Statewide Ranking of Ecological Value of CRP and other Critical Lands

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Introduction

Minnesota's natural lands face many kinds of pressures, from human development to increased demands on agricultural productivity. This project is designed to identify ecologically important land parcels, with the objective of more effectively targeting conservation programs to Conservation Reserve Program (CRP) and other critical lands. Other critical lands could include marginally productive crop-lands, surface water protection areas, or important habitat areas.

As defined for this project, the conservation value of a parcel of land is based on several factors:

- the soil erosion risk of the land based on soil and slope characteristics
- the water quality risk of the land based on the shape of the terrain and its proximity to surface water
- the habitat quality based on the Statewide Conservation and Preservation Plan

These factors are integrated into an Environmental Benefits Index (EBI) - a score which represents a summary of the above factors. This methodology has unique characteristics; it includes soils and landscape (terrain) analysis which are relatively new to conservation targeting efforts. It addresses erosion potential and runoff potential. It also includes surface water quality, and wildlife habitat factors. Finally, the EBI integrates these layers to address multiple conservation benefits simultaneously.

A web site was produced (*www.nrri.umn.edu/EcolRank*) to provide a mapping tool by which natural resource managers can visualize and interact with spatial data layers developed for the project. Managers have the ability to specify the relative importance of habitat, soil erosion potential, or other components of the EBI, and view how the ecological ranking of parcels changes under different scenarios. All data developed by the project can be downloaded.

The ecological ranking tool has several applications. It can be used to identify parcels of high conservation value within a county, township, watershed, or other area of interest. The ecological ranking can be coupled with an economic analysis to identify parcels that, because of their economic value, are likely to exit the CRP. This information can inform the targeting of conservation activities to best balance land conservation, surface water quality, and economic objectives. The ecological ranking tool provides a methodology that may help guide the allocation of conservation funds to the most critical lands.

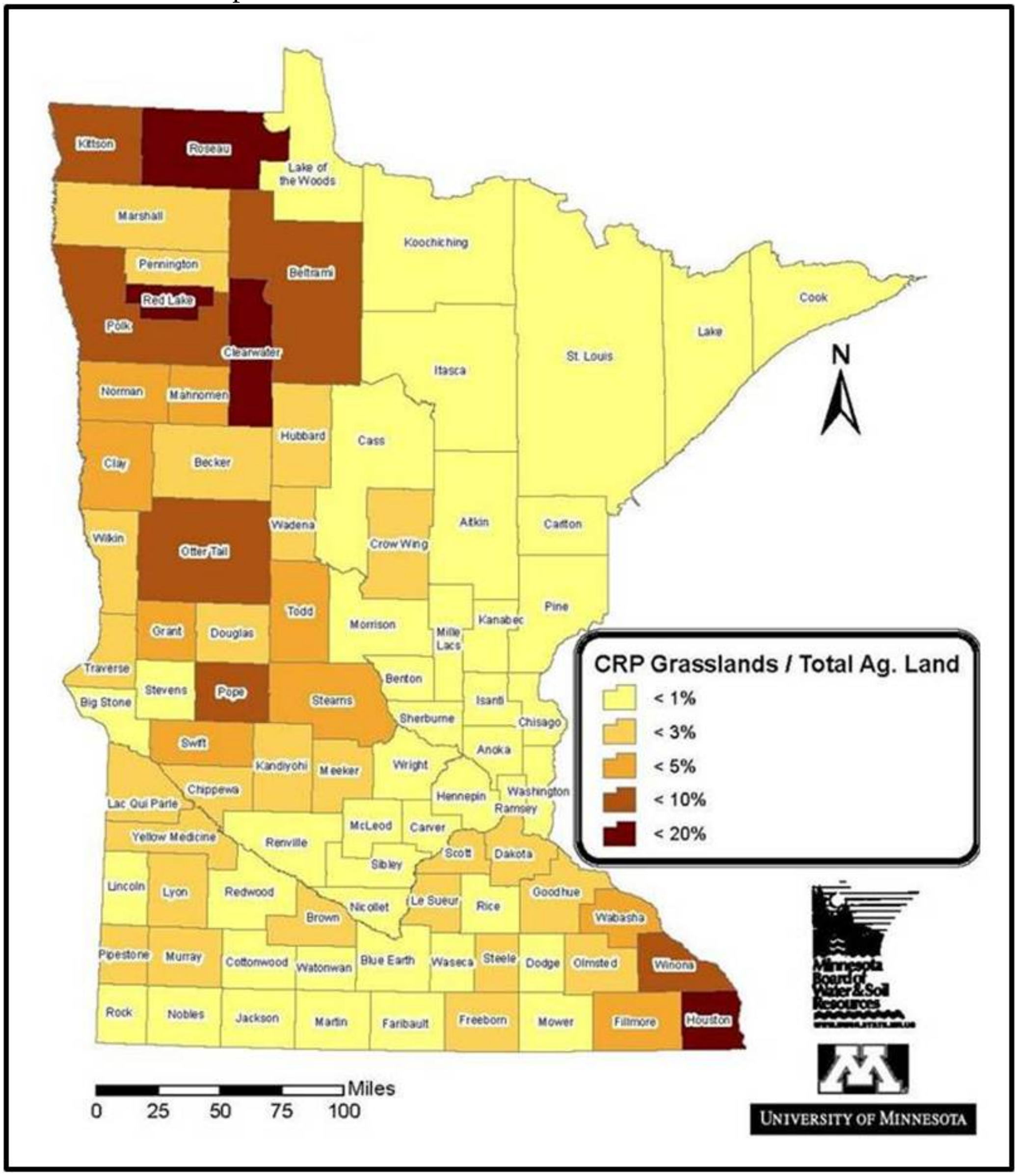
This work is a collaborative effort between the Board of Soil and Water Resources and the University of Minnesota.

Economic Model

An economic model was developed to analyze all CRP parcels and determine whether contract renewal was financially prudent. The economic model is similar in concept—but not in detail—to those used in Valentas et al. (2009) and in Turner et al. (2010). The logic is simple: if the price offered for a given crop is high enough, the owner will switch from whatever was being grown before (if different) to the demanded crop. In the present version, each Conservation Reserve

Program (CRP) parcel owner faces the decision: given 2010 prices and costs, is it financially prudent to renew the existing CRP contract? For present purposes, it is assumed that all examined contracts expire in 2010 and can be renewed or not renewed without penalty.

Fig. 1: Percent CRP grassland acres potentially expiring relative to total agricultural land area. Many of these acres are expected to be re-enrolled.

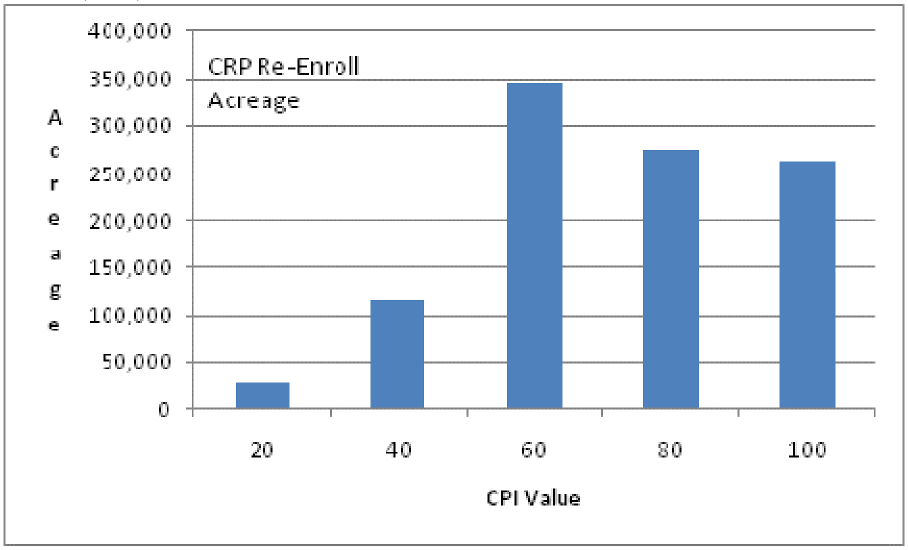


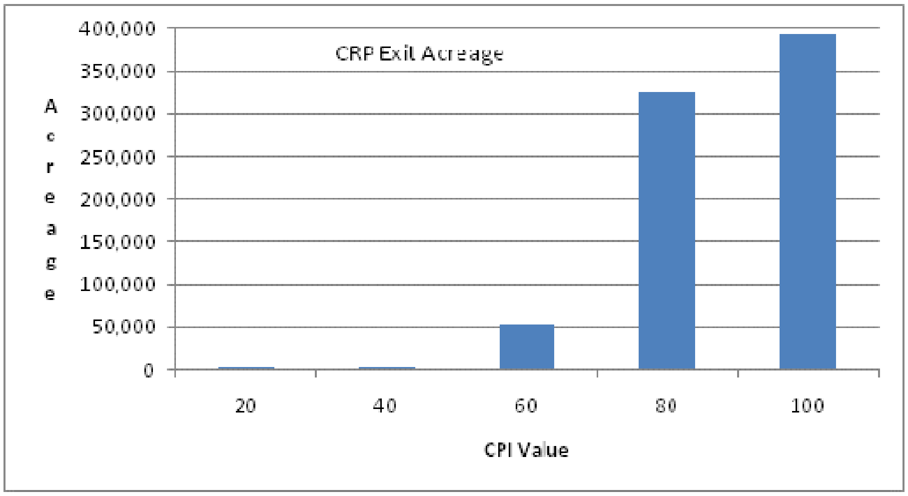
The prediction model is a set of Microsoft Access queries that mimic farmer crop selections for each parcel at each crop price level. The variable factors are crop choices, crop yields, crop production costs (including shipping and handling), and crop prices. Land owners are assumed to select the crop that promises the highest annual net return. Decisions on crop selection are made at CRP parcel level. In the model, "parcels" are defined as all geographically discrete parcels currently (2007) in CRP.

Results of the CRP economic analysis predicted that 47,195 CRP parcels covering an area of 774,540 ac are predicted to exit the CRP program based on current economic data. Keeping all of these parcels in CRP would require incentive payments totaling $95,327,478/yr.

There are significant differences in the productivity of soil for CRP parcels predicted to exit the program as compared to the productivity for CRP parcels predicted to re-enroll in the program. The average area weighted crop productivity index (CPI)[1] value for CRP parcels predicted to exit the program is 78.1, whereas it is only 62 for parcels predicted to re-enroll in the program. Even more telling is the variation in CRP acreage by CPI value for parcels predicted to exit the program as compared with parcels predicted to re-enroll in the program (Fig. 2).

Fig. 2: a) Acreage of CRP parcels predicted to re-enroll in the program by Crop Productivity Index (CPI) value, and b) acreage of CRP parcels predicted to exit the program by Crop Productivity Index (CPI) value





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[1] CPI, or Crop Productivity Index, is based on soil physical and chemical properties important to crop growth. The index ranks all soils from 0 to 100, with 100 being the most productive.

It may be more economically optimum to let highly productive CRP parcels exit the program. Retaining the less productive CRP parcels in the program could be achieved with lower incentive payments. It would cost roughly $3,875,000/yr in incentive payments to keep 56,000 ac of CRP with CPI values less than 60 enrolled in the program. These parcels represent marginally productive land.

Soil Erosion Risk

The potential for soil erosion is based on a number of factors, including climate, soil type, and slope characteristics. We summarized these using factors from the Universal Soil Loss Equation. The Soil Erosion data layer represents a general risk score for potential soil erosion on a 0-100 point scale, 100 being the highest risk. Larger values indicate soils that have a higher potential to erode if no conservation practices were in place and overland sheet or rill runoff was present.

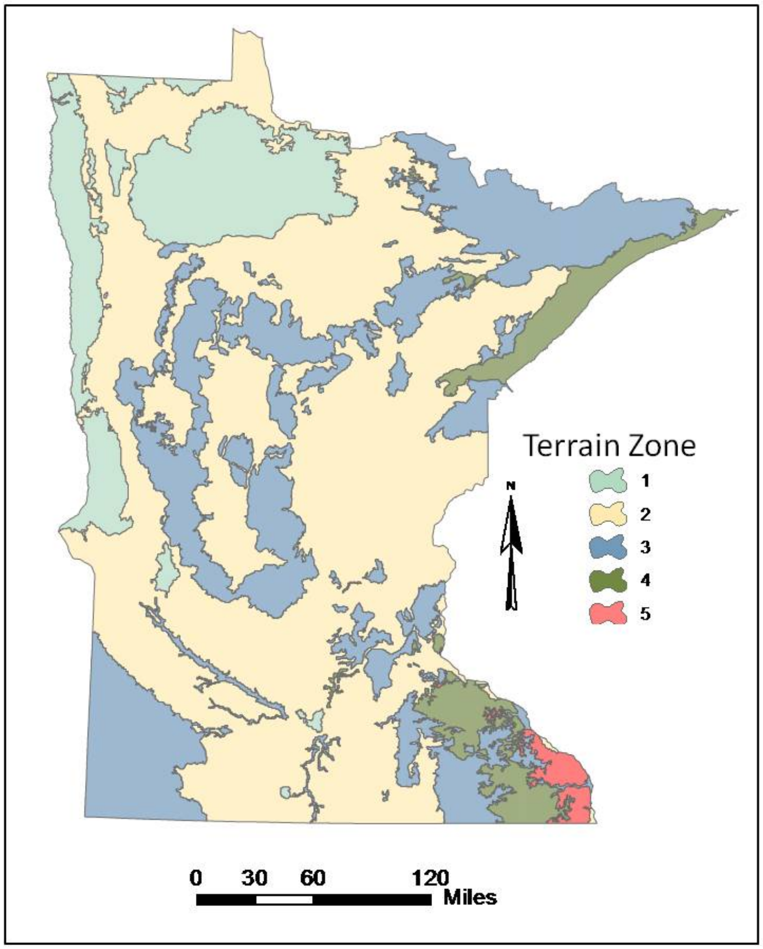
A subset of the Universal Soil Loss Equation (USLE) was used to determine soil erosion risk values. The USLE is a multiplicative equation using the formula $A = R \times K \times LS \times C \times P$ where:

- A = potential long term average annual soil loss in tons/acre/year
- R = rainfall and runoff erosivity factor
- K = soil erodibility factor
- LS = slope length-gradient factor
- C = crop/vegetation and cover management factor
- P = support practice factor

The R (Rainfall Runoff Erosivity), K (Soil Erodibility), and LS (Length/Slope) factors were used and calculated based on NRCS spatial and tabular Soil Survey Geographic (SSURGO) Database soils data, statewide county climate maps, as well as mathematical formulas based on standard USLE calculations.

These data were divided into five state-wide terrain zones, and percentile ranks were assigned to erosion risk values for each individual zone, and then spatially merged into one data layer. These terrain zones used to stratify slope-related data represent physiographic regions of Minnesota with similar slope characteristics, and remove bias from landscapes with extremely high relief (Fig. 3).

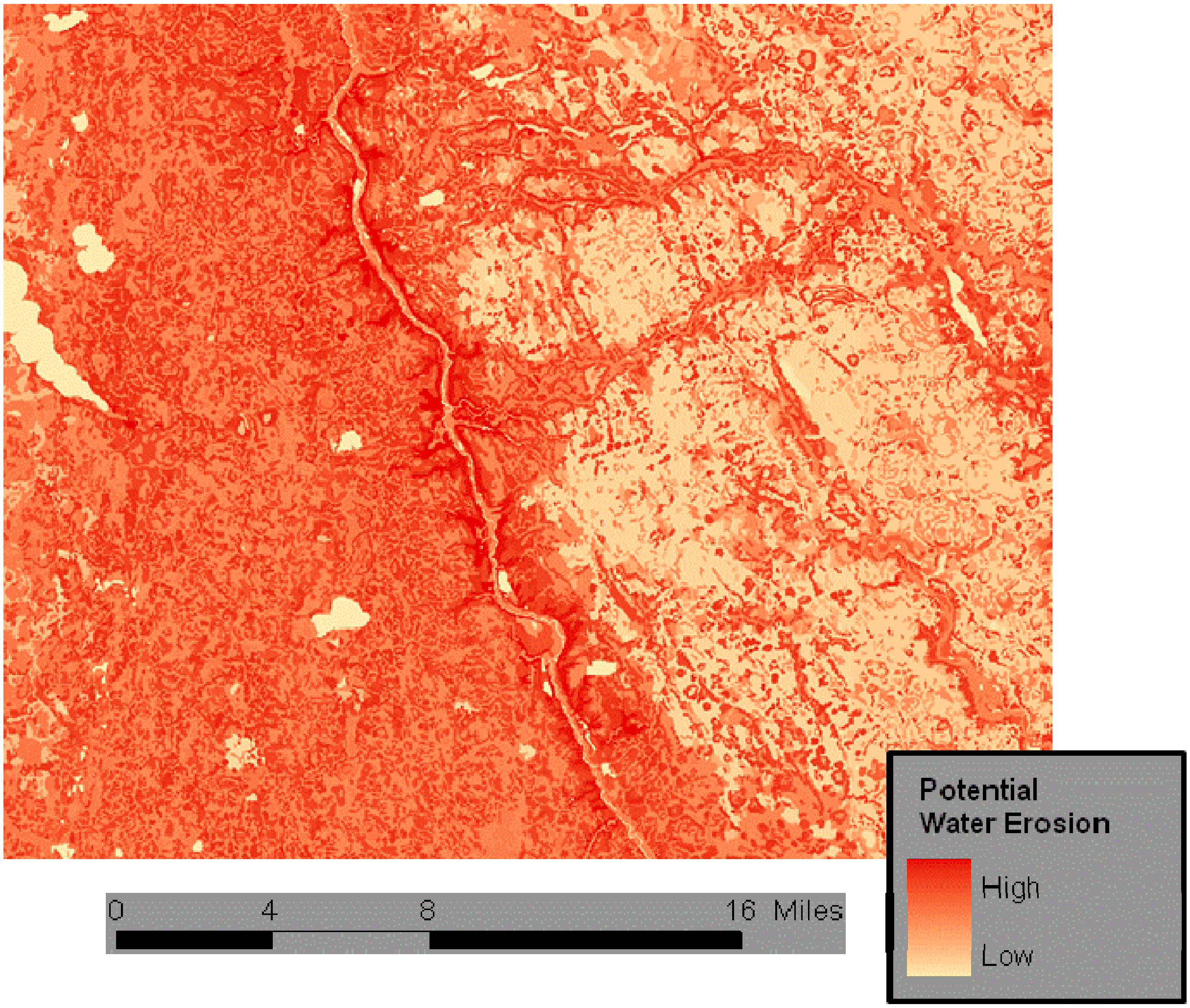
Fig. 3: Terrain zones used to stratify slope-related data statewide.



The crop/vegetation and cover management factor (C) and support practice factor (P) were not used. This is because there are no reliable statewide spatial data that represent these factors. Although statewide data depicting current cropping practices exist, there are no statewide data representing current tillage methods (e.g. fall plow, ridge tillage, no-till) or support practice (e.g. cross slope, contour farming, strip cropping) that are required for these calculations. Furthermore these factors are temporal and will therefore shift over time.

Since only non-management factors were used, the resulting data layer should be viewed as a "worst-case" scenario, i.e. highest potential soil erosion of bare soil with no mitigating land use practices in place (Fig. 4). Although quantitative soils loss numbers (tons/acre/year) may be exaggerated under this model, the resulting data layer is used here in a qualitative, comparative capacity in order to evaluate the relative differences in soil loss risk between various parts of the landscape. The higher the erosion potential, the greater the conservation need.

Fig.4: Potential risk from water erosion for a selected region of Minnesota.



Water Quality Risk

The risk score for Water Quality ranges from 0-100, with larger values indicating areas that are more likely to contribute overland runoff than smaller values. This risk was defined using two data sources: Stream Power Index and proximity to water.

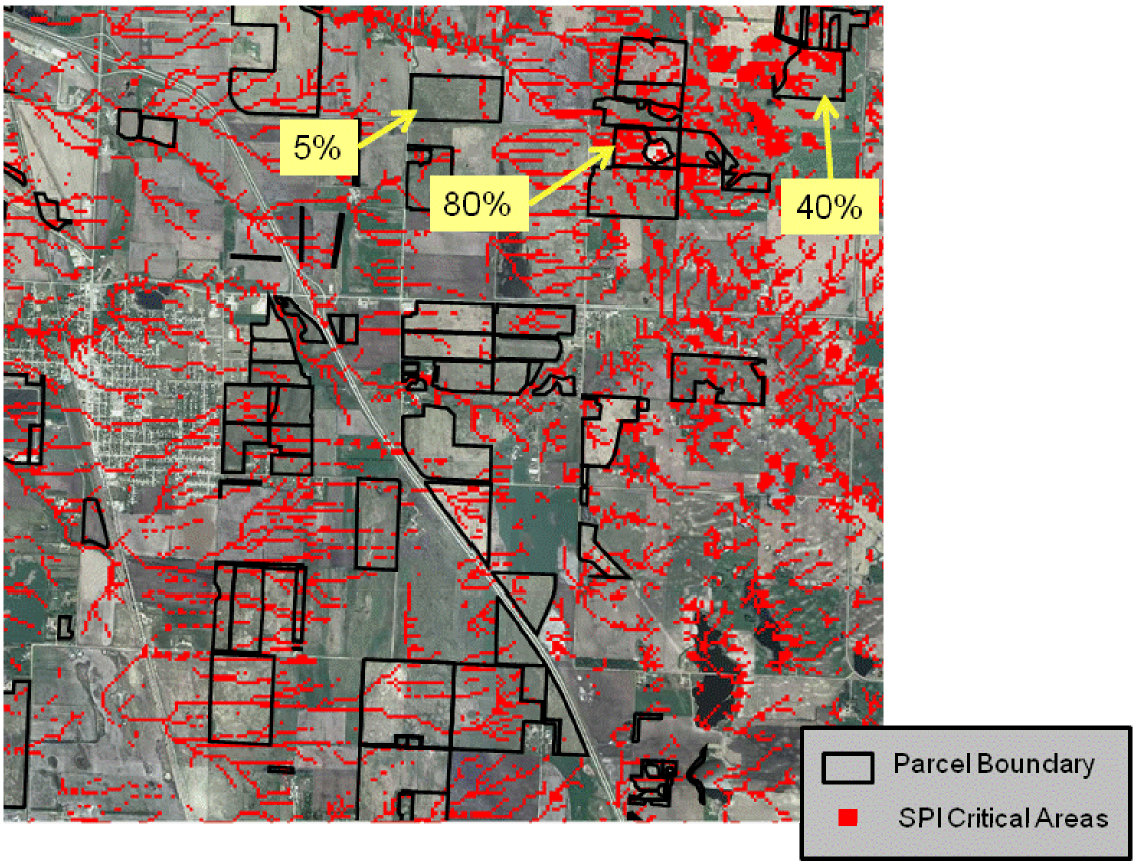
Stream Power Index

Terrain analysis is used to estimate Stream Power Index (SPI), a runoff potential based on 30 m Digital Elevation Models (DEMs). SPI is estimated from flow accumulation and slope steepness. As flow accumulation and slope steepness increase, runoff potential also increases.

Stream Power Index (SPI) measures the erosive power of overland flow. SPI was calculated statewide, but summarized by terrain zones, which represent physiographic regions of Minnesota with similar slope characteristics. The use of terrain zones again removes bias from landscapes with extremely high relief. Large SPI values (i.e. those in the 85th percentile or higher) from each of the five terrain zones were used to create a critical area layer where overland erosion is likely to occur. These critical SPI areas were summarized by SSURGO soil polygons: the proportion of SPI critical areas within each SSURGO polygon was used to assign a percentile rank to these polygons, the larger the proportion of critical SPI data, the larger risk score for that polygon. This percentile rank represents 50 of the total 100 points for this risk layer.

The proportion of any parcel above the SPI critical threshold can be calculated (Fig. 5). These are then ranked and assigned values. Highest conservation value is given to parcels with the highest proportions of area above the SPI critical threshold.

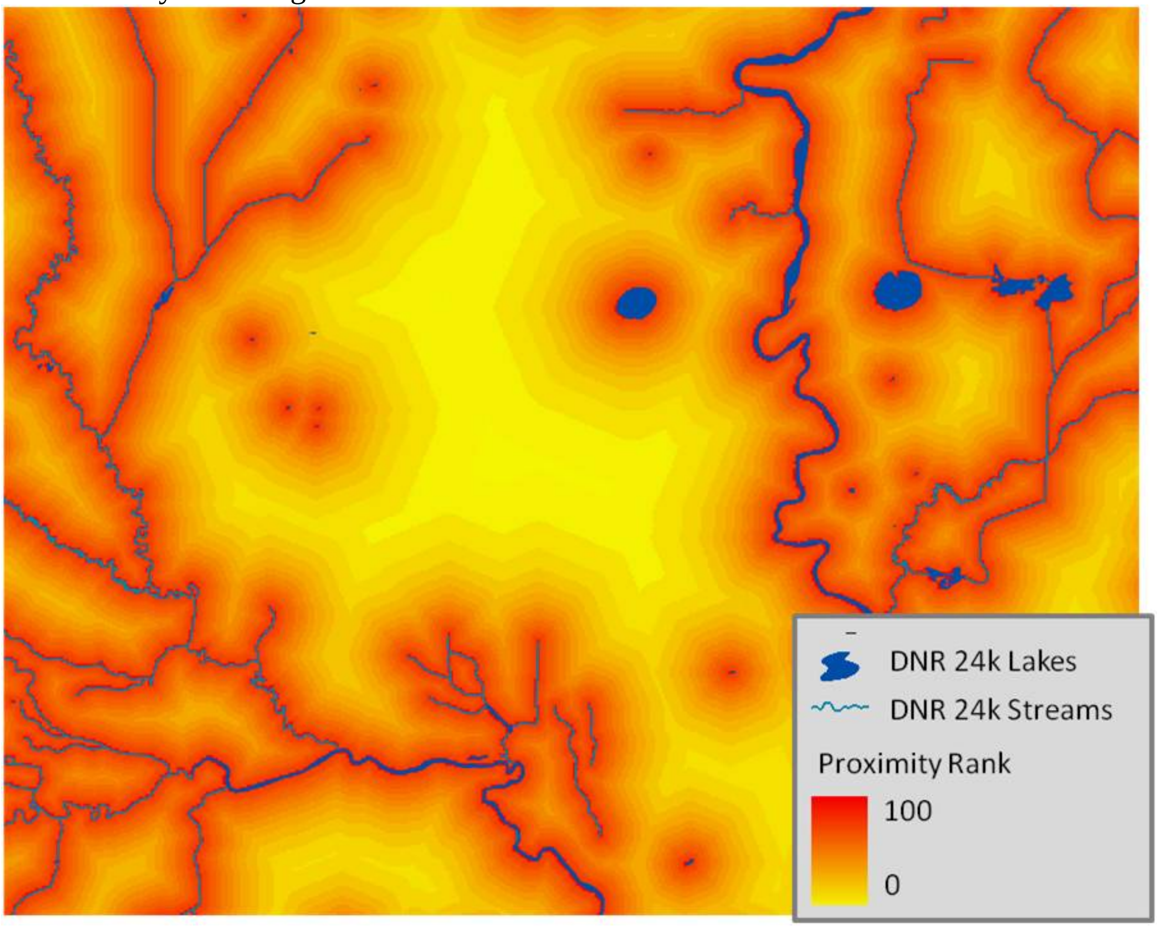
Fig. 5: Percentage of selected land parcels having Stream Power Index (SPI) values above the critical threshold value.



Proximity to Water

The remaining points in the Water Quality Risk layer were determined by calculating proximity from each 30 m pixel to the nearest DNR 24k surface water feature (Lake or Intermittent/perennial stream). Proximity to surface water affects delivery of sediment and other pollutants in runoff (Fig. 6). Land in close proximity to surface water generally has a higher sediment delivery ratio than land farther away. A percentile rank of these proximity values assigned to each 30 m pixel represents the remaining 50 points, where the highest risk scores are given to the pixels closest to water features.

Fig. 6: Proximity of 30 m grid cells to surface water.



Habitat Quality Mapping

The habitat mapping used in this plan was updated from the work done as part of Minnesota's Statewide Conservation and Preservation Plan (SCPP) (LCCMR, 2008). The primary goal of habitat mapping was to collate available information for Minnesota to prioritize important areas for conservation (protection, acquisition, restoration) by integrating both positive (resources) and negative (threats to resources) information on biodiversity, habitat quality, outdoor recreation (e.g., hunting and fishing), and water quality. Positive components included features such as known occurrences of rare species, sites of biodiversity significance, or high levels of game species abundance, while negative components included the dominant drivers of environmental change such as human development, land use, and road density. By acquiring and objectively processing information related to these components, it was possible to rank areas in Minnesota according to their conservation priority.

The habitat analyses for the statewide plan are unique for several reasons. First, the analysis team comprised the major natural resource management agencies in the state, including several divisions of the DNR, the MPCA, BWSR, MN Dept of Agriculture, and others with a wealth of expert knowledge. Second, the analyses were highly integrated: composite maps of critical terrestrial and aquatic habitat were integrated across taxa and habitats, providing a ‘weight-ofevidence' approach to the habitat rankings. Finally, the intersection of high-quality terrestrial and aquatic habitat with the composite environmental risk map identifies those regions of the state where critical habitats are most 'at-risk'.

Twelve terrestrial data sets from a variety of sources were compiled for the habitat analysis (Table 1). Each of these data sets were available on a statewide basis. High resolution data were derived or gridded to 30 m cells, the resolution of Landsat satellite imagery used for many of the statewide land cover classification and subsequent habitat analyses.

Table 1: Data sources for terrestrial habitat model.

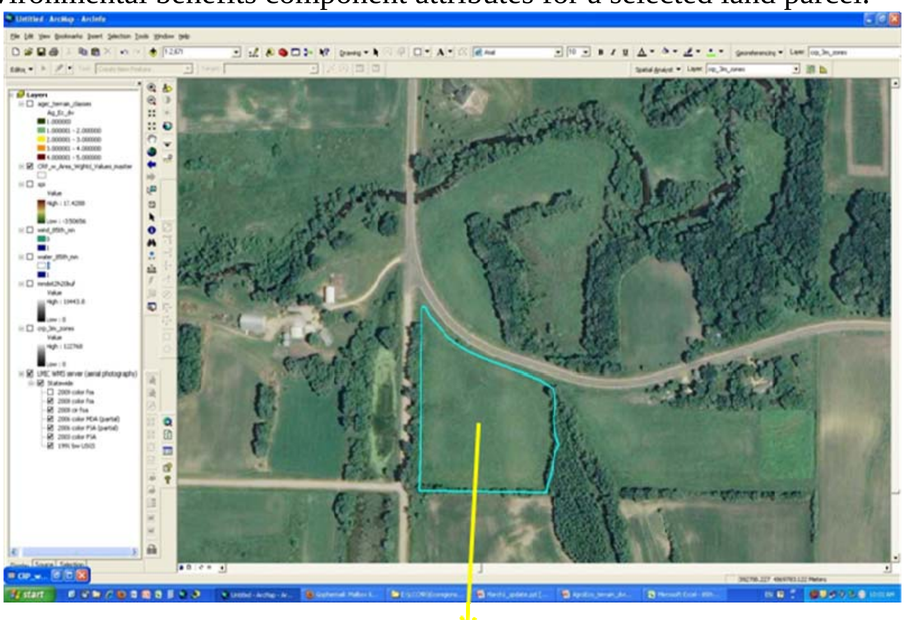
Habitat Model Input	Description
Sites of Biodiversity Significance	A multi-faceted assessment of this land for its importance from a regional perspective in terms of biodiversity and ecosystem function. Higher values indicate higher biodiversity significance.
MN DNR GAP terrestrial vertebrate models - Game species	The number of game species for which this land may be habitat. Higher values indicate higher numbers of game species potentially using this land.
MN DNR GAP terrestrial vertebrate SGCN models	The number of Species of Greatest Conservation Need (SGCN) for which this land may be habitat. Higher values indicate higher numbers of SGCN species potentially using this land.
Bird potential habitat models -- USFWS	Probable number of bird species (from a set of 17) using this land. Higher values indicate more of these 17 species using this land.
MN DNR GAP Habitat by protection level	Number of terrestrial vertebrate species potentially using this land weighted by the current level of habitat protection statewide for each species. Higher values indicate more species potentially using this land, weighted as described.
Wildland Urban Interface	Wildland Urban Interface maps initial encroachment of development into areas of largely intact natural cover. Decisions made here determine whether natural areas are preserved or pressured.
Wildland Urban Intermix	Wildland Urban Intermix map intermixing of development and significant natural cover. Connectivity can be maintained or lost by decisions made in these areas.
CRP lands	Lands enrolled in the Conservation Reserve Program, USDA.
Road density	A measure of the density of roads within the township. Major roads receive a higher weighting. Higher values indicate higher density of roads in the township.
Housing density 2000	Housing density from census data (census blocks) for 2000 for this land. Higher values indicate higher housing density.

Environmental Benefits Index

This Environmental Benefits Index (EBI) is a composite score of multiple ecological benefits. The score is based on a 0-300 scale, where a score of 300 is most valuable from a conservation perspective. The EBI is the sum of the three independent layers described above: soil erosion risk, water quality risk, and wildlife habitat quality values (Fig. 7). Each of those component layers contributes 0-100 points to the EBI. High EBI translates into high risk (e.g. water erosion), or high quality (e.g. habitat). Therefore, a high EBI score implies the site has a high value for conservation.

The EBI layer was created with the intention to rank CRP and other critical lands on multiple ecological benefits simultaneously. This approach is similar to the EBI used by the USDA-NRCS Farm Service Agency to rank farmers requests to enroll land in the Conservation Reserve Program. Our approach differs in that it offers flexibility in the weighting scheme, and allows users to explore both the spatial distribution of the data and the consequences of using alternative weighting systems. For example, if identifying land having high soil erosion risk is important, the habitat quality and water quality risk maps can be down weighted (e.g. scaled from 0-50). This would produce a map that differs from one where all attributes are weighted equally.

Fig. 7: Environmental benefits component attributes for a selected land parcel.



Soil Degradation risk	Water Quality risk	Habitat Quality Score	EBI score
86	33	67	186

The Ecological Ranking Tool can be used to quickly identify land with a high conservation need anywhere in Minnesota. Some examples of ecological rankings are shown below (Figs. 8-9). Land with high EBI scores adjacent to lakes or rivers is particularly important from a conservation perspective.

Fig. 8: Environmental Benefits Index (EBI) scores for agricultural land in a selected region of central Minnesota.

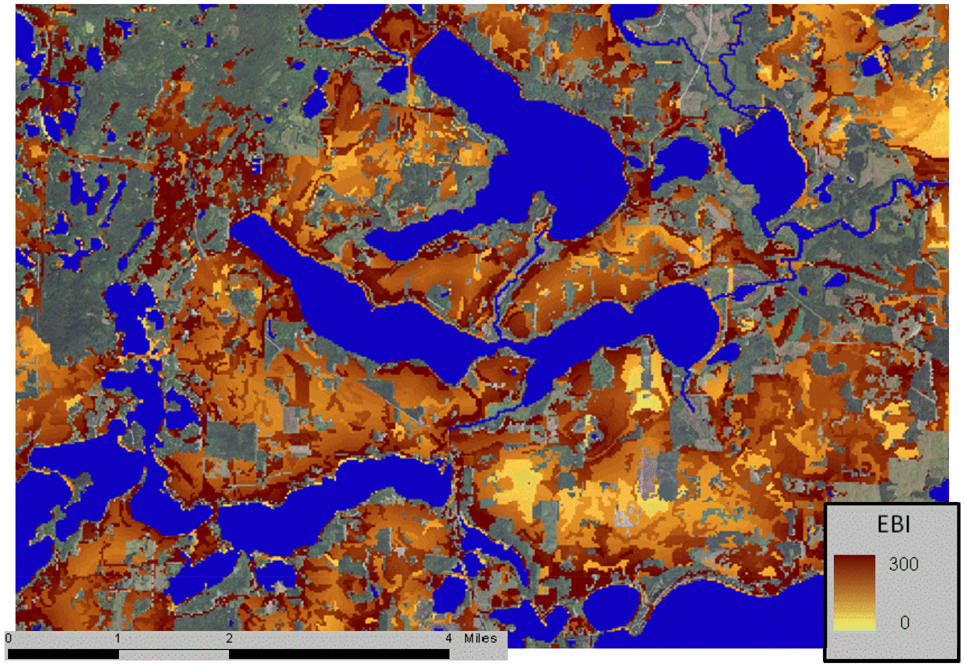
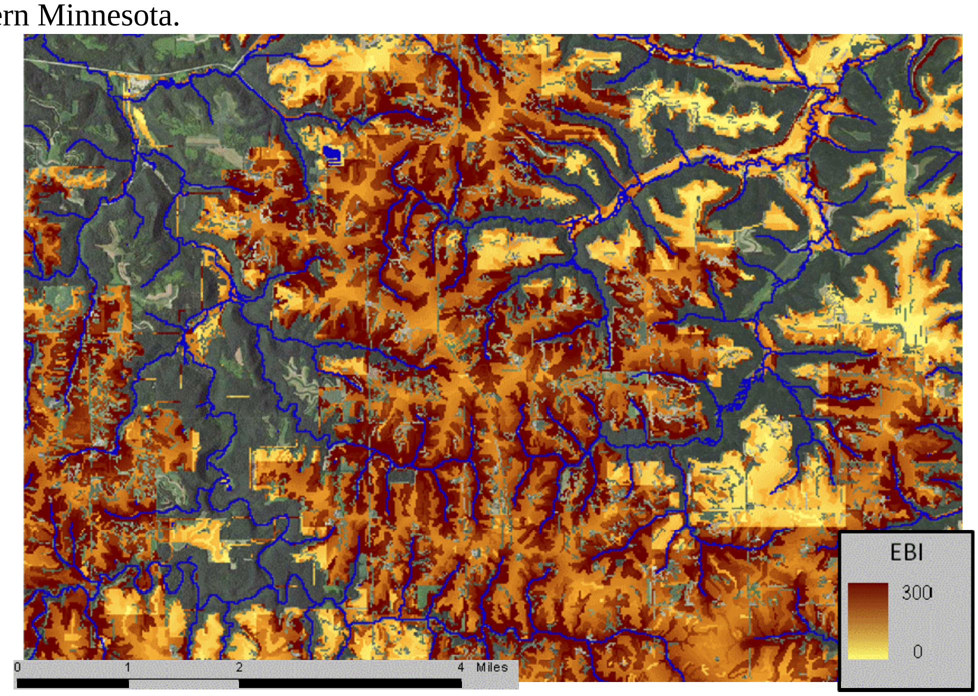


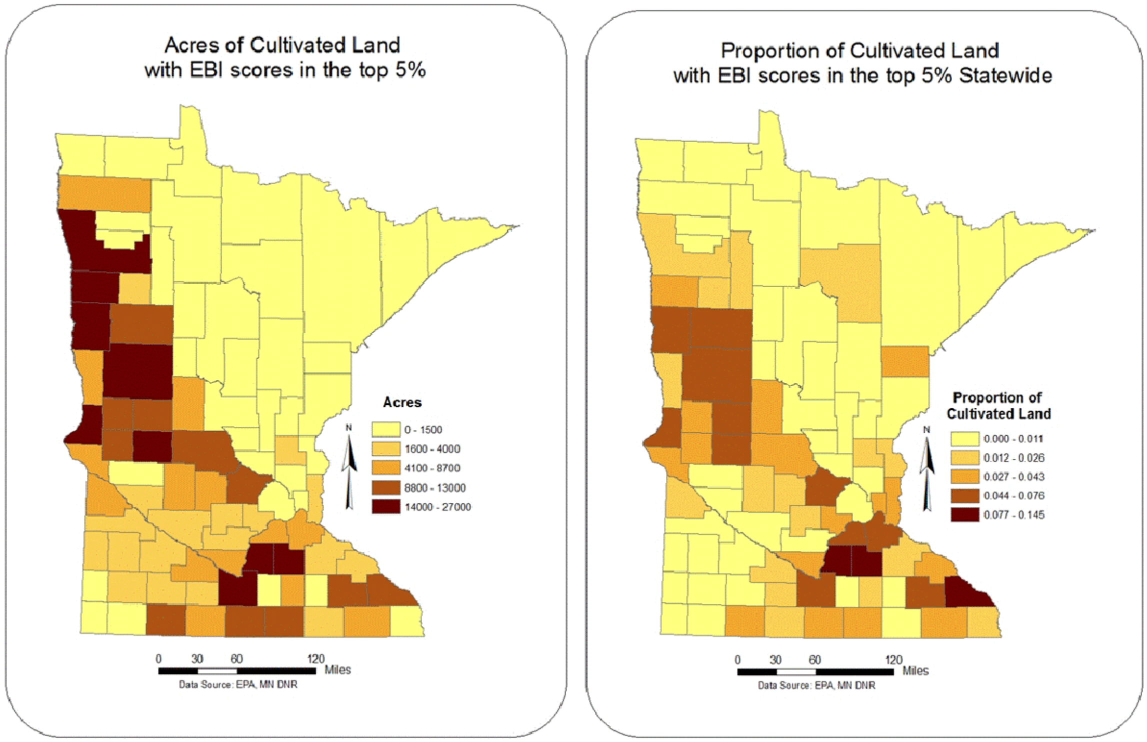
Fig. 9: Environmental Benefits Index (EBI) scores for agricultural land in a selected region of southeastern Minnesota.



The Ecological Ranking Tool can be used to identify Minnesota counties that have a high need for conservation. Counties with a high acreage of cultivated land with EBI scores in the top 5% are shown in Fig. 10. These counties are clustered in the Red River Basin of the North, the southern and eastern portions of the Minnesota River Basin, in portions of the Upper Mississippi

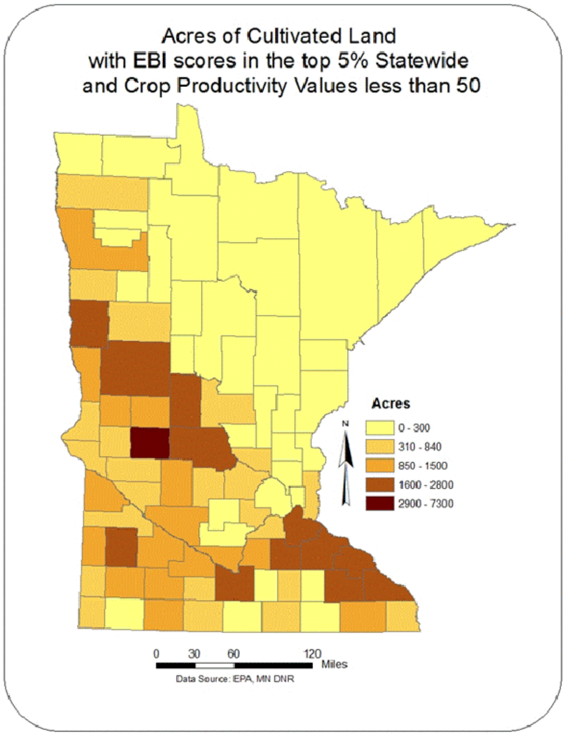
River Basin near St. Cloud, and in southeastern Minnesota. A total of 487,000 ac statewide is in the top 5% of EBI scores.

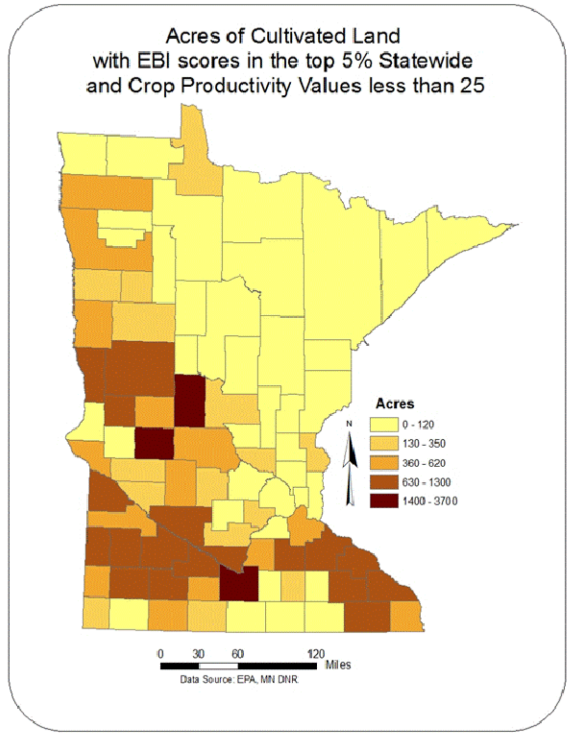
Fig. 10: a) Acres of cultivated land with the highest 5% of EBI scores and b) proportion of cultivated land with EBI scores in the top 5%.



Areas with high acreage of land with high conservation need (high EBI scores) can be further screened by Crop Productivity Index (CPI) values (Fig. 11). The rationale behind combining these two values is that incentives to place marginal land in conservation programs will generally be less costly than incentives to place productive crop land in conservation programs. Roughly 67,000 ac of cropland statewide are marginal for crop production (CPI values <50) and have very high EBI scores (Fig. 11a). This is a much lower acreage than high EBI scoring land statewide, and it is perhaps feasible to construct an incentive program to put this land into conservation programs. Only 36,000 ac of cropland statewide are extremely marginal for crop production (CPI values <25) and have very high EBI scores (Fig. 11b).

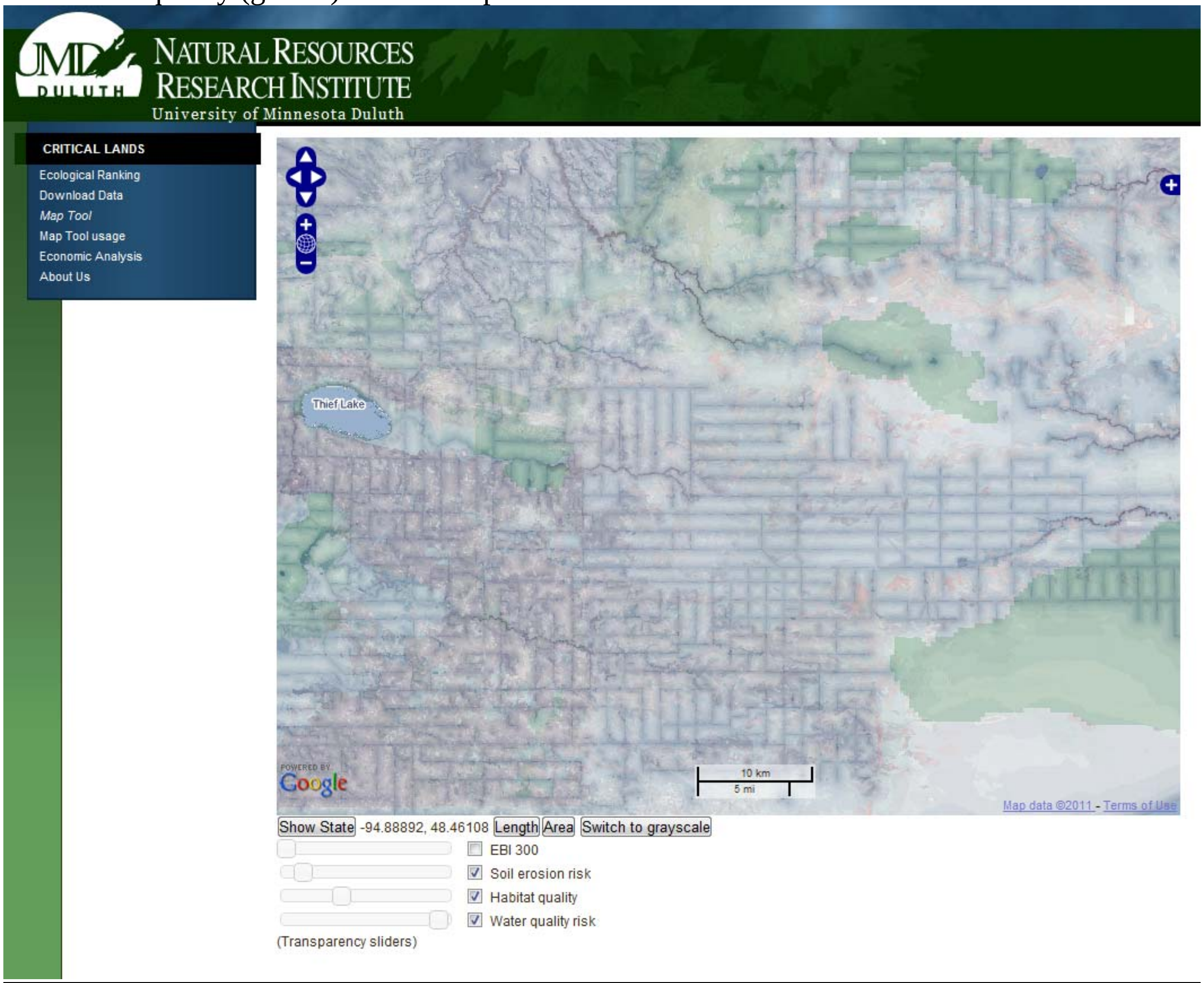
Fig. 11: a) Acres of cultivated land with EBI scores in the top 5% and Crop Productivity Index values less than 50, and b) acres of cultivated land with EBI scores in the top 5% and Crop Productivity Index values less than 25.





In addition to the county summaries presented above, this project developed an interactive map-based tool to explore the EBI and its three component layers at a fine spatial resolution. The tool allows a user to view how each of the layers independently contributes to the overall EBI. The tool is based on slider bars which adjust the transparency of the three different layers, either in color or in grayscale (Fig. 12). It uses a Google-like open map platform that allows the user to pan and zoom around the map, turn on other layers of interest, and explore the EBI data. This tool is available at *www.nrri.umn.edu/EcolRank*.

Fig. 12 Interactive map tool, showing detail of soil erosion risk (reds), water quality risk (blues), and habitat quality (greens) in an example area of northwestern Minnesota.



Technical Training Sessions

Three hands-on technical training sessions were held during June 2011 in St. Cloud, Moorhead and Marshall, Minnesota to provide data and methodology on the Ecological Ranking Tool to local units of government and other local conservation partners. The purposes of these training sessions were to:

- Introduce Environmental Benefits Index (EBI) and components to local GIS users
- Train local GIS users on performing EBI calculations
- Provide examples of how to supplement EBI with a variety of different data sources
- Interpret results on the landscape for specific examples provided

A workbook with GIS training material was developed for these sessions. There were several learning objectives for the workshops, including:

- Learn about the four data layers in the Ecological Ranking Tool, and how they were created
- Learn to access the data layers
- Learn to adjust weightings for the Environmental Benefits Index (EBI)
- Learn to incorporate ancillary data (i.e., understand how to resample layers and incorporate weightings into a customized EBI)
- Learn the process for incorporating LiDAR-derived hydrologic data
- Learn the process for identifying priority lands
- Learn how to explain the Ecological Ranking Tool to others

Technical training sessions were attended by 42 conservation professionals. Thirty-eight percent represented local government (SWCDs, Watershed Districts, counties, or cities); 33% represented state or federal agencies; 15% were from non-profit, non-governmental organizations; and the final 15% were from educational institutions or private companies.

Despite the challenge of training people with diverse GIS technical experience, the evaluations of the training sessions were overwhelmingly positive. People appreciated the organization and presentation of the material. Attendees said they understood how the ecological ranking approach was developed, and what each layer represented. Of the four layers, the habitat layer was the least well understood. They were confident of their ability to use, modify and teach the ecological ranking tools to others. Participants were interested in learning more about auxiliary information that could be incorporated into the tool, advanced data processing such as the use of LiDAR data, and examples of how the tool could be applied to support local decision making.

A majority (70%) said they planned to use the ecological ranking tool in their professional work, and they provided many different examples of how it would improve their ability to identify and rank high priority conservation areas. Thus, it appears that the development of the ecological ranking tool achieved all of its initial objectives.

Summary

The ecological ranking project provides information to support decisions on land conservation at a time of shifting economic conditions and new demands on lands, especially lands used for crop production. It does not provide a final decision, but does allow resource managers to assess how different weightings of soil erosion, water quality, and wildlife habitat factors influence the relative conservation value of agricultural lands, particularly those enrolled in the conservation reserve program. To this end, it is an innovative approach that incorporates the best current information available statewide to make informed conservation decisions.

Acknowledgements

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