City of Duluth
Guidelines for Selecting Tax Forfeit Open Space Parcels
for City Ownership and Protection
(approved by the Duluth Natural Resource Commission – July 1, 2020)

Introduction and Purpose

When a property owner in the State of Minnesota persistently fails to pay their property taxes, the State eventually assumes ownership of the property. The resultant tax forfeit land is managed on behalf of the State by the county where the land is located. Within the boundaries of Duluth, there are approximately 5,802 acres of such lands comprised of more than 4,500 individual parcels, all managed by St. Louis County.

As in other Minnesota cities, many tax forfeit properties in Duluth are isolated parcels, often small, often located in developed areas. In most cases, St Louis County works with City support to cycle properties of this sort back to private ownership within a few years.

Unlike other Minnesota cities, Duluth also has unusually large swaths of tax forfeit open space parcels that have been in tax forfeit status for decades. Seamlessly interspersed with City-owned parks and natural areas, these tax forfeit properties are integral parts of a distinctive Duluth system of public open space. Numerous plans and studies (Appendix A and References) have shown the high value Duluth residents place on preserving, protecting and restoring this open space.

The County and the City have come to an understanding that much of the tax forfeit property that is essential to Duluth's system of public open space should be permanently preserved under City ownership and management. To that end, the County and the City have agreed upon a process by which the parties will negotiate the selection of tax forfeit property to transfer to City ownership.

The purpose of this document is to describe the internal process and guidelines the City will use to select the tax forfeit open space parcels that the City will seek to acquire in negotiations with the County.

Basis in the City 's Comprehensive Land Use Plan

The City of Duluth's *Imagine Duluth 2035 Comprehensive Land Use Plan* (the Plan) directs the City to manage the City's open space in accordance with the following mission: *"Duluth will strive for a sustainable open space system that enriches the lives of all Duluthians. These open spaces will reflect the community's ecological, historical, cultural, and recreational values, and will contribute to its resilience to natural disasters."*

In support of this mission, the Plan's Open Space Principle #2 states that the City shall: *"Declare the necessity and secure the future of undeveloped places."* The Plan directs the City to fulfill Open Space Principle #2 by implementing Open Space Policies #1 and #2

> Open Space Policy #1 – *"Improve Duluth's resiliency to flooding and natural disasters."*
>
> The underlying aim of Open Space Policy #1 is to help provide for resiliency from severe storm events where increased runoff causes flooding, erosion and sedimentation, and damage to city infrastructure and water quality.
>
> The Plan outlines six strategies for fulfillment of Open Space Policy #1. Strategy #3 speaks to the goal of better aligning the ownership for the public good.
>
> > Strategy #3 - *"Retain in City/State ownership or preserve through conservation easement those tax forfeit lands needed for stormwater management purposes including important wetlands, flood plains, and stream corridors."*
>
> Open Space Policy #2 - *"Examine the value and need for all of Duluth's publicly owned open space."*
>
> The underlying aim of Open Space Policy #2 is to better align the ownership and use of greenspace in Duluth with the public good, preserving essential greenspace that deserves protection and relinquishing greenspace that should be prioritized for other public purposes such as housing and economic development. Open space lands to be protected are the lands that form the green belt of Duluth's urban form and include forests, wetlands, stream courses, bedrock bluffs, parks, and trails. Open space lands to be sold for redevelopment include lands with access to utilities and transportation infrastructure that can be economically developed in alignment with the Plan.
>
> The Plan outlines eight strategies for fulfillment of Open Space Policy #2. Strategies #1, #4, and #8 speak to the goal of better aligning the ownership and use of public greenspace with the public good.
>
> > Strategy #1 - *"Review all government-owned land in the city and prioritize lands according to ecological importance and other public uses (i.e. recreation, transportation, infrastructure) for more permanent protection. Areas to be protected include forested areas, wetlands, stream courses, and bluff areas as well as lands important in forming the green belt as part of Duluth's urban form."*

Strategy #4 - *"Increase efforts to streamline management of public lands within the City's borders."*

Strategy #8 - *"Review studies that have analyzed City-owned and tax forfeit land and prioritize lands according to ecological/recreational/cultural/historic importance and infrastructure availability. Lands not needed for protection should be made available for development after further ecological research, including on-the-ground analysis."*

Focus on Tax Forfeit Greenspace Administered by St. Louis County

The Plan highlights the importance of wisely deciding the future ownership and use of one category of public greenspace - tax forfeit properties administered by St. Louis County. The outcomes of this land selection process will be the transfer of some tax forfeit parcels to the City for open space protection and the de facto release of other tax forfeit parcels to be auctioned by the County for private ownership and, in some cases, development. Minnesota State Statute § 282.01, Subd. 1a(e) and (h) authorizes the County to convey select tax forfeit property to the City at no cost or reduced cost for the purposes of preserving wetlands, providing for storm water storage, preserving land in its natural state, and/or siting public parks and trails.

Land Parcel Selection Process

These guidelines describe the process the City will use to select tax forfeit open space parcels for City ownership and protection and designate others for private ownership and potential development. The output of the process will be the identification of each tax forfeit parcel for open space or private ownership.

The selection process will include:

1. Geospatial mapping analysis that converts the conceptual criteria in the Plan to systematic measures that can be applied to each tax forfeit parcel to determine the appropriateness of each parcel for open space or private ownership.
2. Professional city staff analysis of the tax forfeit parcels that rate moderate to high for both open space and private ownership. The staff team will be comprised of professional city staff with expertise in Engineering, Planning and Economic Development, Natural Resource Management, and Parks and Recreation. The team will assess and debate the proper designation for each such parcel.

For the geospatial analysis, the City will utilize three pre-existing geospatial analytical tools created to provide guidance on the preferred ownership and use of land in the City consistent with the Plan. (Note: Geospatial maps and/or other data sets developed at later dates may be used to fine-tune parcel lists at the

time City and County professional city staff negotiate a list of parcels for demarcation.)

1. **The Sensitive Lands Overlay**. The Plan includes a Sensitive Lands Overlay intended to identify lands that have high natural resource value. The basis of the Sensitive Lands Overlay is the 2006 natural resource analysis conducted by the Natural Resources Research Institute (Appendix B). The NRRI analysis was completed to help identify ecologically significant areas using existing data sets to rank the natural resource value of non-developed uninterrupted areas of forest or other habitat types.

2. **Trails Overlay.** This map layer was created to capture current recreational use of open space with current and future trail alignments from the 2011 Trail & Bikeway Plan and the 2015 Cross Country Ski Trail Master Plan. The trail alignments layer includes all trails with a 250-foot buffer (125-foot setback on each side) around the trails.

3. **The Development Suitability Index.** Tax forfeit parcels that were included in the Sensitive Lands Overlay and/or the Trails Overlay will then be subjected to an additional analysis of development suitability. The Development Suitability Index uses a matrix of land use variables (e.g., distance to infrastructure, major arterials, and core investment areas, slope, depth to bedrock, floodplains, shoreland, soils, wetlands) to assess the relative suitability of each parcel for development (Appendix C). Parcels classified as high or moderate for development will be flagged for further evaluation by a panel of professional city staff. Parcels classified as low for development will often default to the open space protection list unless the parcel is notably isolated, small, or otherwise lacking in significance or manageability.

Professional City Staff Review: Professional city staff with expertise in Engineering, Planning and Economic Development, Natural Resource Management, and Parks and Recreation will meet as a team to study and deliberate on those parcels that rate moderate to high for both open space protection and private ownership. In this phase, the team will weigh and debate the competing values of natural resource preservation, floodwater/stormwater retention, wetland protection, recreation, public access, land re-use, housing, and economic development in order to recommend the future ownership and use of each developable parcel. The analysis will be based on maps, existing plans and policies, and professional city staff expertise and experience.

Negotiation, Review, and Approval of City Parcel Selections

The process of selecting and conveying parcels for protection will take years to complete. To break the process into manageable chunks, the City has divided Duluth into eleven geographic project areas (Figure 1). The City and the County will proceed one project area at a time, deciding the future ownership and use of

every tax forfeit open space parcel in one project area before proceeding to properties in the next project area.

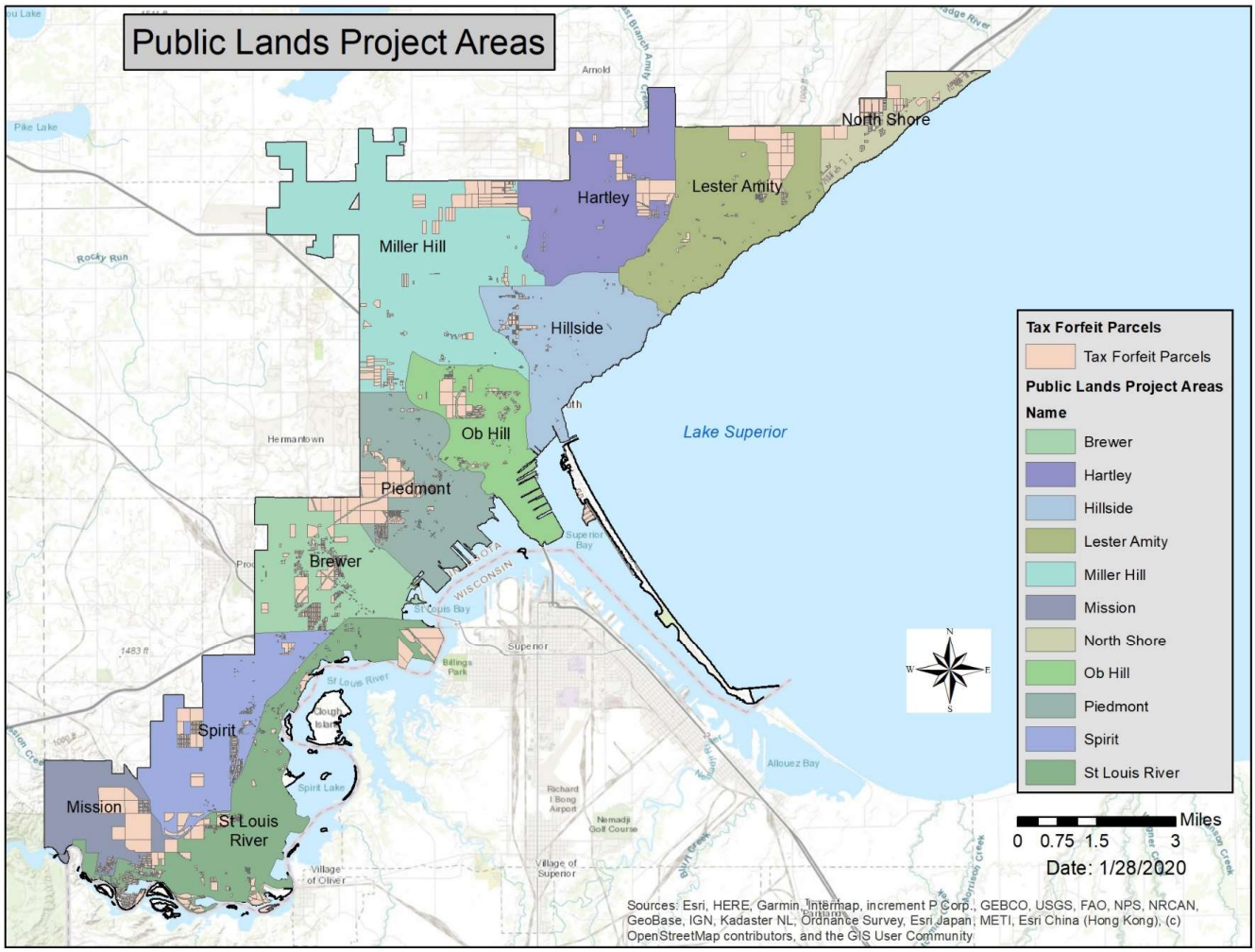
For each project area, City staff will apply the guidelines in this document to develop a list of tax forfeit open space parcels the City wishes to acquire for permanent protection. The City will then submit that list to the County as an opening bid in what will be an intensively negotiated real estate transaction. The County's obligations to assent to City selections are limited and nuanced. On the one hand, the County Board has formally committed to cooperate with the City to transfer ownership of a large volume of appropriate tax forfeit open space parcels to the City for permanent protection at no cost or reduced cost to the City. On the other hand, the County has no obligation to assent to transfer any one parcel identified by the City.

Following completion of City-County parcel negotiations on each project area, the list of preliminarily negotiated parcels will be submitted for review, public comment, and approval at one regular meeting of the Natural Resources Commission, one regular meeting of the Planning Commission, and one regular meeting of the City Council, in that order. First, City staff will bring the negotiated list of parcels to the Natural Resource Commission for review and comment. Second, City staff will bring the negotiated list of parcels to the Planning Commission along with the review and comments from the Natural Resource Commission. Finally, the negotiated list of parcels will be brought to the City Council along with the findings of the Natural Resource Commission and Planning Commission for final approval.

After the City Council has approved the negotiated list of parcels, the County will seek County Board approval of the same list. Once City and County elected officials have approved the list, City and County staff will transact the change of ownership, returning to the City Council and the County Board as necessary for transactional authorizations.

The City's objective is to initiate the first of the tax forfeit parcel transfers with the County by the end of 2020.

Figure 1: Project Areas for Duluth Tax Forfeit Open Space Land Parcel Review



References

1. A Natural Resources Analysis for Duluth's Natural Resources Inventory. Brown, Terry and Tom Hollenhorst. University of Minnesota, Duluth – Natural Resources Resource Institute. 2006.
2. Duluth Comprehensive Land Use Plan. Duluth, MN. 2006.
3. Duluth Cross Country Ski Trail Master Plan. 2015.
4. Duluth Trail & Bikeway Plan. 2011.
5. Duluth Values Open Space. Glenn Kreag. Minnesota Sea Grant. 2002.
6. Imagine Duluth 2035 - an update to the 2006 Comprehensive Land Use Plan. 2018.
7. Mayor's Task Force on Reuse and Protection of Public Lands. April 2012.
8. Methodology for City-Wide GIS Development Suitability Index. Technical Memorandum. December 27, 2018.
9. St. Louis County, MN Comprehensive Land Use Plan. 2019.

Appendix A

Brief History of Plans and Policies in Support of Securing the Future of Undeveloped Lands for Open Space Protection

- 2001, a community-wide "2001 & Beyond" visioning process (completed in 1997) where participants indicated maintaining Duluth as an "urban wilderness" was a priority
- In 2002, a report by Minnesota Sea Grant documented how residents perceive the importance of open spaces in Duluth. The survey showed overwhelming support for the value of natural open spaces, maintaining its' natural character and preserving it for future generations to enjoy.
- In 2006, a natural resources analysis was completed to help identify ecologically significant areas using existing data sets to rank non-developed uninterrupted areas of forest or other habitat types to be considered along with other information within the development of the 2006 Duluth Comprehensive Plan. This work led to the creation of the following key principles and policies related to protection of open space:

    Principle #2 – Declare the necessity and secure the future of undeveloped lands

        Policy - The City will prioritize for permanent protection viable (self-sustaining) ecosystems and areas critical for sustaining those ecosystems but in need of restoration…

    Principle #6 - Reinforce the place-specific

        Policy - Open space, natural areas, and recreational areas are more valuable if interconnected. The City will strive to connect its green space and recreational areas through natural corridors on public or private land, trail systems, and creation of boulevard corridors on public right-of-ways.

    Principle #11 – Take sustainable actions

        Policy - Duluth has an abundance of valuable natural areas, some in near pristine condition, others in need of restoration. To achieve preservation outcomes identified in the principles and on the future land use map, the City will utilize scientifically-based resource indicators in preservation priorities.

        Policy - Water is a defining element in Duluth's physical and cultural landscape. Consistent with the sensitive lands overlay on all stream corridors and shorelines, the City will protect and enhance the quality of streams, rivers, and Lake Superior

- In 2012, a mayor's task force addressed how the City should balance demands for revenue-generating reuse of Duluth's public lands with the substantial benefits this "green infrastructure" offers. The primary recommendations from this report included:
    - Create a holistic vision for a city-wide network of "greenspace"…
    - Institutionalize a formal program to implement and market this vision….
    - Simultaneously develop a proactive plan for the strategic reuse of public land….
    - Implement a process using publicly-vetted criteria for shaping this vision…
    - Revise the City's procedure for selling lands to increase public awareness…
- In 2018, the City updated its' 2006 Comprehensive Land Use Plan and called it Imagine Duluth 2035 Comprehensive Land Use Plan. This work led to the creation of the City's Open Space mission: "Duluth will strive for a sustainable open space system that enriches the lives of all Duluthians. These open spaces will reflect the community's ecological, historical, cultural, and recreational values, and will contribute to its resilience to natural disasters."

  Open Space Principle #2 and Policy #1 and #2 is stated below. It directs the City to implement the strategies toward achieving the goals set forth by the Open Space mission.

  Open Space Principle #2 – "Declare the necessity and secure the future of undeveloped places."

  Open Space Policy #1 – "Improve Duluth's resiliency to flooding and natural disasters."

  Open Space Policy #1, Strategy S3 speaks to the goal of better aligning the ownership for the public good.

  Open Space Policy #2 – "Examine the value and need for all of Duluth's publicly owned open space."

  Open Space Policy #2, Strategy S1, S4, and S8 speak to the goal of better aligning the ownership and use of public greenspace with the public good.

  For more information see the Open Space chapter of the Imagine 2035 Comprehensive Land Use Plan.

- In 2019, the St. Louis County, MN Comprehensive Land Use Plan was completed which included open space goals and objectives as follows:
    - Goal Natural Environment -1: Strive for local decision-making that balances social, economic, and environmental concerns
        - Objective NE-1.1: County policies and approvals related to land use, development, and management will be made to address current needs without compromising the ability to meet future needs.
        - Objective NE-1.2: County operations, land use, and management will be refined to be more efficient and environmentally-responsible.

Appendix B

A Natural Resources Analysis for Duluth's Natural Resources Inventory

A Natural Resources Analysis for Duluth's Natural Resources Inventory.

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1. Document status

This document was generated 3:20pm Wed. Jan. 25 2006. This webpage and associated images may be downloaded as a single .zip file here (CPOSweb200601251520.zip).

2. Introduction

Although a natural resources inventory had been developed for Duluth and its watersheds, this inventory had not yet been integrated with other information to identify ecologically significant areas (ESAs) in Duluth. Identifying ESAs through some sort of natural resource analysis (NRA), is an important step in comprehensive planning. Understanding where ESAs exist, and developing an accepted plan for their long term conservation, furthers both conservation and development efforts, by providing more certainty about the appropriate use for non-developed areas throughout the city. More certainty about the appropriate use of non-developed lands reduces the controversy often associated with newly proposed developments.

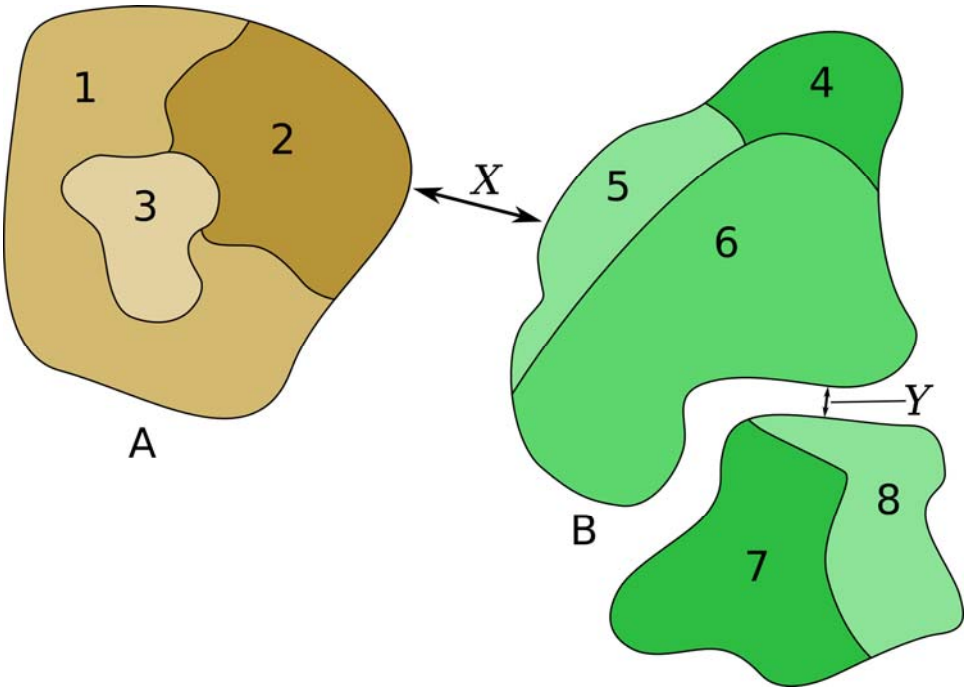
The following is an Natural Resources Assessment for Duluth, within a natural areas assessment framework, designed to help identify ESAs in Duluth. We used data from Duluth's Natural Resources Inventory, the Minnesota County Biology Survey, and other existing data sets, to rank existing non-developed patches in Duluth for their ecological significance. The rank is a composite score based on measures of land cover types, patch size and shape, plant composition, and connectivity with other patches. The specific fields and their descriptions are listed in . These measures were all normalized with scores ranging from 0 to 1. For some categorical measures, relative rarity was used to rank classes, so that rare types are valued more highly (i.e. white cedar vs aspen).

The results of this analysis are expressed in the attached map overlay of NRA scores from which significant ecological areas can be identified. This value representing the ecological significance of specific non-developed areas in Duluth can be considered along with other information contained within the comprehensive plan. This ESA overlay will then provide long term guidance for specific land use considerations

3. General Approach and Goals

The main components of the Duluth Natural Resource Inventory (NRI) are detailed GIS polygon maps of all forest stands, wetlands, and other undeveloped lands within the city. Combining the forest and wetland polygon maps yields 6808 polygons. These polygons will be referred as "stands", although they may be non-forested wetland or other treeless natural land cover types. Playing fields and golf courses are also included. These stands can be grouped together into "clusters" based on some threshold distance at which two stands are considered to be close enough to be connected in an ecological sense. The term "patch" is often applied to an uninterrupted area of forest or some other habitat type. In the context of this analysis it may be appropriate to describe some clusters as patches, but because of the high level of detail in the NRI it is better in general to think of the stands as sub-patch units and the clusters as dense collections of one or more patch like units.

Figure 1. Stands and clusters.



Two clusters comprised of 7 stands. These clusters are defined for some connectivity threshold Z; X is larger than Z, but Y is smaller than Z.

The idea of connectivity between stands forming clusters is highly species dependent. While many bird species may require larger patches of habitat for protection from predators, birds can easily cross large gaps between patches. On the other hand small plants that prefer the interior of more mature forest patches may find it very difficult to propagate across even small breaks in the natural land cover.

4. Specific Methods

4.1. Data import and preparation

Table 1. Initial data import and preparation.

Data layer	Modifications
`forest_final.shp` and `wetlands_final.shp`, polygon coverages	• Acquired from Paul Meysembourg's collection of Duluth NRI files. • Split multi-part polygons (a small number) into single part polygons. Used test-case to confirm that polygons containing holes are not multi-part polygons. • Added ID values, 1 and 3692 inclusive and 10000 and 13423 inclusive for forest and wetland polygons respectively.
`forwet2.shp`, polygon coverage	• Created by merging `forest_final.shp` and `wetlands_final.shp` using Arcview X-Tools extension. • Arcview extension "Add-XY" was used to add X and Y coordinates for each polygon. This extension ensures that the point occurs within the polygon even in those cases where the center of the polygon's bounding box is not part of the polygon. • Added `connects` field, see the section called Connectivity classification. • Added `type` field; F, W, or U for Forest, Wetland, or Unnatural.
`forwetpnt.shp`, point coverage	• Created from `forwet.shp` X- and Y-coord fields via the "Event theme" mechanism.

4.1.1. Connectivity classification

The shapefile `forwet2.shp` was classified into 58 broad classes listed in . A field was added to the shapefile `forwet.shp`, `connects`. This field was used to distinguish between cover types that act as a break in the natural landscape (`connects`="N") and those that don't (`connects`="Y"). See for assignment details. In practice assigning a non-connective status to some recreational developments will have very little impact on overall connectivity as they almost always occur on the edge of an urban development and as such are not disconnecting natural areas.

Table 2. `connects` field assignments in the shapefile `forwet.shp`.

Type	`connects` field assignment	Comment
Industrial devel.	N	
Urban devel.	N	
Road	N	
Bare soil	Y	Small forest clearings or stream banks
Recreation devel.	Y or N	Individually assessed and assigned either "N" if they were fenced (baseball diamonds) or predominantly impervious surface (parking lots, buildings), and "Y" otherwise (golf courses, city parks, playing fields).
Permanent water	Y or N	A few large water bodies were assigned "N".
Upland grass	Y	There were too many polygons in this class to assess individually. Most polygons in this type will be passable by many species, although areas maintained in mowed grass are a barrier to plant species dispersion and some smaller animals.
All other types	Y	These are forests, wetlands, upland and lowland brush, and lowland grass.

4.2. Data processing

4.2.1. Cluster mapping

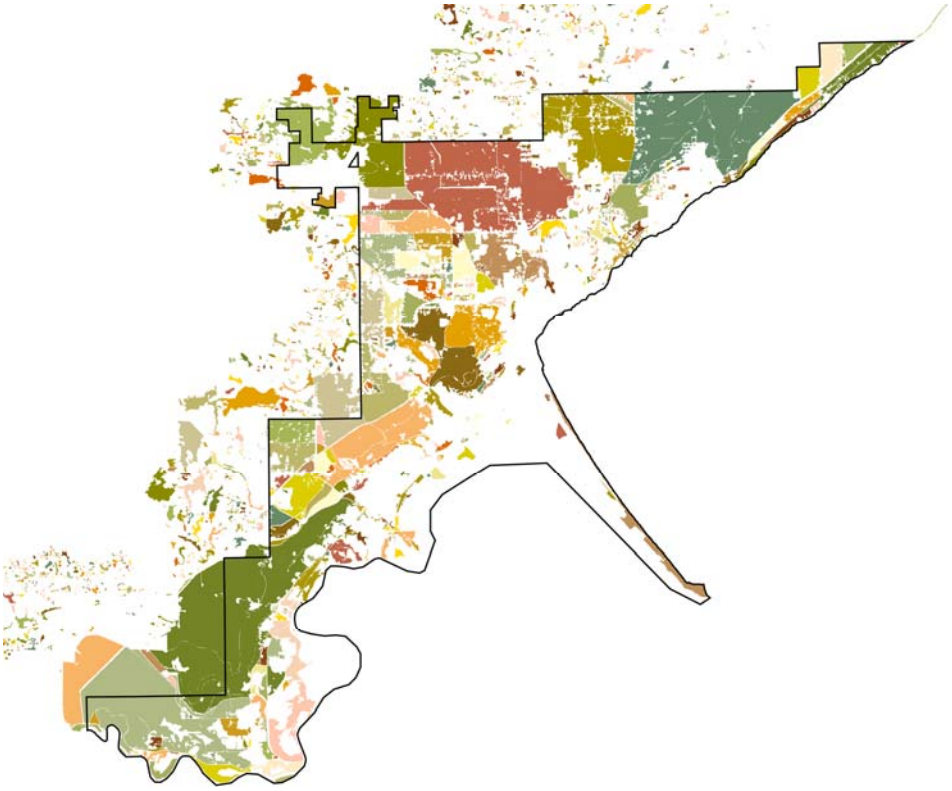
Clusters of connected stands were identified at 1, 10, 25 and 150Â m connectivity thresholds. In each case the base stand coverage (forwet2.shp) was buffered out by the required distance, and the buffered stand polygons were related to the original stand polygons using the ArcView X-Tools extension "Union" function. This process yields a table of paired ID codes for every pair of stand polygons that are within the connectivity threshold distance of each other. Custom ArcView and C++ computer code was then applied to identify connected clusters of stands. The ArcView and C++ code produced the same results, the C++ version was necessary only because ArcView was unacceptably slow for the larger clusters.

Table 3. Components of connectivity analysis

Component	Purpose
ForwetXXm.shp	The base stand coverage buffered out XX m.
ForwetXXmint.shp	The X-Tools "Union" of the base stand coverage and ForwetXXm.shp.
ForwetXXlink.shp	A line coverage showing connections between stands at XX m, used for visualization only.
ClusterXX.shp	Clusters of stands merged together at connectivity threshold XX m.
ClusXXcoreYY.shp	ClusterXX.shp buffered inwards YY m to determine cluster core area.

The clusters identified at the 10Â m threshold were considered to be the most informative in terms of ecological function. At this threshold trails and other small breaks in natural stand cover would not separate clusters, but sealed roads and larger breaks would. shows the distribution of clusters at this threshold.

Figure 2. Clusters at the 10 m connectivity threshold.



Different colors identify different clusters.

4.2.2. Scoring analysis

Each stand was scored according to several attributes. These attributes are listed in and then covered in more detail in following subsections. For each attribute there is an input value which is an actual measure of some characteristic of the stand, and a corresponding score, which is a number between zero and one. This allows the scores to be averaged together to form an aggregate score of ecological value for each stand.

With one exception (the ftype attribute) scoring is based on the stands position within the range of values for each attribute. For example the tree size attribute ranges from 2 to 6. A stand with a tree size of 2 would score zero, and a stand with a tree size of 6 would score 1. A stand with a tree size of 4, half way between the minimum and maximum for that attribute, would score 0.5. So no matter what the range of the attribute, 2 to 6 or -1.8 to -1.2, the score always ranges from zero to one. In general terms the score is:

$$S = \frac{A - Min}{Max - Min}$$

where

Min	= the minimum value in the the attribute's range (closest to negative infinity).
Max	= the maximum value in the the attribute's range (closest to positive infinity).
A	= the stands value for the attribute in question.
S	= the stands score for the attribute in question.

Table 4. Stand attribute scoring

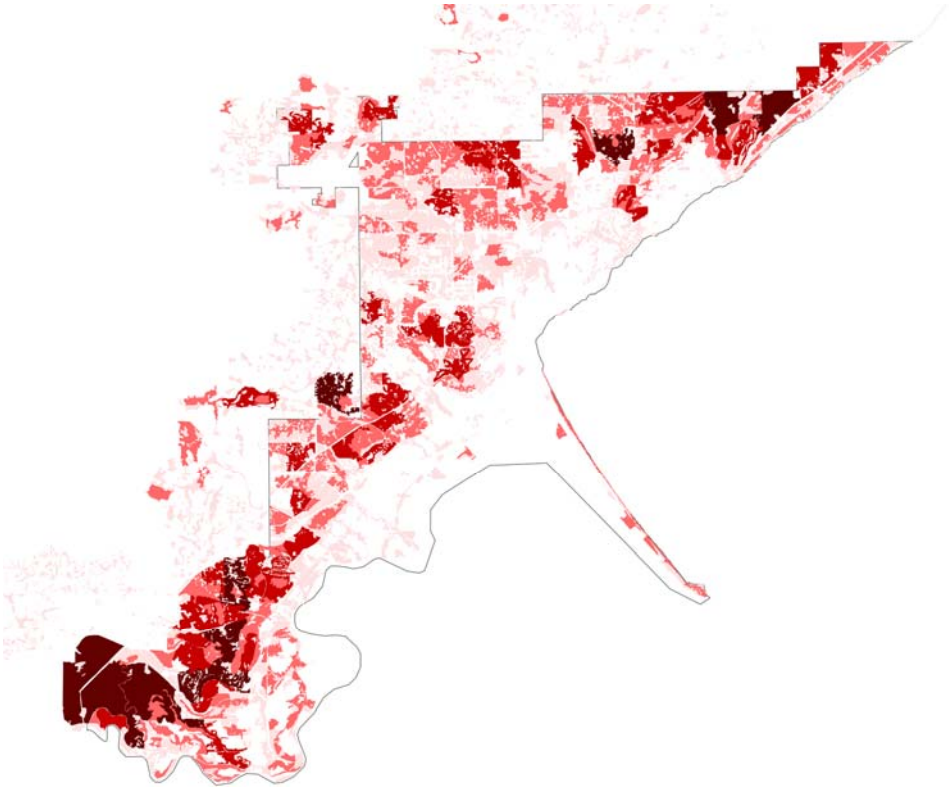
Attribute name	**Source**	**Interpretation**
size	Area of stand in meters, from forwet2.shp.	Generally large stands are have greater ecological value than small stands, particularly in a landscape where the number of larger stands has been significantly reduced.
treesz	Tree size class recorded in forwet2.shp. Ranges from 2-6.	While healthy ecosystems contain trees of all sizes, stands with larger trees are unnaturally rare in northern Minnesota, and consequently more ecologically valuable.
shape	-2*ln(perimeter)/ln(area) where perimeter and area are calculated from forwet2.shp.	Generally the closer to circular a stand is the less edge habitat it contains and the more protection it offers to plants and animals from predators and physical stresses that enter the stand from the edge.
wsbo	Mean impervious land cover in the stand. 0-100 percent.	The higher the proportion of impervious surface in the watershed or immediate catchment of a stand, the more valuable the stand is in terms of its ability to slow runoff.
mcbs	Number of Minnesota County Biological Survey records intersecting the stand. 0-32.	MCBS survey records indicate the presence of an endangered, rare, or threatened species or community.

Attribute name	**Source**	**Interpretation**
conn	Index of the impact of removing this stand on cluster connectivity.	Stands whose removal would break large clusters into smaller clusters are valuable for their role as connectors.
pcarea10	Core area (more than 150 m from edge) of the stands cluster.	Stands that form clusters that have significant core area are valuable because such core area habitat is rare.
water	A zero or one score, is the stand within XX feet of a stream, YY feet of a trout stream, or ZZ feet of the St. Louis River Estuary or Lake Superior.	Stands of natural land cover close to water bodies are valuable as buffers to those water bodies.
ftype	Relative rarity of a forest type, between zero and one (but not zero or one).	Generally the less common a forest type is the more valuable it is ecologically. In order for this to be true the distribution of forest types in Duluth needs to match that in the region, which it does.

4.2.2.1. Stand area (`size`)

Input for scoring this attribute is simply the area of the stand in square meters. The six highest areas are 2701440, 1450338, 1450197, 1393860, 1371585, 1270889. The largest stand, at almost twice the size of the next largest stand, is clearly an outlier, which would compress the scoring for the remaining stands into an approximately 0-0.5 range. To avoid this the largest stand was considered to have an area equal to that of the second largest stand for the scoring of this attribute.

Figure 3. Four level map of stand area score (darker colors are higher scores).



4.2.2.2. Tree size (`treesz`)

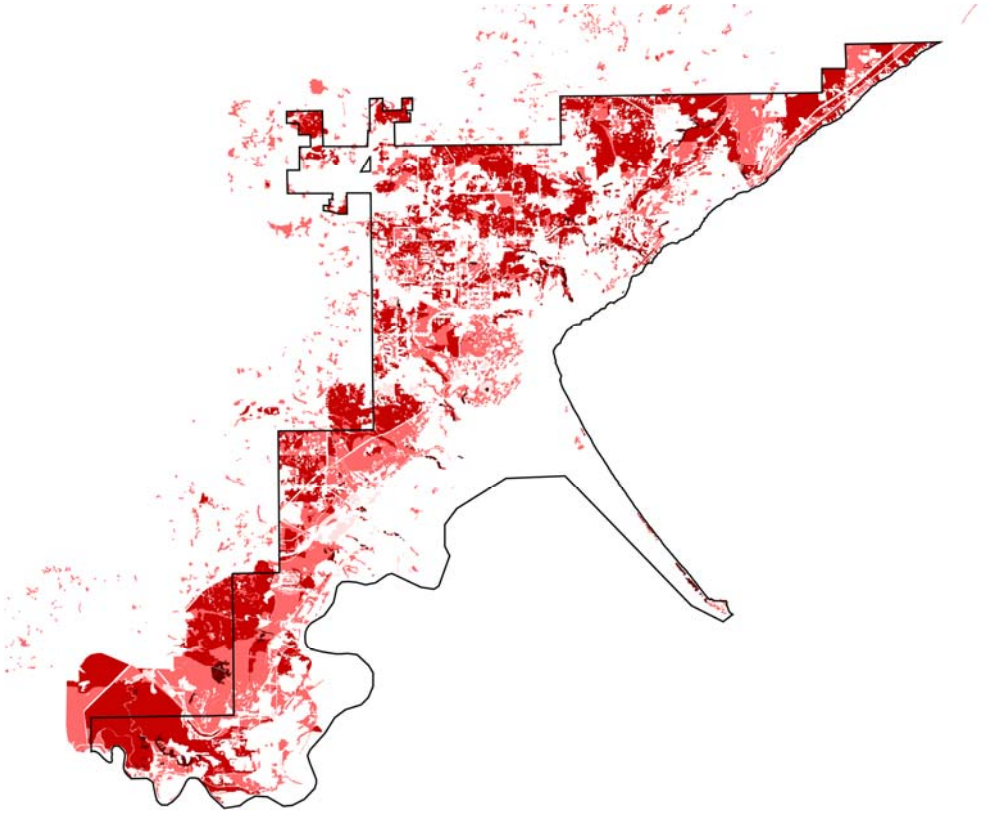
The Duluth NRI estimated tree sizes in DNR inventory classes:

Class	Size
2	1 to 2.9 inches
3	3 to 4.9 inches
4	5 to 8.9 inches
5	9 to 14.9 inches
6	15 to 19.9 inches

Examining the distribution of tree sizes in the NRI data it may appear that the smaller classes are under represented and should be valued for their rarity. This is misleading,

as no size class values were recorded for the common "Upland Brush" category, and in fact smaller size classes are not rare.

Figure 4. Four level map of tree size class score (darker colors are higher scores).



4.2.2.3. Stand shape (shape)

In general habitat patches are considered more closely their shape approaches that of a circle. This is because a circle has the lowest possible perimeter to area ratio, so patches that are roughly circular have less "edge" than patches that have more complex shapes. Plants and animals are subject to stresses (predator, parasite, and micro-climate) which are often associated with edges. Three shape indices were evaluated.

perimeter/area. This indice is highly area dependent, large polygons will always score well, even if they have highly convoluted shapes which expose their occupants to a lot of edge stress. This indice was not used.

perimeter/circle_perimeter. By dividing the perimeter of a stand by the perimeter of a circle with equivalent area a pure shape indice which is completely area independent is obtained. This indice will rate very small roughly circular patches very highly even though they are prone to edge based stresses. This indice was not used.

-2*ln(perimeter)/ln(area). By taking the natural log (log base e) of perimeter and area their ranges are condensed so that an indice that is only moderately area dependent is obtained. This is the indice that was used in this analysis. The value is multiplied by two for consistency with other applications of this indice, and negated to provide the "higher is better" ordering required for the scoring used in this analysis.

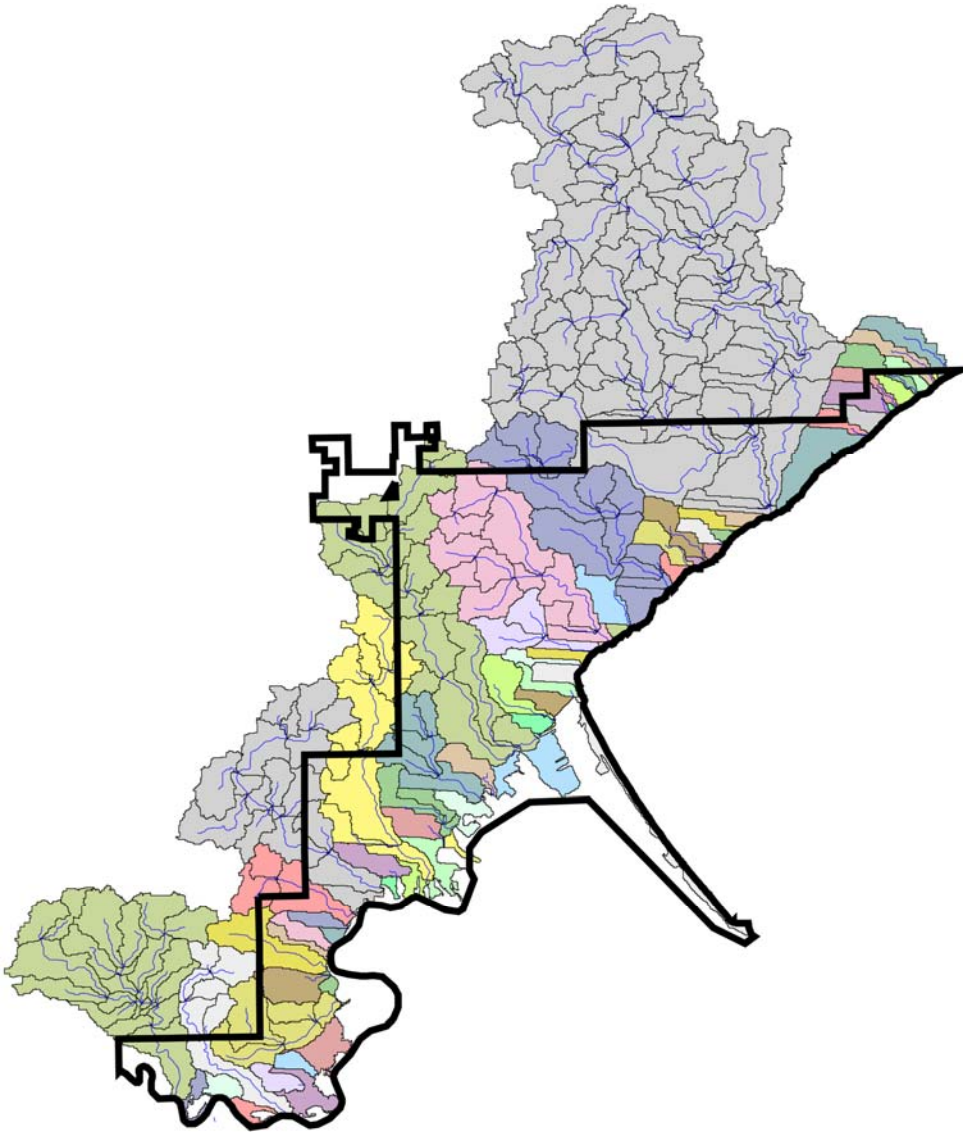
Figure 5. Four level map of stand shape score (darker colors are higher scores).

4.2.2.4. Impervious surface (wsbo)

The Arc-Hydro model was used to delineate watersheds and sub-catchments that intersect Duluth (). The input for the impervious surface score was the higher of either the sub-catchment or watershed

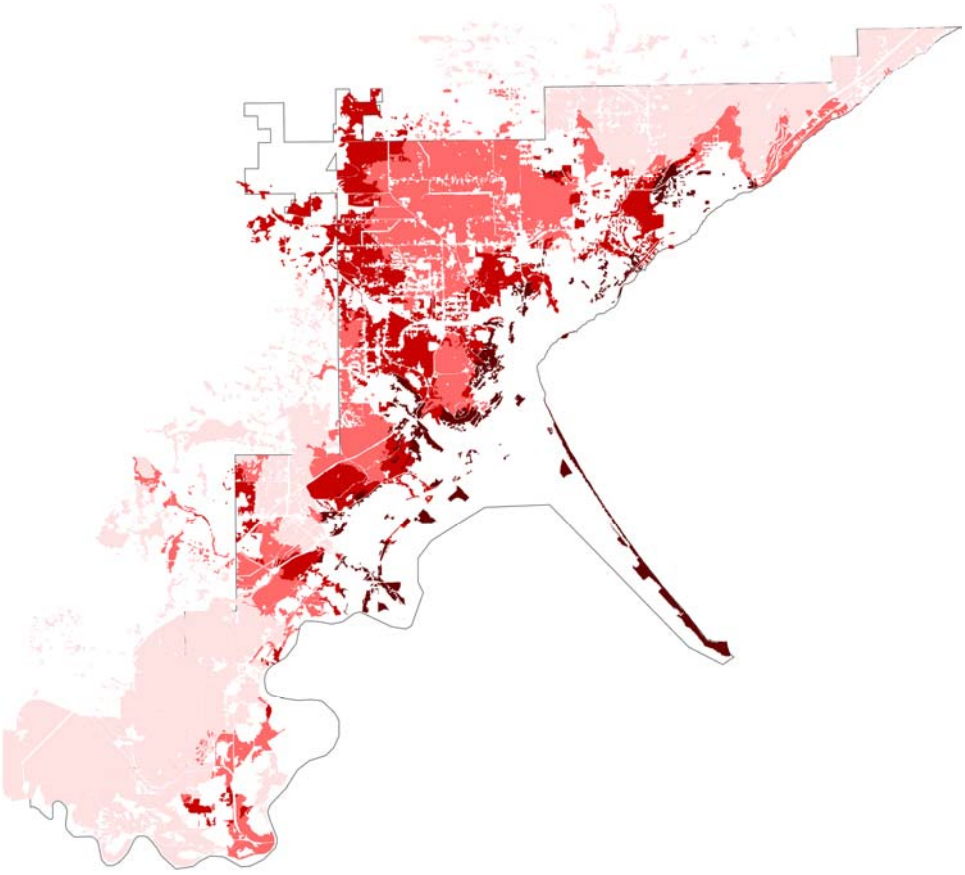
impervious surface proportion. In general the more impervious surface in a watershed or sub-catchment the more valuable the remaining natural land cover for watershed protection. By using the watershed proportion when it is higher than the sub-catchment proportion the value of relatively undeveloped sub-catchments in the headwaters of some watersheds is recognized.

Figure 6. Watersheds and sub-catchments



Watersheds (distinct colors) and sub-catchments (smaller polygons) in Duluth. Streams are shown as blue lines.

Figure 7. Four level map of stand watershed impervious cover score (darker colors are higher scores).



4.2.2.5. Minnesota County Biological Survey records (`mcbs`)

Minnesota County Biological Survey data was supplied as a collection of mostly circular polygons with areas ranging from 0.5 to 1,700 acres. MCBS staff advise against using the centers of these polygons, as polygon area reflects site size. Relating the individual MCBS polygons to the Duluth NRI forest and wetland polygons is problematic. A large MCBS polygon near Fon du Lac representing reed canary grass could be considered to apply only to the NRI wetland polygons in the St. Louis River in that vicinity. It might also be argued that the MCBS record should also be applied to the NRI upland forest polygons in the area as they represent the immediate watershed of the reed canary grass site. A nearby MCBS polygon representing a bald eagle nesting area should more obviously apply to all the wetland and forest NRI polygons it overlaps, as all these cover types are utilized by the bald eagle or its prey. MCBS sampling patterns and the rarity of some community types cause hot spots of overlapping observations. MCBS records are also graded according to level of rarity and state and federal status.

Treating these records as a general indicator of valuable habitat, we simply counter the number of MCBS polygons intersected by each NRI polygon (stand).

An ArcView GRID coverage was constructed such that each grid cell value was the number of overlapping MCBS polygons occurring at that point (). This illustrates MCBS observation overlap and hot spots. The ArcView extension X-Tools Union shapefiles operation was used to intersect and associate the MCBS and NRI polygons.

Figure 8. Density of overlapping Minnesota County Biological Survey observations.

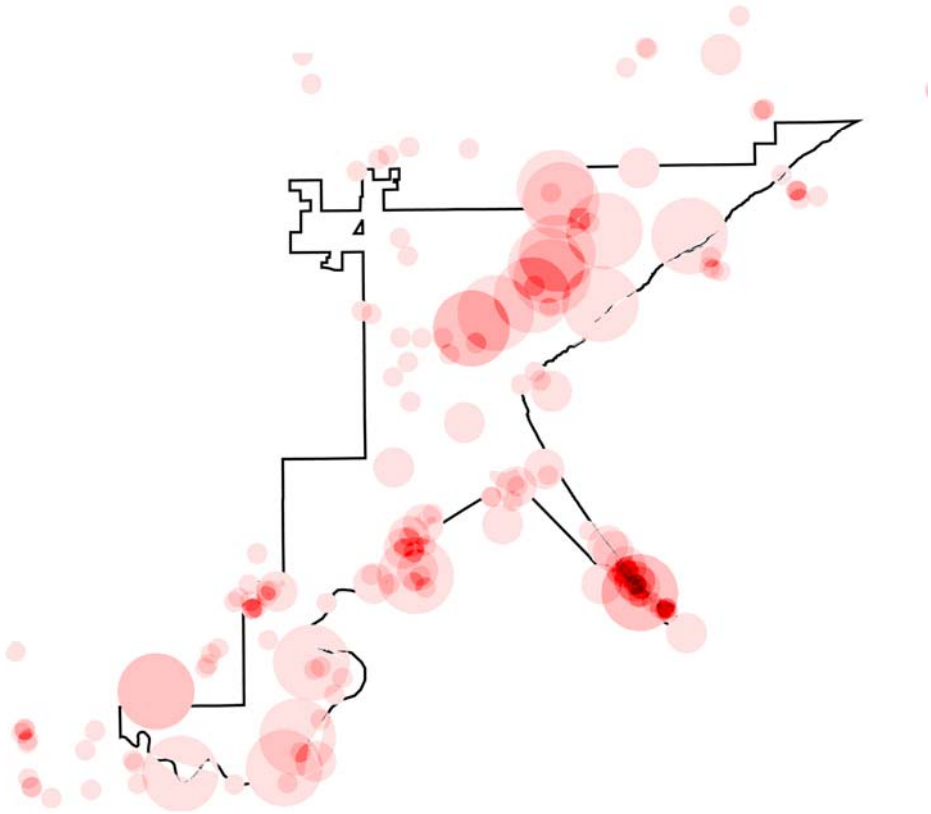
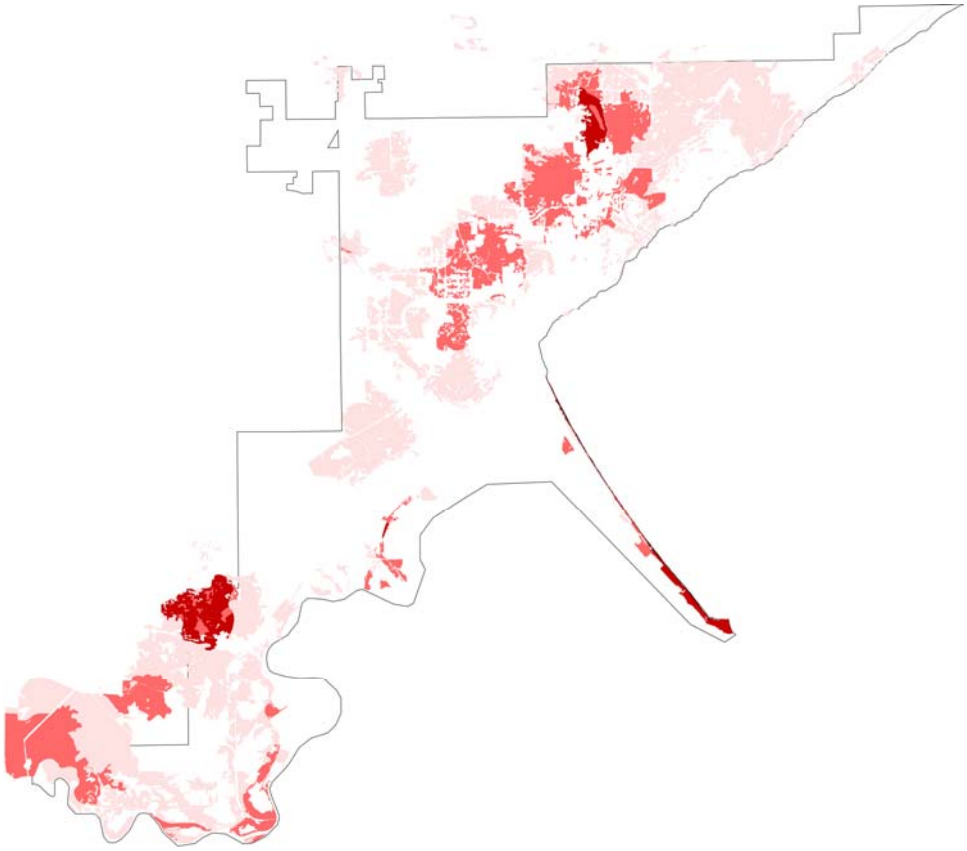


Figure 9. Four level map of Minnesota County Biological Survey records score (darker colors are higher scores).



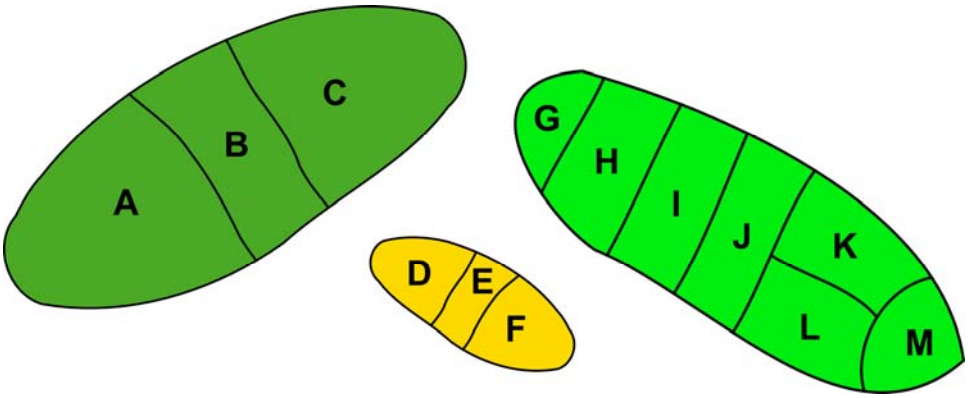
4.2.2.6. Connectivity impact (conn)

To calculate the impact on cluster connectivity of removing any one stand, the C++ computer code described previously () was modified to compare the total number of clusters present at a given connectivity threshold with and without the stand in question. Stands which do not break their cluster into two or more smaller clusters when they are removed returned an intermediate value "I" of zero. Stands which do break their cluster into two or more smaller clusters when they are removed returned a value I:

$$I = \frac{\text{Area of unbroken cluster}}{\left(\frac{\text{Area of largest new cluster}}{\text{Area of second largest new cluster}}\right)}$$

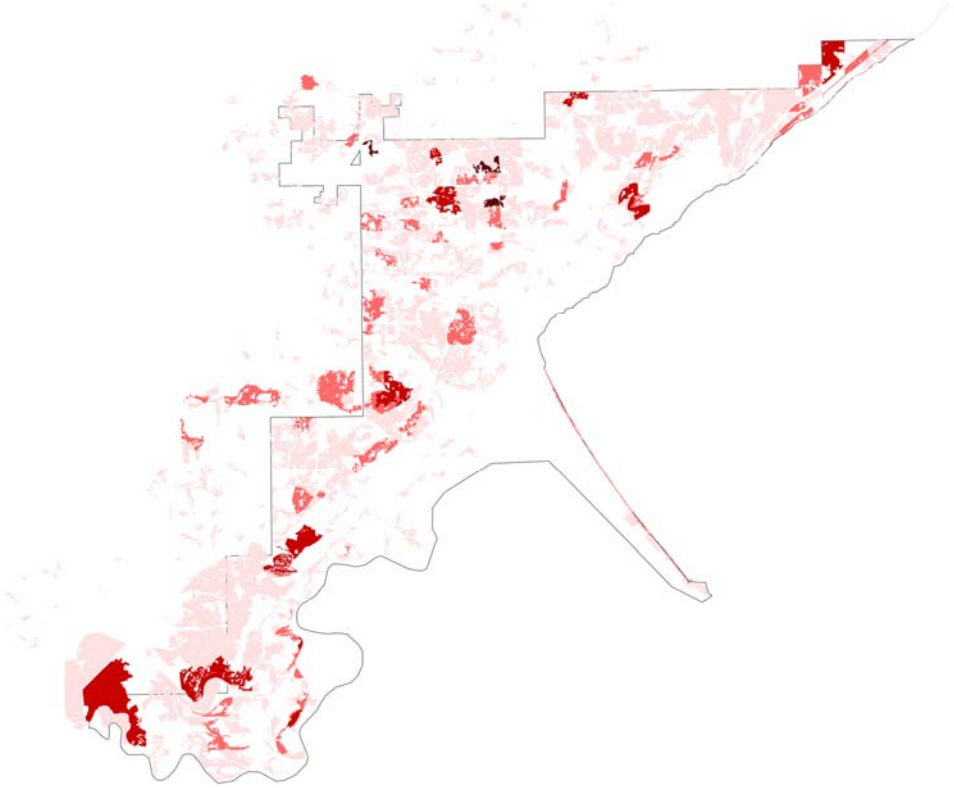
This gives a higher value to stands whose removal breaks a cluster approximately in half than those whose removal isolates only a small part of the cluster. Also the value of I is proportional to the size of the original cluster, so stands whose removal would break larger cluster score more highly. Figure illustrates various possible scoring scenarios.

Figure 10. Explanation of connectivity scoring



Three separate clusters. Removing stands A, C, D, F, G, or M would not increase the number of clusters, so these stands score zero for connectivity. Likewise removing stands K or L would not increase the number of clusters, as in each case there is an alternate route from J to M, so these stands also score zero for connectivity. Removing B would break a large cluster almost exactly in half, so B scores very highly for connectivity. Likewise removing J would break a large cluster almost exactly in half, so J scores very highly for connectivity. I scores a little lower than J, because its removal would break and cluster more unevenly than the removal of J. H scores even lower than I, because its removal would cause a very uneven break. Finally E gets a low score because while its removal breaks its cluster roughly in half, it was a small cluster to start with.

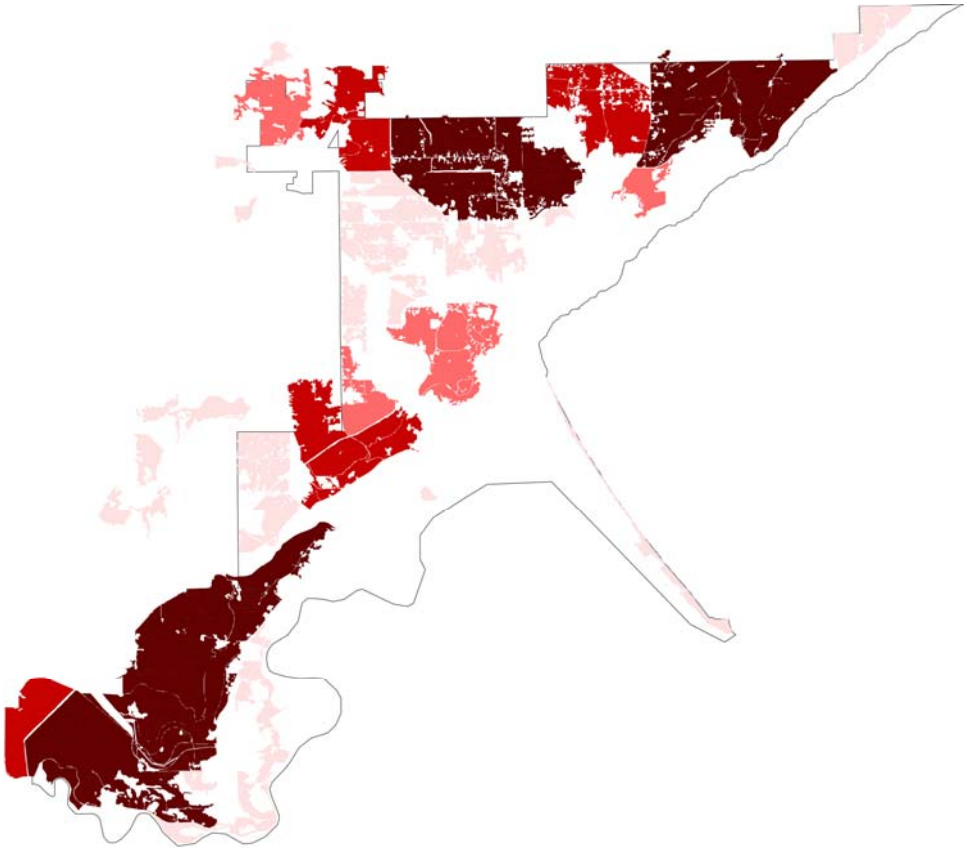
Figure 11. Four level map of stand connectivity score (darker colors are higher scores).



4.2.2.7. Parent cluster core area (`pcarea10`)

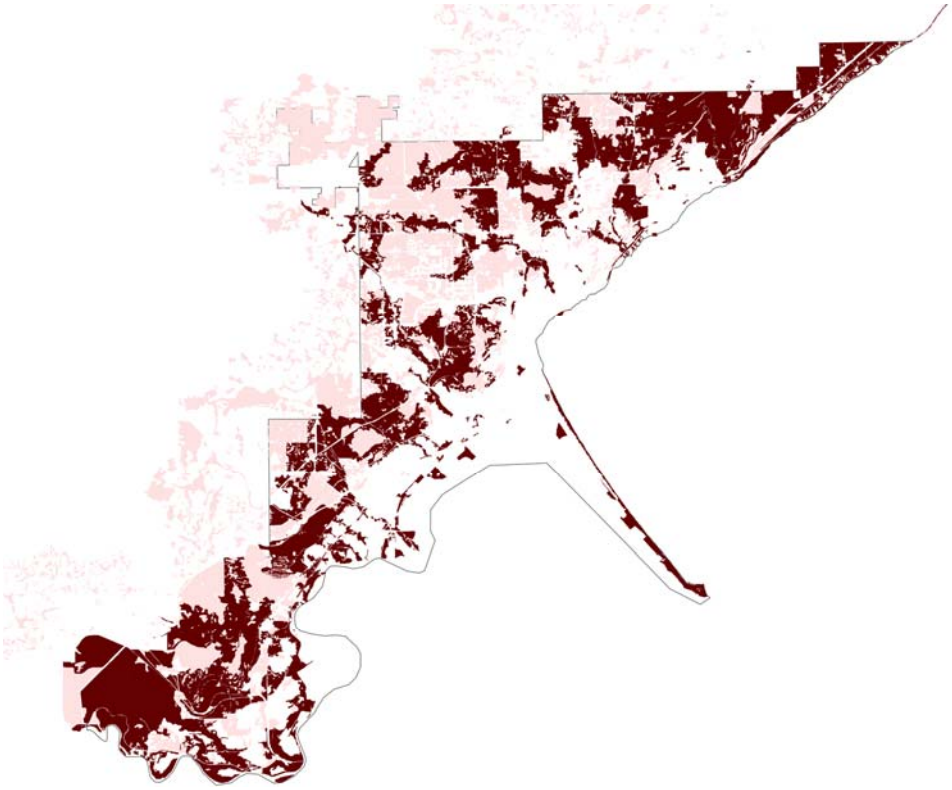
Stands were scored according the the amount of "core area" (area more than 150Â m from an edge) in the stand's cluster. 150Â m is a distance commonly given as the upper bound for edge derived stresses (for example).

Figure 12. Four level map of stand parent cluster core area score (darker colors are higher scores).



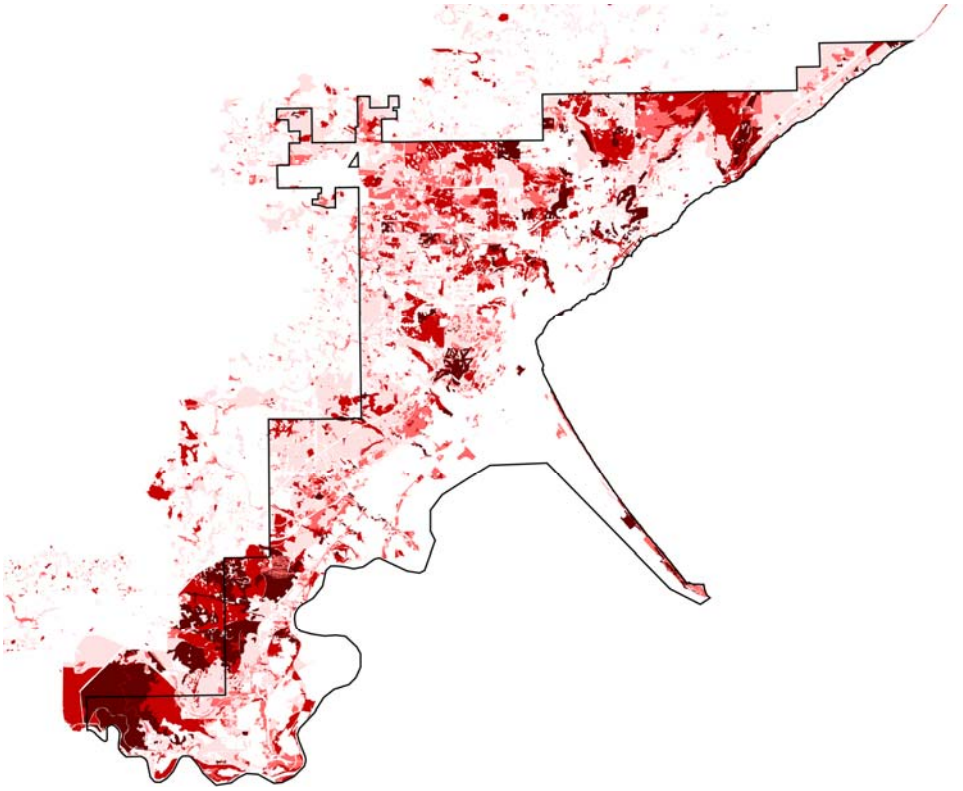
4.2.2.8. Water contact (`water`)

Figure 13. Four level map of stand water proximity score (darker colors are higher scores).



4.2.2.9. Forest type (`ftype`)

Figure 14. Four level map of stand forest type score (darker colors are higher scores).

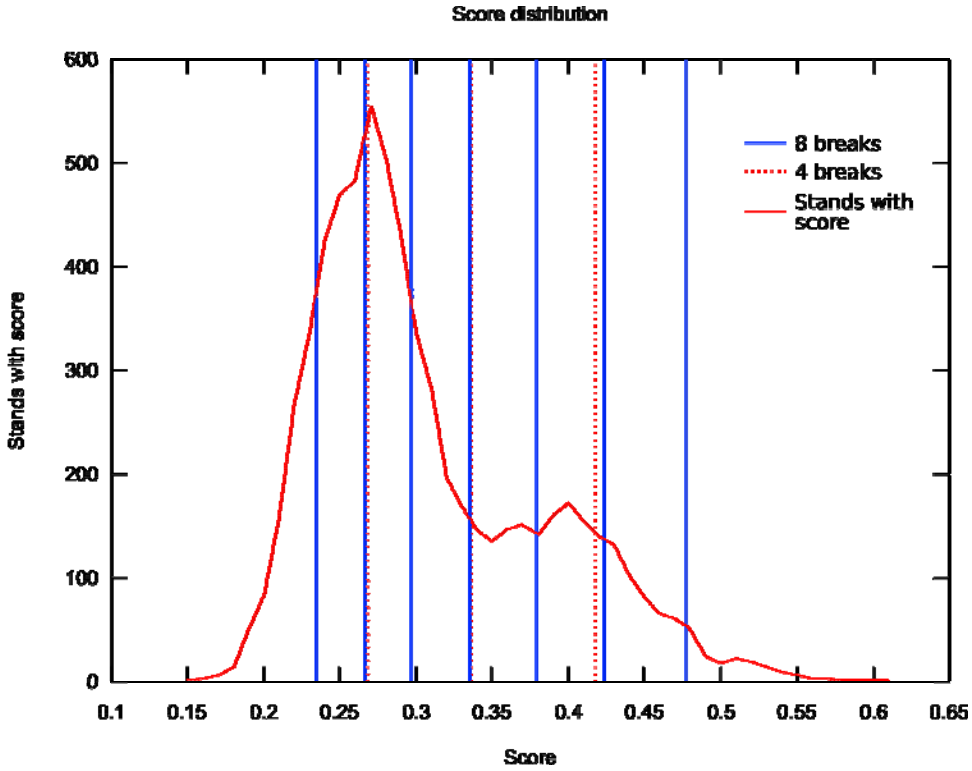


5. Results

5.1. Score distribution

The distribution of scores or ranks for all stands is shown in . Scores ranged from 0.15 to 0.6, to score zero or one a stand would need to score all zeroes or all ones on each individual attribute, which is unlikely. also shows the break points for a 4 and 8 level classification using ArcView's "natural breaks" classification scheme. These classifications should not be over-interpreted, they are an aid to visualization only. When using a map of these stands and scores we would *strongly encourage* the user to use an 8 level classification. Using the 8 level classification makes it much easier to identify cases where stands are in different classes but not very different from each other (any pair of adjacent classes, e.g. 3 and 4), and to identify cases where more significant differences exist (any pair of non-adjacent classes, e.g. 3 and 5).

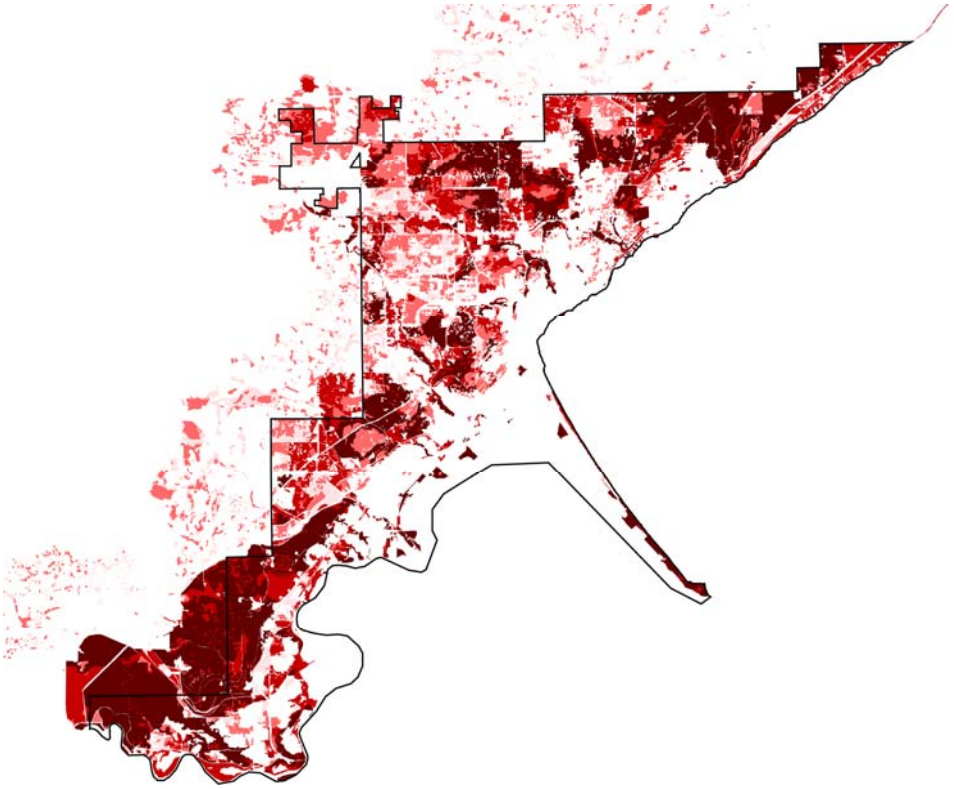
Figure 15. The distribution of scores or ranks for all stands.



5.2. General ecological value map

illustrates the distribution of ecological value based on the analysis of stands described here.

Figure 16. Map of regions of high ecological value in Duluth.



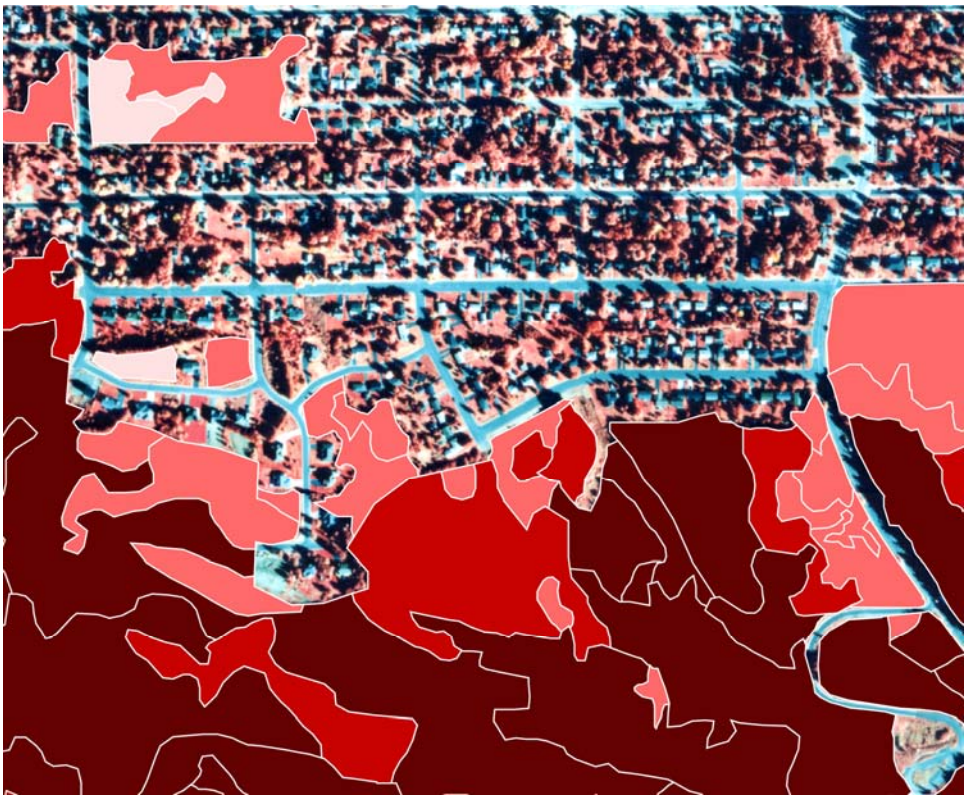
6. Discussion

6.1. Possible application

Figure 17. Possible application scenario for results.

When attempting to layout zoning for the undeveloped area (vegetated areas in image above), or place a development within it, the ecological value map should be used as a guide.

Figure 18. Possible application scenario for results.



Here it can be seen that the vegetated land adjacent to existing housing score lower on the left than on the right, suggesting that that might be the better area to consider for development.

6.2. Caveats and things to bear in mind

This Natural Resource Assessment scores and ranks almost seven thousand stands of natural or semi-natural land cover within the city of Duluth. It is intended for large scale planning and screening applications. While it provides an excellent starting point for evaluating specific sites, any project tied to a specific site should conduct an early on-site inspection and consult other map layers as necessary.

Stands of natural land cover may have value for reasons not considered by this analysis, and low scoring stands should not be regarded as disposable without further site specific analysis.

Bibliography

Biodiversity Guidebook, 1995, Ministry of Forests and Range, Canada.

A. Duluth NRI cover types

Csa_type_ field	Description	Number	Total area
Agriculture	Agriculture	6	46.4
Ash	Ash	968	2625.5
Ash/Aspen	Ash/Aspen	2	20.9
Ash/B.Fir	Ash/Balsam Fir	2	39.4
Ash/W.Cedar	Ash/White Cedar	3	7
Aspen	Aspen	1138	11382.1
Aspen/B. Fir	Aspen/Balsam Fir	3	25.4
Aspen/Birch	Aspen/Birch	105	2187
Aspen/N.Hardwood	Aspen/Northern Hardwood	59	2117.1
Aspen/Oak	Aspen/Oak	2	38.6
B. Fir/B. Spruce	Balsam Fir/Black Spruce	1	1.4
B. Fir/W. Cedar	Balsam Fir/White Cedar	1	1.8
B. Fir/W. Spruce	Balsam Fir/White Spruce	1	2
Balsam Fir	Balsam Fir	12	37.8
Bare Soil	Bare Soil	10	72
Birch	Birch	115	1432.8
Birch/Aspen	Birch/Aspen	13	218.1
Birch/N.Hardwood	Birch/Northern Hardwood	5	518.2
Birch/Red Pine	Birch/Red Pine	1	5.3
Birch/W. Cedar	Birch/White Cedar	2	14.7
Black spruce	Black spruce	95	454.3
Cottonwood	Cottonwood	2	1.2
Jack Pine	Jack Pine	14	20.8
LF	LF	5	3
Lowland Brush	Lowland Brush	1258	3517.8
Lowland Grass	Lowland Grass	483	1019.7
Lowland Hardwood	Lowland Hardwood	117	439.9

Csa_type_ field	Description	Number	Total area
Marsh	Marsh	106	439.2
N. Hardwoods	Northern Hardwoods	151	2431.2
N.Hardwood/Aspen	Northern Hardwood/Aspen	1	9.7
N.Hardwood/Birch	Northern Hardwood/Birch	1	10.7
Non-Permanent Wa	Non-Permanent Wa	111	116.1
Oak	Oak	16	237.2
Permanent Water	Permanent Water	235	459
Recreation Devel	Recreation Devel	89	1050
Red & White Pine	Red & White Pine	5	21
Red Pine	Red Pine	98	200
Roads	Roads	37	115.2
Rock Outcrop	Rock Outcrop	154	191.1
Scotch Pine	Scotch Pine	5	32.4
Upland B. Spruce	Upland Black Spruce	1	1
Upland Brush	Upland Brush	438	1705.9
Upland Grass	Upland Grass	767	2290.7
Urban Development	Urban Development	114	728
W. Cedar/Aspen	White Cedar/Aspen	2	23.6
W. Spruce/Aspen	White Spruce/Aspen	1	2.1
W. Spruce/B. Fir	White Spruce/Balsam Fir	3	13.4
W. Spruce/R. Pin	White Spruce/R. Pin	1	2.1
W. Spruce/W. Pin	White Spruce/W. Pin	1	1.1
W.Spruce/Aspen	White Spruce/Aspen	1	7.5
White & Red Pine	White & Red Pine	1	9.4
White Cedar	White Cedar	3	9.6
White Pine	White Pine	40	240.2
White Pine/Spruce	White Pine/Spruce	1	2.9
White Spruce	White Spruce	26	45.2
Willow	Willow	24	56.7
[Blank]	Non-forested wetland	103	395.7
Industrial Devel	Industrial Development	116	2045.9

Appendix C

Development Suitability Index Technical Memorandum

TECHNICAL MEMORANDUM

To: Development Suitability Index File

From: Diane Desotelle, Natural Resources Coordinator, Ben Van Tassel, Community Planning, Chad Ronchetti, Business Development, Heidi Timm-Bijold, Business Development, Bryan Pittman WSB & Associates, Inc.

Re: Methodology for City-Wide GIS Development Suitability Index

Date: December 27, 2018

The City of Duluth used agreed upon variables and a scoring/ranking matrix to determine suitable areas for development across the city. The result is a GIS layer that shows areas on a continuum from lowest to highest for development suitability. This memo describes the variables included in the analysis. The data is stored with the city's GIS department. If the analysis is amended or adapted in the future, this memo should be updated as well.

The variables and the weights used for the analysis include:

Slope
Source: Lidar Elevation, Arrowhead Region, NE Minnesota, 2011. Minnesota Department of Natural Resources (MnDNR)

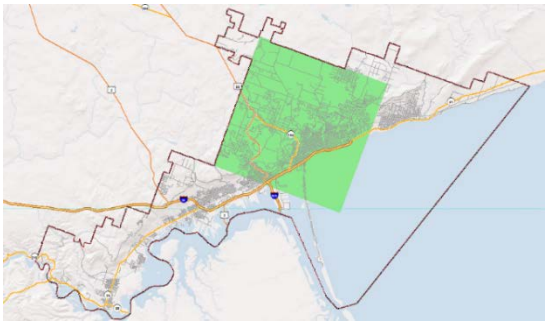
Weight:

- 20% or Greater (score = 0)
- 10.00% - 19.99% (score = 3)
- 9.99% - 0% (score = 5)

Natural Heritage Information System (NHIS)
Source: Rare Natural Features – Polygons, 1800's to Present. The Natural Heritage & Nongame Research Program of the MnDNR, Division of Ecological Services

Weight:

- The land associated with a threatened, endangered or special concern species and its buffer area. (score = 0)
- A historic piece of data attributed all of Township 50 Range 14 of the Public Land Survey System as a distorted buffer (see figure), and therefore, the team decided it was appropriate to increase the development potential in that area. (score = 1)
- The land not associated with a threatened, endangered or special concern species. (score = 3)



Highways
Source: City of Duluth, Classification based on the Route System and Route Number provided by Minnesota Department of Transportation

Weight:

- Under ¼ mile from Interstate (score = 5)
- ½ mile from Principal Arterial (score = 3)
- everything else (score = 0)

City Parks, Duluth Natural Areas, and MN Science and Natural Areas
Sources: City of Duluth's Parks and DNAP areas and MnDNR, 2003 - MN Scientific and Natural Areas

Weight:

- Inside any of these areas (score = 0)
- Outside any of these areas (score = 1)

Sensitive Lands Overlay
Source: City of Duluth's sensitive lands overlay resulting from the report associated with the 2006 Comprehensive Land Use Plan. Report: Brown, Terry and Tom Hollenhorst, A Natural Resources Analysis for Duluth's Natural Resources Inventory, University of Minnesota, Duluth – Natural Resources Resource Institute, 2006.

Weight:

- Inside the sensitive lands overlay (score = 0)
- Outside the sensitive lands overlay (score = 1)

Union of both the Shoreland Overlay and the 500 year Floodplain
Floodplain Source: Federal Emergency Management Agency (FEMA), Digital Data Created in the 1980s & 1990s
Shoreland Overlay Source: City of Duluth, 2010 revision as part of the development of the Unified Development Chapter. These are Lands within 1,000 feet of a lake or within 300 feet of a river and its floodplain and is designated on the City's Natural Resources Overlay (NR-O) map. *(Note: The limits of shorelands may be less than the above limits whenever the waters involved are bounded by topographic divides that extend landward from the waters for lesser distances and when approved by the commissioner.)*

Weight:

- Inside the total merged area of these two data sets (score = 0)
- Outside the total merged area of these two data sets (score = 5)

National Wetlands Inventory
Source: MnDNR, Ducks Unlimited, and St. Mary's University of Minnesota, 2018.

Weight:

- Wetland (score = 0)
- Not a wetland (score = 1)

Soils
Source: Natural Resource Conservation Service (NRCS), United Stated Department of Agriculture (USDA). Accessed November 2018.

Weight:

- A or B Hydrologic Group (score = 3)
- C or D Hydrologic Group (score = 0)

Depth to Bedrock
Source: Minnesota Geological Survey (MGS), 2010. These depths were chosen for the feasibility of constructing a foundation or putting in utilities. Bedrock within 8 feet of the surface makes it difficult to put in a foundation and utilities, bedrock 8-14 feet under the surface may cause some disruption with construction, bedrock more the 14 feet under the surfaces typically doesn't cause any disruption.

Weight:

- 0 feet – 7.99 feet (score = 0)
- 8.00 feet – 13.99 feet (score = 2)
- 14.00 feet or Greater (score = 5)

Brownfield Sites
Source: Brownfield sites were inventoried (2014) in the West Port Area Neighborhood Plan (Irving and Fairmont) and digitized (2017) as a part of the Area Wide Plan. Brownfield inventories were limited to those neighborhoods.

Weight:

- Inside a brownfield (score = 3)
- Outside a brownfield (score = 0)

Core Investment Areas (CIAs)

Source: City of Duluth, 2018 - Twelve initial CIAs were identified during the Imagine Duluth, Comprehensive Plan 2035. The CIA boundaries have not been officially determined. Intersections identified were buffered by 500-ft to create an estimated boundary. The Kenwood CIA has been refined through rezoning, and was included, but it was not officially adopted at the time of this analysis.

Weight:

- Within 500 feet of a core investment area (score = 3)
- Greater than 500 feet from a core investment area (score = 0)

Core Investment Area Name	Approximate Location
Gary New Duluth	Commonwealth & Gary
Morgan Park	88th & Edward
Spirit Valley	Central & Grand
Piedmont	Morris Thomas & Chambersburg
Lincoln Park	Superior St. – 22nd to 17th Ave. W.
Mall Area	Matterhorn / Decker
Duluth Heights	Central Entrance & Arlington
Hillside	4th St. – Lake to 6th Ave. E.
Kenwood	Kenwood & Arrowhead
Mount Royal	St. Marie & Woodland
Woodland	Calvary & Woodland
Lakeside	Superior St. – 43rd to 46th Ave. E.

Sewer & Water Utilities

Source: City of Duluth, 2018. The average depth of utilities in the City is 7.5 feet and the minimum depth to prevent freezing is 6 feet, which is a 1.5-foot difference. Using an average slope of 0.5%, which is standard for the City of Duluth, utilities can be extended outwards 300 feet (1.5 feet/.005) before reaching minimum depth. Therefore, locations within 300 feet of a sanitary sewer or watermain pipe are more suitable for development.

Weight:

- Within 300 feet of a sanitary sewer or watermain (score = 3)
- Greater than 300 feet from a sanitary sewer or watermain (score = 0)

GIS Analysis

The GIS methodology used to assess the matrix of variables involved converting all data layers into raster data. All layers started as vector data except slopes and depth to bedrock. The raster data was then reclassified to match the agreed upon scoring values, for example anything within a brownfield was reclassified to 3 and everything in the city outside a brownfield was reclassified to 0. These reclassified raster data layers were then overlaid and summed together using the raster calculator tool within ArcGIS.

The final suitability layer can be shown using both a 5-class and 3-class breakdown. The 5-Class breakdown shows areas in the city as Lowest Suitability, Low-Moderate Suitability, Moderate Suitability, High-Moderate Suitability, and Highest Suitability. These break points were chosen to show approximate percentages per class, with the lowest 2 classes comprising half of the city, and the highest 3 classes comprising the other half. The 3-Class breakdown shows areas in the city as Recreational Development, Low Impact Development, and Standard Development. These break points were also chosen as an approximate percentage per class, with the lowest class (Recreational Development) comprising about 40% of the city, the middle class (Low Impact Development) comprising the next 30%, and the highest class (Standard Development) also comprising 30% of the city.