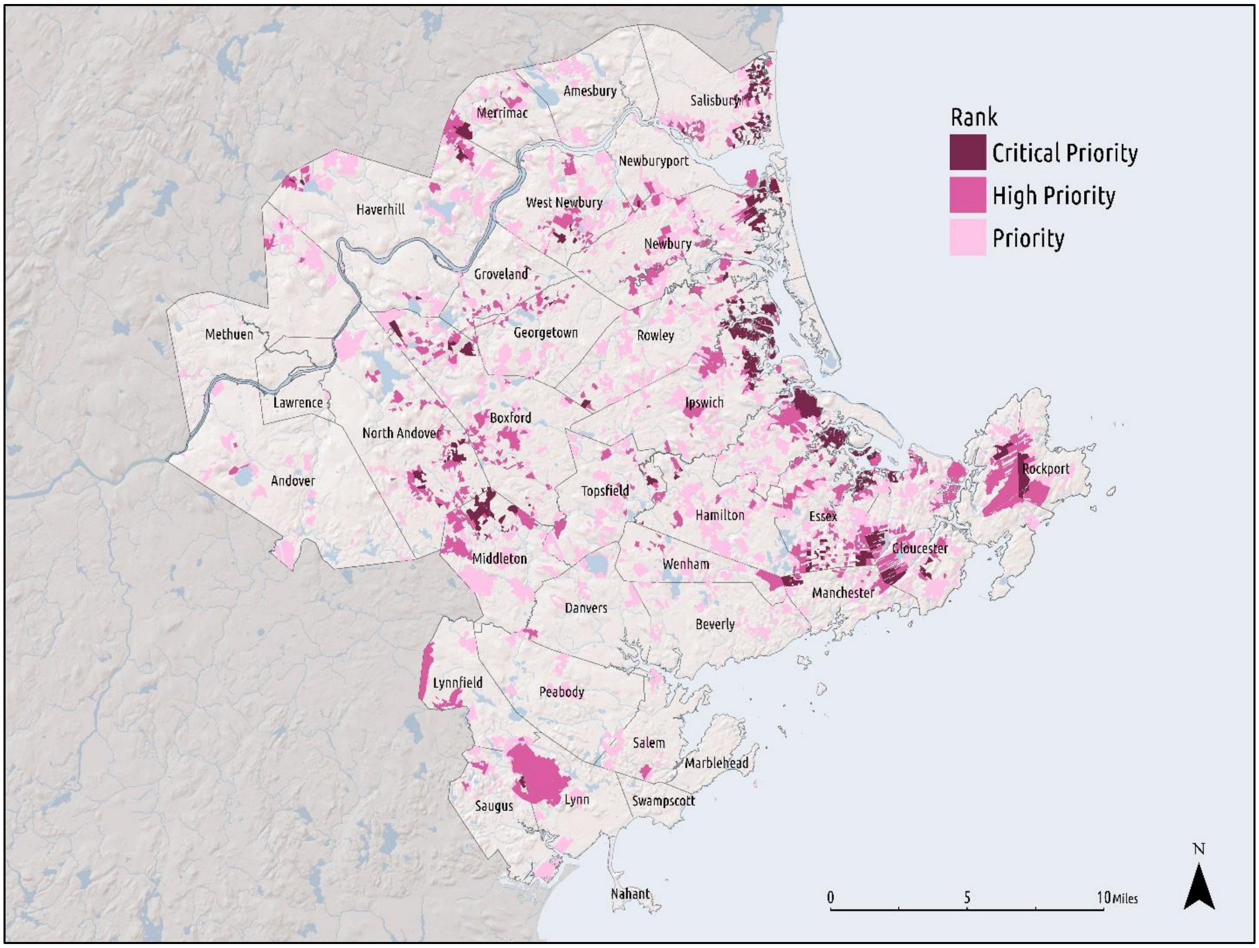


TNC Coastal Resilience (left) and TNC Terrestrial Resilience (right) data layers used in the analysis. The highest score from either layer is applied to each parcel.



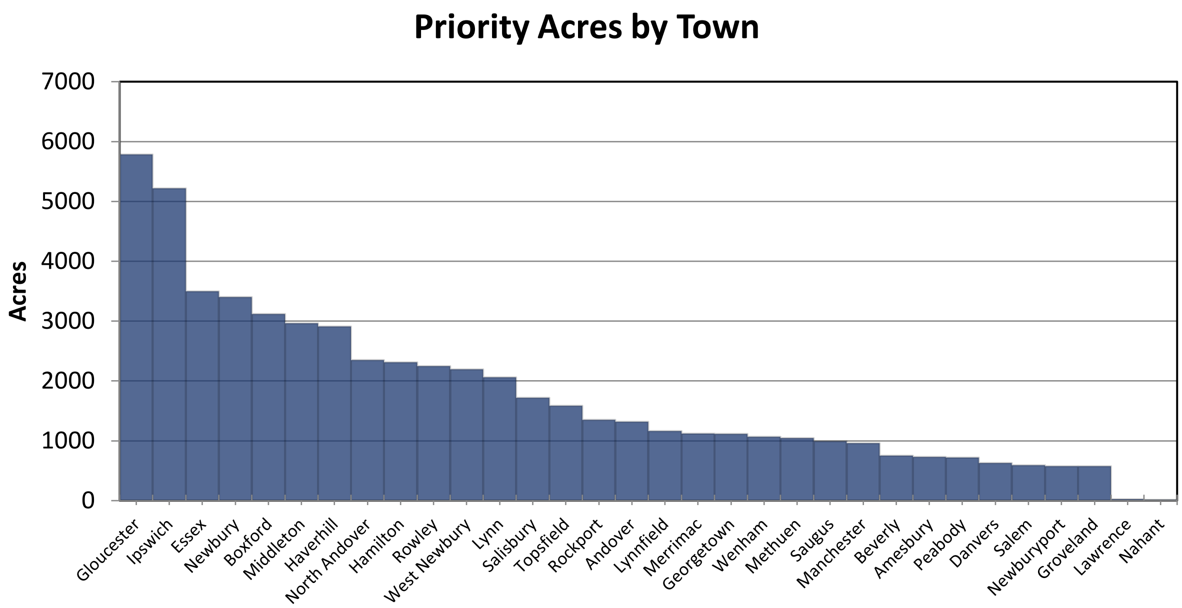
Four of the data layers included in the analysis: BioMap2 Core Habitat and Critical Natural Landscape (top left), Open Space Density (top right), CAPS (bottom left), and Priority Habitat (bottom right).

Results



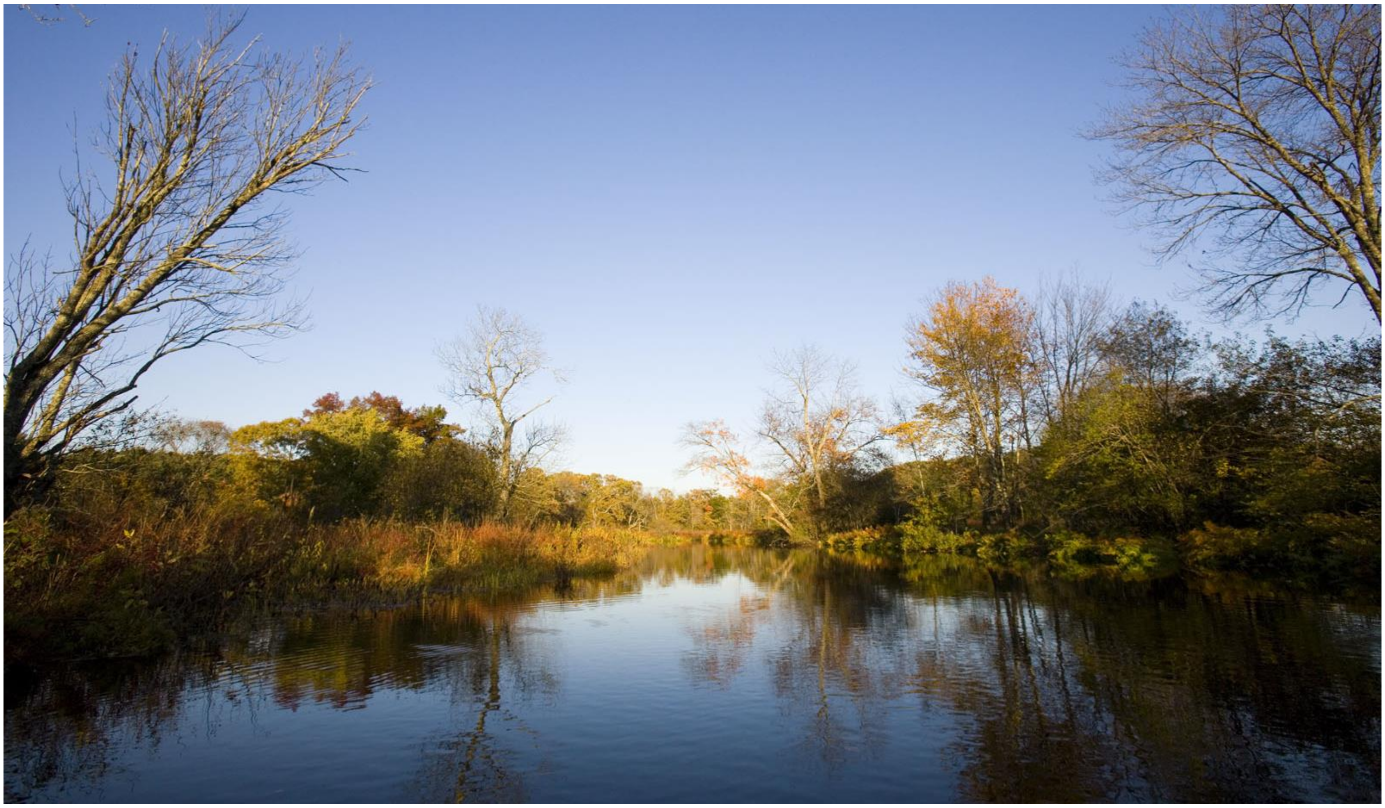
These results reinforce Greenbelt's understanding of these parcels as critical habitats to protect, while a number of other standalone parcels throughout the county that provide important habitat in their communities were also highlighted.

Massachusetts is fortunate to have access to abundant environmental data as the result of analyses performed by conservation organizations and academic institutions. Greenbelt has previously made use of this wealth of data by creating maps and assessing parcels on an individual basis. This analysis helps to package this existing data together in a way that allows the organization to utilize it fully, and have the most comprehensive understanding of the habitat value of a given parcel in relationship to the neighborhood, town, or county. This analysis will also assist Greenbelt in pursuing funding for conservation projects, communicating the importance of habitat value to municipal decision makers, and monitoring the effects of land cover change over time.



** Towns of Swampscott and Marblehead had zero acres in the top quartile*

Drinking Water Prioritization Methodology



Purpose

Water quality and ecological function are so intricately connected that Greenbelt has long partnered with water protection organizations such as the Ipswich River Watershed Association. In our 2017 strategic plan, clean water was identified as one of the anticipated benefits of successful land conservation. Additional priorities that were identified included strengthening our relationships with municipal water departments and focusing on protecting watershed lands. We have seen firsthand the importance of drinking water to our municipal partners and how protecting drinking water resources resonates with residents.

For a number of years, staff have included drinking water data in natural resource maps and during project evaluation. Conducting parcel based drinking water analysis is a new area for Greenbelt, however. When we embarked upon the prioritization project we decided very early on that we wanted to include a drinking water module. The goal was to combine the drinking water data to help us determine the value of land protection for conserving drinking water resources. For example, we weighted surface water data more than ground water, due to the impact of land use on surface water. An additional goal was to have one comprehensive drinking water rank per parcel to allow us to identify the most critical parcels for drinking water protection in the county.

Definitions *(from 310 CMR 22.02)*

Wellhead Protection Areas

Zone I - the protective radius required around a public water supply well or wellfield. For Public Water System wells with approved yields of 100,000 gallons per day (gpd) or greater, the protective radius is 400 feet. Wellfields and infiltration galleries with approved yields of 10,000 gpd or greater require a 250-foot protective radius. The size of the radius is determined by the yield of the well or wellfield. The minimum radius for a Zone I is 100 feet.

Zone II – the area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated (180 days of pumping at approved yield, with no recharge from precipitation). Certain land uses may be either prohibited or restricted in both approved (Zone II) and interim (IWPA) wellhead protection areas (MassGIS).

Interim Wellhead Protection Area (IWPA) - for public water systems using wells or Wellfields that lack a Department-approved Zone II, DEP will apply an Interim Wellhead Protection Area. This Interim Wellhead Protection Area shall be a one half mile radius measured from the well or Wellfield for sources whose approved pumping rate is 100,000 gpd or greater. For wells or Wellfields that pump less than 100,000 gpd, the IWPA radius is proportional to the approved pumping rate.

Surface Water Supply Protection Areas

Zone A – a) the land area between the Surface Water Source and the upper boundary of the Bank; (b) the land area within a 400-foot lateral distance from the upper boundary of the Bank of a Class A Surface Water Source, as defined in 314 CMR 4.05(3)(a): Class A; and (c) the land area within a 200-foot lateral distance from the upper boundary of the Bank of a Tributary or associated Surface Water body.

Zone B - means the land area within ½ mile of the upper boundary of the Bank of a Class A Surface Water Source, as defined in 314 CMR 4.05(3)(a): Class A, or edge of Watershed, whichever is less. However, Zone B shall always include the land area within a 400-foot lateral distance from the upper boundary of the Bank of the Class A Surface Water Source.

Zone C - means the land area not designated as Zone A or B within the Watershed of a Class A Surface Water Source as defined at 314 CMR 4.05(3)(a): Class A.

Reference Layers

Data	Reason for Inclusion	Source	Notes
Assessor's Parcels	Land ownership boundaries to assess conservation project opportunities.	MassGIS Data: Level 3 Standardized Assessors' Parcels	The unprotected portion of parcels 5 acres or larger were included. 7,068 in total.
MassDEP Wellhead Protection Areas	Wellhead protection areas are important for protecting the recharge area around public water supply (PWS) groundwater sources.	MassGIS Data: MassDEP Wellhead Protection Areas (Zone II, Zone I, IWPA)	
Surface Water Supply Protection Areas	This datalayer contains the watershed extents for all surface water supplies including active, inactive, emergency, sources outside of Massachusetts, watersheds that extend into other states and watersheds of sources from other states that extend into Massachusetts. However, only parcels in Essex County were evaluated for this analysis.	MassGIS Data: Surface Water Supply Protection Areas (ZONE A, B, C)	
Aquifers	The analysis calculates natural land cover areas within aquifers that provide quality drinking water recharge.	MassGIS Data: Aquifers	
Land Cover	Impervious surface negatively impacts the drinking water value of a parcel. Analysis of aquifers and subwatersheds are limited areas of natural land cover.	MassGIS: 2016 Land Cover / Land Use	Land cover codes included: 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22
Public Water Supplies	Using public drinking water intake data, and research of town water supplies, public surface water bodies were selected for inclusion into the analysis. These water bodies have been identified as providing drinking water for Essex County residents, and are used to create sub-watershed areas.	MassGIS Data: MassDEP Hydrography (1:25,000), Water Supplies, Integrated List of Waters (303(b)/303(d))	Intakes were limited to those serving public water supplies and manually reviewed to select their associated water bodies from the MassDEP Hydrography layer.
Public Watersheds	These watersheds delineate areas where runoff contributes to public drinking water supplies. Preserving natural land cover within these areas is critical to the protection of drinking water quality. These subwatersheds were created using a digital elevation model and public water supply polygons using the Arc Hydro extension.	MassGIS Data: Digital Elevation Model (1:5,000), Public Water Supply polygons	A number of culverts had to be 'burned' through the DEM in order to capture the full extent of the subwatersheds. Arc Hydro tools Fill Sinks, Flow Direction, and Batch Watershed Delineation for Polygons were used.

Parcel Scoring System

Surface Water Protection Areas:

Zone A:	**3 points**
Zone B:	**2 points**
Zone C:	**1 points**

Wellhead Protection Areas:

Zone 1:	**3 points**
IWPA:	**3 points**
Zone 2:	**1.5 points**

Drinking Water Supply Watersheds:

If parcel includes over 10% of a watershed area:	**3 points**
If parcel includes 1% - 10% of a watershed area:	**2 points**
If parcel includes less than 1% of a watershed area:	**1 point**

Proximity to Public Drinking Water Supplies:

If within 100 feet of a water supply:	**3 points**
If within 200 feet of a water supply:	**2 points**
If within 300 feet of a water supply:	**1 point**

Proximity to Public Drinking Water Intakes:

(Parcels must be within the intake's watershed, and upstream if the water supply is a river)

If within 0.1 miles of an intake:	**3 points**
If within 0.25 miles of an intake:	**1.5 points**

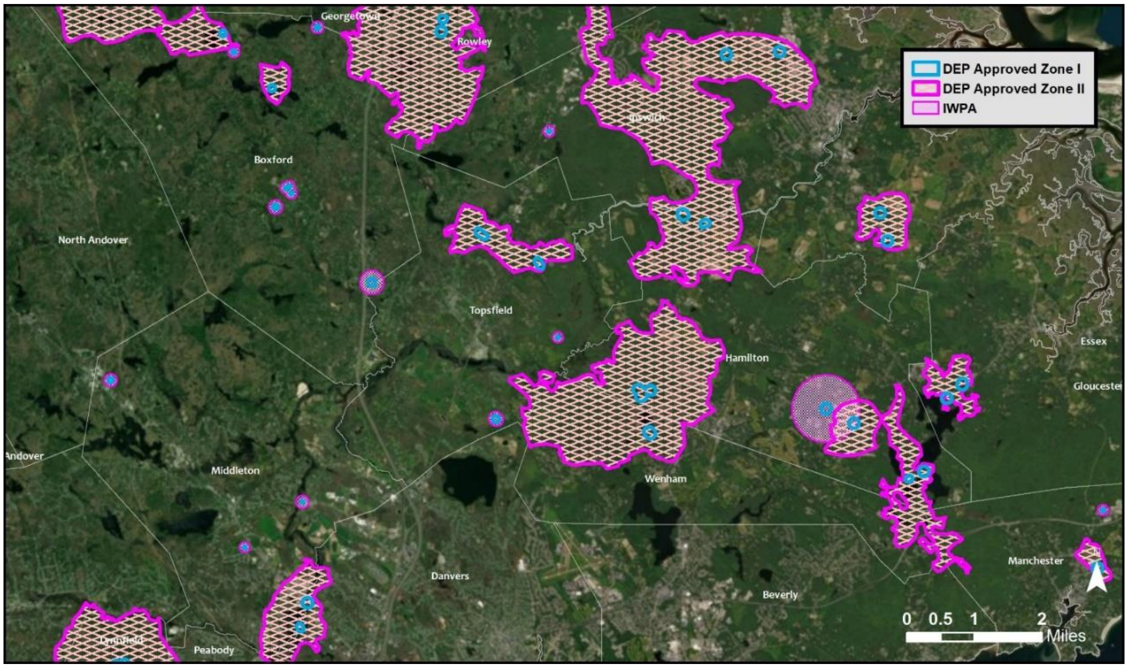
Presence of an Aquifer:

Natural land cover within an aquifer:	**1 point**

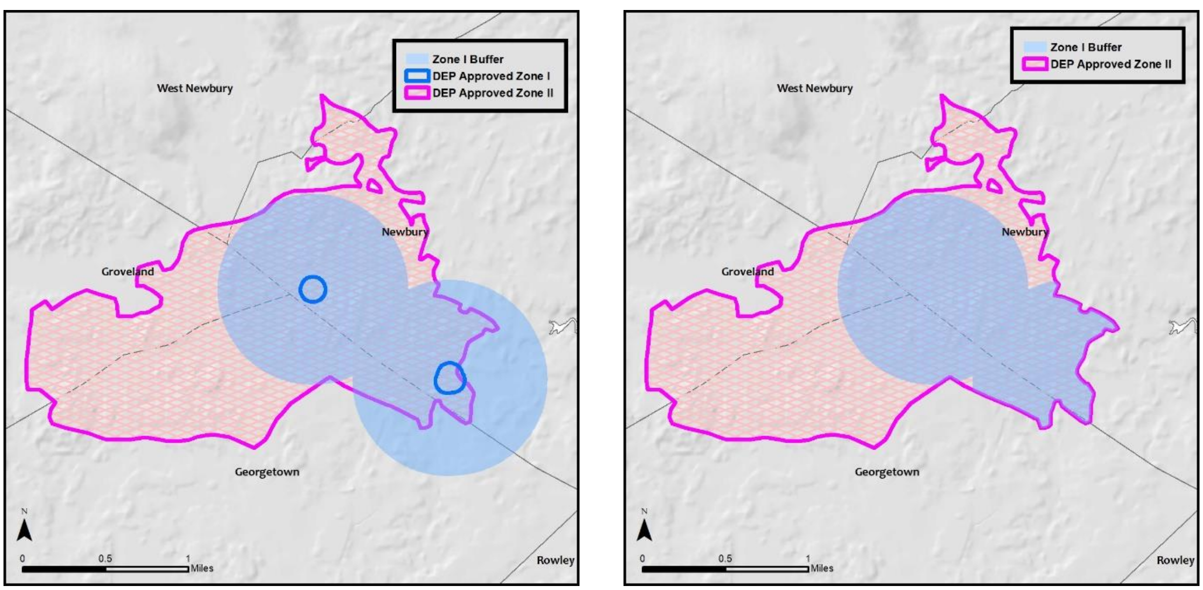
Methods

This prioritization uses GIS analysis to assess the drinking water value of land parcels in Essex County. This is done by measuring the coverage of Wellhead Protection Areas and Surface Water Protection Areas on each parcel and scoring them according to the scoring system metric. The analysis is performed as follows:

- Zone 1 Wellhead Protection Areas serving public water supplies are buffered ½ mile since their footprints are small. This value serves as the default buffer for IWPA public groundwater sources in MassDEP's data. We felt this made it an appropriate value to buffer the Zone 1 areas.
- The Zone 1 buffer area is removed from Zone 2 Wellhead Protection Areas to create distinct wellhead protection zones.
- Surface Water Protection Areas, and the modified Wellhead Protection Areas are calculated for acreage per parcel.
- Surface Water Protection Areas are weighted 60% vs 40% for Wellhead Protection Areas to emphasize the fact that land use is more directly related to surface water quality.
- Natural land cover is calculated within aquifers, WPA Zone 2's erased, and summed per parcel.
- Coverage of subwatersheds per parcel are calculated. This value is additive if the subwatersheds belong to rivers, otherwise the highest value is kept.
- Within each watershed, water bodies are buffered 100 feet, 200 feet, and 300 feet. The coverage between these buffers and parcels are calculated.
- Each public drinking water intake is buffered 0.1 miles and 0.25 miles (upstream only for rivers), and this coverage is summed per parcel.
- Unprotected areas of tax parcels are scored according to the parcel scoring metric.

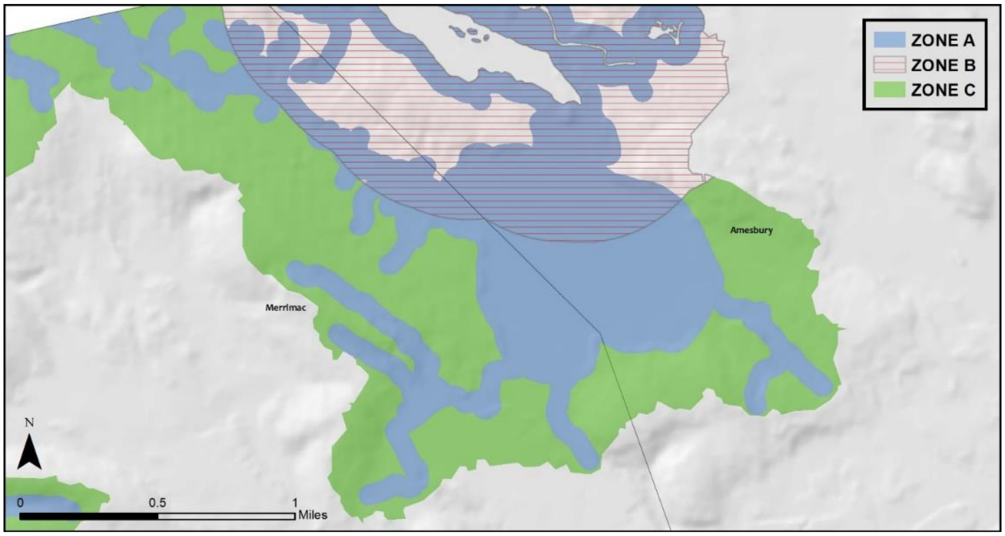


Zone 1 Wellhead Protection Areas cover a relatively small area. They are surrounded by Zone 2’s, which can sprawl across hundreds of acres, or be limited to a buffer of just a few hundred feet. It was decided that the importance of Zone 1 areas should be reflected in the analysis, as parcels closest to them are at the greatest risk of contaminating wellhead water sources. Zone 1’s were buffered ½ mile each to increase the value of parcels in close proximity, but only within existing Zone 2 areas. This process is shown in the maps below:

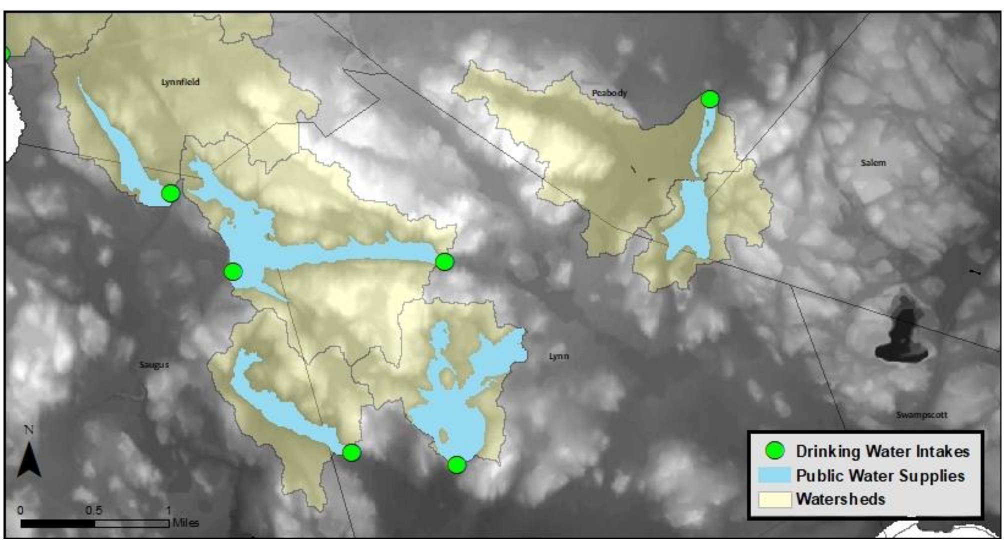


The map on the left shows a Zone 1 Wellhead Protection area buffered ½ mile which exceeds the Zone II boundary. The map on the right shows the buffer clipped to the Zone II, and is the resulting Zone 1 area used in this analysis.

Surface Water Protection Area data were used in the analysis without any modification. It is worth noting that in some areas Zones A and B overlap, which returns a score higher than 3 points for the Surface Water Protection scoring metric. The result is that a handful of parcels score close to 5 points for their Surface Water Protection coverage rather than being capped at 3 points. This overlap between a Zone A and Zone B is shown in the map below:

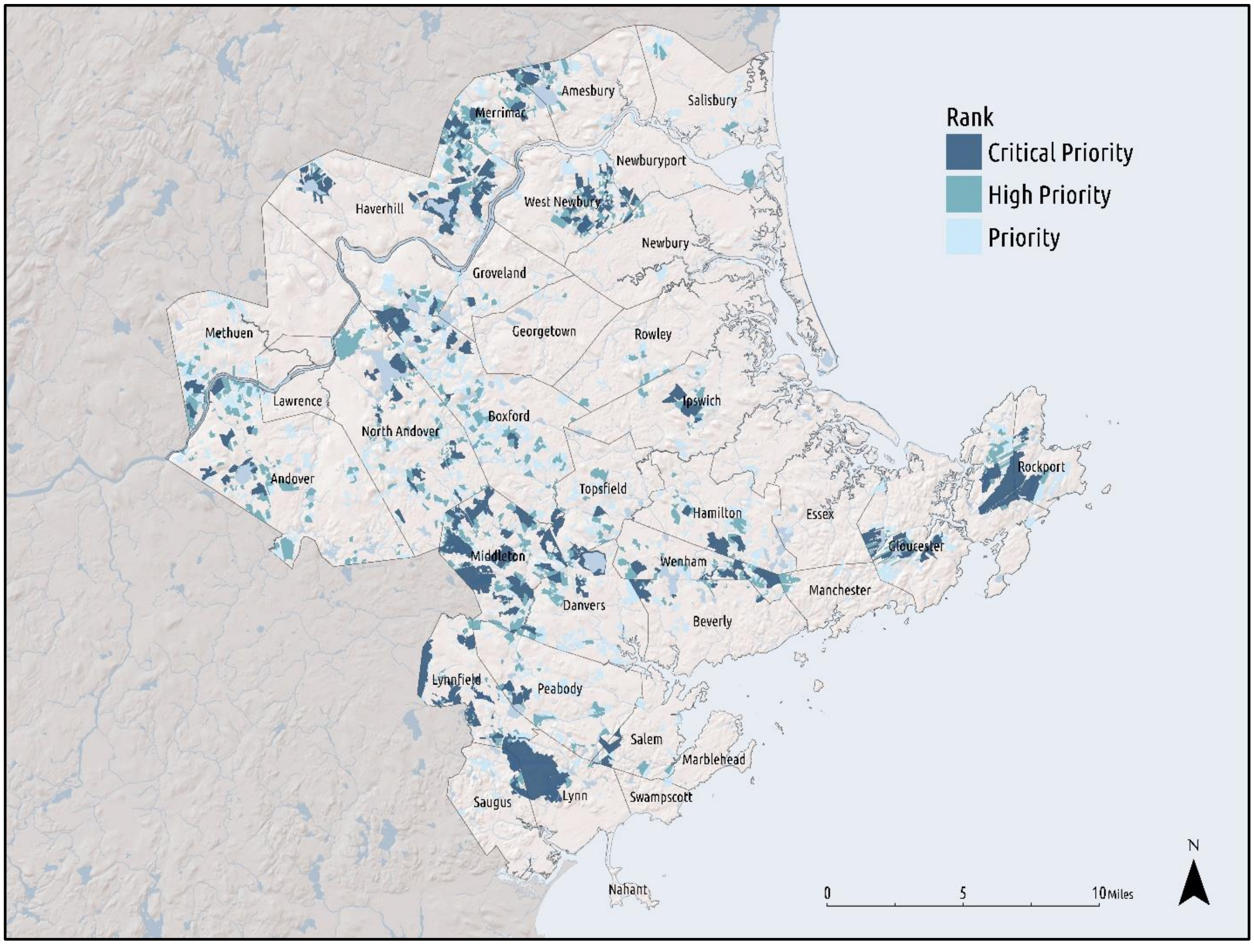


While Surface Water Protection zones help to capture the value of land adjacent to public drinking water supplies, we found that the dataset did not include all public water supply bodies. The Ipswich and Merrimac rivers in particular were absent, which provide drinking water to a large number of Essex County residents. In response we created our own subwatershed data by identifying all public drinking water bodies, processing a digital elevation model through the Arc Hydro extension, and generating subwatersheds around the selected water bodies.

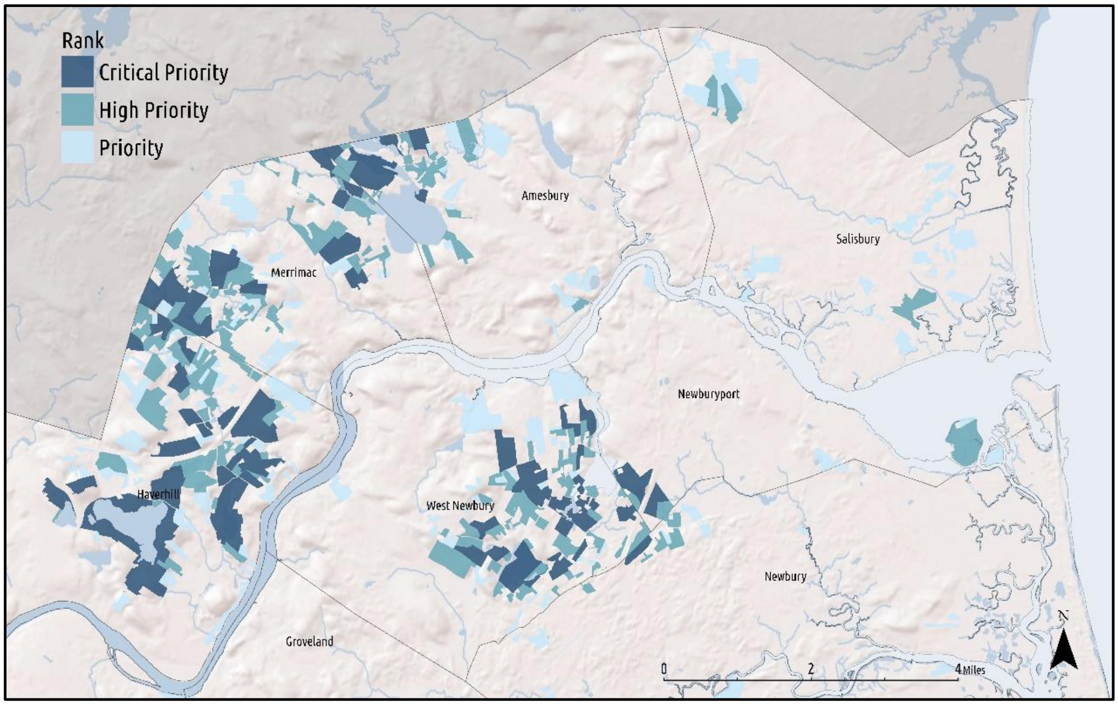


This portion of the analysis helped to recognize the value that natural land cover areas provide in protecting drinking water, even if they are not included as part of a regulatory area. This point was emphasized by members of the Advisory Panel who communicated that while regulatory drinking water areas have been designated for a reason and are critical for protection, to consider them comprehensive of drinking water protection would be inaccurate. This approach also enabled us to identify parcels that include a large percentage of a subwatershed, and if protected would have significant long-term impacts on protecting individual public drinking water supplies.

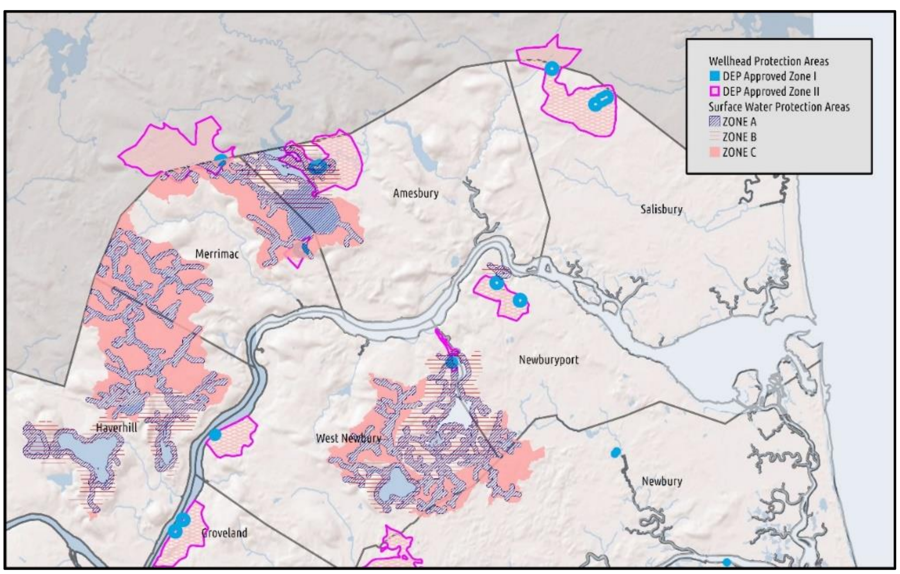
Results



The analysis returns a large number of priority drinking water parcels in the Merrimack Valley, Middleton, and Gloucester. While there are some restrictions to land associated with drinking water sources, none of the priority parcels we identified are permanently protected. It is critical to the residents of these towns, and Essex County as a whole, that these watersheds are conserved in order to preserve drinking water quality into the future. The continued development of the region paired with the effects of climate change will likely only increase demand on our existing public drinking water supplies.

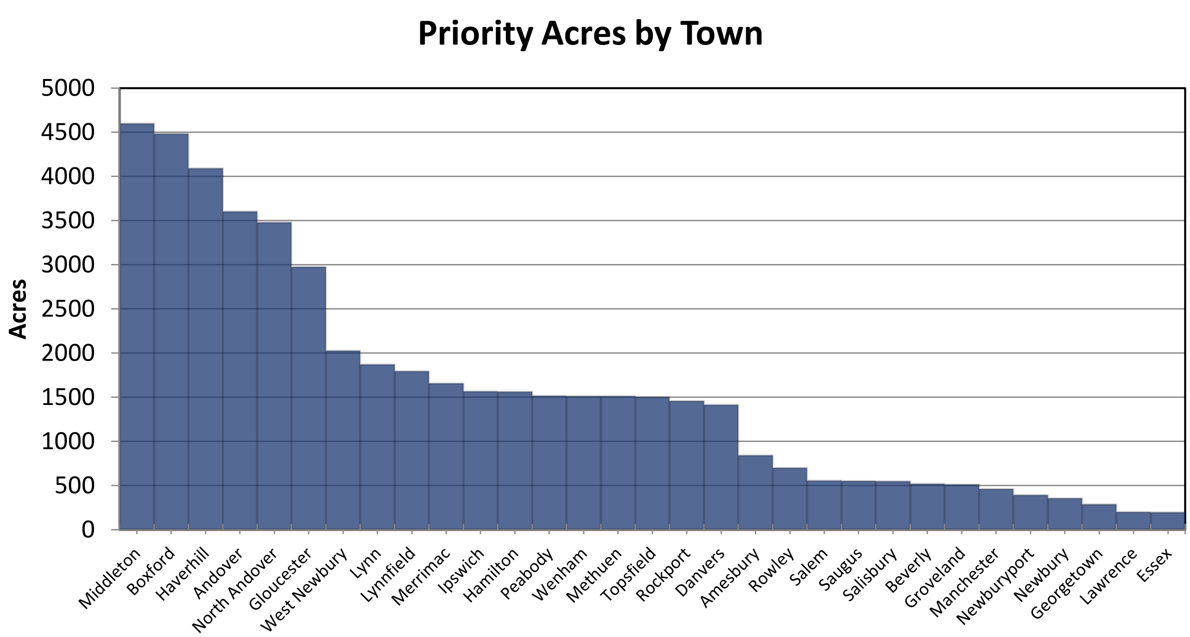


These parcels in the towns of Haverhill, Merrimac, Amesbury, and West Newbury scored particularly well because of a large presence of both Wellhead and Surface Water Protection Areas. Public drinking water intakes include the Artichoke Reservoir, Indian Hill Reservoir, Lake Attitash, Kenoza Lake, Round Pond, Millvale Reservoir, and the Merrimack River. The parcels shown in the map above total over 8,000 priority acres.



The map above shows the influence of regulatory drinking water data on the final parcel ranks. Not shown are public drinking water intakes, watersheds, and aquifer areas.

With these results, Greenbelt will be able to more effectively communicate the importance of drinking water protection in Essex County. The analysis incorporates six data layers through a single scoring metric, which provides a more structured way of interpreting this data as compared to a simple visual analysis. This will assist Greenbelt in connecting with municipal water supply decision makers, pursuing funding for conservation projects, and integrating the organization's strategic goals with conservation planning efforts.



** Towns of Swampscott, Nahant, and Marblehead had zero acres in the top quartile*

Flood Mitigation Methodology

Purpose

Essex County is characterized, in part, by its ocean, coastline, and the expansive Great Marsh. Over half of the 34 cities and towns in Essex County border the Gulf of Maine, providing economic opportunities for fishing and lobstering, recreational activities such as whale watching and water sports, and research opportunities for environmental and biomedical organizations.

The northeast is experiencing a range of climate related impacts, but is particularly susceptible to sea level rise and flooding. According to the Fourth National Climate Assessment Report "… higher-than-average rates of sea level rise measured in the Northeast have … led to a 100%–200% increase in high tide flooding in some places, causing more persistent and frequent (so-called nuisance flooding) impacts over the last few decades." (Dupigny-Giroux, et. al, 2018). Due to these types of flooding events, infrastructure, such as roadways and parking lots in low lying areas, are now flooding regularly.

As part of our climate focus for this project we reviewed the ten available Municipal Vulnerability Planning (MVP) reports for municipalities in Essex County. Sources of flooding listed in the reports included coastal flooding and storm surges from Nor'easters, winter storms, king tides, sea level rise, and freshwater flooding caused by severe precipitation events. With all ten municipalities listing flood events as major hazards in their MVP reports, we felt it was important to include it as a component of our prioritization.

According to the EPA "(a) one-acre wetland can typically store about three-acre feet of water, or one million gallons" (EPA, 2006). This natural ability for wetlands to absorb large volumes of water makes them an asset to nearby municipalities who seek to protect critical infrastructure. A 2016 cost-benefit analysis performed by The Nature Conservancy found that wetland restoration reduced flood risk to nearby property more than any other nature-based or traditional mitigation measure (The Nature Conservancy, 2016). This dynamic was apparent in the aftermath of Hurricane Sandy where townships with presence of wetlands had significantly reduced property damages compared to those without (Narayan, et al. 2016).

In addition to wetlands, members of our review panel expressed that upland natural land cover can also provide significant flood mitigation value, particularly in areas where there are gravel and sand deposits that help to drain sitting water, as well as large forest blocks that help to capture runoff. In response to this feedback, we included parcels with these features within floodplains in the prioritization. This change helps the analysis to look at flooding issues in Essex County more comprehensively without performing hydrological modeling on a site-by-site basis.

Through multiple rounds of review of the results, and revision to the methods, it was decided that splitting the inland and coastal results was most beneficial. While it is not uncommon for parcels to help to mitigate the effects of both of these types of flooding, this approach helps to understand these impacts separately and compartmentalize the influence of saltmarsh on the results. These distinct methodologies will be presented separately within this section.

Flood Mitigation: Reference Layers

Data	Reason for Inclusion	Source	Notes
Assessor's Parcels	Land ownership boundaries to assess conservation project opportunities	MassGIS Data: Level 3 Standardized Assessors' Parcels	Protected areas were removed from parcels. If parcels were over 5 acres after the protected land was removed they were included in the analysis, 7,068 in total.
Land Use	Forest, wetland, and open land provide improved flood storage over impervious surface land cover types.	MassGIS 2016 Land Cover / Land Use	Analysis was limited to these land use areas within flood risk areas.
FEMA National Flood *Hazard*	Served as flood risk layer where Hurricane Surge is not present.	MassGIS Data: FEMA National Flood Hazard Layer	Risk zones simplified to two categories: 1% annual flood risk (100-year flood) and 0.2% annual flood risk (500-year flood).
Hurricane Surge Inundation Zones	Served as flood risk layer for coastal areas where present.	MassGIS Data: Hurricane Surge Inundation Zones	Risk zones simplified to two categories: hurricane categories 1/2 and hurricane categories 3/4.
Soil Drainage Class	This is the rate that water flows into and through soils. This influences the speed that water can be absorbed by the land as well as quality of water and the recharge of drinking water sources.	NRCS SSURGO Database	Excessively Drained class merges NRCSS categories "Excessively drained" and "Somewhat excessively drained". Well Drained class merges NRCSS categories "Well drained" and "Moderately well drained".
Forest Cores	Large forest blocks were created using methods laid out by the BioMap2 project. Forested land use is clipped by roads and crossings, then grouped based on continuity. Cores over 100 acres were retained, rather than the 200-acre threshold set by BioMap2. They were then manually reviewed for inclusion into the flooding analysis.	MassGIS 2016 Land Cover / Land Use	MassDOT road data was used to bisect the forest land cover. From the 2016 Land Cover dataset, deciduous forest, evergreen forest, and forested wetlands were included.

BioMap2 Aquatic Layers: • **Aquatic Core** • **Wetlands** • **Vernal Pool Core** • **Coastal Adaptation**	Used as resilience bonus for coastal and freshwater wetlands in flood risk areas to benefit wetland that are most likely to retain flood storage function in a changing climate. These layers were identified in the BioMap2 report as having climate adaptation strategies incorporated into the mapping.	BioMap2: produced by the Natural Heritage and Endangered Species Program (NHESP) of the Massachusetts Division of Fisheries, and Wildlife and the Massachusetts Program of The Nature Conservancy (TNC).	These four aquatic layers were merged and treated as one layer in the analysis.

Inland Flood Mitigation: Parcel Scoring System

Risk:

FEMA:

1% Annual Chance of Flooding: **2 points**

0.2% Annual Chance of Flooding: **1 point**

Forest Blocks **2 points**

In Freshwater Wetland Areas (saltmarsh removed):

Resilience:

BioMap2 Aquatic Layer: **50% bonus**

In Non-Wetland Natural Land Cover Areas:

Soil Drainage Class: Excessively Drained/Somewhat Excessively Drained/Well Drained

and

Slope: Gentle/Intermediate **50% bonus**

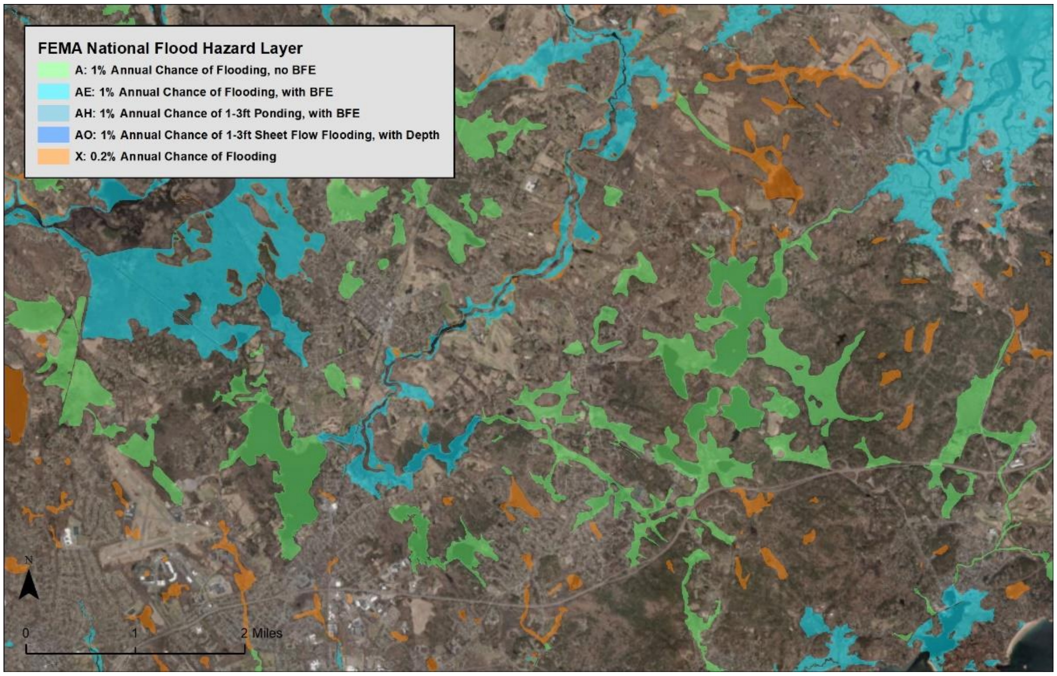
Inland Flood Mitigation Methods

This prioritization uses GIS analysis to evaluate the flood mitigation value of unprotected parcels in Essex County. The analysis looks at wetlands, natural land cover, forest core coverage, and soil attributes of a parcel and evaluates their flood storage value by scoring them on flood risk and resilience. The analysis:

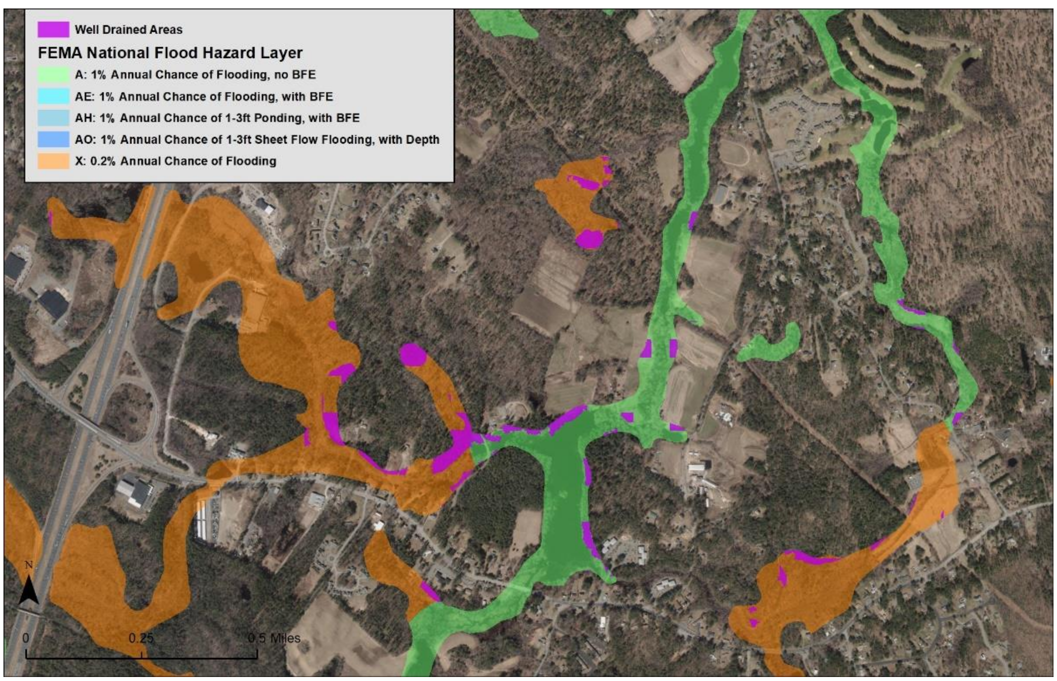
- Delineates the freshwater wetland area within each tax parcel
- Calculates the wetland area that intersects FEMA risk zones
- Within these risk zones, calculates the area included in BioMap2 aquatic layers
- Delineates the natural land cover (non-wetland) area within each tax parcel
- Within these natural land cover areas, identifies those which have gentle slopes and high soil permeability (sand and gravel deposits)
- Calculates coverage of forest core areas

The flood storage value score is calculated by multiplying each category by its point score, applying a bonus for BioMap2, and summing these values.

This flooding analysis aims to answer the question: what parcels are most critical for protection in order to prevent flood hazards due to climate change? While advanced hydrological modeling could answer this question with the most precision, it is not an approach that would be scalable to the entire county. Our approach utilizes land characteristics understood by area hydrologists to be influential in flood mitigation for Essex County, and addresses threats seen by both coastal and inland communities.

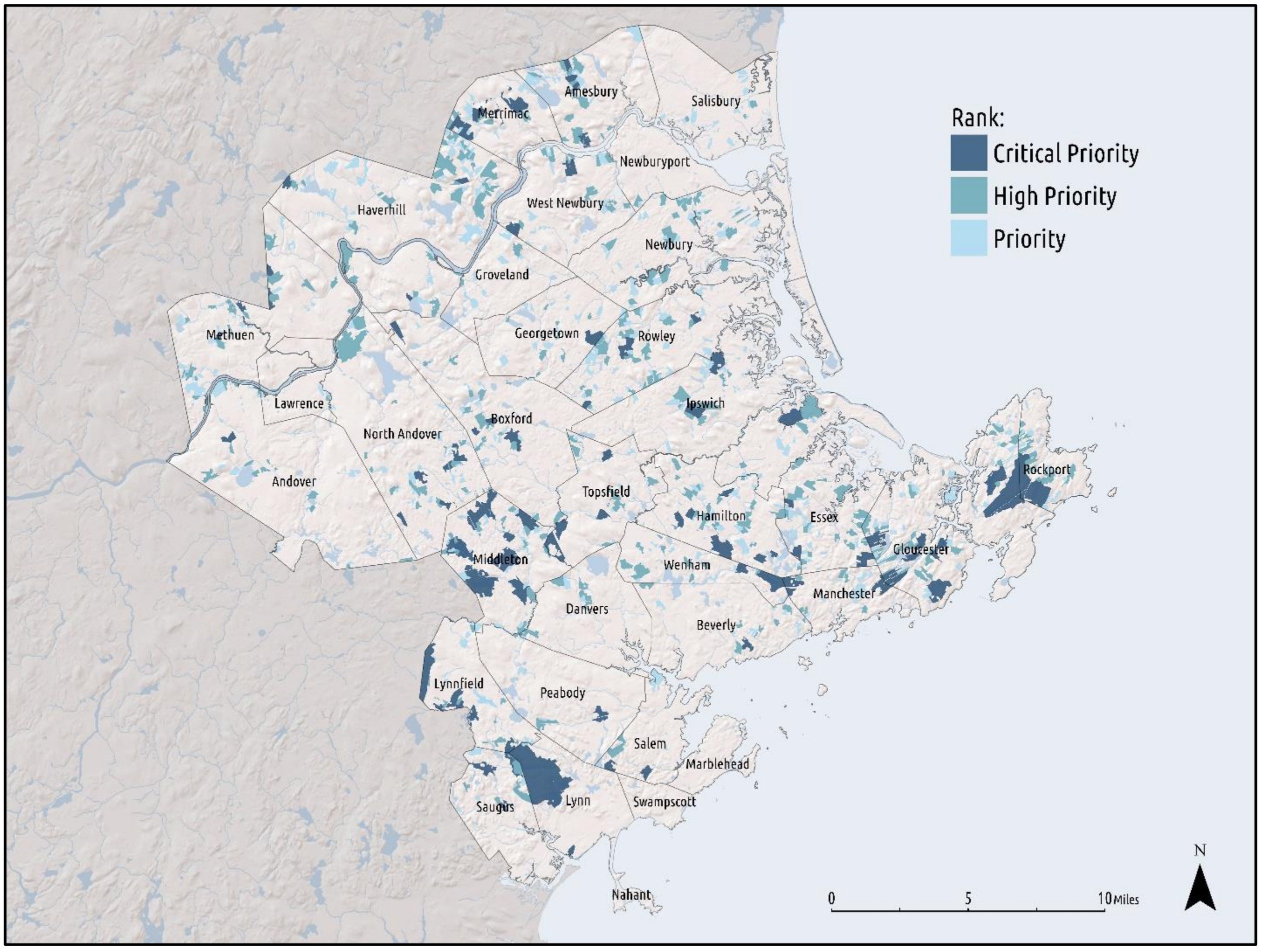


The map above shows an example of the FEMA flood zone data. The analysis evaluates the wetland areas within each category and sums their acreage per parcel. Additionally, it calculates the volume of overlapping BioMap2 coverage. These values are multiplied by their corresponding point values (as shown in the scoring metric) to create a score for each parcel.



In addition to assessing wetlands, we also evaluated other natural land cover types that help to store floodwaters. This was performed by calculating the natural land cover area within flood risk zones, generating the mean slope, and identifying soil permeability. Areas with gentle slopes and high permeability were identified to assign additional points to a parcel. The map above shows patches of well-drained soil (purple) within hurricane surge zones that help to absorb excess water at higher rates than other land cover.

Inland Flood Mitigation Results



This analysis reveals parcels throughout the county which help to mitigate the hazards of inland flooding. There are a number of factors that can influence the flooding hazards on a case by case basis, however these methods help us to assess these threats at a county scale and look to where land conservation can play a role in flood mitigation.

Coastal Flood Mitigation: Parcel Scoring System

Risk:

Hurricane Surge Inundation Zones:

Categories 1 and 2:	**2 points**
Categories 3 and 4:	**1 point**

In Wetland Areas (saltmarsh included):

Resilience:

BioMap2 Aquatic Layer:	**50% bonus**

In Non-Wetland Natural Land Cover Areas:

Soil Drainage Class: Excessively Drained/Somewhat Excessively Drained/Well Drained

and

Slope: Gentle/Intermediate **50% bonus**

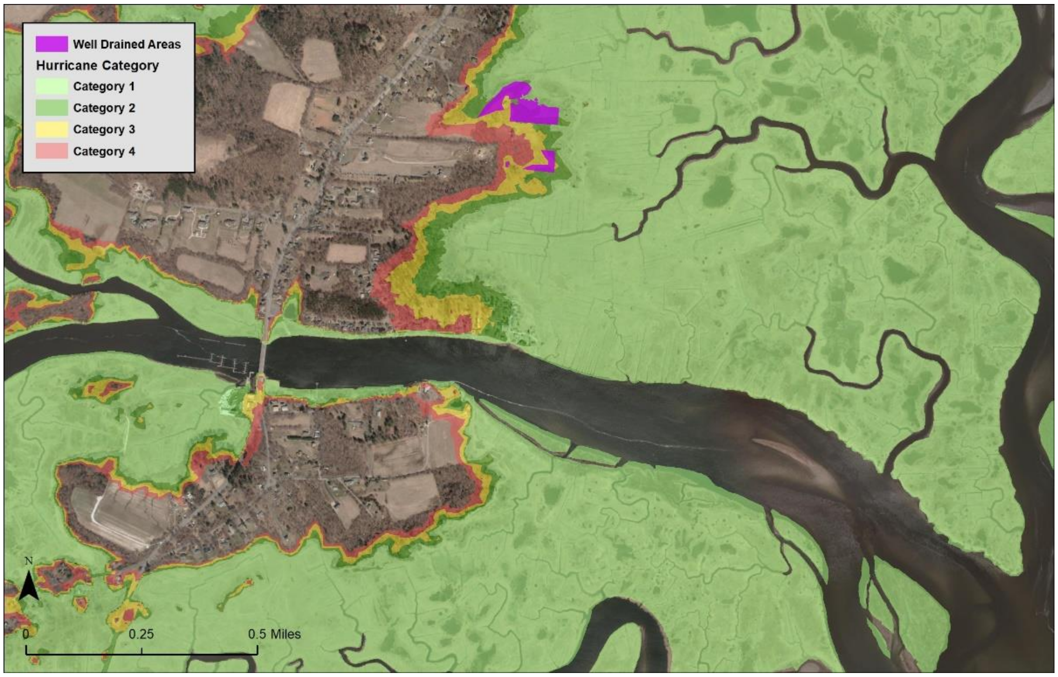
Coastal Flood Mitigation Methods

The coastal flood mitigation analysis is similar in approach to the inland model, but includes saltmarsh as a component of wetlands, and does not analyze forest cores. Instead of using FEMA to evaluate risk, the coastal analysis uses Hurricane Surge risk zones to assess those areas most impacted by storms and coastal threats. The analysis:

- Delineates the wetland area within each tax parcel (both freshwater and saltwater wetlands)
- Calculates the wetland area that intersects Hurricane Surge risk zones
- Within these risk zones, calculates the area included in BioMap2 aquatic layers
- Delineates the natural land cover (non-wetland) area within each tax parcel
- Within these natural land cover areas, identifies those which have gentle slopes and high soil permeability (sand and gravel deposits)

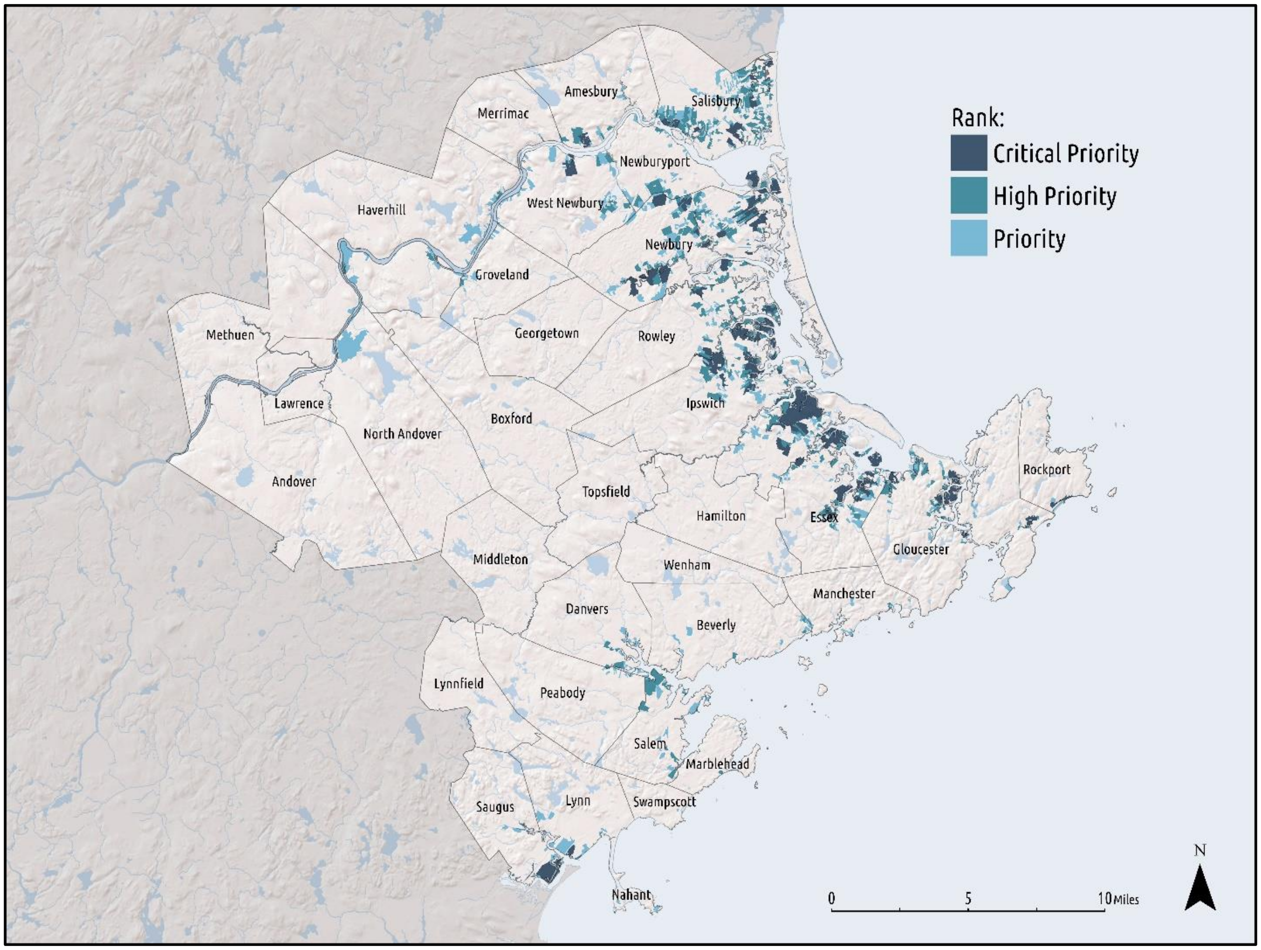
The flood storage value score is calculated by multiplying each category by its point score, applying a bonus for BioMap2, and summing these values.

This flooding analysis aims to answer the question: what parcels are most critical for protection in order to prevent flood hazards due to climate change? While advanced hydrological modeling could answer this question with the most precision, it is not an approach that would be scalable to the entire county. Our approach utilizes land characteristics understood by area hydrologists to be influential in flood mitigation for Essex County, and addresses threats seen by coastal communities.



The map above shows an example of the Hurricane Surge flood zone data. The analysis evaluates the wetland areas within each risk category and sums their acreage per parcel. Additionally, it calculates the volume of overlapping BioMap2 coverage. These values are multiplied by their corresponding point values (as shown in the scoring metric) to create a score for each parcel. Well drained areas within these risk zones are also calculated and summed per parcel, providing an additional bonus to a parcel.

Coastal Flood Mitigation Results



The analysis highlights parcels in the Great Marsh which has expansive, climate resilient wetlands. This reinforces Greenbelt's understanding that these areas should be protected, as they provide tremendous benefits to our coastal communities. The analysis also shows the value of several parcels up along the Merrimack River that, in times of severe coastal surge, help to fend off these excessive floodwaters.

Greenbelt continues to incorporate climate concerns into conservation planning. These flooding analyses will help to bring context to this process by identifying parcels that provide the most flood mitigation value to our constituents and municipal partners. Additionally, the results will assist in pursuing funding for conservation projects and provide inroads for discussion with town decision makers.

Greenbelt

Urban Cooling Analysis Methodology

Greenbelt
Essex County's Land Trust

Purpose

The impact of climate change is perhaps most apparent in dense, urban areas. An excess amount of impervious surface creates an environment where much of the sun's energy is retained, leading to higher ambient temperatures. This has a human impact as it can increase the prevalence of heat-related illness, such as heat exhaustion and heat stroke (Shishegar 2014). Planting street trees and installing green roofs are helpful ways of preventing sunlight from reaching absorbent surfaces, but urban forests can also benefit neighborhoods by emanating cool air to the surrounding area. While this "park cooling effect" is wind-dependent, there are observed cases of parks providing a cooling effect up to 840 meters away (Doick, Peace and Hutchings 2014).

Greenbelt is dedicated to addressing the challenges of climate change through its work to protect and manage land. To that end, we are interested in protecting those parcels that help to combat the urban heat island effect. For this analysis, we scored parcels on the potential cooling value they provide to abnormally warm areas in their proximity. This is performed by comparing the quantity of tree cover within a parcel to the thermal readings of its surrounding areas. High scores reflect parcels that may possess the ability to provide cooling benefits and, if developed, would have significant negative climate impacts on their surrounding neighborhoods.

This research complements initiatives laid out in Greenbelt's latest strategic plan that seek to incorporate climate change issues, and better serve urban communities in Essex County.

Reference Layers

Data	Reason for Inclusion	Source	Notes
Assessor's Parcels	Land ownership boundaries to assess conservation project opportunities.	MassGIS Data: Level 3 Standardized Assessors' Parcels	Unprotected portions of parcels were included if over 5 acres. 7,068 in total.
Parcel Buffers	These buffers were used to calculate the heat island areas surrounding individual parcels.	Created from MassGIS Standardized Assessors' Parcels	A buffer of 500 meters emerged through academic review as a reasonable value to use for this analysis. The inside area of the parcels are erased so that heat island values are only summed from the surrounding area.
Landsat 8: Provisional Surface Temperature	Measures surface temperature of different land cover types to compare temperature of parcel to its surrounding area.	USGS Earth Explorer	Imagery captured 7/19/2018. Converted from Kelvin to Fahrenheit, and clipped to Essex County with a buffer of 1 mile to allow space for the individual buffers of parcels on the county border.
Forested Land Cover	Parcels are assessed for acreage of forested land, which helps to cool heat islands. This data is generally reliable despite its age. However, if a parcel was shown from recent orthophotos to have been deforested, its forested acreage was manually corrected to 0.	MassGIS Data: Land Use (0016)	Selected from Land Use dataset using forest and shrub land covers. Clipped to Essex County.
Environmental Justice Populations	The urban heat island issue is of large importance to human health, particularly among populations who are already at risk for heat-related illness. Environmental justice data helps add value to greenspace that is located in these communities.	MassGIS Data: 2010 U.S. Census Environmental Justice Populations	From MassGIS: "Polygons in the (EJ) Populations layer represent areas across the state with high minority, non-English speaking, and/or low-income populations." Data compiled from 2010 census and ACS 5-year estimates.

Methods

Heat islands can be defined in several ways. The EPA states that the air temperature of urban heat islands are generally 1.8 - 5.4ºF warmer than their surroundings during the day, and up to 22ºF warmer at night (EPA 2019). Looking at the issue from a public health perspective, it is common to use a minimum threshold value to signify when abnormally warm temperatures become a health risk for residents. The EPA and CDC's Extreme Heat Guidebook states "…a May temperature of 92°F in Boston is extreme heat, whereas a May temperature in Phoenix would have to reach more than 100°F to be considered extreme (EPA, CDC 2016)." These values remain relative to the daily mean temperature of the study region.

For this analysis we defined heat islands as areas one standard deviation warmer than the mean for Essex County. The standard deviation approach has been used in several urban heat island studies (Effat, Taha, and Mansour 2014; Y. Ma, Y. Kuang, and N. Huang. 2010) and is a straightforward way of identifying significantly hot areas for a region. A Landsat 8 Provisional Surface Temperature product captured on 7/19/2018 was used. Temperatures were converted from Kelvin to Fahrenheit, then clipped to the Essex County boundary plus one mile to allow space for buffers. The mean surface temperature for the imagery was 85.3ºF with a standard deviation of 7.53. Areas over 93 ºF were then extracted from the thermal raster to represent significantly warm areas in the analysis.

The buffer distance used to sum the surrounding thermal values for each parcel was 500 meters. This value has been used previously to measure urban heat island intensity (Cao et al., 2010), and was in line with the distances cited by several articles on the influence urban forest can have on cooling nearby areas (Doick, Peace and Hutchings 2014). Future work could include modifying the buffer distance and shape for each parcel depending on its characteristics. We determined doing so would involve advanced modeling that is beyond the level of detail needed for this prioritization.

Since the study of urban heat islands is largely concerned with human impacts, we decided to incorporate an element of at-risk populations into the analysis. This aspect was expressed by our review panel who pointed to previous studies that took such an approach. Our response was to include environmental justice areas. These have been identified by the Executive Office of Energy and Environmental Affair's Environmental Justice Policy as areas containing a high percentage of minority, non-English speaking, and/or low-income populations. These areas were intersected with urban heat islands in the analysis, and assigned a 40% bonus.

This prioritization assesses unprotected land parcels five acres or larger in Essex County on their ability to mitigate the effects of urban heat islands. Existing conserved land is first removed from parcels to assess only the unprotected area. The analysis is then performed as follows:

- Parcels are buffered 500 meters each, outside of polygons only.
- Percentage of forested land cover is calculated per parcel. Parcels must be at least 50% forest to be included in the analysis.
- Areas of high surface temperature are extracted, and summed within each parcel and its 500-meter buffer. The internal value is subtracted from the buffer value as it indicates the parcel is contributing to heat islands.
- Heat island areas are intersected with Environmental Justice areas, and assigned a 40% bonus where they are coincident.

Parcels are scored by multiplying the forested value within a parcel with its surrounding thermal value.

Potential UHI Cooling Score =

Percent Forest * Thermal Value + Residential Bonus + Environmental Justice Bonus / 10,000

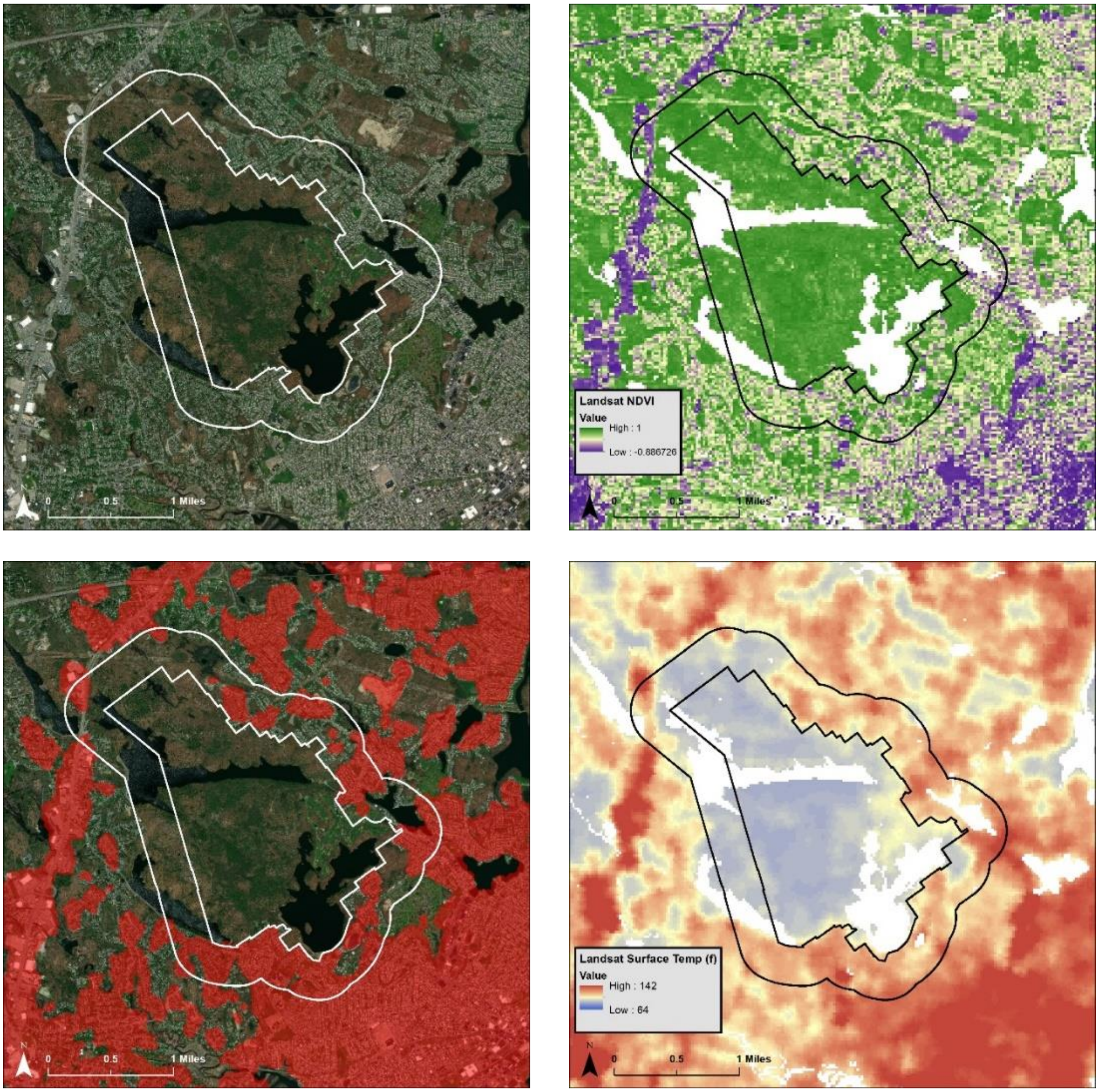
Where Percent Forest is the percentage of the parcel that is forested.

Where Thermal Value is the sum of temperature values of pixels with temperatures of 1 SD+ above the average for the county (94F+) and falling within a 500m buffer around the perimeter of the parcel.

Where Residential Bonus is 20% of the sum of temperature values of pixels with temperatures of 1 SD+ above the average for the county (94F+) and falling within residential land use areas within a 500m buffer around the perimeter of the parcel.

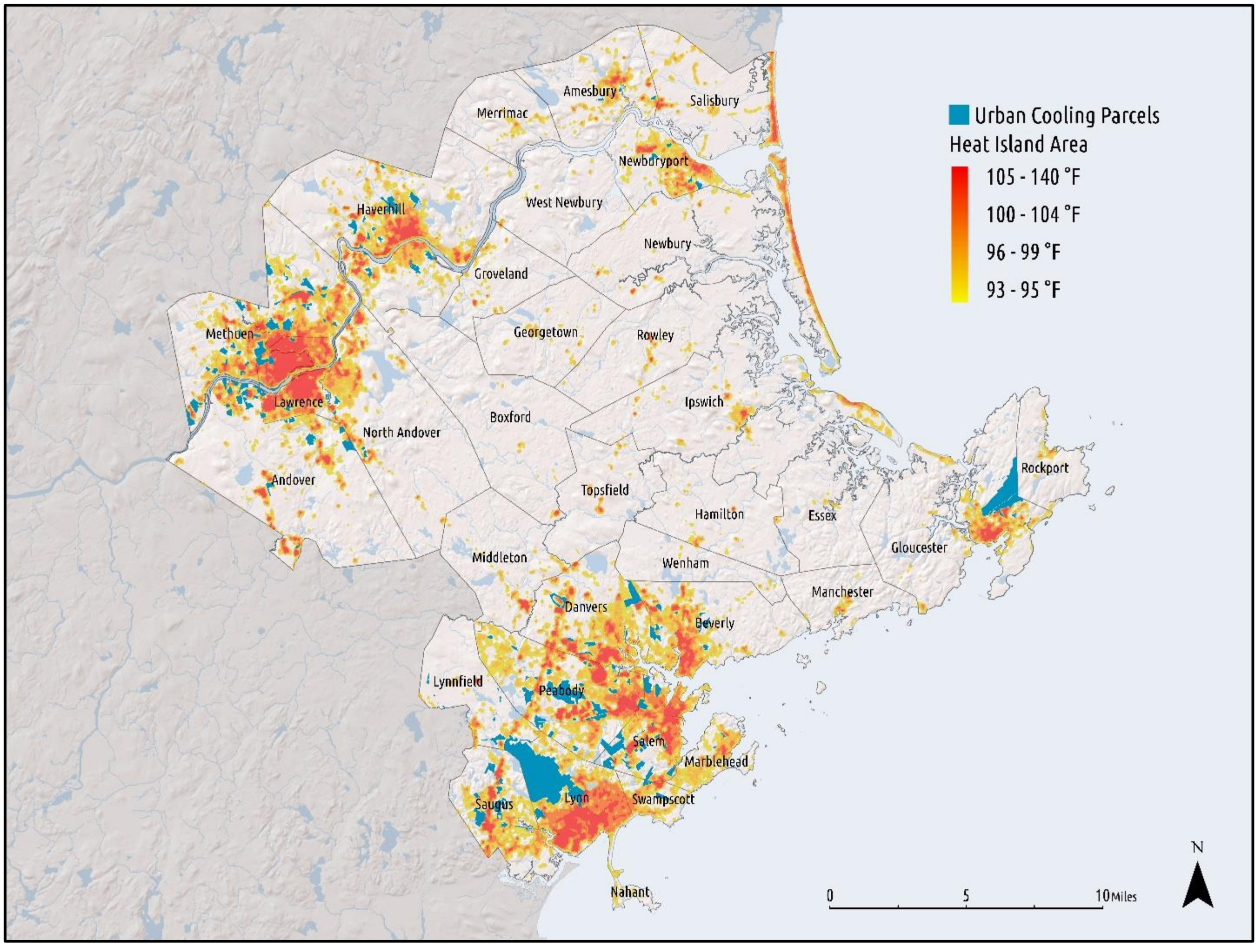
Where Environmental Justice Bonus is 40% of the sum of temperature values of pixels with temperatures of 1 SD+ above the average for the county (94F+) and falling within environmental justice areas within a 500m buffer around the perimeter of the parcel.

Scores are divided by 10,000 to adjust final scores to a more readable scale of 0 to 20.



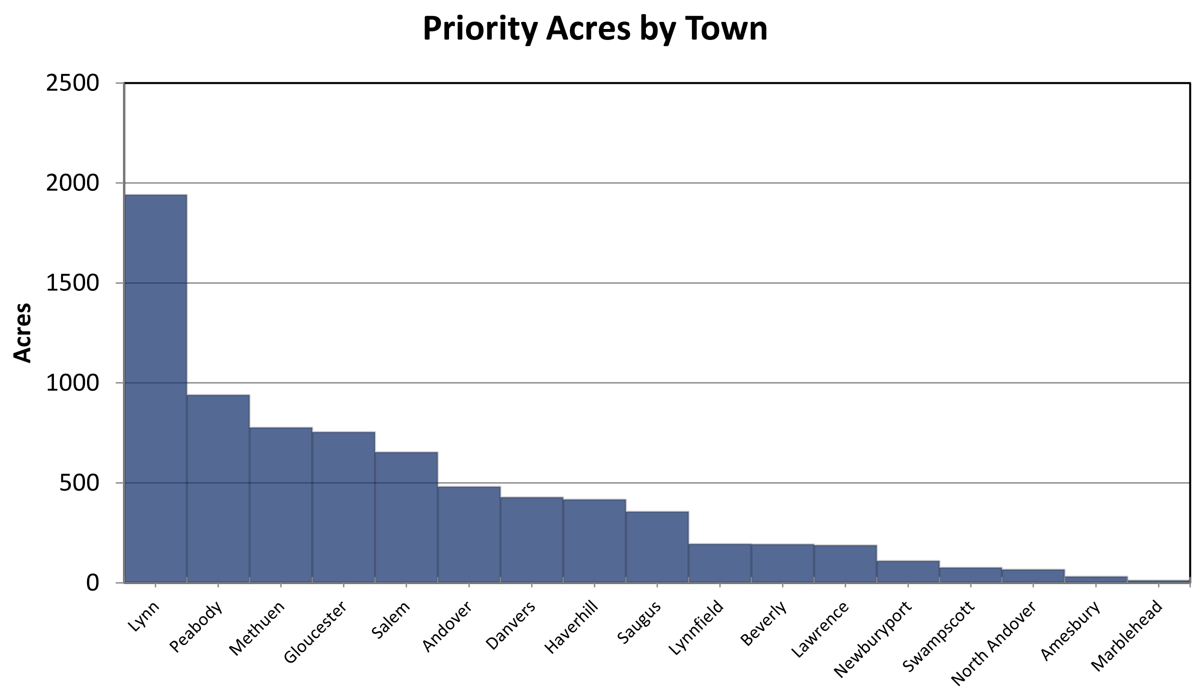
Images above show the Lynn Woods parcel with a 500-meter buffer. Orthophoto (top left), NDVI (top right), areas 1 std. dev. above the mean (bottom left), and surface temperature (bottom right)

Results



The analysis highlights the top scoring parcels that have potential to reduce the heat island effects in Essex County. Realistically, there exists a relatively small number of parcels that play an active role in cooling urban heat islands, since there are only so many urban forest parcels over five acres. For this reason, we have focused our attention on the top scoring 200 parcels. These are located primarily in the municipalities of Lynn, Peabody, Methuen, Gloucester, Andover, Salem, and Haverhill. The size of each parcel ends up playing a considerable role in its final score, which gives the southern portion of the county some of the higher scoring parcels.

This analysis helps Greenbelt respond to the challenges of climate change faced by urban communities, and makes a clear case for the impacts of land use change in Essex County. Using the parcels scores and regional trends, these results will aid Greenbelt in identifying at-risk areas for heat islands and communicate the issue with municipal decision makers. In the future, this analysis may be revisited to more precisely measure the cooling effect being emanated by each parcel. This level of detail would increase Greenbelt's ability to target individual parcels for conservation projects based on the intensity and reach of their cooling ability.



Agricultural Prioritization Methodology

Greenbelt
Essex County's Land Trust

Introduction

Preserving farmland is one of Greenbelt's core mission areas; as such, developing robust agricultural data was a critical driver for the prioritization project. Greenbelt has a long history of conserving farmland, including one of the first agricultural preservation restrictions in the state on what is now Russell Orchards in Ipswich. Some examples of farms protected in the last few years include Green Meadows Farm in Hamilton, Mehaffey Farm in Rowley and Leonhard Farm in North Andover. In total, we have protected nearly 3,000 acres of agricultural properties across the county.

Greenbelt's commitment to the agricultural community has led to investments in programing, such as farmer focused succession planning workshops, the creation of an innovative young and beginning farmer outreach program, and increasing the number of agricultural events we hold. The farmland conservation effort has been further supported by Greenbelt's acceptance into a one million dollar USDA Regional Conservation Partnership Program (RCPP), which will fund the conservation of farmland in the Merrimack River Valley. Given Greenbelt's focus on and commitment to farmland conservation, developing a reliable metric for prioritizing large, well-established farms, and smaller, locally important farms emerged as a goal for this project.

Data Development & Purpose

In our project work and during the RCPP planning process it became evident that a lack of farmland focused data for the county was inhibiting conservation planning. In response to this, Greenbelt began mapping active farmed areas. Active farmland was defined for this project as areas that are currently used for agricultural production or grazing. Interns and staff mapped these areas by identifying potential farms from land use/cover and assessors' data, which was augmented by local knowledge of farm locations. Active areas were then drawn based on aerial photography. The Merrimack River Valley active farm areas were first drawn in 2016 as a part of an application to the RCPP. During the planning process for this prioritization project, we determined that finishing this work for the rest of the county, while time consuming, was important.

Developing a countywide agricultural dataset was critical to the accuracy of this analysis. In addition to active farmland delineation, the prioritization team sought to assess farms as a whole rather than on a parcel-by-parcel basis. To address this, staff and Greenbelt volunteer Jan Klein started by identifying businesses throughout the county, which were then located by Greenbelt staff. Additionally, parcels that had agricultural use, but were unassociated with a larger farming operation, were included in the analysis as isolated farm parcels. Isolated farm parcels were located by Chapter 61 status, MassGIS Land Use data, and the created active farmland mapping layer to identify parcels associated with agricultural use. Parcels with shared ownership were grouped together and treated as a single farm entity. Parcels that are leased by a farmer were not grouped with that farmer's land holdings, because leased lands can change hands more easily than those in ownership.

Greenbelt's former prioritization included an agricultural analysis, but recent improvements in quality of agricultural data sources opened new doors for analysis methods. In the last few years, Greenbelt has acquired and processed Chapter 61 data from each town in Essex County. Additionally, assessor's parcel records from MassGIS have increased in quality with "Level 3" standardization, now including more descriptive land use designations.

With the combination of improved parcel data, updated Chapter 61 data, land use data, and new data on active farm areas and farm entities, we set out with the goal of combining these datasets to identify the most important land for conservation to ensure the persistence of agriculture in our region.

Reference Layers

Data	Reason for Inclusion	Source	Notes
Farms Entities	Grouping parcels based on ownership allows for a more accurate assessment of farms, and their conservation opportunity by scoring farms as a whole rather than on a parcel by parcel basis.	Level 3 Assessor's Parcels of Essex County Towns, MA Chapter 61 data, MassGIS Land Use (2005), and research by Greenbelt staff and volunteers.	In addition to farmland belonging to active farm businesses, miscellaneous parcels over 5 acres that had MA Chapter 61A status or active farm areas were incorporated. Permanently protected areas were erased from farm entities.
Active Farmland	Actively farmed area speaks to the scale of an agricultural operation, and delineates area for soil analysis.	USGS Color Ortho Imagery (2013/2014). Polygons identified and drawn by Greenbelt staff and volunteers.	Active farm areas were drawn within parcels if they had clear agricultural land use. Tree farms and plant nurseries were included. Equestrian operations were excluded, unless row crops were detected.
Massachusetts Chapter 61 Data	This tax designation helps to identify parcels used for agriculture, forestry, or recreation. Landowners of these parcels have already engaged in some land use planning and parcels are subject to a right of first refusal by the Town if the use of the parcel is changed.	Received from town assessor's offices during a previous analysis and Level 3 data.	A join was used to tie Chapter 61 status to assessor's parcels.
Farm Soils	Presence of certified soils can be indicative of farmland quality. Additionally, it adds merit to grant applications and is a requirement of the APR program.	NRCS SSURGO-Certified Soils	Dataset was limited to prime soils, and soils of statewide importance. Soil was only calculated within actively farmed areas.
Permanently Protected Land	Farms adjacent to permanently protected land provide additional value by contributing to Greenbelt's overarching mission.	MassGIS Data: Protected and Recreational OpenSpace and Greenbelt's protected land dataset	Dataset was limited to only permanently protected land.
Roads	Length and quality of road frontage can be important to the long term viability of a farm business.	Massachusetts Department of Transportation (MassDOT) Roads	Roads split by class (1-6) to assess quality of frontage.
Buildings	Parcels with existing agricultural infrastructure have greater long term viability.	MassGIS Data: Building Structures (2-D)	Limited to buildings with footprints larger than 1000 sq. ft. to exclude sheds and outbuildings.

Methods

This prioritization uses GIS analysis to assess the potential conservation value of unprotected agricultural land in Essex County. Only parcels with an existing agricultural land use were included in the analysis. 674 individual tax parcels were consolidated by ownership down to 468 farm entities, and used as an analysis input. 121 of these entities were able to be tied to a named farm business, with the rest included as miscellaneous farm parcels. As we continue to work with this data and learn more about the agricultural landscape in Essex County, these numbers will be updated in response to new understandings of the configuration of farm entities and isolated farm parcels.

The analysis scores farm entities on their agricultural value according to six weighted categories:

Agricultural Threshold[1]**:** the ratio of active farmland to overall farm entity size is used to assess the extent of the farming operation

Farm Entity Size: parcels are merged based on landowner and classified according to six acreage breaks

Agricultural Land Use: score is assigned using Chapter 61 tax status

Agricultural Soils: soil value is derived by calculating the percentage of active farmland that is considered USDA Prime Farmland Soils or of Farmland Soils of Statewide Importance

Infrastructure: the length and quality of road frontage, as well as number of buildings over 1000 square feet, is calculated and scored accordingly

Adjacency Protection Level: farm entities are given a bonus point if they are within 100 feet of permanently protected open space

The final agricultural value score is calculated by multiplying each category score by its weight, summing, then dividing by the best possible score. This produces indexed values from 0 to 100.

[1] *The agricultural component of the New Jersey Conservation Blueprint project served as an inspiration for this project. A 2017 joint effort between The Nature Conservancy, New Jersey Conservation Foundation, and Rowan University, the analysis became an effective conservation planning tool for the state of New Jersey. Their analysis scored parcels for agricultural land use, soil quality, proximity to existing preserved agricultural lands, and agricultural threshold (ratio of active farmland to parcel size). Sharing regional similarity, and comparable input data layers, Greenbelt felt the Conservation Blueprint methods could be adapted to fit a prioritization of Essex County to achieve its prioritization goals.*

Parcel Scoring System

Agricultural Threshold (weight: 25%):

Farm entity over 50 acres with at least 20 acres farmed:	**3 points**
Farm entity is 20-49.99 acres with at least 10 acres farmed:	**2 points**
Farm entity is 5+ acres and at least 25% actively farmed:	**1 point**

Agricultural Soils (weight: 25%):

Active farmland is over 50% Prime/Statewide soils:	**2 points**
Active farmland is 30% - 49.99% Prime/Statewide soils:	**1 point**

Farm Entity Size (weight: 17.5%):

Over 100 acres:	**5 points**
50 to 99.99 acres:	**4 points**
20 to 49.99 acres:	**3 points**
10 to 19.99 acres:	**2 points**
5 to 9.99 acres:	**1 point**

Agricultural Land Use (weight: 17.5%):

Contains designated Chapter 61A land:	**2 points**
Contains designated Chapter 61 or 61B land:	**1 point**

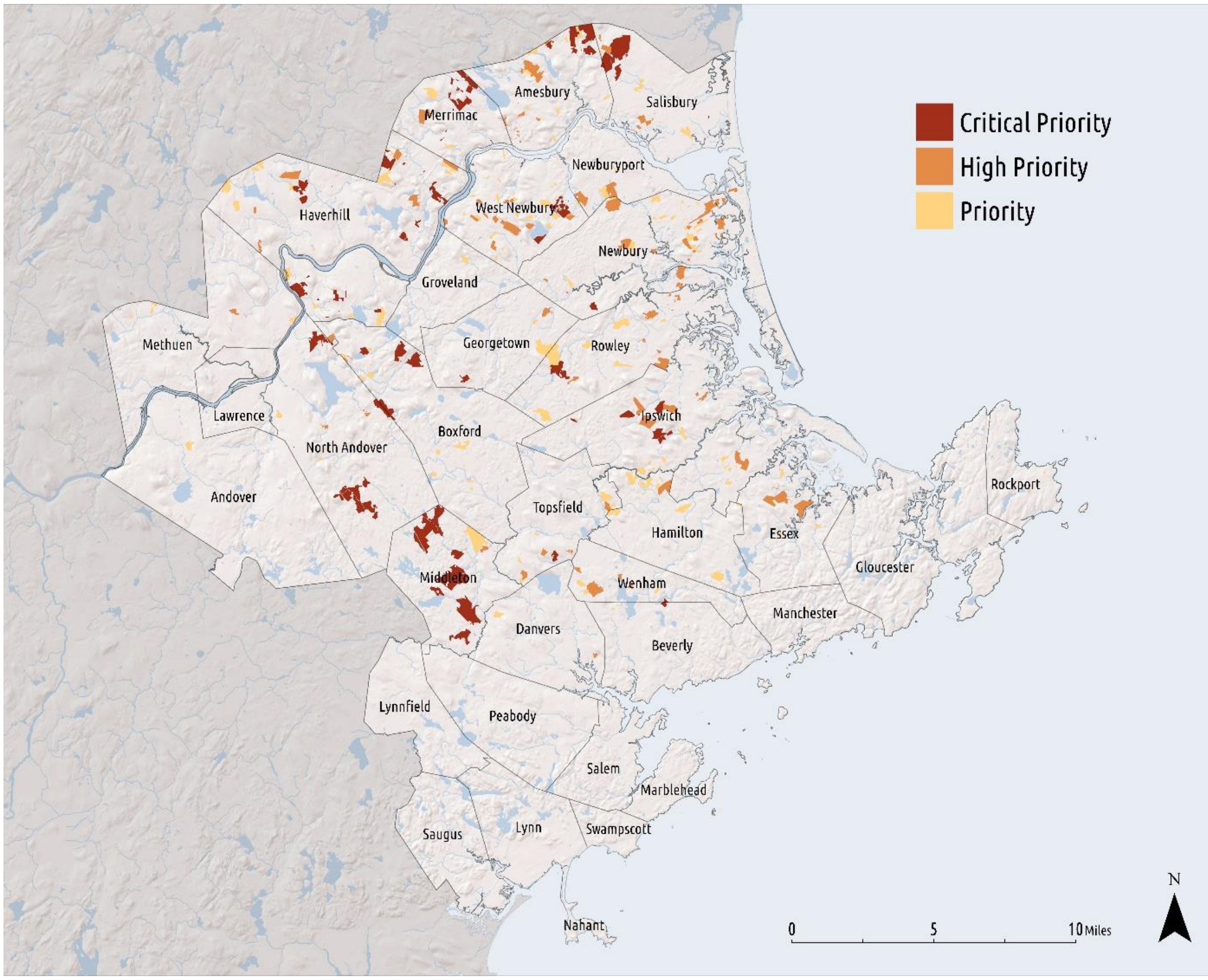
Infrastructure (weight: 10%):

Road Frontage:	
Above average road frontage within its farm size category:	**2 points**
Over 100 feet of road frontage:	**1 point**
Buildings:	
Farmland includes 3 or more buildings:	**2 points**
Farmland includes at least 1 building:	**1 point**

Adjacency Protection Level (weight: 5%):

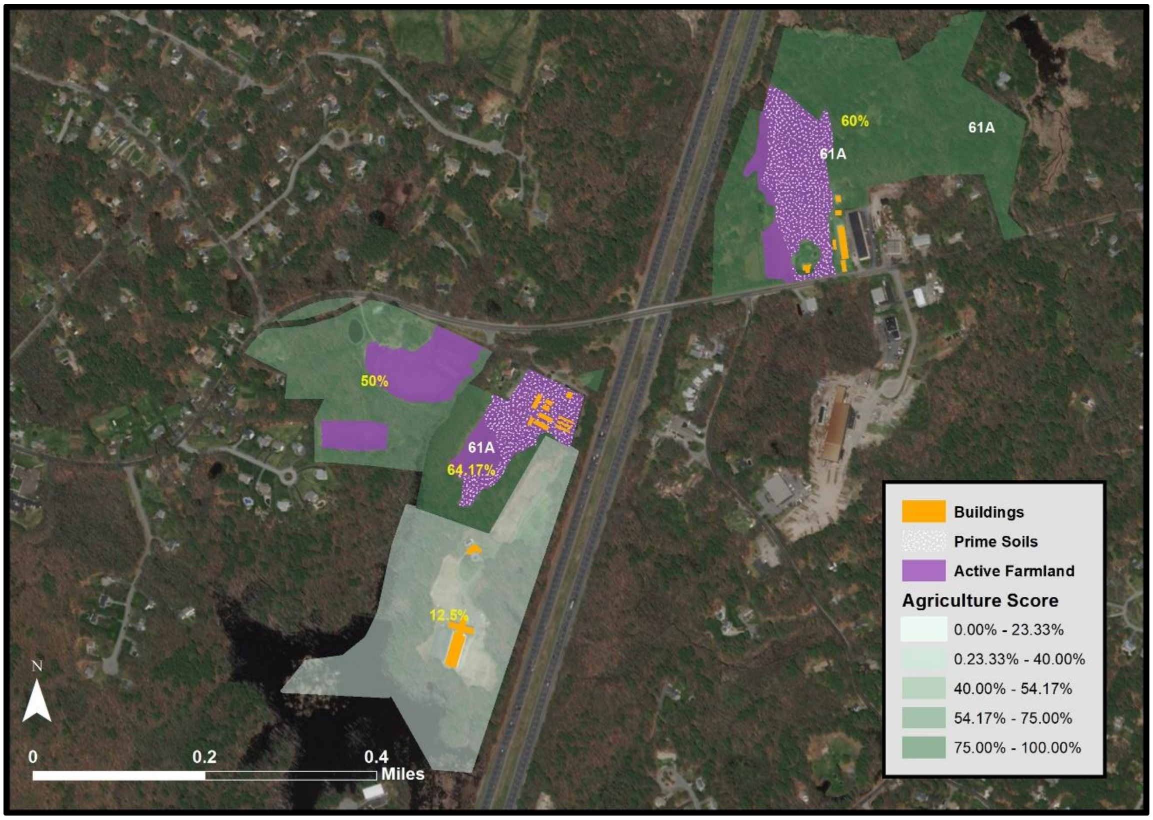
Within 100 feet of permanently protected land:	**1 point**

Results

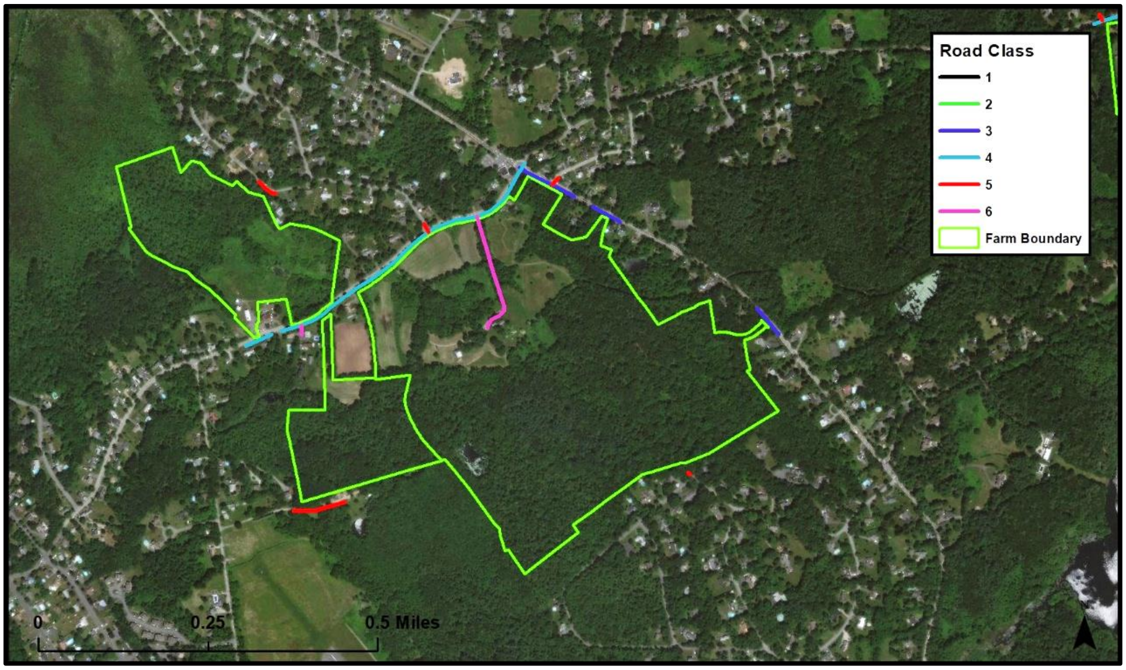


This analysis helps to identify the most important farms to protect Essex County's agricultural resources. Creating scores for each farm helps to put into perspective the conservation value of each farm in the county, though ultimately intangible factors such as local importance and historical value must also be taken into account.

As shown in the map above, the Merrimac River Valley scored particularly strong for farm conservation opportunities. Haverhill alone contains over 600 actively farmed unprotected acres of and over 1,800 acres of unprotected agricultural land. Top scoring unprotected farms include: Rogers Spring Hill Farm, Srybny Farm, Fletcher Community Farm, Lesiczka Farm, and Fitzgerald Farm. While the value of Haverhill's farmland was already understood by Greenbelt prior to this analysis, these results help to reinforce our commitment to working to expand our efforts in this region.

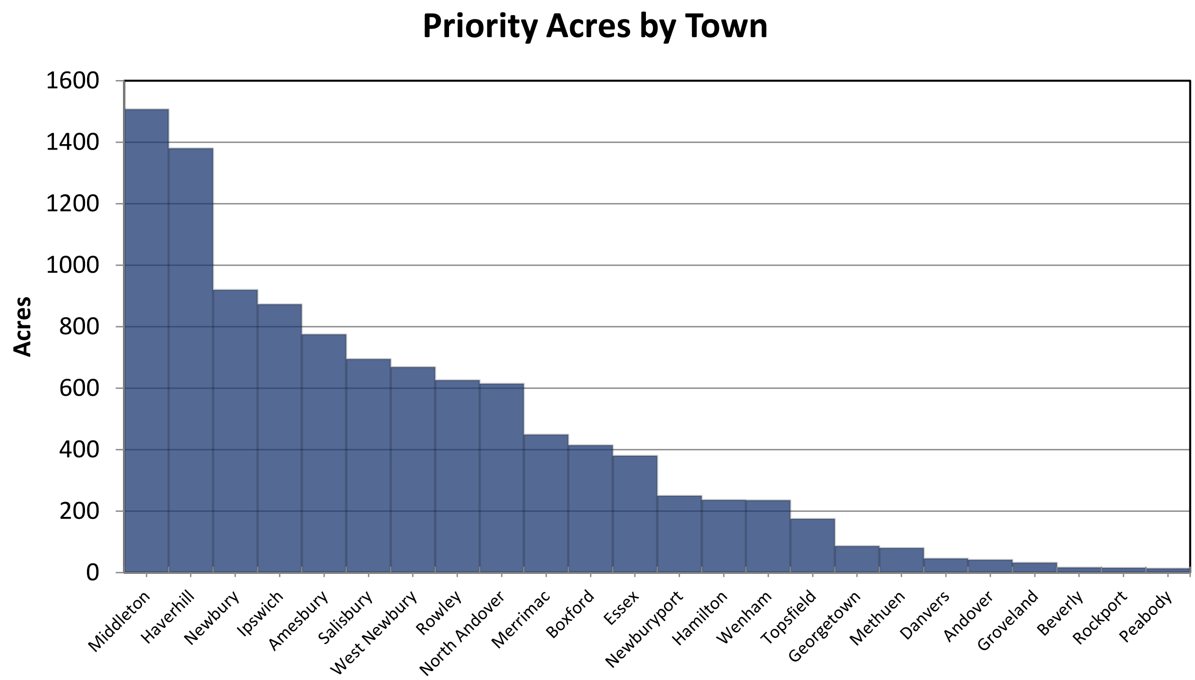


Shown above, the map displays how various characteristics contribute to the agriculture score. The southernmost parcel has considerable acreage and infrastructure, however it contains no active farmland because it's an equestrian facility, which limits its ability to score highly in the analysis. The parcel directly above it, while much smaller, contains a high proportion of actively farmed land with Prime Farmland soils, resulting in a higher score. While the acreage of a farm is a critical contributor, we structured the scoring metric in a way that elevates farm quality. This allows the results to speak to the importance of large, active farming operations while also uncovering smaller farm operations that could provide opportunities for young or beginning farmers.



The above map is an example of how road frontage contributes to the agriculture score of a farm. As shown in the map above, roads bordering a farm are categorized by their class, which can range from a minor street to a limited access highway such as I-95. Points were awarded to a farm based on the length and class of their road frontage, as these attributes correlate with the accessibility and visibility of a farm.

These results will assist Greenbelt's conservation planning process by providing insight into the agricultural value of parcels throughout the county. Prior to this analysis, the agricultural attributes of each town were difficult to quantify. With these newly created data and analysis results Greenbelt will be able to generate agricultural statistics, track land cover changes over time, focus our conservation outreach, and better communicate the importance of agricultural protection to municipal decision makers, potential grant funders, and the constituents of Essex County.


Priority Acres by Town
Acres
1600
1400
1200
1000
800
600
400
200
0
Middleton
Haverhill
Newbury
Ipswich
Amesbury
Salisbury
West Newbury
Rowley
North Andover
Merrimac
Boxford
Essex
Newburyport
Hamilton
Wenham
Topsfield
Georgetown
Methuen
Danvers
Andover
Groveland
Beverly
Rockport
Peabody

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Appendix A: GIS Methods

Natural Resilience:

The GIS methods were scripted using the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. TNC Terrestrial Resilience, TNC Resilient and Connected, and Open Space Heatmap raster layers are converted to polygons and split by category.
2. Feature layers TNC Coastal Resilience and TNC Connected flow are split by attribute.
3. BioMap2 Aquatic layers are merged into a single layer 'BioMerge'.
4. With all necessary splits now performed on dataset attributes, each layer is intersected with tax parcels, dissolved based on "LOC_ID" and acreage calculated. This value is joined to the tax parcels layer.
5. Field "TNC_Coast_sc" is created and calculated using the formula:
   (!TNC_coast_FAA_ac! * 3) + ((!TNC_coast_AA_ac! + !migration_space_slr06_ac!) * 2)
   + (!TNC_coast_SAA_ac!)
6. Field "TNC_Terr_sc" is created and calculated using the formula:
   (!TNC_terrpoly_FAA_ac! * 3) + (!TNC_terrpoly_AA_ac! *2) + (!TNC_terrpoly_SAA_ac! *1)
7. Field "BioMap_sc" is created and calculated using the formula: (!BioMerge_ac! * 2)
8. Field "Priority_Connected_sc" is created and calculated using the formula:
   (!TNC_ResilConpoly_ClimCorr_wDiv_ac! * 2) + (!TNC_ResilConpoly_ClimCorr_ac! * 1)
9. Field "Flow_sc" is created and calculated using the formula:
   ((!Flow_Hi_Conc_ac! + !Flow_Conc_ac!) * 2) + (!Flow_Const_ac! * 1)
10. Field "OSHeatmap_sc" is created and calculated using the formula:
    (!OS_Heatmappoly_FAA_ac! * 2) + (!OS_Heatmappoly_AA_ac! * 1)
11. Field "Natural_Res_Score" is created and calculated using the formula:
    "Natural_Res_Score" = (max(TNC_Coast_sc, TNC_Terr_sc, BioMap_sc) + Flow_sc
    + ((Priority_Connected_sc + OSHeatmap_sc) * 0.3))

Greenbelt

Habitat:

The GIS methods were scripted using the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. TNC Terrestrial Resilience, TNC Resilient and Connected, and Open Space Heatmap raster layers are converted to polygons and split by category.
2. Feature layer TNC Coastal Resilience is split by attribute.
3. BioMap2 Aquatic layers are merged into a single layer 'BioMerge'.
4. With all necessary splits now performed on dataset attributes, each layer is intersected with tax parcels, dissolved based on "LOC_ID" and acreage calculated. This value is joined to the tax parcels layer.
5. Field "TNC_Coast_sc" is created and calculated using the formula:
   (!TNC_coast_FAA_ac! * 3) + ((!TNC_coast_AA_ac! + !migration_space_slr06_ac!) * 2) + (!TNC_coast_SAA_ac!)
6. Field "TNC_Terr_sc" is created and calculated using the formula:
   (!TNC_terrpoly_FAA_ac! * 3) + (!TNC_terrpoly_AA_ac! *2) + (!TNC_terrpoly_SAA_ac! *1)
7. Field "BioMap_sc" is created and calculated using the formula: (!BioMerge_ac! * 2) + !BM2_Critical_natural_landscape_ac!
8. Field "PriorityHab_sc" is created and calculated using the formula:
   (!PRIHAB_POLY_ac! * 3)
9. Field "CAPS_sc" is created and calculated using the formula:
   (!CAPSpoly_FAA_ac! * 3) + (!CAPSpoly_AA_ac! * 1.5)
10. Field "OSHeatmap_sc" is created and calculated using the formula:
    (!OS_Heatmappoly_FAA_ac! * 2) + (!OS_Heatmappoly_AA_ac! * 1)
11. Field "ParcelSize_sc" is created and calculated using the formula:
    ```
    if   !GIS_ac! >= 100:
            !Parcelsize_sc! =  3
    elif   !GIS_ac! >= 50:
            !Parcelsize_sc! =  2
    elif   !GIS_ac! >= 10:
            !Parcelsize_sc! =  1
    Else:
            !Parcelsize_sc! =  0
    ```
12. Field "OSAdjacency_sc" is created and calculated by selecting parcels within 100 feet of 1 point, then inverting the selecting and assigning 0 points to all other parcels.
13. Field "Habitat_Score" is created and calculated using the formula:

((Max(TNC_Coast_sc, TNC_Terr_sc) + BioMap_sc + PriorityHab_sc + CAPS_sc + OSHeatmap_sc) / GIS_ac)) + (OSAdjacency_sc + ParcelSize_sc)

Drinking Water:

The GIS methods were scripted using the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. Permanently protected open space and Greenbelt properties were erased from the tax assessor's parcels layer. Parcels remaining over 5 acres were used in the analysis.
2. Surface Water Protection zone layer is split by attribute for zones A, B, and C.
3. Public water supply features from Wellhead Protection Zone 1 are selected are buffered 1/2 mile. This feature layer is then clipped to only include area within Wellhead Protection Zone 2's. New field for acreage is created and calculated, and joined to the parcel layer.
4. Using the 1/2 mile buffer created from Zone 1 areas, an erase is performed on Wellhead Protection Zone 2 features. New field for acreage is then created and calculated, and joined to the parcel layer.
5. Wellhead Protection Zone IWPA, and each Surface Water Protection category is calculated for acreage and joined to the parcel layer.
6. Natural land cover area is clipped to the aquifers layer. Wellhead Protection Zone 2 areas are erased, then this area is summer per parcel.
7. Coverage of subwatersheds is intersected and summed per parcel.
8. For each watershed, parcels are intersected, and percentage calculated of watershed coverage.
9. Each drinking water body is buffered 100 feet, 200 feet, and 300 feet, and coverage is summed per parcel.
10. Each drinking water intake is buffered 0.1 miles and 0.25 miles (upstream direction only for rivers) and coverage is summed per parcel.
11. Field "DWI_Reg_Score" is created using the following formulas:

    SurfaceWater_score = ((!SWP_A! * 3) + (!SWP_B! * 2) + (!SWP_C! * 1) * 0.6)

    GroundWater_score = ((!WellsZ1! * 3) + (!WellsZ2! * 1.5) + (!WellsIWPA! * 3) * 0.4)

    DWI_Reg_Score = SurfaceWater_score + Groundwater_score
12. Field "DWI_Score" is created using the following formulas:

    DWI_Score = DWI_Reg_Score + Aquifer Area + (Watershed Acres * Watershed Percentage) + Watershed 100 ft buffer + Watershed 200 ft buffer + Watershed 300 ft buffer + Intake 0.10mi buffer + Intake 0.25mi buffer

Greenbelt

Inland Flooding:

The GIS methods were scripted using the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. FEMA risk zone layers are clipped to Essex County
2. From the MassDEP Wetland layer, “POLY_CODE” are 2, 3, 5, and 8 are selected to create a wetland layer without open water features.
3. FEMA risk zones are split and consolidated to 1% and 0.2% annual risk categories using the formulas: "FLD_ZONE" IN ('X')   and   "FLD_ZONE" IN ('A' , 'AE' , 'AH' , 'AO', 'VE')
4. Hurricane Surge Inundation Zones are split into two risk categories using the formulas:
   "HURR_CAT" IN (3,4)   and   "HURR_CAT" IN (1,2)
5. Each of these risk layers for FEMA and Hurricane Surge Inundation is intersected with the tax parcels layer, and dissolved based on the “LOC_ID”.
6. BioMap2 aquatic layers are merged, intersected with the tax parcels layer, and dissolved based on the “LOC_ID” field for each risk layer. Acreage is calculated for each and joined to the parcels.
7. Acreage is calculated for each FEMA and Hurricane Surge Inundation risk category, and joined to the parcels.
8. Soil Drainage Class data is split by categories ‘Well drained’, ‘Somewhat excessively drained’, and ‘Excessively drained.’ These categories are intersected with natural land cover (non-wetland). Acreage is calculated for each and joined to the parcels.
9. Using the ‘surface slope’ data, the mean slope is calculated per parcel using raster zonal statistics. Acreage of a slope less than 15 degrees is calculated and joined to each parcel record.
10. Field “FloodScore” is created. The score calculates the wetland area flood storage score per parcel using the formula:
    max((((!Fema1!) + (!BioFema1! /2)) * 1) + (((!Fema2!) + (!BioFema2! /2)) * 2), (((!Hurr1!) + (!BioHurr1! /2)) * 1) + (((!Hurr2!) + (!BioHurr2! /2)) * 2))
11. Field “NLC_FloodScore” is created. The score calculated the natural land cover flood storage score per parcel using the formula:
    FEMA_score = (((Fema1_NLC_ED + Fema1_NLC_WD + Fema1_NLC_SED) + ((Fema2_NLC_ED + Fema2_NLC_WD + Fema2_NLC_SED) * 2)) / 2) + (Fema1_NLC) + ((Fema2_NLC) * 2)
    Hurr_score = (((Hurr1_NLC_ED + Hurr1_NLC_WD + Hurr1_NLC_SED) + ((Hurr2_NLC_ED + Hurr2_NLC_WD + Hurr2_NLC_SED) * 2)) / 2) + (Hurr1_NLC) + ((Hurr2_NLC) * 2)
    NLC_FloodScore = max(FEMA_score, Hurr_score)

Urban Cooling:

The GIS methods were performed using ArcGIS Desktop, with some parts utilizing the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. Assessors' parcels are buffered 500 meters, outsides only.
2. Surface temperature raster is converted to points, with each point representing a raster cell. Points over 1 standard deviation warmer (94ºF) than average are selected to create a new data layer.
3. A spatial join is used to sum the 94ºF+ surface temperature points for each parcel buffer. Another spatial join is performed to sum the 94ºF+ surface temperature within each parcel. A field "Therm_Difference" is created and calculated by subtracting the internal thermal values from the thermal values in the 500-meter buffer for each parcel.
4. Forested land cover is intersected with assessors' parcels, dissolved based on each parcel's LOC_ID, acreage calculated, and joined back to the tax parcels as field "Forest_ac".
5. Field "UHI_Score_Norm" is created and calculated using the formula:

   ("Forest_ac" * "Therm_Difference" / "Acres") / 10,000

   This field is divided by 10,000 to reign in the values to more easily comparable quantities.

Agriculture:

The GIS methods were scripted using the ArcPy package in Python 2.7. Analysis tools are executed as follows:

1. Land parcels are dissolved based on “FarmCode” field to consolidate farm entities
2. New field for total acreage is created and calculated. Farms are intersected with the active farmland layer, dissolved based on “FarmCode”, acreage field created and calculated, then joined to the farm entity layer.
3. Field “AG_Land_Use_Points” is created, and calculated by selecting farms containing Chapter 61B land and assigning 1 point, then selecting farms containing Chapter 61A land and assigning 2 points. Null values are assigned 0. Field “AG_Land_Use_Score” is created and calculated using the formula (“AG_Land_Use_Points” / 2).
4. Farm soils layer is intersected with farm entities and active farmland, and “FarmSoils_ac” field is created and calculated. This layer is then dissolved based on “FarmCode” while summing “FarmSoils_ac”. Fields “Farm_Soils_Points” and “Farm_Soils_Score” are created.
5. “Farm_Soils_Points” assigns 2 points if over 50% of active farmland includes certified farm soils and 1 point if over 30%. “Farm_Soils_Score” is calculated using: (“Farm_Soils_Points” / 2).
6. Fields “Farm_Size_Points” and “Farm_Size_Score” are created. “Farm_Size_Points” is assigned up to 6 points using the farm’s overall acreage using the breaks 5, 10, 20, 50, 100, and 200. “Farm_Size_Score” is calculated using: (“Farm_Size_Points” / 6).
7. Fields “AG_Thresh_Points” and “Ag_Thresh_Score” are created. “AG_Thresh_Points” is assigned up to 3 points using the logic:

   ```
   if (Total Acres >= 50 and Actively Farmed Acres >= 20 ):
         “AG_Thresh_Points” = 3
   else if (Total Acres >= 20 and Total Acres < 50 and Actively Farmed Acres >= 10 ):
         “AG_Thresh_Points” = 2
   else if  (Actively Farmed Acres / Total Acres >= 25% ):
         “AG_Thresh_Points” = 1
   else:
         “AG_Thresh_Points” = 0
   ```

   “Ag_Thresh_Score” is calculated using: (“Ag_Thresh_Points” / 3).
8. Fields “Prot_Level_Points” and “Prot_Level_Score” are created. Farms within 100 feet of permanently protected land are selected and assigned 1 point in the field “Prot_Level_Points”. Selection is then inverted and all other records are assigned 0 points. “Prot_Level_Score” is calculated using: (“Prot_Level_Score” / 1).
9. Farms are buffered 30 meters, intersected with MassDOT roads, and dissolved based on “FarmCode”. Length in miles is calculated. Farm roads are split by attribute “CLASS”.

10. The lengths of the six road classes are calculated per farm, with an accompanied field joined to the farms layer. Fields “Roadfront_Points” and “RoadFront_Score” are created.
11. “Roadfront_Points” are calculated by adding road class values with a weight increase for classes 2, 3 and 4, using the formula:

    ((MilesClass2 + MilesClass3 + MilesClass4) * 1.3) + (MilesClass1 * 1) + (MilesClass5 * 1)
12. Average “Roadfront_Points” is calculated by farm size, using the breaks of 5 ac, 10 ac, 25 ac, and 50 ac.
13. “Roadfront_Score” field is assigned 1 point if a farm has at least 100 “Roadfront_Points”, 2 points if it has higher than average “Roadfront_Points” for its size category, or 0 points if fits neither of the criteria. “Roadfront_Score” is then recalculated using: (“Roadfron_Score” / 2)
14. Square footage is calculated per building structures. Those over 1000 square feet are selected and intersected with farms. Statistics are performed on farm buildings to sum the square footage, and count of buildings over 1000 sq footage per farm. These fields are joined the farm layer.
15. “Building_Score” field is created and assigned 2 points if there are 3 or more buildings, 1 point if there is at least one building, and all others assigned 0 points. “Building_Score” is then recalculated using: (“Building_Score” / 2)
16. “Infrastructure_Score” field is created and calculated using the formula:

    ((“RoadFront_Score” + “Building_Score”) / 2)
17. “AVI_Score” field is created and calculated by multiplying each score by its weight, summing each category, then dividing by the max score to create an indexed value for each farm.
18. Farms layer is copied to feature layer: Farms_AVI_output