Journal of Environmental Planning and Management,
Vol. 47, No. 5, 709–736, September 2004

Carfax Publishing
Taylor & Francis Group

Conservation Planning at the Landscape Scale: A Landscape Ecology Method for Regional Land Trusts

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(Received July 2003; revised January 2004)

ABSTRACT *This paper illustrates a landscape ecology approach for land trusts undertaking conservation at the watershed scale. A conservation plan was created for the Grand Traverse Regional Land Conservancy (GTRLC) in the headwaters of Michigan's Manistee River Watershed (USA). Eight conservation drivers were devised to identify Conservation Focus Areas (CFAs) of highest ecological importance. The CFAs were ranked based on ecological importance, feasibility of protection and size. Parcels were ranked, totalling nearly 5000 ha, within the three highest-ranking CFAs in one key county. This approach is useful to land trusts trying to operationalize three distinct goals in conservation planning: to find areas of high ecological importance, to promote the landscape's spatial integrity and to delineate threats to ecological systems and processes.*

Introduction

Non-profit land trusts play an increasingly important role in protecting millions of hectares of private land throughout the USA. Private land conservation is one of the fastest-growing segments of the environmental movement. Currently 1263 local and regional non-profit land trusts are operating in the USA, a 42% increase over 1990 levels (Land Trust Alliance, 2002). While land trusts' growth and achievements have been significant, these organizations often lack a clear process for identifying the most important areas to conserve. Given persistent resource constraints and the vast number of conservation opportunities, organizations clearly benefit from a systematic method for ranking land for potential protection. Such methods are becoming even more important as land trusts evolve from making opportunistic land deals to developing more active conservation strategies.

This project develops a method of applying a landscape ecology approach to land trust conservation at the landscape scale. (Landscape scale is used here

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0142-6397 Print/1469-9710 Online/04/050709-28
DOI: 10.1080/0964056042000274443

as the scale at which multiple ecosystems are situated across the landscape. It is the scale at which ecological processes and human use are critically linked through developed infrastructure, ownership, and management.) A land conservation plan was designed to guide the efforts of the Grand Traverse Regional Land Conservancy (GTRLC) in the 12 uppermost sub-watersheds of the Manistee River in northwestern Lower Michigan. By ranking lands for conservation according to ecological criteria, the research team identified over 4856 ha across 63 parcels on which to focus GTRLC's protection efforts in the upper part of the watershed, and documented the threats to ecological integrity. This method can be useful to land trusts or conservancies wishing to find areas of high ecological importance, based not only on species richness or rarity, but also on other factors contributing to ecological soundness.

Background

Transition from Species to Landscape Approach to Conservation

Natural areas have often been characterized and evaluated in terms of the rare species, exemplary communities or other unique features they contain. Individual species harbour unique genetic material and comprise important components of functional ecosystems, making the preservation of species undeniably important (Knight, 1998). Such scientific evidence has supported a strong push for conserving biodiversity in the USA and around the world.

With the passage of the Endangered Species Act and the development of state and federal threatened and endangered species lists, the public began to advocate for protection of individual species and community types. Proponents of the species-level approach stress that the public easily grasps its aims. People inherently understand, and feel more emotionally connected to, individual species more than they do large ecosystem processes. Species gain more public support because people can see the results of conservation efforts more clearly with the survival or improvement of a population (Knight, 1998).

Given this traditional focus, most conservation efforts protect local, island-like preserves. However, a landscape-scale approach is gaining scientific justification, public credibility and conservation funding (Slocombe, 1993; Lapin & Barnes, 1995; Cowell, 1998; Soule & Terborgh, 1999; Poiani *et al.*, 2000). According to O'Neill *et al.* (1997), the simplest indicator of biotic integrity is total change in land cover; therefore, understanding and guiding larger landscape changes will help protect biodiversity. Conservation biologists Soule & Terborgh (1999) proposed a national scientific programme for ecosystem protection, regional connectivity and ecological restoration at unprecedented scales. Their work promotes what they call "geographically extensive conservation projects".

Since political decisions are made at broad scales—river basins, forest districts, counties—protection at that scale is logical. The argument that the environment should be managed in whole ecological units based on integrated biological, physical and/or socio-economic analyses is not a new one. However, the shift from species to landscape conservation has generated a number of new questions. Implementation is difficult, and a number of scholars have proposed organizing frameworks (Slocombe, 1993; Poiani *et al.*, 2000; Shindler, 2000; Loehle *et al.*, 2002; Ferrier, 2002). In addition, various reserve selection algorithms have been devised for selecting conservation sites (Csuti *et al.*, 1997), although these are usually limited to species richness or rarity. They do not typically address size, location or quality of a natural area—all factors that play into functional ecosystems.

Proponents of landscape-level approaches assert that long-term maintenance of biodiversity requires a strategy that considers regional biogeography and landscape pattern above local concerns. Landscape ecology offers a framework for broader landscape planning; it is being used as a framework for the preservation of spatial connections among ecosystems to maintain important ecological structures, such as corridors for animal movement, and vital ecological functions such as hydrological flux and storage (Knight, 1998). Landscape ecology also emphasizes the interface between humans and nature and recognizes that change is a fundamental landscape component (Naveh & Lieberman, 1984; Forman & Godron, 1986; Hall, 1991; Hersperger, 1994).

Over the past 20 years, the literature describing landscape ecological approaches to conservation has proliferated. For example, Hawkins & Selman (2002) explored the methodological issues in landscape ecological planning by comparing three schools of thought, which they categorize as landscape stabilization, focal species and greenways. Vos *et al*. (2001) proposed a framework of ecologically scaled landscape indices and Botequilha Leitão & Ahern (2002) devised a conceptual framework for sustainable landscape planning, applying multiple metrics in a landscape ecology model for a Massachusetts (US) watershed.

Increasingly, watersheds are used as the logical boundaries for undertaking landscape ecological planning (Daily, 1997; Wooley & McGinnis, 1999; Kraft & Penberthy, 2000; Randhir *et al.*, 2001) and for predicting landscape change (Steinitz *et al.*, 2003). Some state governments are developing their own large-scale conservation plans based on watershed boundaries and landscape ecology principles (Michaels, 1999), aided by contemporary Geographic Information Systems (GIS). GIS is a primary tool for much of the work being done in landscape and watershed planning (Lovejoy *et al.*, 1997; O'Neill *et al.*, 1997; Heikkila, 1998; Theobald *et al.*, 2000).

Importance of Conservation Strategies for Private Land: The Role of Land Trusts

Decisions about changing land uses are generally made by individual landowners; cumulatively these decisions drastically change spatial landscape patterns (Beatley, 2000). Suitability analysis methods for landscape planning, used primarily to find suitable locations for development and protected farmland, were developed in the last third of the 20th century (Pease & Coughlin, 1996; Hopkins, 1999; Steiner, 2000). The ranking and weighting schemes that were developed have been used for selecting conservation sites on both public and private land. There is a growing awareness, within both private organizations and public agencies, of the importance of protecting ecological values on private lands (Morrisette, 2001), but few frameworks for choosing which lands to protect. Over 90% of endangered species in the USA are estimated to occur on at least some private land (James, 1999). Habitat Conservation Planning at the federal level is a prime example of public efforts to control landscape change on private landscapes, but its effectiveness is debated (Noss *et al.*, 1997; Polasky *et al.*, 1997).

Land trusts and conservancies play an increasingly important role in landscape-scale conservation, in partnership with governmental jurisdictions. By 2000, land trusts had protected more than 2.5 million ha in the USA, a 226% increase over the 769 000 ha protected as of 1990 (Land Trust Alliance, 2002). Granted, most of this protection is site specific and does not encompass entire landscapes. However, the pace of large-scale conservation by land trusts is increasing, particularly as land trusts collaborate with government agencies, citizen groups, and other non-profit organizations. (Brammeier, *et al.*, 1998; MacDonald, 2002). Examples are diverse, from the Fox River Watershed Land Alliance in Illinois, to the New England Forestry Foundation in Massachusetts, and the Wildlands Conservancy in California (Land Trust Alliance, 2002).

Many of these projects have adopted a landscape ecology approach (Poiani *et al.*, 2000). The Trust for Public Land and the Open Space Institute used landscape ecology principles to protect the 7244-hectare Sterling Forest on the New York-New Jersey border from large-scale commercial and residential development (Lathrop & Bognar, 1998). On the other coast, the non-profit Environmental Alliance in Contra Costa County, California worked with federal partners on a watershed plan for the Alhambra Creek Watershed (Myers *et al.*, 1999). Both The Nature Conservancy (TNC) and World Wildlife Fund (WWF) have set conservation priorities at the scale of eco-regions, or large geographic areas delineated by climate, vegetation, geology and other ecological patterns (Groves *et al.*, 2002). TNC seeks to protect biodiversity by using two complementary planning activities (Poiani *et al.*, 1998). An eco-regional plan identifies a portfolio of priority sites within a particular TNC-delineated eco-region. A site conservation plan then more closely examines the ranked sites within the eco-region and offers on-the-ground conservation strategies. Each of the selected sites contains a subset of the entire eco-region's biodiversity so that, in theory, the conservation of all sites will collectively safeguard the biodiversity unique to that eco-region. TNC conservation sites range in size from a few to millions of hectares. TNC identifies species and natural communities as targets, analyses threats to their viability and ranks land areas most important to conserve biodiversity (The Nature Conservancy, 2001).

The conservation planning efforts described above share a number of common strategies for ranking protected lands: established conservation goals; designated conservation targets; and weighted schemes to rank targets. Land trusts without the resources of the nation-wide organizations, such as smaller regional conservancies, need methods that are explicit, efficient, and reliable (Church *et al.*, 1996) and they need to do the work in a cost-effective manner (Polasky *et al.*, 2001). This project developed a method for conservation planning that builds on landscape ecological approaches and is replicable for other regional land trusts.

Research Objectives

This project was designed to identify areas of high conservation value and rank privately owned land parcels for the Grand Traverse Regional Land Conservancy (GTRLC) in the upper Manistee River Watershed. Conservation planning involves a number of stages, participants, and processes. Although the results are only briefly summarized here, the research team did a comprehensive analysis of historical land use, current land use and ownership, demographic composition, land-use regulation and stakeholder groups. Subsequent planning by GTRLC will involve continued work with watershed stakeholders.

The first goal was to find areas of high ecological importance, judging a land area's conservation value based on its ecological soundness relative to the surrounding landscape. Specific objectives included protecting hydrologic integrity, conserving wetland ecosystems, maintaining species biodiversity, protecting a diversity of local ecosystems and conserving natural areas with a high quality and resiliency.

The second goal was to promote the landscape's spatial integrity, using the knowledge that large and intact natural areas ensure greater ecological health than do smaller, fragmented areas (Noss & Cooperrider, 1994; Dale *et al.*, 1999). Specific objectives included conserving unfragmented landscapes, promoting the expansion and connectivity of existing protected areas, and targeting large land parcels.

The third goal was to identify and delineate threats to ecological systems and processes. This goal sought to present the extent, severity and location of key threats and, where possible, illustrate their geographic and causal relationships to identified areas of conservation importance.

Project Context

Grand Traverse Regional Land Conservancy

Founded in 1991, the Grand Traverse Regional Land Conservancy is a leading regional land conservancy in Michigan's northwestern Lower Peninsula. It has a five-county service area. In the face of the area's struggle with sprawl, farmland loss, fragmented forests and degraded natural areas, GTRLC's mission is "to protect significant natural, scenic and farm lands for present and future generations". By 2002 GTRLC had preserved over 5800 ha, including 27 nature preserves, 108 conservation easements, and nearly 66 km of lake, river and stream shoreline (Grand Traverse Regional Land Conservancy, 2003). In addition, GTRLC often assists governmental and local communities working to conserve land. To address the growing impact of development in the region, GTRLC is transforming its land protection efforts from an opportunistic to a proactive and planned operation. It wants to generate long-term watershed plans that will maximize landscape impact and avoid protecting isolated tracts of land in a sea of development.

Spurred by The Nature Conservancy's designation of the Manistee River as regionally significant within the larger Great Lakes eco-region (DePhillips, 2001), GTRLC turned its attention to the Manistee River and its watershed. GTRLC conducted a quick assessment of the area and reached two conclusions. First, the ecological features and processes present in the watershed were a high priority for conservation. Second, the size of the watershed, coupled with its boundaries beyond GTRLC's traditional service area, meant that GTRLC had limited knowledge of the key lands to protect. Therefore, the Manistee River watershed represented a significant opportunity for the organization to develop its conservation planning and prioritization protocols.

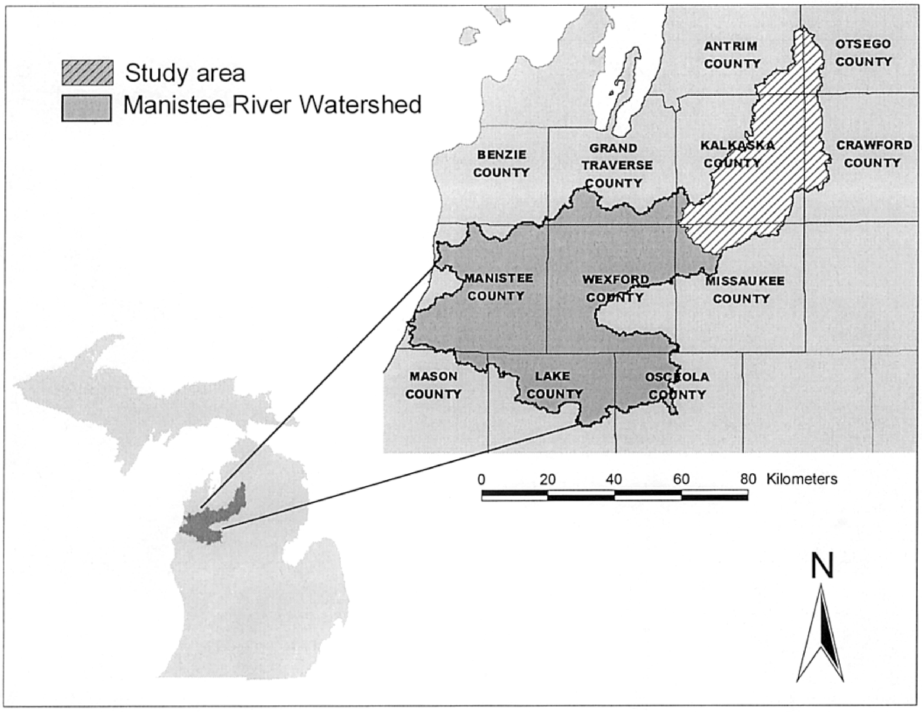

Figure 1. Location of the Manistee River Watershed in northern Michigan.

The Manistee River Watershed

The Manistee River lies in the northwestern portion of Michigan's Lower Peninsula, flowing south and then southwest for nearly 371 km from its headwaters in Antrim County to its mouth at Lake Michigan in Manistee County (Figure 1). The river's watershed is one of the largest and healthiest in the state. It drains over 5000 km^2 and covers portions of twelve counties (Rozich, 1998). Forty-two kilometers of the river are designated under the National Wild and Scenic Rivers system (US Forest Service, 1983) and the Upper Manistee was included in Michigan's Natural Rivers Program in 2003 (a programme protecting rivers by establishing management practices for development on and immediately near the water).

Although human activity has impacted the Manistee River along its entire length, it remains one of Michigan's healthiest and most scenic rivers and one of its most popular for fishing and recreation (Figure 2). The substrate geology is characterized by thick layers of highly permeable sands that filter run-off and reduce pollutant loads in the river. Groundwater-dominated hydrology also helps support relatively cool and stable flows year-round, making the river prime habitat for trout and other cold-water organisms (Rozich, 1998). Large amounts of public land and historically low development pressures have combined to protect many of the watershed's natural and scenic resources. Forest, wetland, and non-intensive agriculture are the dominant land covers.

Protecting the upper reaches of a watershed is essential to long-term health and integrity (Doppelt *et al.*, 1993), and GTRLC stressed the importance of the watershed's upper reaches for its work. Therefore, the 12 uppermost sub-water-

Figure 2. The Manistee River and its floodplain in northern Michigan.

sheds were selected for conservation planning (Figure 1). The study area covers approximately 1370 km^2 and includes portions of five counties.

Social/Political Setting

Massive logging operations felled great tracts of virgin forests in the watershed during the late 1800s and early 1900s, and the ecological impact is still evident throughout much of the study area. Roads, many unpaved, interlink across the Upper Manistee, as shown in Figure 3. Currently, recreational and natural resource-based industry dominates land use, and public lands represent over half the study area. The Michigan Department of Natural Resources is the largest and most important land manager in the region. Residential development covers only a small portion of the region, but it is growing faster than any other use. As the subdivision of parcels increases, larger numbers of people own smaller tracts of land. Although population density in the study area is much lower than the state as a whole, the population is growing faster than the state average. The study area's population is slightly less educated, less affluent, older and less racially and ethnically diverse than the population of the entire state (US Bureau of the Census, 2002).

A number of environmental regulations and programmes at the federal, state and local levels aim to protect important ecological features and processes. Few of these regulations afford absolute protection, and most private land is still vulnerable to unregulated development. Most local master plans communicate goals of steering development in desirable directions and ensuring preservation of natural features. However, most jurisdictions lack the basic zoning and regulatory provisions necessary for successful land-use planning. As shown in

Figure 3. A grid of unpaved roads fragments the landscape across the Upper Manistee River Watershed.

Figure 4, a patchwork of governmental units is responsible for planning and zoning activities in the study area.

Research Methods

The conservation planning method occurred in three main phases. The first phase involved ranking lands for protection at the regional scale. Lands identified as high priority formed discrete units called Conservation Focus Areas (CFAs). The second phase consisted of ranking individual land parcels within the larger CFAs (Figure 5). A third phase analysed threats and sources of threats in relationship to CFAs. Table 1 summarizes the relationship of project goals, objectives and conservation drivers.

Phase One

The basic steps in the Phase One analysis included:

(1) Develop conservation drivers to represent project objectives spatially.
(2) Spatially represent and weight conservation drivers.
(3) Use raster grids in GIS to conduct overall ranking analysis.
(4) Delineate CFAs.
(5) Rank CFAs according to ecological, spatial, opportunity and feasibility criteria.

The study area was analysed using a GIS. Conservation drivers—spatial representations of the project's objectives—were the foundation of this analysis. The conservation drivers included:

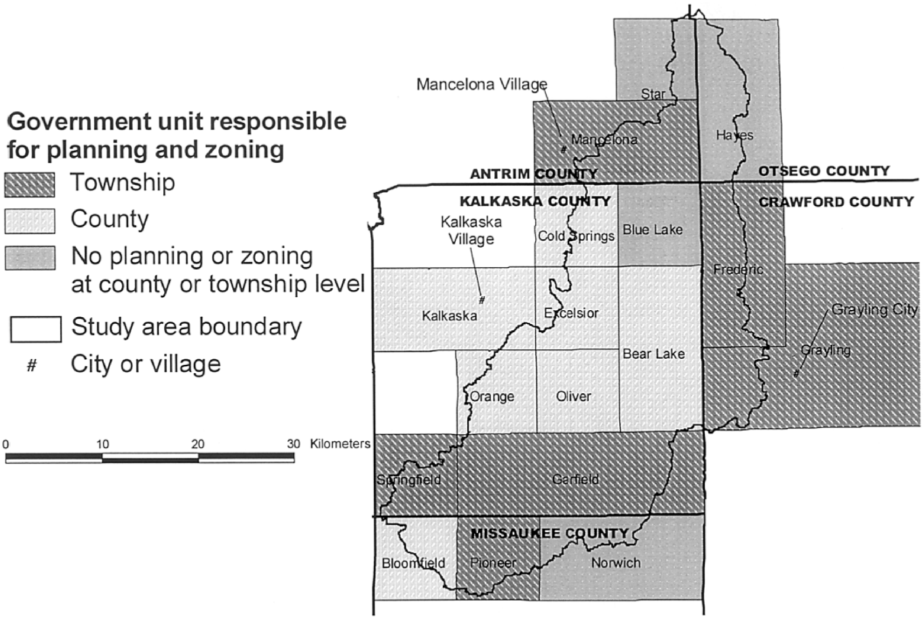

Figure 4. Jurisdictions within the study area that have adopted, or are responsible for, planning and zoning.

Areas of high groundwater accumulation: identified and ranked groundwater accumulation areas to conserve hydrological function (Baker *et al.*, 2001).

Wetland ecosystems: identified and ranked wetland ecosystems (Mitsch & Gosselink, 2000).

Riparian ecosystems: delineated and ranked buffers surrounding streams and lakes (Gregory *et al.*, 1991).

Element occurrences: incorporated species information into the overall analysis by identifying lands with a high density of documented rare plants, animals, or communities (Michigan Natural Features Inventory, 2002).

Rare land-type associations: identified and ranked rare land-type associations, which are large-scale local ecosystems delineated based on physiography, soils and vegetation (Albert, 1995; Corner & Albert, 1999).

Pre-European settlement vegetation: identified lands with vegetative communities resembling those existing before European settlement (Landres *et al.*, 1999).

Large tracts of unfragmented natural areas: identified and ranked large tracts of natural, vegetated land, unfragmented by major roads (Forman & Alexander, 1998).

Expansion and integrity of protected areas: identified and ranked lands adjacent to protected areas (i.e. state lands and privately owned land under conservation easement) and lands that could contribute to the spatial integrity of existing protected lands (Noss, 1987; Gascon *et al.*, 2000).

Based on the established criteria, the project team assigned scores to each driver to differentially value land areas within the study area. Once each individual driver was scored, the researchers overlaid all eight data layers to create a composite grid for the entire area. The maximum score for any one driver was

Table 1. Relationship of project mission, goals, objectives and conservation drivers

Mission: To guide future work and investment of the Grand Traverse Regional Land Conservancy in the Manistee River watershed, this project will identify areas of high conservation value and, within those areas, rank privately owned land parcels for protection efforts.

Goals	Objectives	Conservation Drivers
Conserve areas of high ecological importance	Protect hydrologic integrity of the upper Manistee River watershed	Groundwater accumulation
	Conserve wetland ecosystems	Wetlands
	Conserve riparian ecosystems	Riparian ecosystems
	Maintain biodiversity	Element occurrences
	Protect a diversity of local ecosystems	Rare land-type associations
	Conserve natural areas that exhibit a high degree of integrity and resiliency	Pre-European settlement vegetation
Promote spatial integrity of the landscape	Conserve unfragmented landscapes	Large tracts of unfragmented natural areas
	Promote the expansion and integrity of existing protected areas	Expansion and integrity of existing protected lands
	Target large land parcels	Parcel size*
Identify and delineate threats to ecological systems and processes	Analyse threats and their sources and, when possible, map those sources	Sources of threats** Development Oil and gas drilling Incompatible logging Invasive species Road development Off-road vehicle use Fire suppression Dams

Note: *Not a weighted conservation driver but used in parcel analysis and prioritization.
**Not weighted or used on CFA or parcel prioritization.

10. Seven of the eight drivers used three classifications to assign weights: 10 points, 5 points, and 0 points. One driver, wetlands conservation, was considered simply as present or absent and thus classified the study area into only two categories, those lands receiving 10 points and those lands receiving 0 points. Given the eight drivers with a maximum of 10 points each, cumulative grid cell scores potentially could have ranged from 0 to 80 in multiples of five. The team reclassified the full range of raw scores into three categories: low, medium, and highest priority in order to more clearly view areas of relatively high conservation value.

Specific high-value areas, CFAs, were delineated by digitizing polygons around clusters of high- and highest-scoring grid cells. Once established, the CFAs were ranked based on their mean score (area weighted average of composite grid cell scores), size, shape, conservation opportunity and conservation feasibility. Therefore, the final output of Phase One was a map of prioritized CFAs.

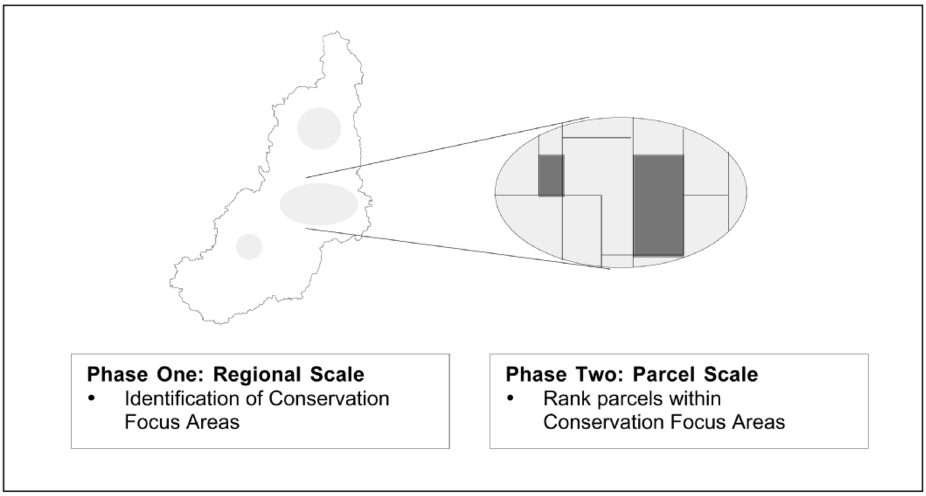

Figure 5. Spatial analysis: relationship of phases one and two.

Phase Two

In the second phase, the researchers examined, analysed and scored every private parcel 16 ha or larger associated with the top three CFAs in Kalkaska County (GTRLC's highest-priority county within the watershed). The team used the 16-ha threshold since GTRLC is interested in conserving parcels of at least 16 ha, and usually much larger. To complement available GIS data, aerial photographs from 1998 and 1999 were interpreted for the highest-ranking CFAs. Photographs of each parcel revealed the parcel's land cover and land use, as well as disturbances such as roads and extractive operations. Using the results of the interpretation, the team scored the parcels based on three criteria: ecological score, number of hectares in natural cover, and contribution to the connectivity of the landscape.

The parcel's individual score was not the sole consideration in prioritizing parcels within CFAs for protection. To emphasize the protection of large, contiguous landscapes, the authors also considered the parcels' relationship to the CFA and, when applicable, the landscape feature (a sizable, intact natural area), before determining its final priority. There were thus three basic hierarchical levels: (1) the CFA, (2) the landscape feature, and (3) the parcel itself. After each CFA was ranked, those data served as the foundation for parcel ranking. Then, when determining parcel priority within a given CFA, landscape features were used to provide a second level of ranking hierarchy. Finally, to determine relative conservation priority within a landscape feature, the parcel's final score was used.

Phase Three

Using a framework originally developed by The Nature Conservancy as part of its 5-S Framework to Site Conservation (The Nature Conservancy, 2000), the authors identified and assessed the study area's key threats and their sources. Threats, in this context, are considered processes and events that may cause

Table 2. Conservation driver results

Conservation driver	Received 10 points		Received 5 points		Received 0 points	
	Hectares	% of study area	Hectares	% of study area	Hectares	% of study area
Groundwater accumulation	10 742	7.8%	12 813	9.3%	114 457	82.9%
Wetlands	18 340	13.3%	n/a	n/a	119 672	86.7%
Riparian ecosystems	5969	4.3%	4238	3.1%	127 805	92.6%
Element occurrences	9205	6.7%	20 488	14.8%	108 320	78.5%
Rare land-type associations	7566	5.5%	14 242	10.3%	116 204	84.2%
Pre-European settlement vegetation	10 002	7.2%	45 095	32.7%	82 916	60.1%
Large tracts of unfragmented natural areas	30 765	22.3%	28 697	20.8%	78 550	56.9%
Expansion and integrity of protected lands	13 671	9.9%	20 812	15.1%	103 530	75.0%

Note: *Note that study area totals 138 012 ha; some totals for drivers vary due to rounding.

harmful ecological or physiological impacts on an ecosystem. Sources of threats are actions that cause the threat itself. Sources of threats were identified, and as many as possible were spatially represented. Because each threat has a different likelihood of impacting the study area, the team assigned one of three severity rankings to each threat and source (severe, moderate and minimal). These rankings were assigned primarily based on the research team's subjective assessment of potential impact, but also on the total number of threats and sources.

Mapped sources were overlaid on the CFAs to illustrate their spatial relationship. The researchers did not incorporate the mapped threats into the scores for CFAs or parcels. Unlike the scored drivers and parcels, the impact of threats to conservation priorities is highly subjective. For example, it could be asserted with confidence that conserving an area with a wetland (one of the scored drivers) will benefit ecological health. By contrast, it is much less clear whether focusing conservation in an area with high development pressure (a threat) will ultimately result in better ecological health than concentrating on areas with less development pressure. Given these considerations, the researchers simply overlaid threats on the ranked CFAs to provide insight into the location of existing and potential threats to these priority areas.

Results

Conservation Drivers and Conservation Focus Areas

The spatial extent of each weighted conservation driver across the study area was analysed. Table 2 summarizes the results of this analysis for each driver. The conservation drivers were designed to perform a cumulative ranking analysis. To rank effectively, they must be selective. In other words, if 95% of the

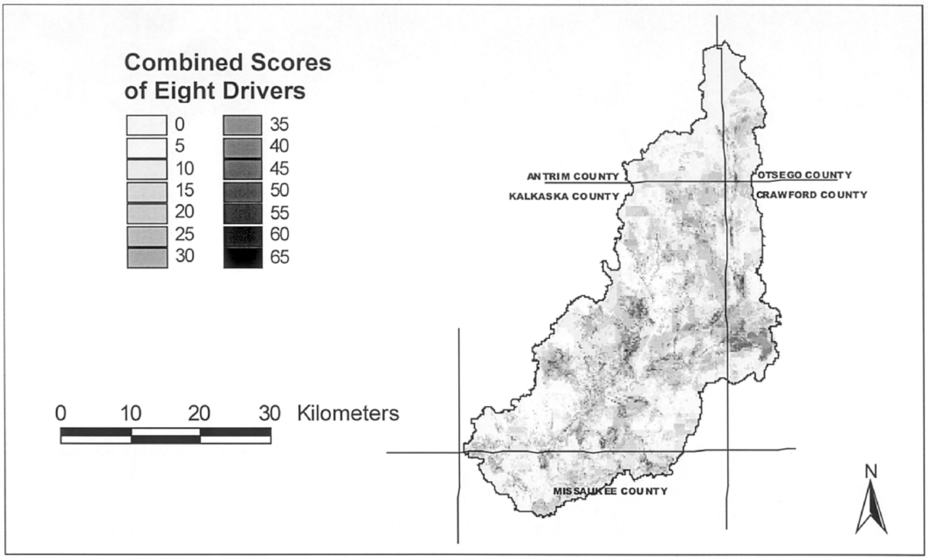

Figure 6. Composite grid: eight drivers combined scores for each grid cell.

study area had received 10 points for the rare land-type association driver, this driver would have done little to help rank lands for protection. On average, the eight drivers used in the analysis awarded 9.6% of the study area 10 points and 13.7% of the study area 5 points. The large tracts of unfragmented natural areas driver was the least selective, and the riparian ecosystems driver was the most selective.

Combining the drivers and analysing the cumulative results provides insight into the overall ecological values of different locations. As the first step in selecting and ranking areas for conservation, the grid values for each driver were added to form a composite grid showing the cumulative scores for each grid cell (Figure 6). Since the eight driver grids had possible individual weights of 10, 5 or 0 points, possible total scores for the composite grid ranged from 0 to 80 in multiples of five. In this analysis, however, the highest-scoring grid cell received 65 points.

The relative dearth of high-scoring grid cells demonstrates the convergence of two phenomena. First, the drivers themselves are relatively selective. Approximately 57% of the study area received 10 points or fewer, and 86% received no more than 20 points. Less than 1% of the entire study area (~ 5665 ha) received 45 points or more. Second, and more importantly, there is not a strong spatial correlation among the eight drivers, and this relative scarcity of spatial overlap magnifies the original selectivity. For example, if the wetlands driver tended to be closely associated with the rare LTA driver, the riparian ecosystems driver, the element occurrence driver and the unfragmented natural areas driver, a much larger percentage of the study area would receive 50 points than actually does so ($<$ 0.2%).

The relative lack of large-scale spatial overlap in the project's drivers highlights the selectivity of the ranking scheme. For example, if certain lands contain the presence of four or more drivers (as do all areas receiving 35 points or more), these lands represent a rare and important convergence of several

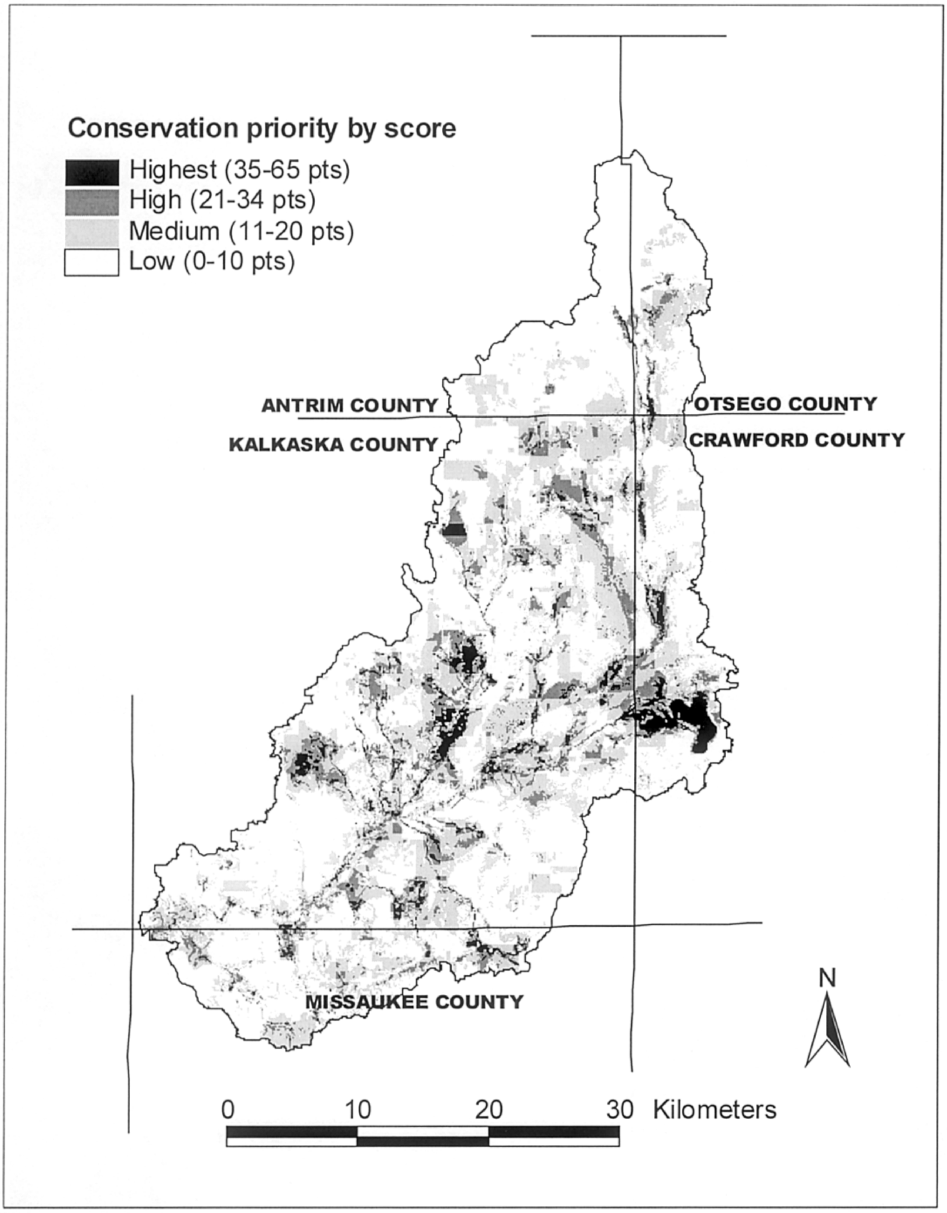

Figure 7. Reclassified composite grid.

critical ecological features. To ease the identification of priority lands, the composite grids were reclassified, and the total cumulative scores were grouped into four categories. Figure 7 shows the resulting grid.

The reclassified composite grid reveals important information. First, a simple visual inspection reveals that high- and highest-scoring grid cells are not distributed equally across the study area. Instead, there are numerous clusters of high- and highest-scoring lands, and these clusters provide the foundation for the identification and delineation of Conservation Focus Areas. Second, a more

Table 3. Reclassified composite grid scores

Classification	Score range	Hectares	% of study area
Low priority	0–10	78 512	56.9%
Medium priority	11–20	40 591	29.4%
High priority	21–34	14 245	10.3%
Highest priority	35–65	4638	3.4%

quantitative examination of the reclassified data reveals that high- and highest-scoring lands account for nearly 19 000 ha, or 13.7% of the study area (Table 3). While only a small fraction of the study area (*highest* category) received scores above 35 points, this scoring distribution still selects an amount of land small enough to narrow GTRLC's focus yet large enough to provide the organization with a meaningful slate of options.

Around these clusters of high and highest priority lands, 60 discrete polygons were digitized. These polygons totaled 19 287 ha and fell into three categories based on size: Conservation Focus Areas (largest), 2nd Tier Conservation Areas (next largest) and 3rd Tier Conservation Areas (smallest). As the largest priority areas, the CFAs represent the top-priority lands and are the clear category of emphasis for further analysis and eventual parcel ranking efforts. Eighteen CFAs were delineated, totaling 16 094 ha, or roughly 12% of the study area. To help reference each CFA individually, each was named based on nearby streams, lakes or other distinctive features (Figure 8). To compare each CFA to its counterparts, all 18 were ranked on three criteria: mean score, size and shape.

Assigning the final rank for CFAs based on the sum total of the individual ranks for size, mean score, and shape allowed analysis of a broader range of important attributes than relying on a single criterion would have done. The Deward CFA provides a good example. With a mean score of 29.9, Deward received the second-highest mean score rank of all the CFAs. However, Deward is also the smallest CFA, and its small size and irregular boundary gave it the second-worst shape rank. Deward's final rank of 14 provides a more accurate measure of its true conservation priority than would its mean score or size alone.

The map of the ranked CFAs (Figure 8) illustrates several interesting facts about the spatial extent and distribution of CFAs. First, CFAs are not clustered in only one or two small portions of the study area. Rather, they are distributed fairly widely and occur in all five counties. However, some parts of the study area support higher concentrations of CFAs than do other parts. Nine of the 18 CFAs are found in a belt that runs through central Kalkaska County to western Crawford County. Second, the CFAs themselves are irregularly shaped; high-scoring lands along stream corridors help shape many of the more linear CFAs. Third, CFAs vary widely in size: the largest (North Branch) is nearly 3240 ha and the smallest (Deward) is less than 240 ha. Finally, the protectable lands (private lands excluding large lakes) within individual CFAs often are disconnected from one another, separated by protected lands or large lakes.

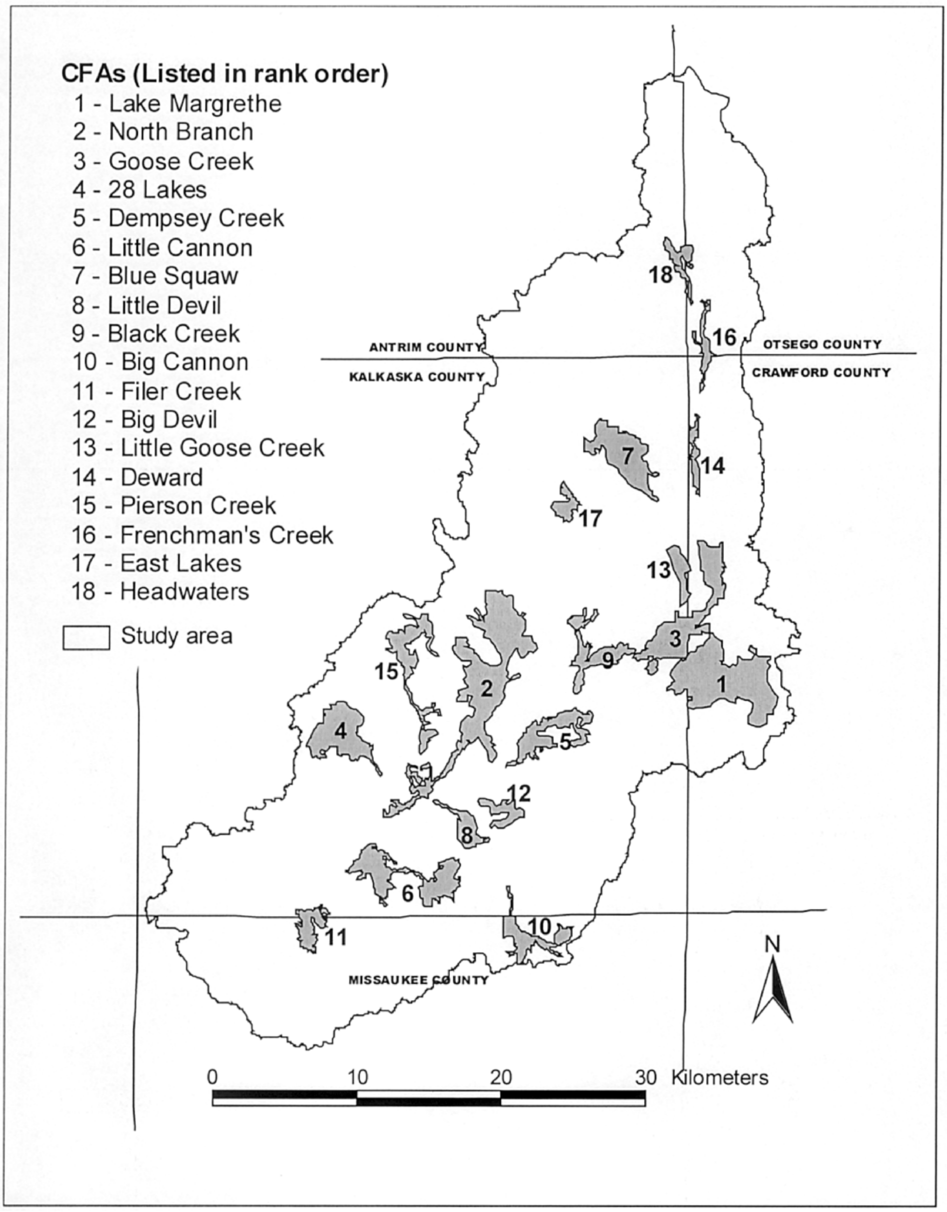

Figure 8. All Conservation Focus Areas with ecological ranks displayed.

Ranked Conservation Focus Areas within Kalkaska County

Parcel analysis was conducted on the CFAs that lie completely within Kalkaska County. For these 10 CFAs, a secondary analysis added two criteria, conservation opportunity and conservation feasibility, to the ranking scheme. Conservation opportunity measures how much land within a CFA is not already protected (as either public land or private land under easement) or is otherwise unprotectable (large lakes). GTRLC is interested in targeting CFAs that contain private land in need of protection. Conservation feasibility measures how much of the land available for protection is found in tracts 16 ha or larger. Given

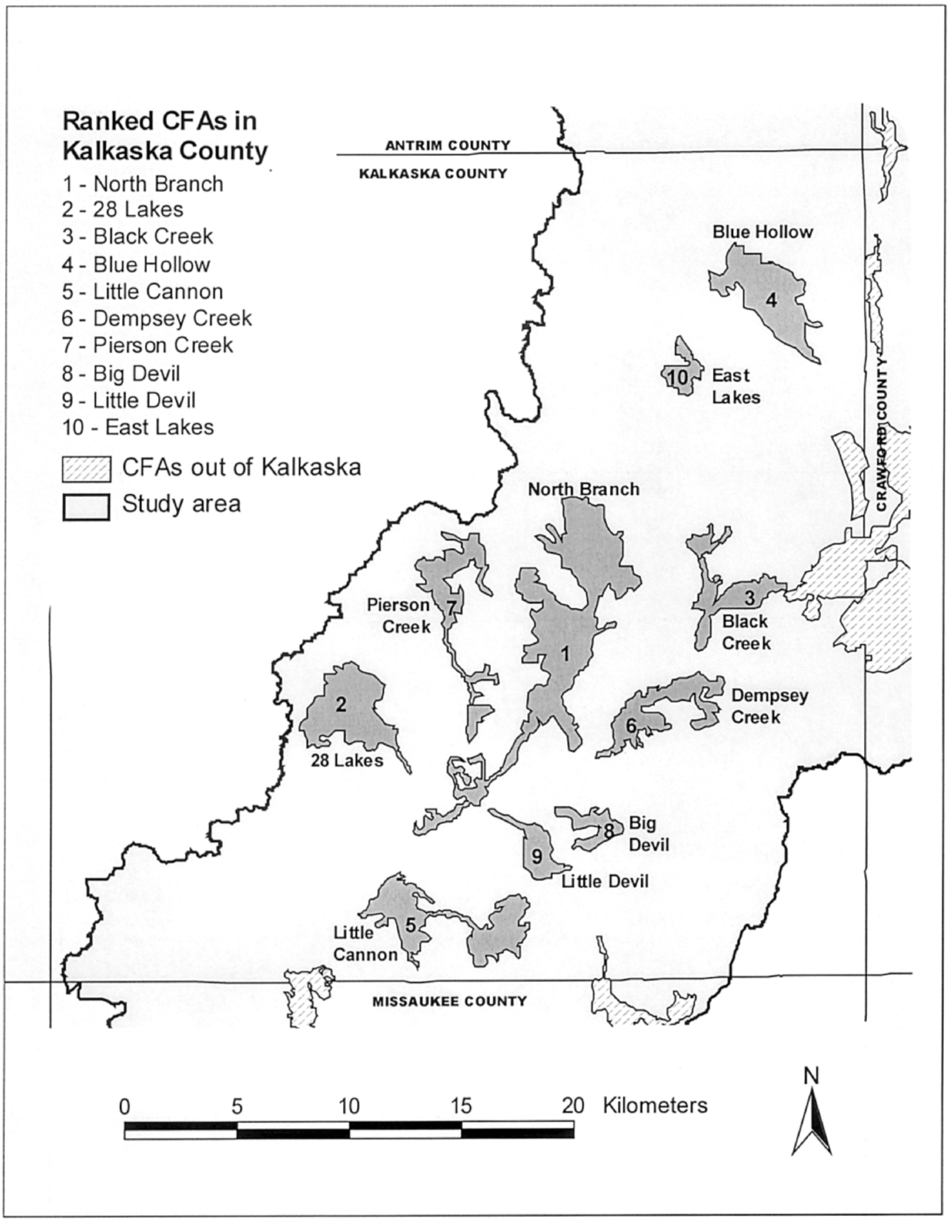

Figure 9. Ranked Conservation Focus Areas in Kalkaska County.

limited time and resources, GTRLC can protect land more efficiently by targeting larger parcels.

Table 4 displays these results, and Figure 9 shows the ranked CFAs in Kalkaska County. Incorporating the conservation opportunity and feasibility criteria into the ranking system changes the final rank of several CFAs. These adjustments are not surprising given that the initial ranking did not consider how the size, shape and extent of private land parcels associated with a given

Table 4. Conservation focus areas within Kalkaska County; ranking scheme and results

	Mean Score		Size		Shape		Opportunity		Feasibility			
CFAName	Mean Parcel Score	Rank	Ha.	Rank	Perimeter to Area Ratio	Rank	Unprotected Hectares*	Rank	Unprotected ha. in 40 + ha. Parcels	Rank	Sum Rank	Final Rank**
North Branch	29.4	1	3217	1	0.00266	3	2661	1	2289	1	7	1
28 Lakes	27.5	4	1172	3	0.00193	1	1594	4	1162	4	16	2
Black Creek	26.7	6	684	7	0.00414	8	1641	3	1641	2	26	3
Blue Hollow	23.9	10	1159	4	0.00198	2	934	5	448	5	26	4
Little Cannon	26.3	7	1223	2	0.00325	4	228	9	157	7	29	5
Pierson Creek	25.1	9	883	5	0.00483	10	1744	2	1410	3	29	6
Dempsey Creek	28.2	2	798	6	0.00396	6	286	7	48	9	30	7
Little Devil	27.0	5	377	8	0.00336	5	229	8	30	10	36	8
East Lakes	25.8	8	244	10	0.00412	7	347	6	162	6	37	9
Big Devil	27.6	3	301	9	0.00436	9	128	10	113	8	39	10

*Unprotected hectares were calculated using parcels that overlap with CFA boundaries. In some cases, the area for parcels exceeds that of the corresponding CFA. Black Creek CFA, for example, contains a very large parcel that is only partially within the CFA. Thus, its unprotected area exceeds that within the boundaries of the official CFA.

**Mean score rank provides the tiebreaker for identical sum ranks.

Table 5. Relationship between threats and sources of threats, arranged by severity.

	Sources of Threats										
	Development (S)	Oil and gas drilling (S)	Incompatible logging	Invasive and alien species (S)	Road development (M)	ORV Use (M)	Incompatible agriculture/grazing (M)	Dams (min)	Fire suppression (min)	Contamination (min)	Total estimated sources of threats for each threat
Threats:											
Altered composition/ structure (S)	X	X	X	X	X	X	X	X	X		9
Alteration of natural fire regimes (S)	X	X	X	X	X	X	X		X		8
Ecological destruction or conversion (S)	X	X	X	X	X	X	X	X			8
Landscape fragmentation (S)	X	X	X		X	X	X	X			7
Extraordinary predation/ competition/disease (S)	X		X	X	X		X		X		6
Erosion (S)	X	X	X		X	X	X				6
Sedimentation (M)			X		X	X	X	X			5
Alteration of hydrology (M)	X	X	X		X		X	X			6
Resource depletion (M)	X	X	X		X						4
Thermal alteration (min)	X		X		X			X			4
Nutrient loading (min)	X						X	X			3
Toxins/contaminants (min)		X				X				X	3
Total estimated threats for each source of threat	10	8	10	4	10	7	9	7	3	1	69

Notes: (S) = Severe; (M) = Moderate; (min) = minimum.

CFA affect its relative importance. The refined ranking for CFAs within Kalkaska County incorporates such considerations directly into the overall analysis.

Individual Land Parcels within the Top Three CFAs in Kalkaska County

For the parcel analysis, the authors examined all privately owned parcels 16 ha or larger in the top three CFAs in Kalkaska County: North Branch, 28 Lakes and Black Creek. The three-tiered hierarchical prioritization scheme (described in Phase Two of the Research Methods section above) was used to identify 63 parcels, totaling over 4856 ha. Aerial photo inspection revealed that more than 4451 of those hectares were natural, having no residential, commercial, industrial or agricultural land uses. These parcels were recommended as immediate conservation priorities for GTRLC's efforts in the Manistee River watershed. Additional detail on ranked parcels is not displayed here due to privacy issues associated with the data.

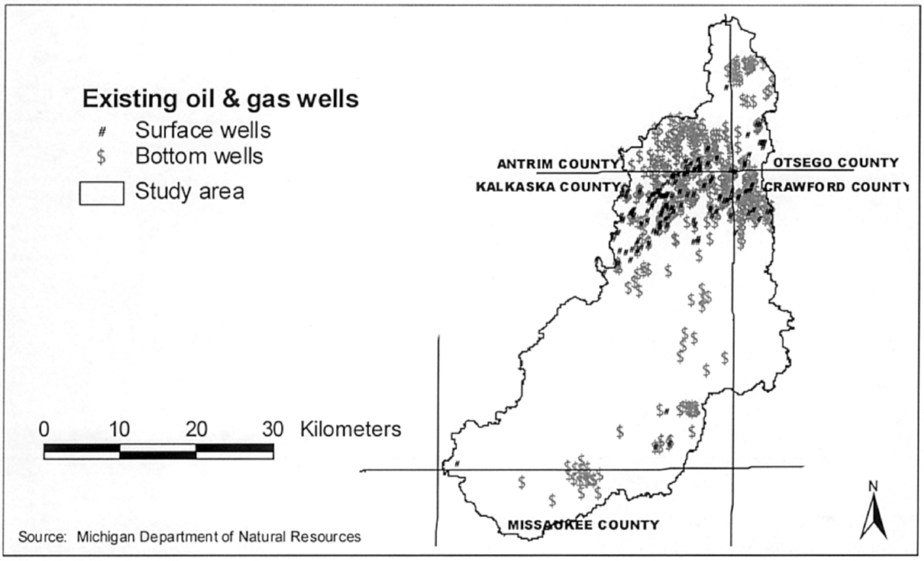

Figure 10. Oil and gas drilling sites as an existing threat source. Source: Michigan Department of Natural Resources (2002).

Threat Analysis

Table 5 shows the study area's key threats, sources of threats and their relationships. Any one threat may have multiple sources and vice versa. Sources of threats were divided into two categories, existing and potential. While existing sources such as oil and gas drilling sites and roads can rarely be removed, it is valuable to know their locations, as many future threats will occur in areas of existing sources. For example, since existing oil and gas drilling pads are positioned over underground oil and gas reserves, new drilling pads will probably be located in the vicinity of the existing sites. Similarly, newly paved or expanded roads can encourage residential development in previously rural areas.

Where possible, existing and potential sources of threats were mapped. For instance, Figure 10 depicts the spatial distribution of existing oil and gas wells. It is difficult to map some sources of threats, such as invasive species and fire suppression. Still, GTRLC and others should consider these sources in making decisions about land protection within the CFAs. For example, invasive species are common in the study area and are often associated with mapped sources of threats such as road development and incompatible logging.

Figure 11 illustrates the existing sources of threats in relationship to the CFAs. This map displays all existing threat sources except roads, which traverse nearly all parts of the study area. Most existing threats are concentrated in the northern third of the study area. Roads are the dominant source of threat and intersect all CFAs. Development occurs mainly around lakes and rivers. ORV/snowmobile trails intersect the CFAs mainly in the central part of the study area, as the abundance of trails on public lands tends to concentrate ORV use there. However, it should be noted that ORV/snowmobile data were available only for Antrim and Kalkaska counties. Existing oil and gas surface and bottom drilling

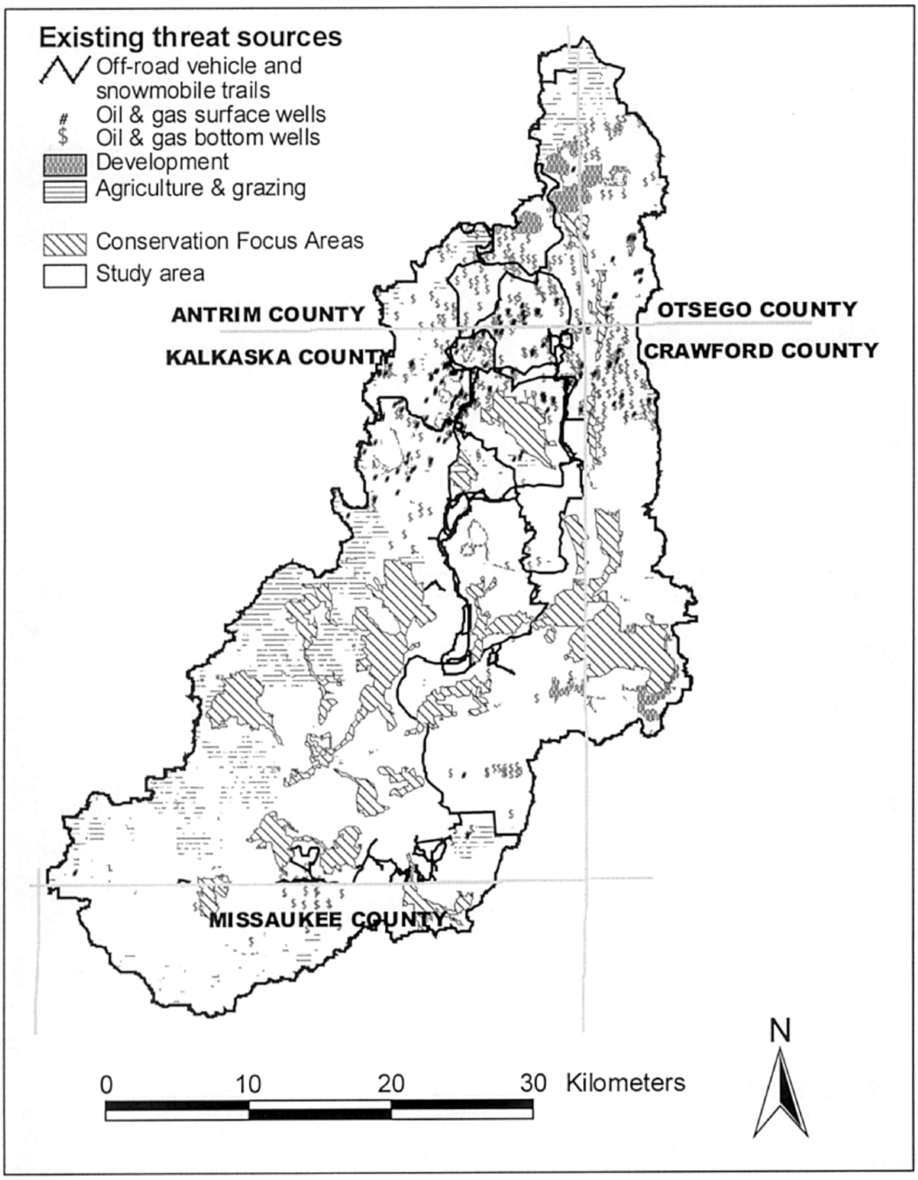

Figure 11. Relationship of Conservation Focus Areas to existing threat sources.

sites occur in CFAs in the northern half of the study area, while agriculture and grazing activity are concentrated on the western side.

Potential sources of threats are scattered throughout the study area. Development potential is highest in CFAs that contain the mainstem of the Manistee River, tributaries and lakes. Potential logging threatens all CFAs, since they all contain forested areas. All lands within CFAs that are close to current oil and gas development are potential lease sites. Although no oil or gas drilling now exists in the East Lakes and Headwaters CFAs, they are still vulnerable to drilling activities because they are located above the Antrim Shale and Niagaran Reef formations. Finally, future extension of highway M-72 will affect the top portion of the North Branch CFA and bisect part of the Goose Creek CFA.

Implementation

To guide the systematic conservation of high-priority parcels, a quantitative hierarchy was established. The three-tiered hierarchy emphasizes that initial conservation efforts should focus on the highest-scored parcels within the highest ranked landscape features of the highest-ranked CFAs. As progress is made on individual parcels, the conservancy can direct resources to the highest-ranked landscape feature of the highest-ranked CFA. This approach drives the protection of a group of adjoining parcels as opposed to a number of dispersed and fragmented ones. However, this hierarchy assumes that the chances for conservation success are equal across all parcels. In practice, landowners will respond differently to proposed conservation strategies. Therefore, GTRLC might use the established hierarchy but also adapt it as necessary depending on the real-world success or failure of protection efforts.

For example, if implementation is slow or unsuccessful in the highest-ranked CFA but conservation strategies are successful in another, additional resources could be directed toward the CFA where success has been achieved, as depicted in the top half of Figure 12. This strategy will help keep protected lands clustered in one area, increasing the overall ecological value of each individual tract. In another scenario, the lowest-ranked parcel of the highest-ranked CFA may be less valuable to GTRLC than the highest-ranked parcel of the second-highest-ranked CFA. If a significant amount of land (but not all) has been conserved in the highest-ranked CFA, GTRLC may choose to begin directing resources to the next CFA. The bottom half of Figure 12 depicts this scenario. Since the vast majority of the highest-ranking CFA is already protected, GTRLC may want to focus its attention on Parcel Y.

Finally, some of the largest parcels may be desirable to GTRLC even though they have a lower mean score than some smaller parcels or are found in a lower-ranked CFA. This is justifiable given the desire to use resources efficiently. Examining the methods used to determine a given parcel's final score provides further insight. A parcel's mean score (the average value of the weighted grid cells that it contained) was used to calculate the parcel's ecological score. This technique can sometimes assign lower ecological scores to larger parcels if they contain areas of low-to-medium-priority grid cells.

For example, a 100-ha parcel may contain 20 ha of highly ecologically valuable land and 80 ha of less ecologically valuable land. Since only 20% of this tract contains high or highest-priority grid cells, its overall mean score might be fairly low. A neighbouring 20-ha parcel may contain 15 ha of highly ecologically valuable land and 5 ha of less ecologically valuable land. In this case, the tract's overall mean score might be fairly high since 75% of the tract contains high- or highest-priority grid cells. Thus, the smaller parcel would receive a higher ecological score than the larger parcel, even though the larger parcel contains more ecologically valuable land. Considering parcel size in the overall final score directly corrects for this issue, but there is no guarantee the overall scoring system captures and addresses every nuance of the interface between mean score, size, and other factors.

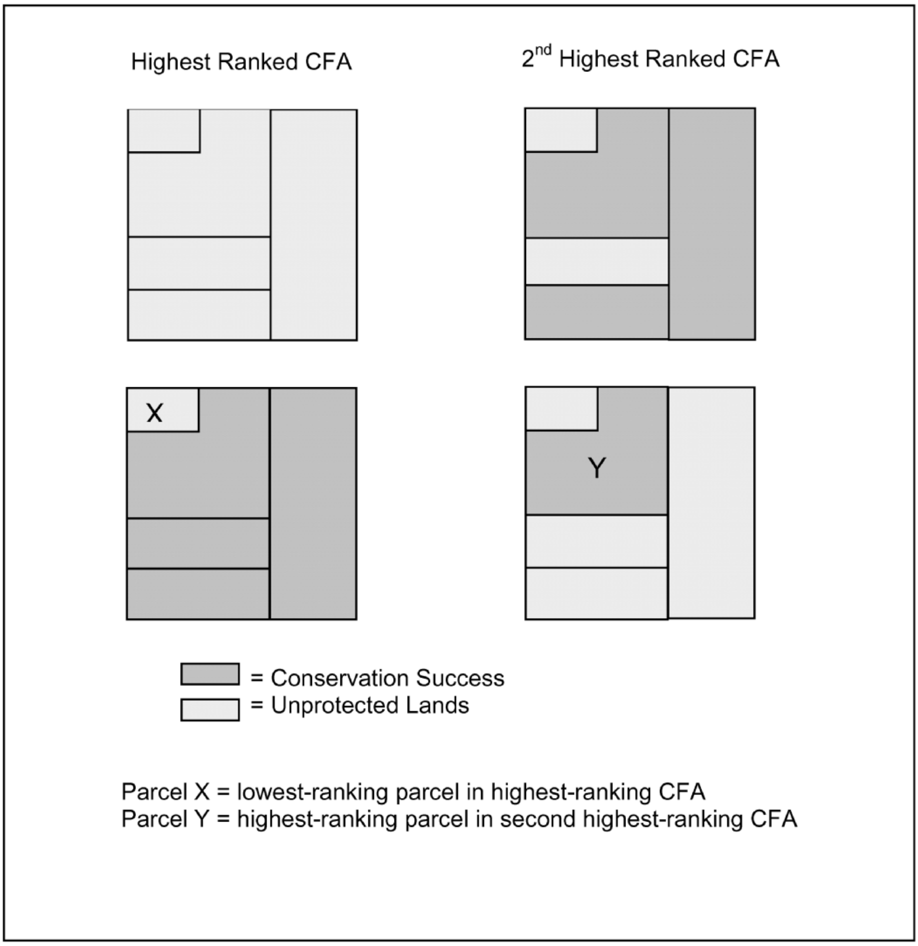

Figure 12. Implementation options: success-based strategy versus Conservation Focus Area progression strategy.

Discussion

The Upper Manistee River Watershed Conservation Plan provides a framework to stimulate and expand the conservation work of land trusts. The plan was developed according to the overarching principles of landscape ecology and ecosystem management. Multiple, landscape-level drivers that are scientifically based and tailored to the study area were used to identify the area's most ecologically valuable land and to prioritize lands at two different scales: regional (Conservation Focus Areas) and local (individual ownership parcels). As GIS technology becomes more accessible to regional land trusts, the methods outlined here could be adapted by non-profit land trusts.

This work has been useful to the Grand Traverse Regional Land Conservancy as it moves forward in landscape-scale conservation. The conservancy is working to normalize its watershed planning efforts across the five-county service area, by using consistent ecological assumptions and drivers. The methods used in this study were critical in forming decisions about future processes.

The conservancy is now preparing watershed plans for all nine watersheds within the five counties of its service area, building on the work shown here. It hopes eventually to protect about 80% of the parcels in the highest-priority protection categories (Rigney, 2003). This study helps highlight issues that will be encountered as conservancies attempt landscape-scale conservation planning, with this or similar methods.

Volume of High-priority Land

One of the potential challenges facing GTRLC as it strives to implement this project's recommendations and achieve landscape-scale success is the sheer amount of land outlined for protection. The study highlights over 4856 ha of private lands as suitable for protection in the top three CFAs in Kalkaska County alone. When all 18 CFAs in the study area are considered, that total rises above 8000 ha. While not an impossible task, it is a challenge to directly protect this much land before it is lost to development or other threats. A number of lessons have been learned in the attempt to focus on the most important conservation opportunities; other questions remain.

Decision Making

Developing a conservation plan requires making numerous discrete decisions that hinge on unique and hard-to-quantify variables. The scientific literature provides few black-and-white answers or objective criteria. For example, it is well established that larger tracts of natural areas are more valuable than smaller tracts, but how large is large enough? Specifically, what area threshold is appropriate for the CFAs? Is 200 ha too small to represent a significant landscape, or does 200 ha set too high a hurdle and exclude more localized, but still highly valuable, sites? While decisions in this study were based on the best data and most relevant conservation principles, there is no denying the subjectivity of some choices. Nor can the potential cumulative impact of that subjectivity on the overall analysis be overlooked.

Data Limitations and Ground Truthing

Existing data sources and simple research techniques were used extensively to identify the most ecologically important lands within the study area. Using existing data was generally advantageous for the project as it greatly reduced completion time and costs. While the GIS data were the most complete and accurate available, all data may have inaccuracies. Some data were collected for large regions, often through the use of remote sensing techniques. Using data collected from imagery with a spatial resolution of 30 x 30 m for a parcel-level analysis may produce generalizations and possibly inaccurate conclusions. While aerial photographs of each parcel revealed important information on land cover, land use and disturbances, they provided little insight into the *quality* of land cover or the occurrence of specific flora or fauna, such as threatened or endangered species. GTRLC should therefore conduct field analyses before making conservation decisions on specific parcels.

Driver Correlation

Prior to selecting the conservation drivers that form the backbone of this analysis, the authors did not determine the relative correlation among the drivers. Nor was any preliminary research conducted to identify the sort of lands the cumulative overlay of all drivers would select as top priority. One interesting issue to consider is the relative contribution of each driver to the cumulative mean score for each CFA. Each conservation driver had equal importance in the overall weighting scheme, but some drivers were clearly more responsible for the high-scoring grid cells within certain CFAs than others. In addition, subtle connections between drivers influenced the location and relative importance of resulting CFAs. For example, many CFAs are focused around hydrologic features such as wetlands or streams. This emphasis may be caused by a correlation among numerous drivers, such as riparian ecosystems, groundwater accumulation and wetlands. Although the emphasis on hydrologic functions was intentional (because of the unique hydrologic characteristics of the Manistee River), the possible correlation of the drivers may have devalued certain upland features such as northern hardwood forests found on glacial moraines. A statistical regression analysis of the drivers would highlight these subtle correlation patterns and help GTRLC and others to better understand the results and improve the replication of the project's approach and method.

Conclusion

Although many conservation-planning schemes use species information to motivate and shape conservation plans, models that include both species factors and other ecosystem factors are needed for determining where to protect natural values on private land. A number of schemes are proposed in the literature for mathematically determining land areas most suitable for protection based on particular wildlife species. This project builds on those ideas and on broader landscape ecology theory; the foundation of the project is built on the scientific literature that documents the importance of groundwater, wetlands, riparian areas and rare land-types. It combines those factors with information not only on rare and endangered species, but also with important spatial variables (large tracts of unfragmented land and contiguity with protected lands).

This project is adapted from The Nature Conservancy's model for conservation planning; however, instead of using specific conservation targets (individual species), it used conservation drivers that represent both biological and physical resources. The conservation drivers, as spatial representations of the project's objectives, were functional as the foundation of the analysis. Like the TNC approach, threats to the viability of ecosystems were analysed and land areas were ranked for protection. The approach taken for GTRLC is unique in trying to operationalize three distinct goals in conservation planning: to find areas of high ecological importance, to promote the landscape's spatial integrity and to delineate threats to ecological systems and processes. The resulting planning model, while imperfect, is pragmatic and feasible with basic GIS tools.

Land conservation organizations are shifting toward conserving the spatial and ecological integrity of landscapes. They face considerable challenges from state and federal policies, funding sources and public opinion, many of which are more accustomed to and supportive of species-based protection efforts. In light of these challenges, it is especially important for practitioners of the landscape approach to rank their conservation efforts using scientifically-based methods. This study illustrates a GIS-based method that other organizations can adapt and apply to a variety of landscapes. In certain cases, an organization may want to use the overall methodology but develop its own conservation goals, drivers and ranking schemes. Regardless, it is clear that conservation organizations need strategies for shifting from site-specific conservation to more landscape-level approaches.

Acknowledgments

The authors appreciate collaborations with the staff at the Grand Traverse Regional Land Conservancy, the editorial assistance of Julie Steiff, and helpful suggestions from two anonymous reviewers. This project was funded by The Prentice Foundation and the Ecosystem Management Initiative, Rackham School of Graduate Studies and School of Natural Resources and Environment at the University of Michigan.

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