GEOG 578 GIS Applications

Conservation Land Acquisition Suitability in the State of Wisconsin

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Ashley Kuehl

Stacey Marion

Ben Schafermeyer

Capstone Statement

Government agencies, conservation organizations, land trusts, and private landowners all play a role in the resilience of Wisconsin's natural lands. The intricate mix of ownership presents a unique challenge to conservation organizations who hope to prioritize land protection. Our goal is to identify opportunity areas for protection. We will create a land parcel suitability index based on proximity to existing protected lands, level of human modification, and landscape heterogeneity. The project aims to further the strategic conservation goals of nonprofit land trusts in the state of Wisconsin.

Introduction

"We abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect." Aldo Leopold, Foreword, A Sand County Almanac.

The state of Wisconsin is home to sixteen ecological landscapes supporting over 1,800 native plants and 700 native vertebrates. These ecological landscapes vary immensely, ranging from southwestern savanna, to the northwest sands, to the north central forest, and Lake Michigan coastal areas to name a few (Wisconsin Department of Resources 2015, A-3). Variability in geology, soils and hydrology among and within landscapes supports a variety of natural plant communities. This diversity results in a state rich in resources that keeps communities healthy through natural systems and provides plentiful recreational opportunities for its citizens.

However, human impacts on the landscape have severely reduced Wisconsin's natural resources. Following European settlement of the nineteenth and twentieth centuries, land conversion to agriculture, development and urbanization, and the introduction of non-native species have contributed to the loss and degradation of Wisconsin's natural communities. The current extent of prairies and oak savannas, for example, represents just 1% of their original pre-settlement land cover. As natural lands have been reduced, they have also become increasingly fragmented (Wisconsin

Department of Natural Resources 2015, 4 - 51). Lands that would otherwise be contiguous environmental corridors are divided by roads, cities, and farms. Not all species are similarly affected. While generalist species are able to change their behavior to survive in a changing environment, specialist species, with particular habitat needs, might be ill-adapted to evolve at the rate at which their environment is changing (Haddad 2015, 7).

In addition to habitat loss and degradation, climate change is one of the most significant challenges species in Wisconsin face today and will continue to face in the future. Between 1950 and 2019, Wisconsin warmed 2°F, and is 14 percent wetter (WDNR, 2015). In the next thirty years the temperature is projected to rise another 2 - 8°F with a higher frequency of extreme heat days. Projections of future precipitation are less certain but are likely to increase. Some precipitation models show not only a higher than average increase in rainfall, but also a higher frequency of extreme rain events (Wisconsin Initiative on Climate Change Impacts 2020, 5).

Despite awareness of the impending impacts of climate change, human modification of the landscape continues at an unsustainable pace. Protecting rare and threatened species has historically been the convention in conservation. However, the conservation community has more recently shifted their focus towards landscape scale conservation (Nick Miller, personal corr.). Landscape resiliency considers the ability of a landscape to support a majority of species under conditions of changing climate. In addressing this foundational shift in conservation prioritization, The Nature

Conservancy (TNC) mapped climate change resilience across the United States, defining a resilient site as, "an area of land where high microclimatic diversity and low levels of human modification provide species with connected, diverse climatic conditions they will need to persist and adapt to changing regional climates" (Terrestrial Resilience Core Concepts). The Resilient and Connected Landscapes for Terrestrial Conservation incorporates landscape heterogeneity as a proxy for areas supporting greater biodiversity and environmental services. Therefore, the model can be used to generally prioritize conservation on a regional and national scale. We focus our analysis on implications for Wisconsin by incorporating areas of known biodiversity value.

Land protection has historically been the mission of state and federal agencies, who collectively manage approximately 16% of land in Wisconsin (Wisconsin Land Legacy Report 2006, 31). The task of maintaining and increasing landscape resiliency now extends to local municipalities, nonprofit organizations, and private landowners. Conservation organizations across the state of Wisconsin are working to protect tracts of lands. While there is no singular way to protect land, one of the most successful and popular strategies of land protection efforts is land trust agreements. Land trusts are non-profit organizations who acquire land for conservation purposes. Land trusts hold agreements with private landowners and/or communities to establish long lasting land protection through conservation easements, permanent legal agreements between a landowner and land trust. Throughout the state of Wisconsin, there are several regional land trusts such as the Prairie Enthusiasts, Landmark Conservancy, Ice Age Trail Alliance, and Northeast Wisconsin Land Trust, in addition to many small local nonprofits. Larger national and international land trusts active in Wisconsin include The Nature Conservancy (Land Protection FAQs 2021).

The aim of this project is to create a common tool to maximize the land acquisition efforts of land trusts and smaller land conservation nonprofits who want to collaborate to expand the landscape resiliency in Wisconsin. We identify high environmental quality areas underserved by land trusts that offer high potential for resilience gains. Additionally, we create a land parcel site suitability index to identify areas with high resiliency and are in close proximity to existing protected lands. This analysis provides a model for how nonprofit land trusts could prioritize properties based on general resiliency and adjacency to other protected lands, while allowing those nonprofits to integrate individual priorities.

> *"Conservation will ultimately boil down to rewarding the private landowner who conserves the public interest." Aldo Leopold, Conservation Economics, The River of the Mother of God.*

Methodology & Research Design

General conceptualization

Part 1. Identify areas in the state with high environmental quality

The first component of the analysis was to identify areas in the state with high environmental quality (Figure 1). Given the recommended benchmark that over one third of the state be retained in natural land cover (Nick Miller, personal corr.), we identified areas in the state generally corresponding to the highest third of environmental quality scores.

Part 2. Case Study Analysis

Within a single defined high environmental quality area, we performed a parcel suitability analysis, prioritizing parcels based on proximity to existing protected land and role in creating larger contiguous corridors (Figure 1).

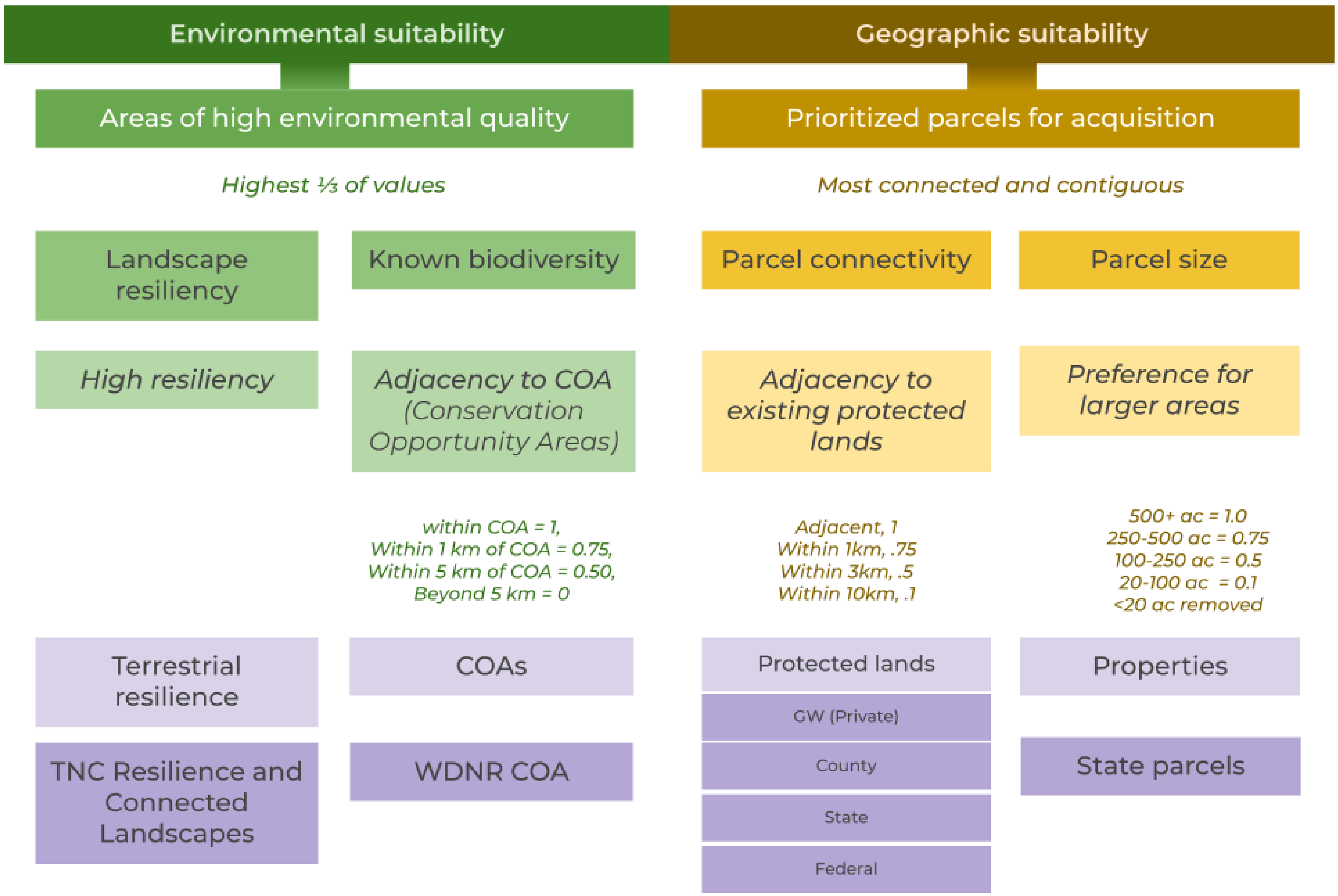

Figure 1. Conceptualization diagram for identifying areas of high environmental quality and geographic parcel suitability.

Table 1. Data sources

Data layer	Data source	Link
Terrestrial resilience	TNC Resilient and Connected Landscape model - Terrestrial resilience	*https://maps.tnc.org/resilientland/*
State managed properties	Wisconsin DNR[a] Managed Properties	*https://data-wi-dnr.opendata.arcgis.com/datasets/dnr-managed-properties?geometry=-92.257%2C44.353%2C-87.200%2C45.036*
Land trust holdings	Gathering Waters Member Holdings for Researchers	*Private Data: available upon request from Gatheringwaters.org*
US Fish and Wildlife Service managed properties	FWS National 2020-2021 Hunt Units	*https://fws.maps.arcgis.com/home/item.html?id=d620712ad5954984bed9e082ccea52d9*
Tribal lands in Wisconsin	Boundaries of American Indian Reservations and Federally Recognized Tribal Entities	*https://geoplatform.maps.arcgis.com/home/item.html?id=2e915ef3df48422283e5b2c7d89dfcba*
State designated Conservation Opportunity Areas	Wisconsin DNR[a] Conservation Opportunity Areas (Terrestrial and Lake)	*https://data-wi-dnr.opendata.arcgis.com/datasets/conservation-opportunity-areas-terrestrial-and-lake*
County Forests	Wisconsin DNR[a] Forest inventory and Reporting Service	*https://dnr.wisconsin.gov/topic/forestmanagement/data*
National Forests System Land Units	United States Department of Agriculture Forest Service	*https://data.fs.usda.gov/geodata/edw/datasets.php?dsetCategory=boundaries*
Wisconsin administrative boundary	Wisconsin DNR[a]: WI State Boundary	*https://data-wi-dnr.opendata.arcgis.com/datasets/wisconsin-state-boundary-24k?geometry=-109.949%2C42.003%2C-69.498%2C47.460*
Statewide parcels	State Cartographer's Office: V6 Parcel Data	*https://www.sco.wisc.edu/parcels/data/*

[a] Wisconsin Department of Natural Resources

Identifying regions with high environmental quality.

Many biotic and abiotic factors influence the provision of ecological services on a landscape scale. Of particular interest is the ability of landscapes to provide ecological services in the future given scenarios of climate change. The ability of a landscape, being the sum of its biotic and abiotic components, to persist despite climate change is considered *resiliency*.

Our environmental quality score incorporated modeled resilience and areas with known biodiversity (Figure 2). We applied The Nature Conservancy's (TNC) terrestrial resilience model for the Great Lakes and tallgrass prairie region as a proxy for landscape heterogeneity and theoretical capacity to support biological diversity (Table 2).

The Nature Conservancy (TNC) defines a resilient site as, "an area of land where high microclimatic diversity and low levels of human modification provide species with connected, diverse climatic conditions they will need to persist and adapt to changing regional climates" (Terrestrial Resilience Core Concepts). The TNC *Terrestrial Resilience* model is predicated on the fundamental assumption that connected areas with higher geophysical variability support greater ecological function and biological diversity than areas with less variable landscapes with higher fragmentation. *Terrestrial resilience* combines metrics of landscape geophysical diversity and local connectedness, a measure of landscape connectivity (Appendix I). We utilized a *Terrestrial resilience* raster downloaded from the clipped U.S. State datasets for Wisconsin (Resilient and Connected Network). Terrestrial resilience ranges -3,500 to 3,500 at a 30x30 m resolution.

We further incorporated areas of known biodiversity value in Wisconsin. These *Conservation Opportunity Areas (COAs)* reflect lands with known biodiversity, presence of rare and threatened species, distinct ecosystem function, large and unfragmented areas of habitat, areas providing connectivity between habitats, and water resources (WDNR 2006, 2015). The *COA* vectors bound specific point and area locations of species of special concern, natural plant community and geological feature occurrence, as captured in the Wisconsin Natural Heritage Inventory. The *COA* layer, therefore, is a generalized representation of areas of known desirable biodiversity. *COAs,* by design, tend to overrepresent known biodiversity on agency-managed properties, but may be limited in representation of biodiversity on private lands.

Whereas the *Terrestrial resilience* model predicts areas of climate resiliency due to geophysical characteristics, the *Conservation Opportunity Areas* layer generally identifies areas known to currently support desirable biological life.

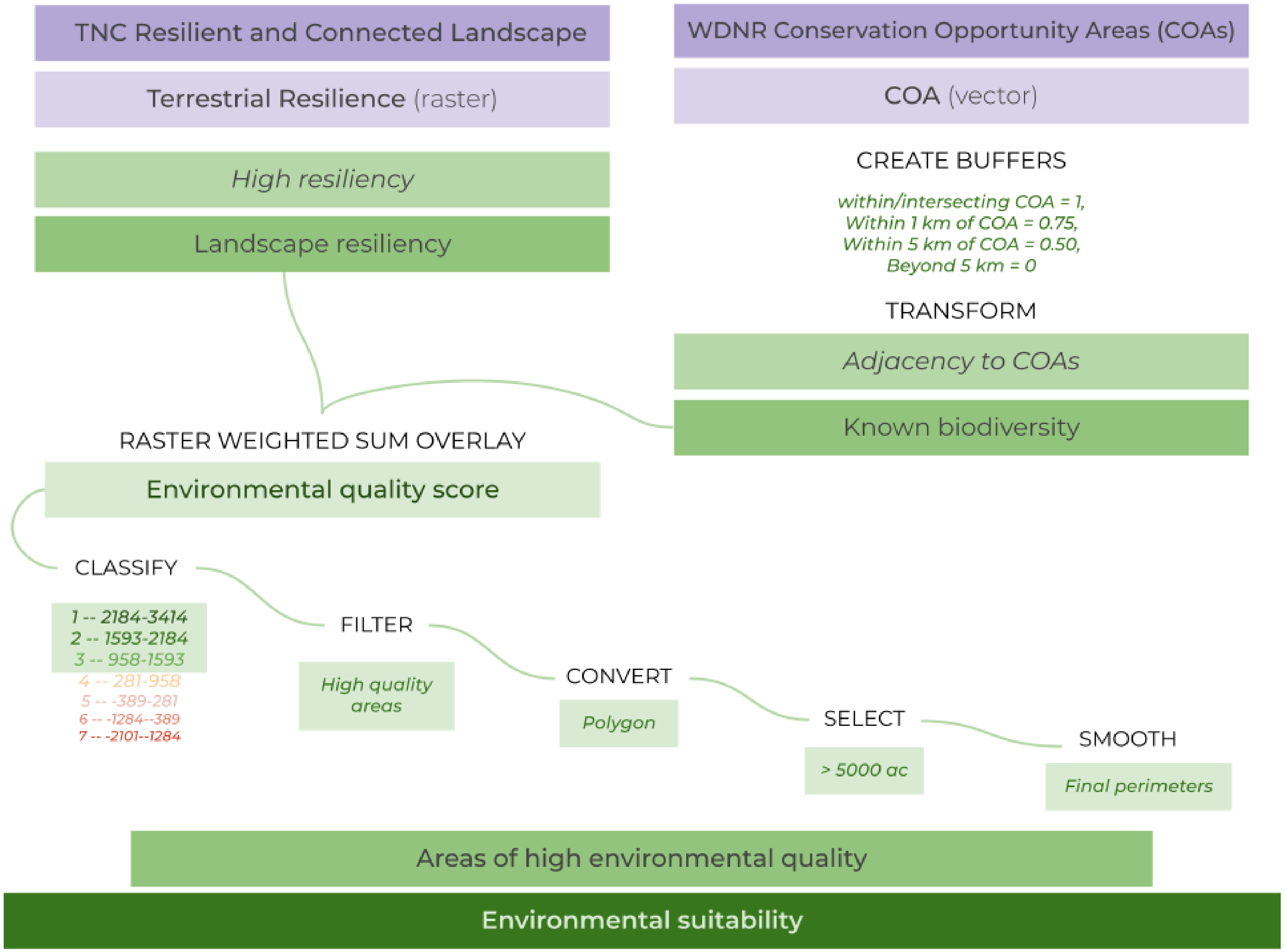

Figure 2. Implementation diagram for identifying regions of high environmental quality.

The *COA* feature boundaries represent a human-drawn boundary enveloping biodiversity of regional, state, and global significance, but are meant to be understood as fuzzy (WDNR 2015). To remove discrete *COA* boundaries, we weighted membership within and around the *COA* features using buffers. Resulting buffer areas were clipped to the Wisconsin state boundary.

Within COA, assign value 3,500
Within 1 km, assign value 2,625
Within 5 km, assign value 1,750
Greater than 5 km, assign value 0

Scores were weighted within an equivalent range to *Terrestrial resilience*, however, the lowest assigned score (0), rendered areas more than 5 km outside the boundary of a *COA* essentially neutral - neither increasing nor decreasing overall environmental quality score. However, areas within and closely around *COAs* received high values. We converted the *COA* vectors to a raster and performed a weighted raster sum overlay using ESRI ArcGIS software (Table 2). We gave slight scoring preference to *Terrestrial resilience* compared to *COAs* to reduce potential overrepresentation of biodiversity on public lands. The product of the weighted sum overlay represents our environmental quality score (Figure 6).

Table 2. Weighted raster sum overlay parameters.

Layer	*Terrestrial resilience*	*Conservation Opportunity Areas (COAs)*
Geometry	raster	Vector (converted to raster)
Resolution	30x30m	30x30m
Projection	NAD_1983_Albers	NAD_1983_Albers
Score range	-3,500 to 3,500 (data range in WI: -2101 to 3,357)	0 to 3,500
Weight	0.6	0.4

We classified the environmental quality score using quantiles and extracted the top third of values as our "high" environmental quality score areas. To create simple and usable high quality environmental regions, we generalized and simplified the high environmental quality score areas as vectors. We first converted the selection of the "high" environmental quality score areas (i.e. top third of environmental score areas) and converted to vector layers. The output generated 155,131 polygon features of variable size. We aggregated all polygon features within 1 km and dissolved any "holes" less than 0.1 km^2. To further simplify our final high environmental quality regions, we removed any aggregated polygon features with a cumulative area of less than 20 km^2. We added a 0.5 km buffer to smooth shape irregularities, again in the interest of simplifying the features.

Identify areas of geographic suitability to determine parcel prioritization

In order to determine suitable sites for conservation, we must also consider the geographic suitability of privately owned land parcels conservation organizations may want to expand into. This process involved identifying parcels and their owners within high environmental quality regions and outside of known protected lands, grouping parcels based on ownership, analysing and scoring the size of parcels, and scoring the distance of parcels to other existing protected lands in close proximity (Figure 3). Combining these analyses gave us a comprehensive layer through which we used to compare geographic suitability and high environmental quality regions. The Wisconsin State Cartographer's Office (WSCO) has a compiled state parcel data layer which we use for the parcel analysis.

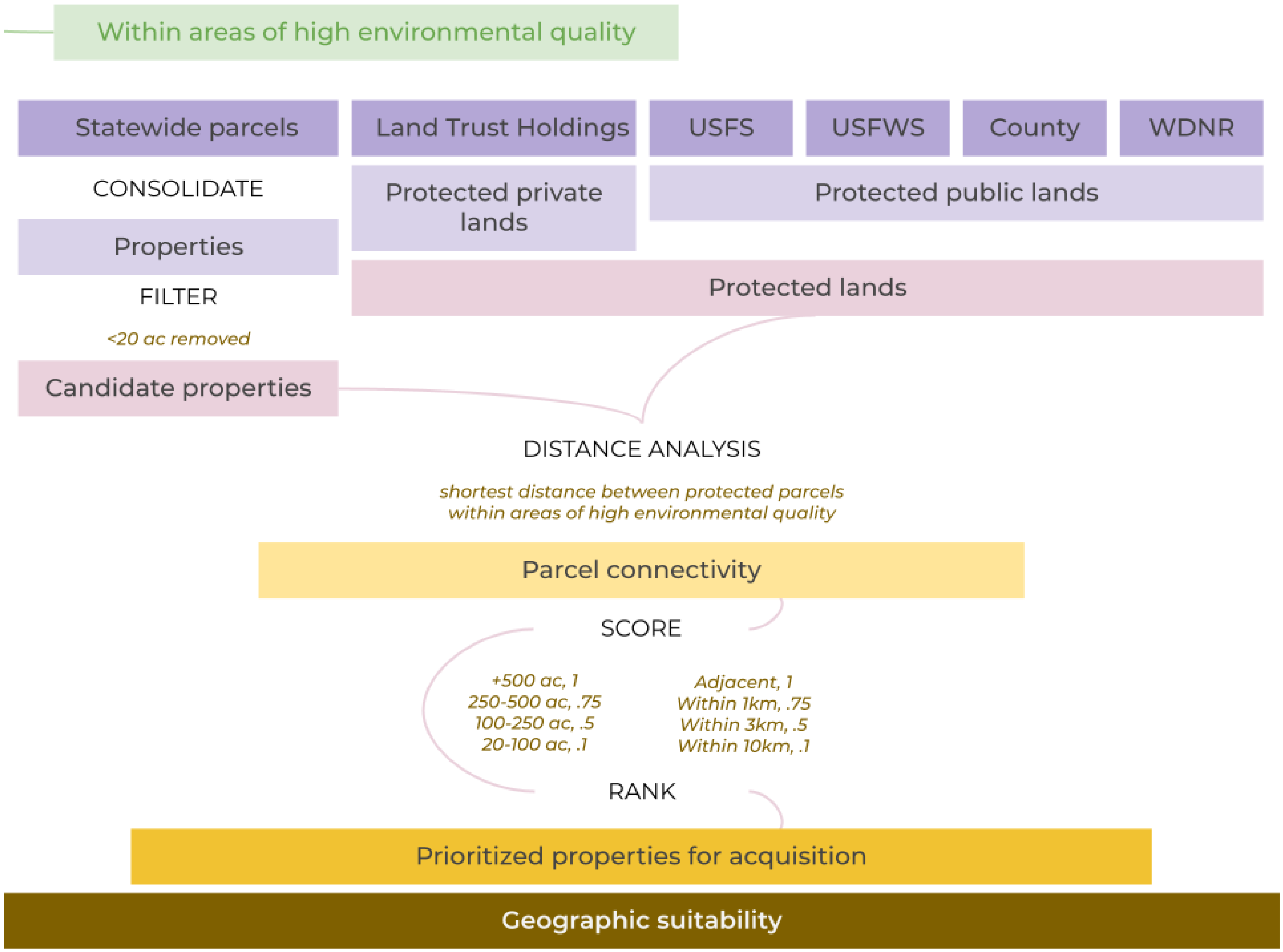

Figure 3. Implementation diagram for identifying areas of geographic suitability.

We began our geographic analysis by first identifying where known protected lands are located in addition to our already established high environmental quality regions (Figure 4). Protected lands in Wisconsin include both private and public lands. Working with the land trust alliance Gathering Waters, we were able to identify most privately protected lands in Wisconsin. Important protected public lands in Wisconsin include U.S. Fish & Wildlife, U.S. National Forests, WI County Forests, WI Department of Natural Resources Managed Properties, and established WI tribal land.

Next we began identifying parcels within our established high environmental quality regions from our environmental suitability analysis and outside identified protected lands. Then we grouped parcels based on their proximity to each other and common ownership. Multiple, adjacent parcels under one owner were treated as a single piece of property, and aggregated the acreage. Performing a clustering analysis based on parcel ownership gave us aggregated parcel groupings, while treating distant parcels under the same ownership as independent parcels. Once parcels are aggregated by the owner, we filtered out parcels smaller than 20 acres, and assigned parcels fuzzy scores based on size.

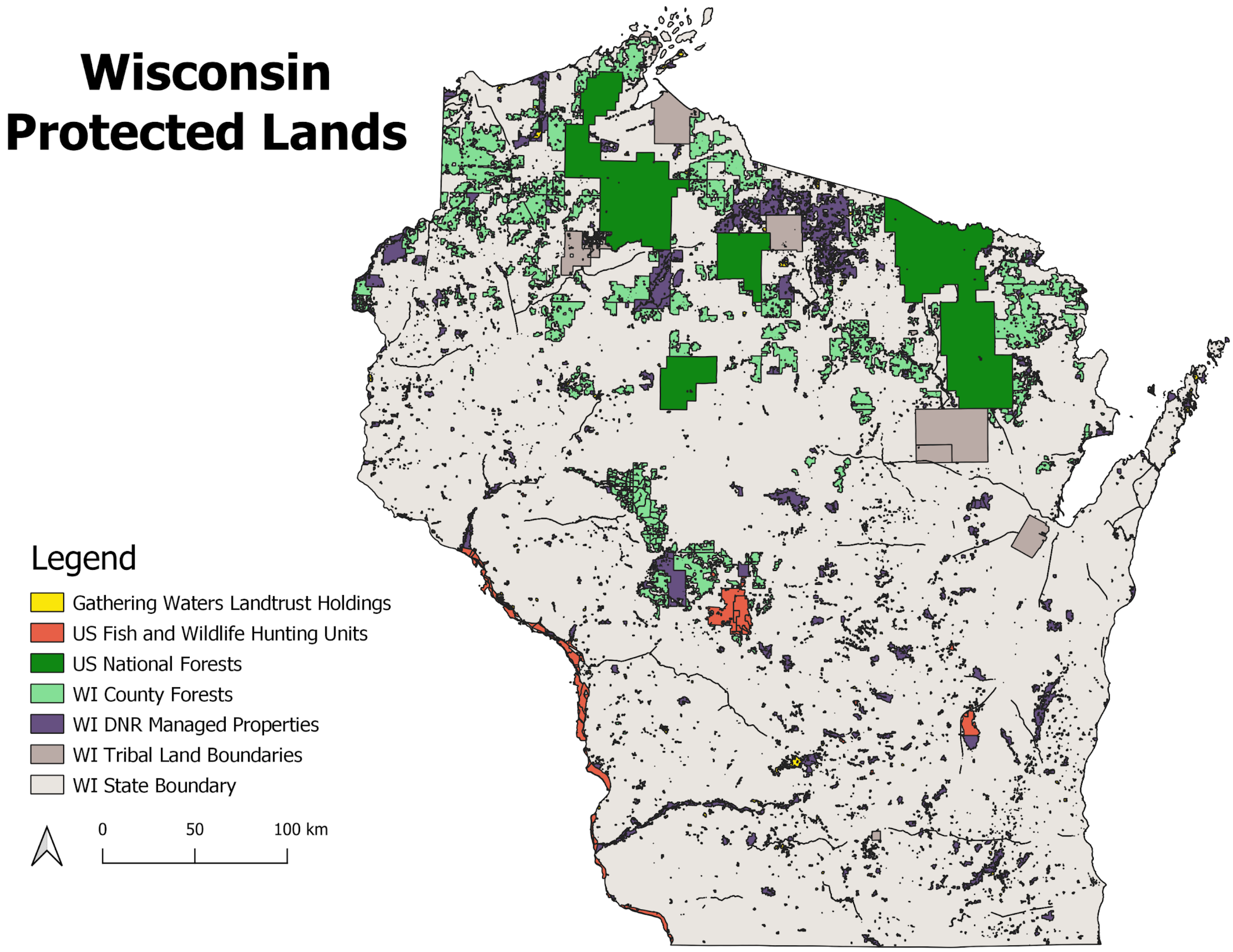

Figure 4. Known protected lands existing in Wisconsin

This step of aggregating parcels by ownership and filtering out smaller parcels serves two purposes. First, we were able to focus the scope of the study and present advantageous areas for conservation. Additionally, in our research stage of this project, we learned that aggregating parcels by owner and targeting larger parcels was helpful for conservation nonprofits conducting outreach to property owners. For a nonprofit with a small outreach budget, creating an efficient method of identifying property owners for marketing purposes is financially necessary. Any duplicate outreach efforts to property owners with adjacent parcels would quickly diminish a marketing budget (Mike Koutnik, personal corr). We feel including this step in our model is important for any organizations looking to re-create the design of this project.

Filtering out smaller parcels was also recommended to us in our interviews with conservation organizations. Land acquisition for parcels below twenty acres were deemed not worth the effort both environmentally and from a marketing standpoint(Mike Koutnik, personal corr). Using the clustered parcel data layer we put together a scoring hierarchy to determine suitable areas based on acre size.

Parcel 500+ acres, score 1.0

Parcel 250-500 acres, score 0.75

Parcel 100-250 acres, score 0.5

Parcel 20-100 acres, score 0.1

In addition to scoring parcels based on their size, we also quantified a parcel’s potential conservation impact based on its distance from existing protected land. This procedure emphasized certain parcels for conservation based on their accessibility to other existing protected areas. A simple euclidean distance calculation tool was used to determine the distance between each parcel and the nearest piece of protected land. A maximum upper limit of 10 km was created to hypothetically eliminate any isolated polygons in the analysis. No parcels were located more than 10 km away. Distance was calculated from the nearest features of the polygon, and accounted for both the vertices and lines that comprised the parcel. Protected land that was outside the region but within scoring distance of a parcel was included (Figure 5).

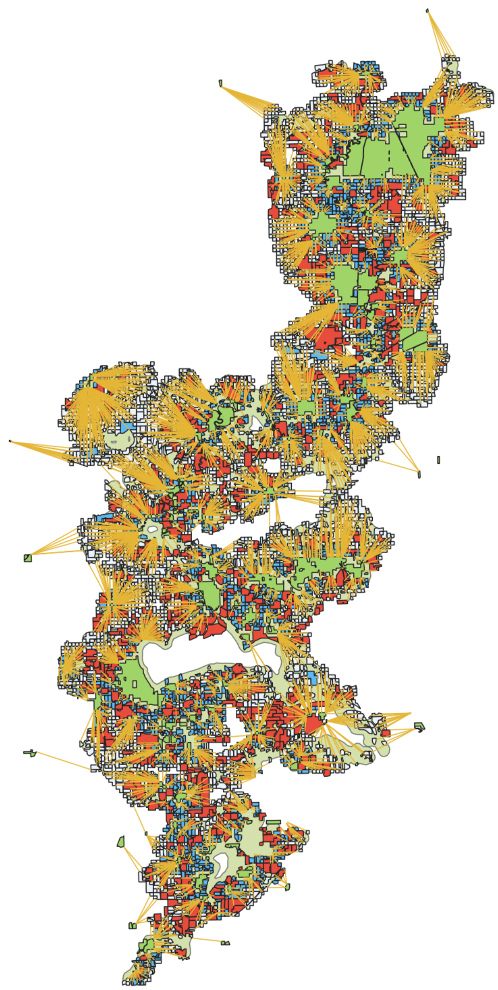

Figure 5. Output from parcel suitability distance to nearest protected land parcel.

After running this analysis, the distance from each parcel to the nearest parcel of protected land was appended to the attribute table of our existing parcel layer. This attribute was then exported into spreadsheet software, where duplicates were removed. Parcel distance was then assigned a score based on a fuzzy classification system, displayed below.

Adjacent to protected area, score 1.0

Within 1 km, score 0.75

Within 3 km, score 0.5

5-10 km, score 0.1

The scoring of both the connectivity and size of parcels were then aggregated to determine a site's overall geographic suitability score. A simple field calculation was used to add the 'parcel size' and 'parcel distance' scores together and record the output as a new attribute, 'comp_score'. This composite score reflected equally a parcel's size and location relative to existing protected land.

In order to give contextual weight to our composite score, a classification scheme was devised to break up parcels based on their overall "priority for conservation". Quartiles were used as class breaks, with the bottom 25% of scores considered "low priority" and the top 25% considered "high priority". This classification aids in visualization and interpretation of our results.

0.1 - 0.6, "Low Conservation Priority"

0.6 - 0.85, "Moderate Conservation Priority"

0.85 - 2.0, "High Conservation Priority"

With the composite parcel scoring overlaid on our high environmental quality region, we were able to make a final assessment of potential land for conservation within our case study.

Results

High Environmental Quality Regions

Environmental Quality Score

The product of the weighted raster sum showed geographic variability of environmental quality score (Figure 6). Based on quantile classification, we extracted scores of greater than 960, representing the top third of values (Table 3).

Table 3. Environmental quality score summaries.

Mean	443	Minimum	-2101
Highest ⅓ of values	> 960	Maximum	3414

High Environmental Quality Regions

We identified thirty-four regions of high environmental quality (Figure 7). The boundaries of these high environmental quality regions should be interpreted as fuzzy boundaries, rather than a discrete designation as “high” or “low” environmental quality (Figure 8). The generalized high quality environmental regions represent around 40% of the state area.

Across all environmental quality regions, a combined 32% of area is currently known to be protected (Table 4). Of all known protected land, 70% occurs within the high quality environmental regions (Figure 9).

Table 4. Land protection in Wisconsin and within high environmental quality regions.

Protected Land Entity	Protected land within high environmental quality regions	
	Area (km^2)	Percent of land protected
Wisconsin DNR	6,152	82%
Land Trust holdings	723	74%
US Fish & Wildlife Service	1,164	75%
US Forest Service	8,100	86%
County Forests	9,646	66%
Tribal lands	2,754	*
All protected land	28,540	70%
State of Wisconsin	169,640	

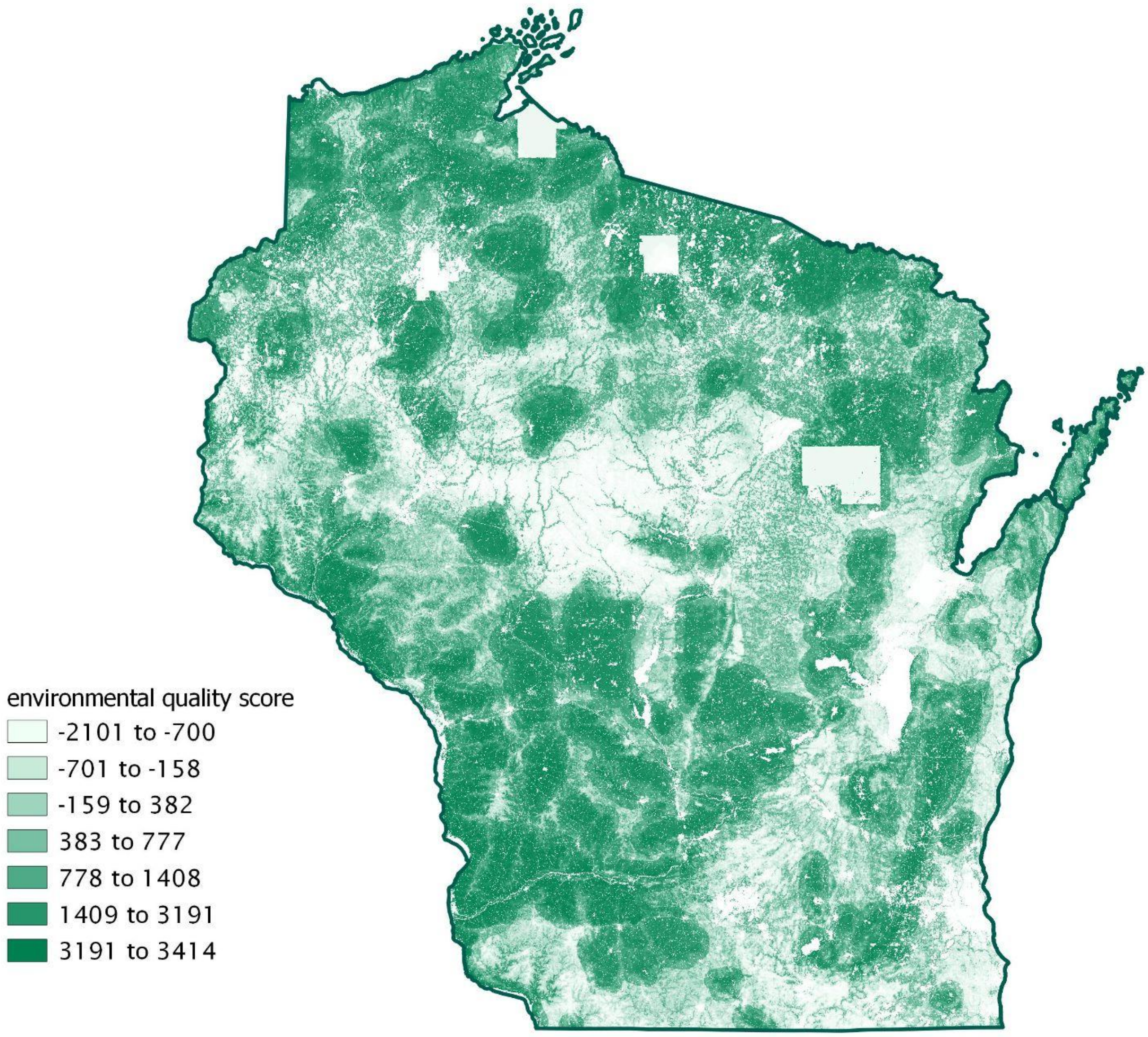

Figure 6. Environmental quality score is a composite of terrestrial resilience and known biodiversity.

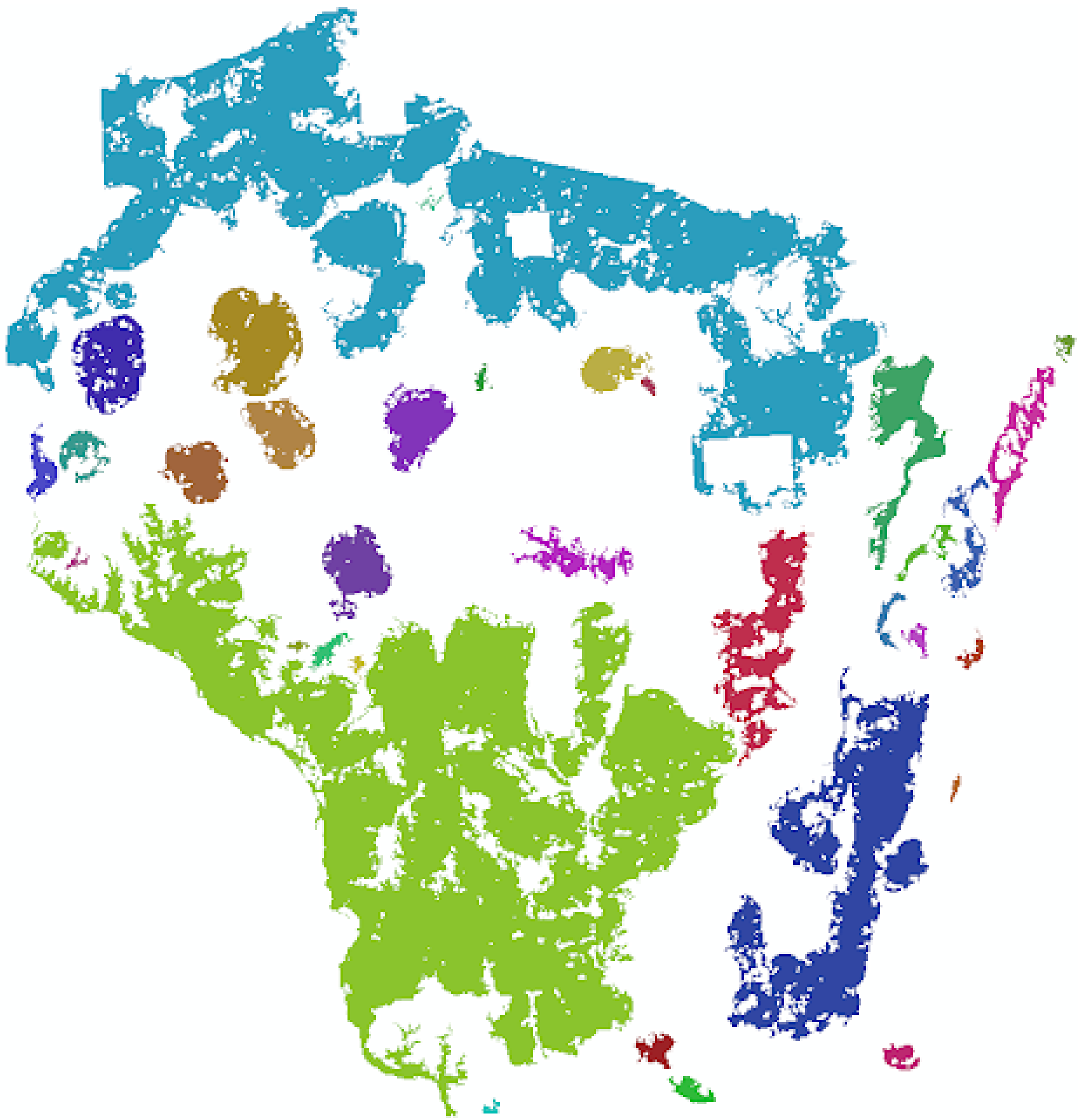

Figure 7. High environmental quality regions are geographically distributed in the state. Areas in the northern forests, along Lake Superior, in the westerns coulees and ridges, i.e. the“Driftless” region, and central sands.

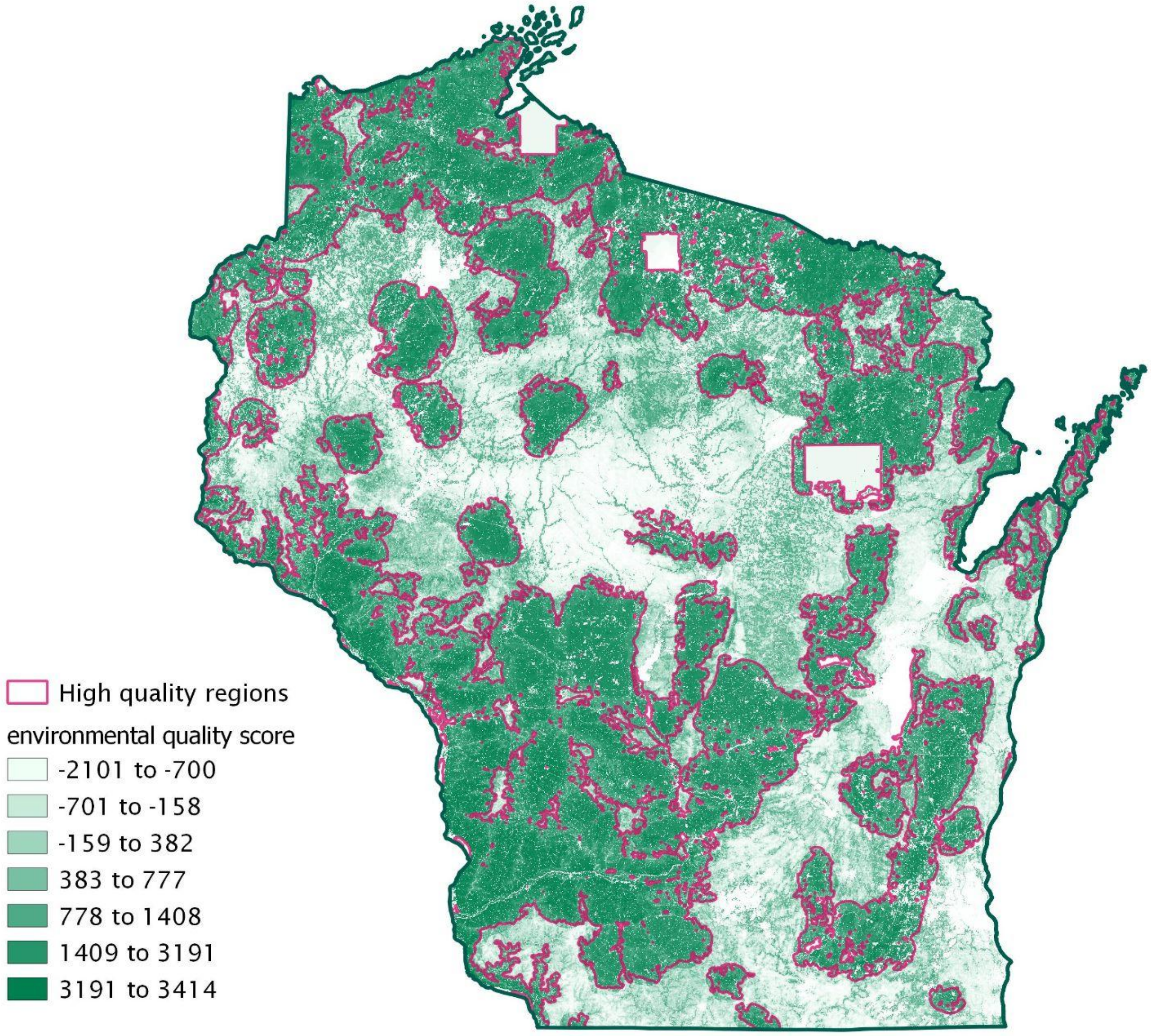

Figure 8. High environmental quality region boundaries represent a fuzzy outline of approximately the top third of environmental quality score values.

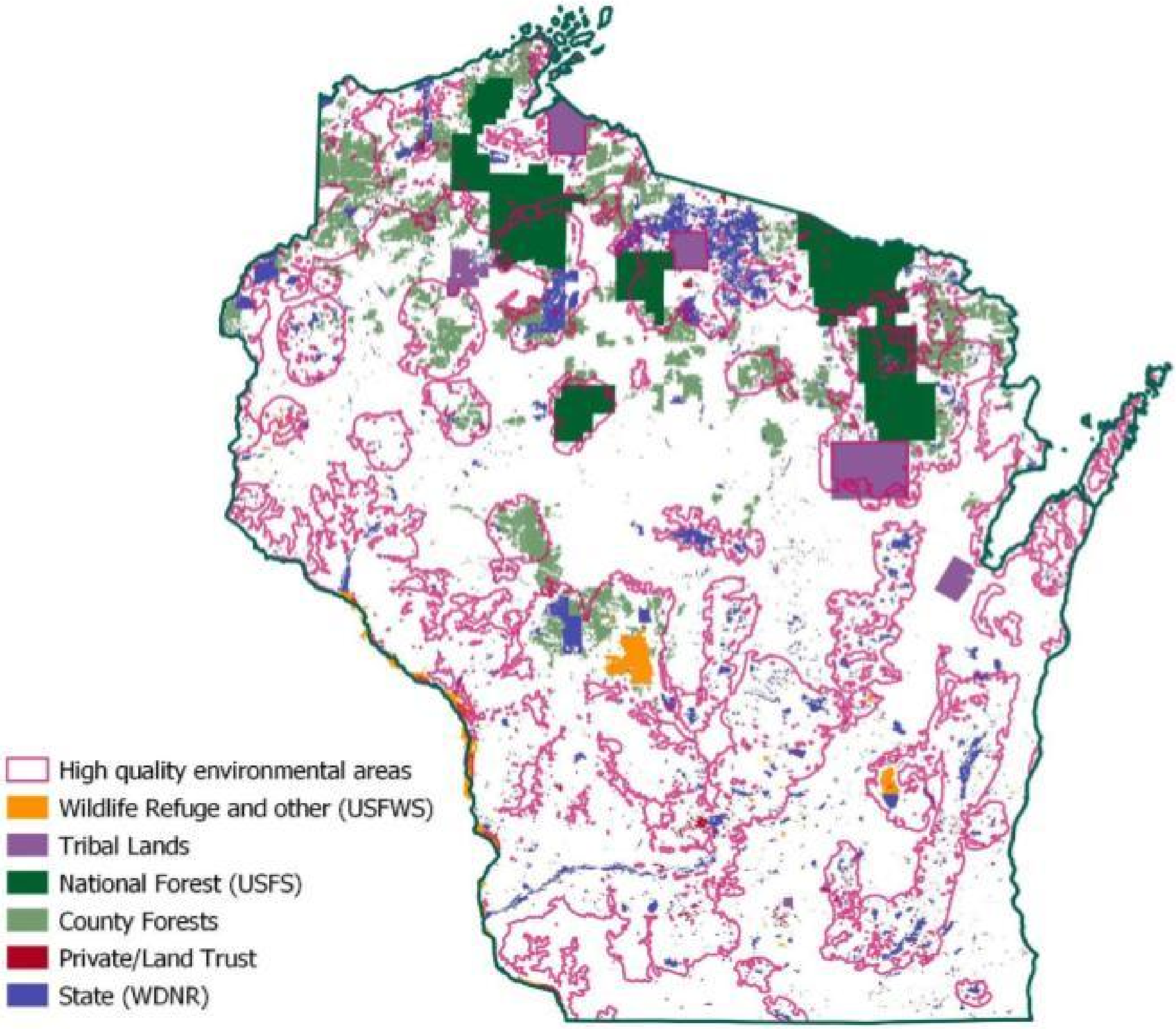

Figure 9. Federal and State owned land accounts for a relatively larger proportion of areas within high environmental quality regions in the northern part of the state. Conversely, high environmental regions in the southern and western portions of the state are weakly protected.

Geographic Suitability Results

To demonstrate the geographic suitability results on a finer scale we conducted a case study of one identified high environmental quality region. The region of the study had a total area of 2,082 km^2 containing 194 km^2 of various protected land. About 9% of land within this region is already protected. After aggregating privately owned parcels by ownership and filtering out parcels smaller than 20 acres within the region and outside of protected lands, 6,067 parcels were identified as being suitable with a total area of 1,504 km^2. Suitable parcels represented about 74% of the high environmental quality region. Suitable parcels identified were then scored based on size (Table 5).

Table 5. Count of parcel aggregated by ownership and score based on size of acreage.

Count of parcels	Parcel Size and Score
21	500 + ac = 1.0
76	250 - 500 ac = 0.75
716	100 - 250 ac = 0.5
5363	20 - 100 ac = 0.1

Our distance analysis within the selected case study yielded data on how far our parcels were from existing protected lands (Figure 10). All parcels were located within 10,000 m of an existing protected land, with the furthest parcel measuring 8,443 m away. Of the 6,067 parcels, the mean distance was 1,945 m, with a standard deviation of 1609 m. As with any scoring system where continuous data is arbitrarily sorted, some data will exist near breaks. For the distance scoring, 10% of the parcels were measured within 50 m of a class break. While different scoring regimes may yield different percentiles within class breaks, ultimately there will always be some resolution lost in categorization of data.

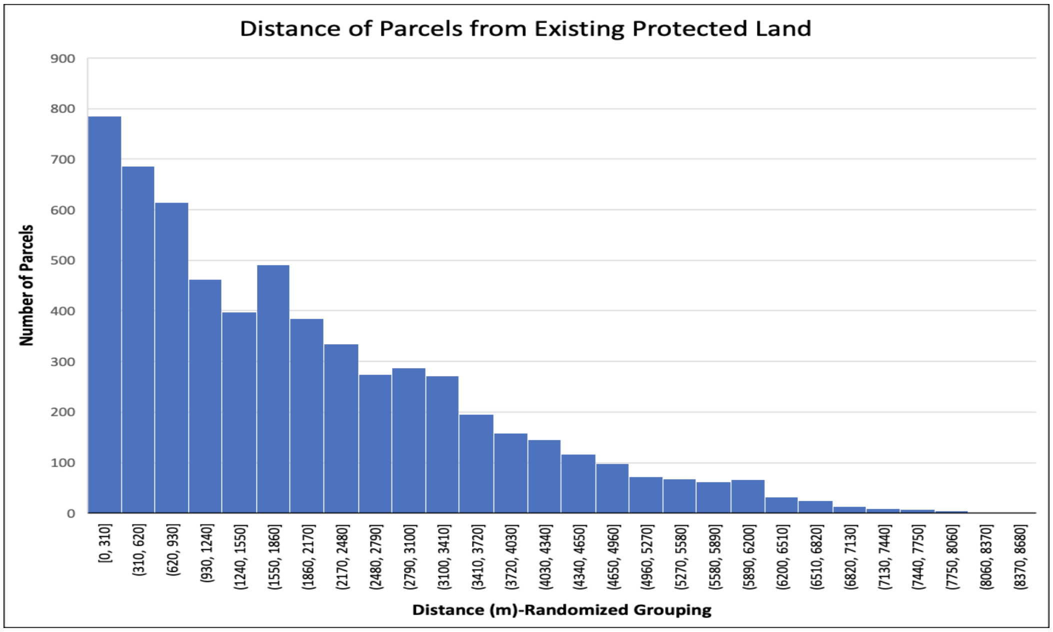

Figure 10. Distribution of parcel distances from nearest protected land.

Using the outputs from both the distance analysis and the size analysis, we were able to score and group each parcel based on their conservation priority (Figure 11). The median score for a parcel was 0.6. 37% of the data was scored as 0.6, which was a result of many small parcels (score 0.1) being located near an existing protected land (score 0.5). Ownership of the highest scoring parcels (1.75-2.0) consisted of businesses (Farm corporations, llc’s), game reserves, private trusts, and one conservation group. Of the parcels deemed high priority (1.0-2.0), 7% were ranked as small (0.1) and close (1.0). With these statistics, conservation groups may be able to better assess land that fits within their goals for land preservation.

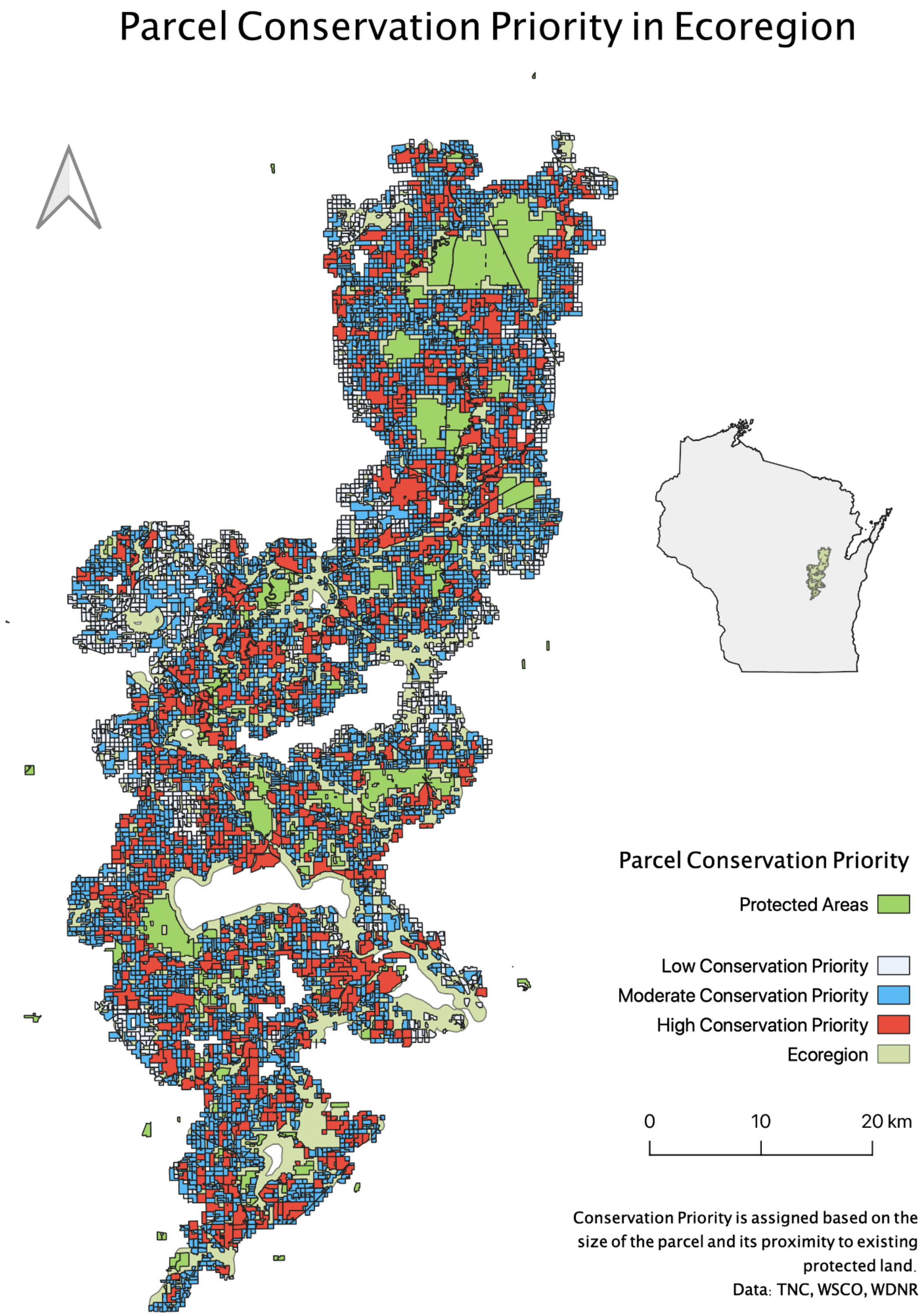

Figure 11. Parcel suitability determined by parcel size and proximity to existing protected lands.

Discussion

Environmental Quality and Parcel Suitability Discussion

The identified high environmental quality regions represent simplified, convenient outlines to identify major conservation opportunity regions in the state. The boundaries should be interpreted as fuzzy, rather than a boolean categorization of environmental quality. In reality, the combined environmental quality score generally is higher near the centers of high environmental quality regions, and tapers off towards the edges (Figure 8). In some cases, areas of median or low environmental quality lie within the outline of the "high" environmental quality regions, and in other cases, small areas of high environmental quality (less than 20 km^2) are excluded from any defined region. Therefore, the regions are not exactly representative of every area of high environmental quality. Rather, the regions provide connected areas that present high opportunity for climate resiliency as a whole.

The majority of protected land (70%) lies within high quality environmental regions, indicating that past protection efforts have successfully identified these important areas even if the explicit goal was not *climate* resiliency. By incorporating *Conservancy Opportunity Areas* into our environmental quality score, however, we may be over representing areas of known biodiversity on State and Federal properties, since knowledge of species of special concern and plant community occurrence on private lands is less known.

Similarly, conservation on private lands is not acknowledged unless protected through a formal easement. Outside of easements, however, many private landowners maintain natural land. This voluntary maintenance of natural land is critical to meeting the state's climate resiliency.

While the role of voluntarily conserved lands may be underplayed, the role of protected lands may be overplayed. "Protected" lands, such as National Forest, are protected from some human modification, like development, but are not immune to productive forest uses. Logging, even when done according to a forest management plan, clearly impacts local and regional climate resiliency depending on the scale and type of logging performed. State and Federal lands also face threat of being sold, as evidenced by recent trends. In essence, the composition of "protected" and "conserved" lands is not truly permanent.

However, the majority of "protected" lands are in-part or wholly maintained as natural land cover, and may even be managed for increased landscape resiliency, through restorative stewardship practices like invasive species removal, prescribed burning, and restoration of hydrology.

High quality environmental regions that are relatively well protected include regions in the northern forests, where State, Federal, County, and Tribal agencies manage large swathes of land (Table 6). In these areas, nonprofits often acquire small inholdings within or directly adjacent to public land, enhancing existing corridors of natural land cover.

Table 6. Representation of protected lands within high quality environmental regions.

Characteristics	*Category*	*Implication*
Regions with high environmental quality and high proportion of protected land	High priority for expansion areas	Areas that should be prioritized for acquisition given opportunity to create larger contiguous habitat areas and corridors. ~low hanging fruit
Regions with high environmental quality and low proportion of protected land	Underserved areas	Areas that are threatened by lack of protection, but may require more resources to protect given lack of current protected lands. ~opportunity areas
Outside of high quality environmental regions but high proportion of protected land	Over served areas	Areas that may hold other value as protected land, but do not protect resilient landscapes. ~should not prioritize

The Western Coulee and Ridges region of Wisconsin, i.e. the Driftless region, and Central Sands regions are underserved comparatively (Figure X). The majority of protected land in these areas is protected by land trusts, rather than agencies. While these regions present the greatest opportunity for conservation, they also present the greatest challenge given the cumulative land area and disparate pattern of existing protecting land (Table 7).

Areas that are well protected but relatively low environmental quality, or overserved areas, include areas around urban centers, like Madison. Although scoring low on the combined environmental quality score, these regions may be locally significant in providing ecosystem services to the local community.

These high environmental quality regions represent prioritization of conservation efforts with a broad stroke. Each region could be subdivided by natural land breaks, such as watersheds, and analyzed at a finer scale. We examined a single high quality environmental region, and ranked specific parcels within that region based on simple proximity to existing public lands and parcel size. Our case study represents one analysis, however, the model could be to specific nonprofit priorities and feasibility constraints.

Table 7. High environmental quality regions ranked by environmental quality score and level of protection.

High quality environmental region	Mean environmental quality score		Region area (km^2)		Percent of protected land within region (%)	
		Rank		Rank		Rank
region 12	1282	1	28599	1	10.79	16
region 14	1273	2	861	8	78.09	1
region 2	1243	3	24318	2	55.85	4
region 5	1213	4	1519	5	30.32	7
region 17	1194	5	633	12	1.71	26
region 20	1142	6	844	9	52.05	6
region 9	1135	7	482	14	52.85	5
region 7	1080	8	1294	6	7.68	21
region 15	1000	9	719	10	20.79	9
region 8	998	10	600	13	15.49	10
region 29	959	11	6302	3	10.21	17
region 6	958	12	1100	7	11.16	14
region 4	943	13	58	28	9.96	18
region 21	942	14	2083	4	9.32	20
region 34	924	15	160	20	12.21	13
region 33	864	16	214	18	5.75	23
region 11	834	17	251	17	6.64	22
region 13	798	18	53	31	58.57	3
region 1	775	19	43	33	1.58	28

region 18	765	20	645	11	23.75	8
region 19	748	21	470	15	5.13	24
region 25	716	22	95	25	13.54	12
region 32	710	23	159	22	13.66	11
region 24	682	24	141	23	1.69	27
region 10	676	25	70	26	2.78	25
region 26	675	26	111	24	0.19	32
region 22	657	27	191	19	0.85	29
region 31	639	28	36	34	10.95	15
region 16	610	29	311	16	9.52	19
region 3	608	30	59	27	65.40	2
region 30	601	31	56	29	0.00	33
region 27	595	32	159	21	0.20	31
region 28	499	33	43	32	0.00	34
region 23	410	34	54	30	0.77	30

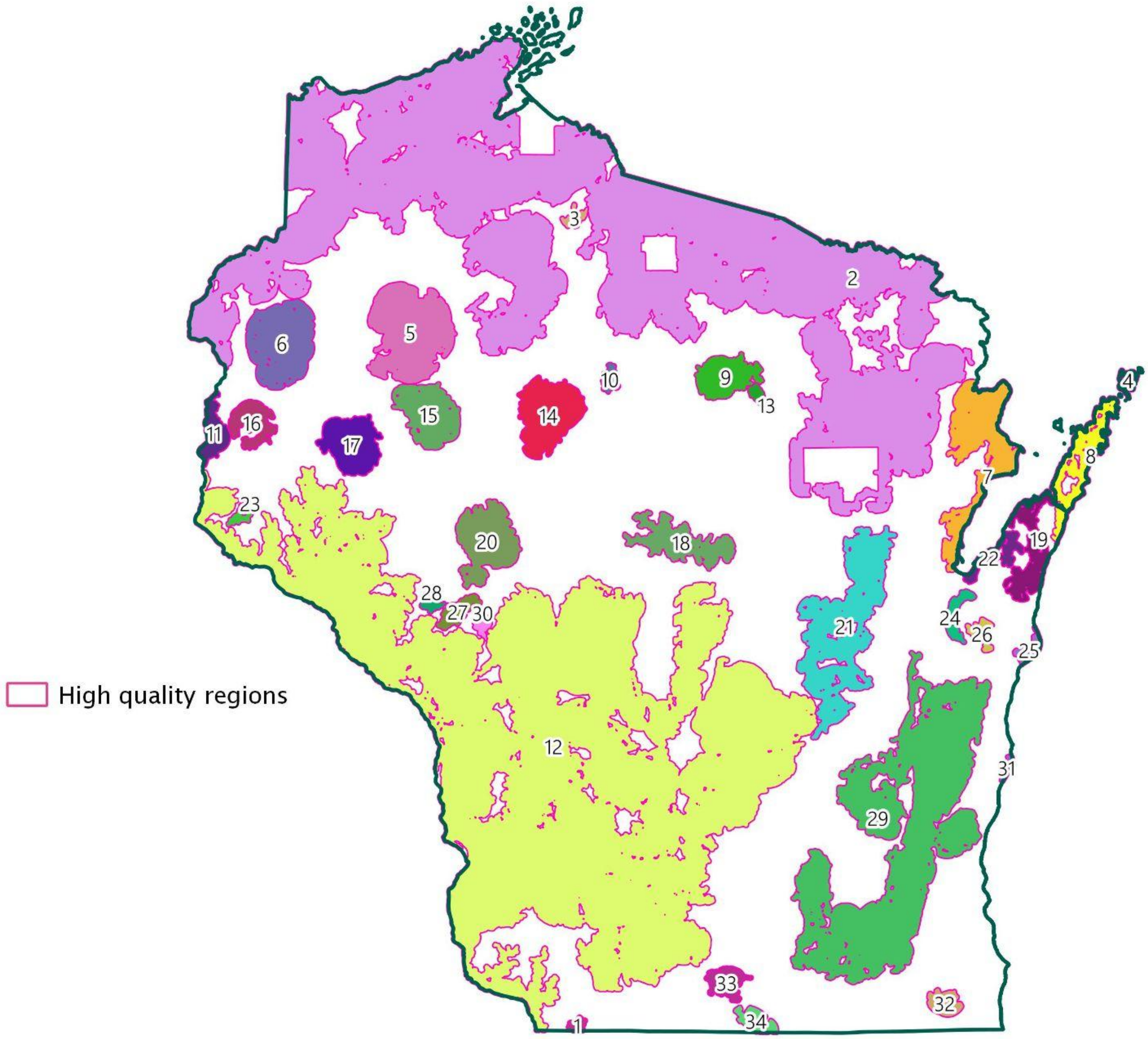

Figure 12. High environmental quality regions labeled.

Case Study Discussion

The case study of a high environmental quality region in north central Wisconsin helps show how our analysis can be used to quickly assess conservation potential in an ecologically important area. By comparing both parcel size and parcel distance, our analysis gives groups a myriad of options when it comes to choosing which land to focus on conserving. For example, larger conservation organizations can use our data to target land with the highest composite scores. These parcels, as discussed in the results section, are primarily owned by established businesses and may require a large amount of capital investment to conserve. Alternatively, parcels that scored low on the size ranking but were close/adjacent to protected areas would be prime targets for small conservation groups with a limited budget.

Within the high priority areas for expansion, more local analyses can inform prioritization of specific parcel acquisitions. The added flexibility of our scoring system means that conservation agencies can add their own variables to further specify conservation priority. While our analysis focused solely on size and distance, other groups may choose to incorporate elements important to their organization, such as feasibility of purchase and land cover.

Conclusion & Future Research

Our model of site suitability for expanding land protection was successful in creating a simple yet usable statewide prioritization, in particular for conservation minded organizations with the goal of land acquisition. We outlined how both environmental suitability and geographic suitability take a role in achieving the desired outcome. We identified low to high priority areas of land acquisition expansion in a case study of a single high environmental quality region. Additionally, we identified areas in Wisconsin that are conservationally underserved and overserved. However, as with any research project, methods can always be improved with future research goals or different modeling techniques. Below we briefly describe future research efforts we feel may improve our existing model.

One particular research goal we would like to explore in the future of land trust expansion includes a least cost path distance analysis for designing corridors through natural land cover. In our current geographic suitability model we use a straight line near distance tool to establish corridors connecting land parcels to the nearest protected land. This technique does not take into account the diversity of land cover that species may need to travel. Species that travel from one area to another are more likely to travel, not necessarily in straight lines, but rather through a route that provides natural land cover, avoiding more developed land.

To create a least cost path analysis from parcel to protected land we need to establish a resistance raster layer and reclass the data for this analysis. Ideally we would use the Wiscland 2 Land Cover data, available through the Wisconsin DNR, and reclass the raster cells for least resistance through natural land cover. Developed and intensive agricultural land would receive a higher resistance score. After conducting a least cost path analysis connecting parcels to protected lands, we would then find the length of each corridor to find the actual distance a species might travel to arrive in the closest protected area. Using a least cost path analysis would also help us identify parcels of land that would be necessary to acquire as a part of the expansion of landscape resiliency. An updated conceptualization diagram establishes how the least cost path analysis would fit into the geographic suitability implementation (figure 12).

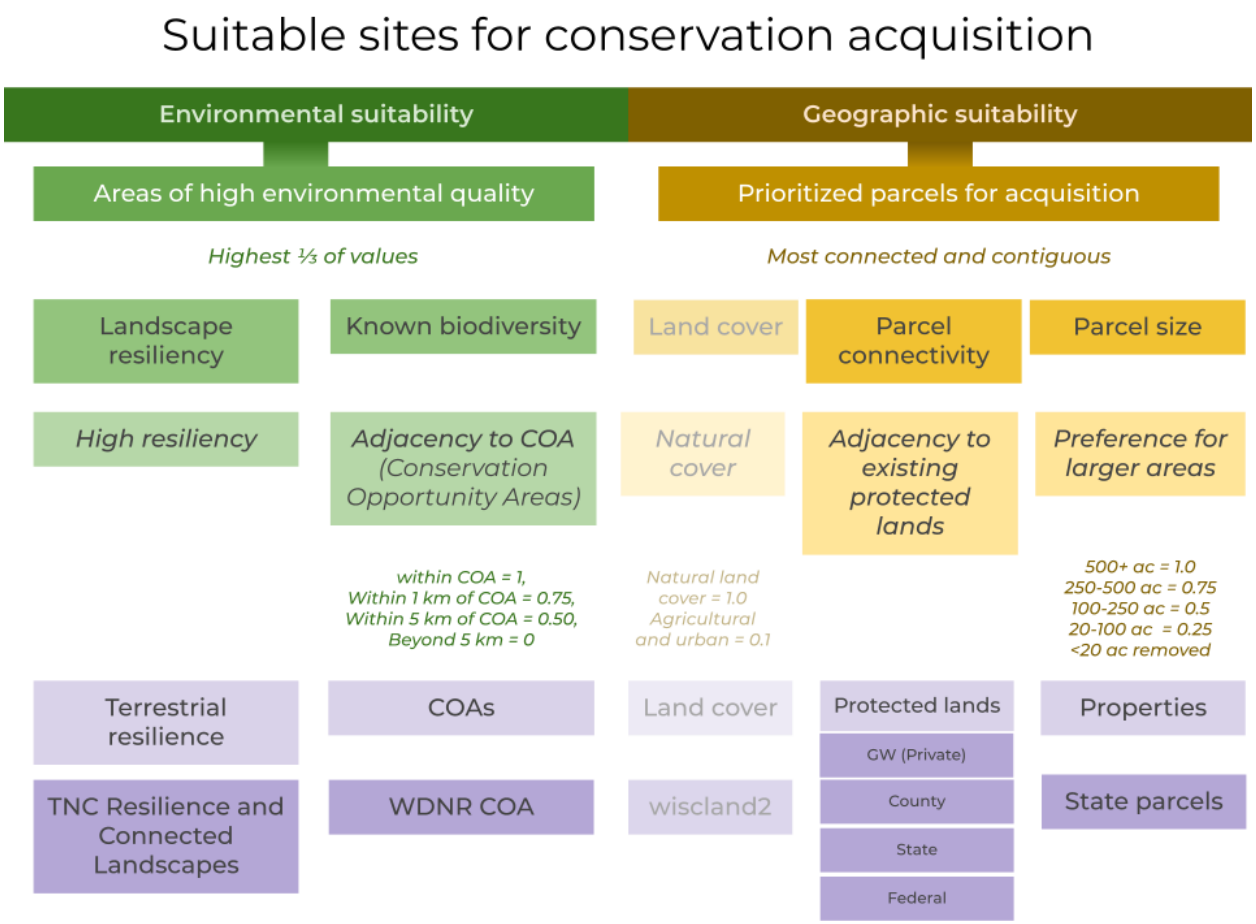

Figure 12. Implementation diagram including the natural land cover variable

The geographic analysis may also benefit from the addition of other variables, in order to more accurately convey a parcels aptitude for conservation. Adding in a score for a parcel's cost/acre, for example, may help small conservation groups identify what areas of land to focus on with a limited budget. Similarly, a conservation organization focusing on water quality may choose to add in data on impaired watersheds, to focus their area of study. These additional variables can easily be added to the composite score, so long as the minimum scale is kept at the parcel level. We recognize that individual organizations may have their own suitability requirements for land acquisition based on their needs, resources, and mission. Thus any future use of the environmental and geographic suitability could be recreated to a finer or border scope.

Final additional future research we believe could be included into our current model would include other topics of conservation concern with the goal of expansion of protected land acquisition. Topics such as expanding land protection for important bird areas and remnant prairies are among top priorities for the conservation community in Wisconsin. With access to these data layers we would incorporate one or more into the environmental suitability analysis in the creation of high environmental quality regions.

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Appendix

Summary of The Nature Conservancy's Resiliency Model

The TNC *Terrestrial Resilience* model is predicated on the fundamental assumption that connected areas with higher geophysical variability support greater ecological function and biological diversity than areas with less variable landscapes with higher fragmentation. *Terrestrial resilience* combines metrics of landscape geophysical diversity and local connectedness, a measure of landscape connectivity

TNC’s Landscape Diversity Score

The landscape diversity analysis and resistance scoring TNC created takes into account topology, elevation, and wetlands in order to understand the capacity in which an area of land can sustain the habitable micro-climates. The estimated landscape diversity of 30m-cells are based on combining three integrated values: analysis of landscape variety (the number and type of topographic landforms), a sub value of landscape variety taking into account coastal lake effect (temperature moderation around the Great Lakes), and wetland influence (density, patchiness, and connectedness) (Anderson(2), pg 38). TNC states in their final landscape diversity map that they transformed z-scores of the landscape variety and sub-value of coastal lake effect, and wetland influence, and combined the values. Landscape variety is weighted twice as much as wetland influence (Anderson(2), pg 64).

TNC's Local Connectedness Score

To understand how a species may move through a landscape, the analysis of TNC's local connectedness of an area was achieved by measuring the land cover, or resistance, around a focal cell of 30 meters. Areas with relatively similar uninterrupted natural land cover received a higher connectivity score, or a low resistance score. Areas with a higher rate of changing land cover and human development received lower connectivity scores, or a high resistance score (Anderson(2), pg 67). Below are two table summaries of the local connectedness resistance scores.

(Table A1) TNC Local Connectedness Resistance Scores (Anderson(2), pg 68).

Land Cover code NLCD	Land Cover Description	Resistance Score	Source
21	Developed, Open Space	8	NLCD 2011
22	Developed, Low intensity	8	NLCD 2011
23	Developed, Medium Intensity	9	NLCD 2011
24	Developed, High Intensity	20	NLCD 2011
31	Barren Land, non-natural	9	NLCD 2011
32	Barren Land, natural	1	NLCD 2011
41	Deciduous Forest	1	NLCD 2011
42	Evergreen Forest	1	NLCD 2011
43	Mixed Forest	1	NLCD 2011
52	Shrub/Scrub	1	NLCD 2011
71	Grassland/Herbaceous	1	NLCD 2011
81	Hay/Pasture	3	NLCD 2011
82	Cultivated Crops	7	NLCD 2011
90	Woody Wetlands	1	NLCD 2011
95	Emergent Herbaceous Wetlands	1	NLCD 2011

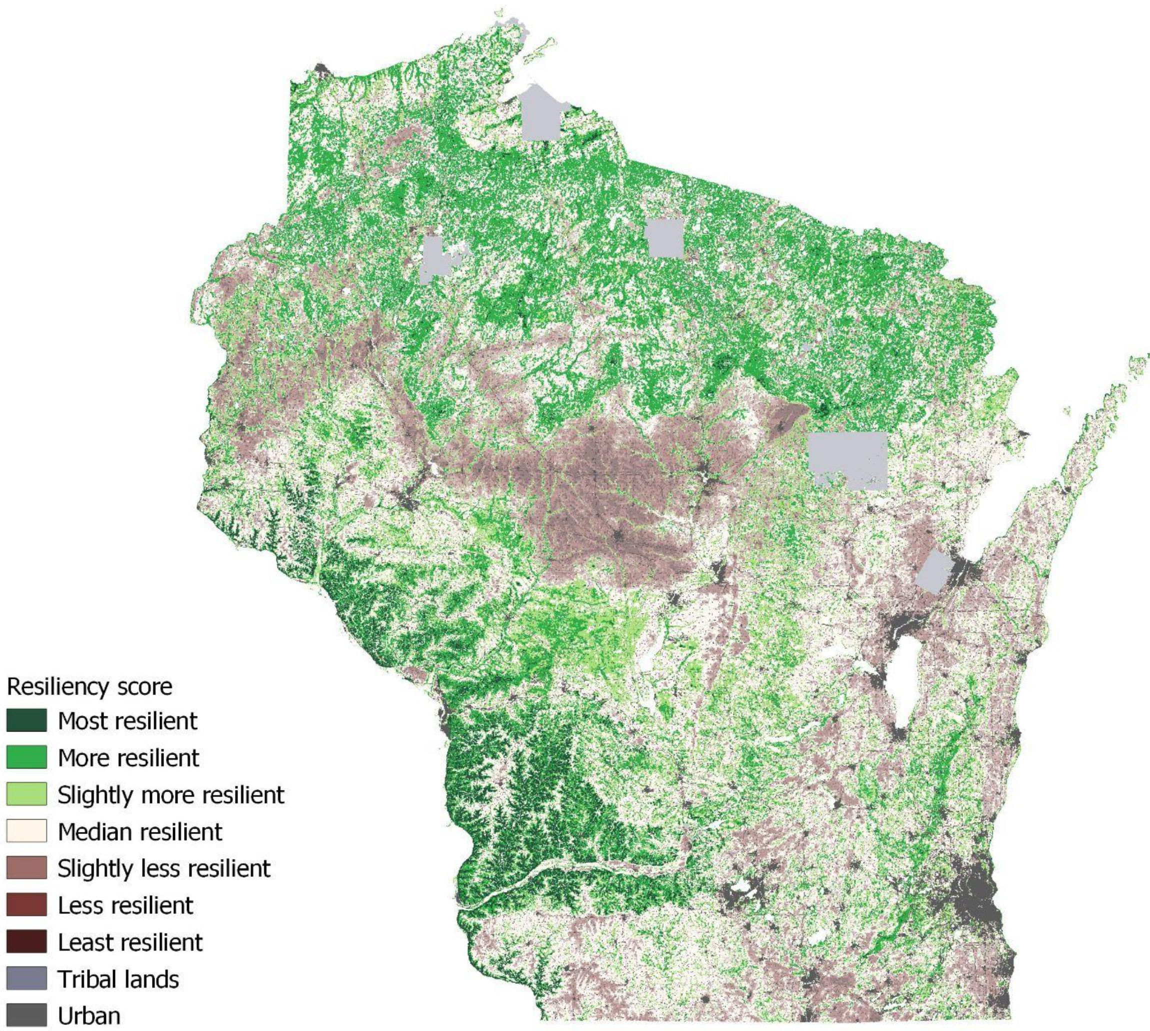
(Table A2) Summary of additional improvements to the TNC Local Connectedness resistance grid (Anderson(2), pg 72).

Landcover	Resistance Score	Source
Prairie/Grassland Areas	1	Nature Serve Eos, Remnant Prairies in Iowa, Gulf Hypoxia, Secured lands
Industrial Forests		
Forest Loss or Gain	3	Global Forest Change Dataset (2016)
Loss or Gain on Secured Lands	1.5	Global Forest Change & Analysis of Secured Lands for the Great Lakes
Waterbodies: Distance to Shoreline		
<200 m	1	NLCD, NHD, NHN, ArcGIS Analysis
200 - 400 m	3	NLCD, NHD, NHN, ArcGIS Analysis
>400 m	5	NLCD, NHD, NHN, ArcGIS Analysis
Grasslands/Pasture		
Grassland/Pasture	3	Cropscape 2016: most years Grassland
High Intensity Agriculture		
Corn and soy agriculture in 2016	9	Cropscape 2016 (US) or presence in of corn/soy in AAFC (CA)
Persistent corn/soy	9	Cropscape: Majority years corn and soy
Roads & Railroads		
Major Roads	20	Tiger 2016 & National Road Network
Minor Roads	10	Tiger 2016 & National Road Network
Dirt Roads	Resistance +1	Open Street Map Tracks (US& CA) and Tiger Vehicular Trail (4WD) S1500 (US)
Railroads	9	CTS 2016
Energy Development		
Transmission lines	7	Ventyx 2017
Pipelines	9	Ventyx 2017

Lastly, TNC combines their analysis scores of landscape diversity and local connectedness by altering the metrics of each score to create a standardized normalized score (z score). This step is done so that the weights for both landscape diversity and local connectedness are equal. The final resilience formula is as follows (Anderson(2), pg 80):

Estimated Resilience = Landscape Diversity (z score) +

Local Connectedness (z score)/ 2



(Figure A1) TNC Resilience Sites Output (https://maps.tnc.org/resilientland/ 2021)