ANALYSIS

Development of an Adirondack Ecosystems Model and Its Implications for Public Forest Preserve Management

By STEPHEN SIGNELL, STACY MCNULTY, BENJAMIN ZUCKERBERG, and WILLIAM PORTER

Introduction

Comprising over 6 million acres, with 2.5 million acres of public land, the Adirondack Park is the largest protected wilderness east of the Mississippi River. Documenting and maintaining biodiversity within the park is one of the major goals of those tasked with managing public park lands (Adirondack Park State Land Master Plan 2001). The Adirondack Park contains many of the most exemplary, contiguous, and best-protected lands in the Northeast. To manage the park's ecosystems, planners should know where ecosystems occur on the landscape, how they are arranged in relation to one another, and to what extent the lands are protected and healthy. Many existing measures of ecosystem health, however, rely on current characteristics such as land cover. Land cover often reflects recovery from disturbance (e.g., agriculture, logging) and is therefore ephemeral. A better ecosystem map would model potential natural communities regardless of disturbance.

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Ecosystems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes. Various combinations of bedrock, soil, elevation, and landform position create unique environments that are amenable to certain organisms and communities. Figure 1 shows how variability in elevation can give rise to different ecosystem types. Note, however, that a single ecosystem type can be expressed as multiple plant community types (2a, 2b), often as a result of disturbance. Species assemblages such as early successional aspen forests or mature hardwood forests may come and go, but as long as the basic underlying processes and site conditions remain fairly constant, the ecosystem type does not change. For this reason, it is important to consider factors such as parent material, physiographic position and moisture conditions along with land cover type when mapping ecosystems.

Toward this end, the Unit Management Planning–Geographical Information System (UMP–GIS) Consortium, an outgrowth of the Adirondack Research Consortium, initiated the Adirondack ecosystems model project with the purpose of producing a GIS-derived ecosystem map of the Adirondack Park. Our objective was to develop a model that would map the distribution and locations of potential ecosystems in the Adirondacks. The term "potential" is meant to describe the process of identifying ecosystems based on GIS data sets including bedrock geology, elevation, land cover, landform, soil depth, and soil moisture. As such, these ecosystems represent the potential of the landscape to support unique communities and are not necessarily a reflection of current land cover and land use practices. The outcome of this project was a spatial model and corresponding map of potential ecosystem types designed for land managers. In this paper, we describe the process by which a potential ecosystem map was developed for the Adirondacks using GIS and remotely sensed data, and an assessment of the map's accuracy with ground-based data.

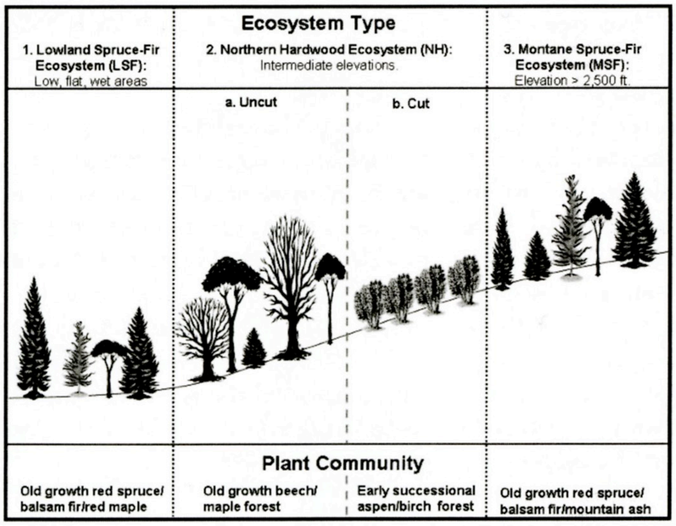


Figure 1. *Ecosystem and vegetation types in relation to landscape position and disturbance regime. Following clear cutting of part of ecosystem 2, two forest types (2a, old growth beech-maple forest, and 2b, early successional aspen/birch forest) are distinguished, illustrating the fact that different cover types are not necessarily different ecosystem types (figure modified from Barnes et al. 1997).*

Methods

The backbone of the ecosystems map was a preexisting GIS layer of ecological land units (ELUs), originally developed by The Nature Conservancy (Anderson et al. 1999). The ELU map was derived from several GIS layers—including elevation, bedrock geology, parent material, moisture availability, and landform—and combined to create ELUs (Appendix A[1]).

To convert the ELUs into an ecosystem map, we had to determine which single ELU or groups of ELUs form distinctive ecosystem types. Regional experts in community ecology participated in two workshops with the aims of (1) deciding on a classification system, and (2) classifying ELUs within that framework. The classification system chosen was derived from NatureServe's *Ecological Systems of the United States* (see http://www.natureserve.org/getData/USecologyData.jsp for more information on these systems). This represents the first version of a mid-scale ecological classification developed by NatureServe for use in conservation and environmental planning (Edinger et al. 2002). We focused primarily on upland forests rather than wetlands, as the Adirondack Park Agency (APA) is developing a high-quality, park-wide wetland cover type map.

We produced an ELU-ecosystem crosswalk which assigned an ecosystem type to each ELU. We felt, however, that the model could be improved by incorporating other data layers such as the APA "mesosoils" layer, and a moisture index layer (SUNY-ESF unpublished data). These layers were used to make decisions in cases where experts believed that two different ecosystems might be represented by a single ELU code. For example, map pixels with an ELU code of 2131 (wet flats on acidic sedimentary bedrock in the 800′–1700′ elevation class) were classified as Lowland Spruce–Fir if the moisture index score was larger than 90; otherwise they were classified as Northern Hardwoods.

[1] For appendices, see http://www.esf.edu/aec/research/UMP-GIS_AJES_Appendix.pdf.

Accuracy Assessment

How does one evaluate the accuracy of a map of "potential" ecosystems? Using land cover or other vegetation data to evaluate the accuracy of an ecosystem model is not ideal, as land cover can vary within an ecosystem, as discussed in the introduction. To illustrate this problem, consider the fact that logging operations of the late 19th and early 20th centuries selectively removed many conifers from Adirondack forests (McMartin 1994). Consequently, conifers are greatly underrepresented in some areas of the park. If the model classifies an area as Lowland Spruce–Fir and the current vegetation data from the area contains mostly deciduous trees and few conifers, one might conclude that the model was wrong. The model may in fact have predicted the ecosystem correctly, however, but logging had changed the cover type from its original configuration. Without detailed spatial information on disturbance history, there is no way to know. Another problem with using vegetation data is that NatureServe ecosystem descriptions contain little information on what differentiates ecosystem types floristically. For example, vegetation data would do little to help elucidate the difference between Acidic Rocky Outcrops (ACRO) and Acidic Cliff & Talus (ACCT), given the ecosystem definitions.[2]

Despite these drawbacks, we used ground-based vegetation data to evaluate the ecosystems model due to a lack of good alternatives. In evaluating our model, we obtained vegetation data for 874 forested plots or stands from four sources: (1) USDA Forest Service's Forest Inventory and Analysis data for 347 plots distributed across the Adirondacks (http://fia.fs.fed.us/); (2) SUNY College of Environmental Science and Forestry's Huntington Wildlife Forest Continuous Forest Inventory for 280 plots located on 15,000 acres in the center of the park (http://forest.esf.edu/); (3) SUNY ESF NASA Forest project for 167 plots, also located in the central part of the park on state Forest Preserve land (http://forest.esf.edu/); and (4) New York State Office of Real Property Services data for 80 upland forest stands from across the Adirondacks. Appendix B describes the procedures used to generate and evaluate the database in more detail.

[2] ACRO: shallow soil, acidic bedrock hilltops at low to mid elevation, with open canopy physiognomy ranging from exposed rock to woodland, *conifer to deciduous*. ACCT: cliff or talus with acidic bedrock (other than shale) on and at the base of steep slopes (>45 degrees) at low to mid elevation, with physiognomy ranging from exposed rock to forest, *conifer to deciduous*.

Results

The final model produced a map with 30 ecosystem types, a small section of which is shown in Figure 2 (see Appendix C for full-color map of Adirondack Park ecosystems). Northern Hardwoods (NH) and Lowland Spruce–Fir (LSF) were the most common ecosystems, together comprising over 65% of the study area (Table 1). Other relatively abundant types were Alkaline Hardwoods (AHF), Lowland Alkaline Hardwood (LAK), Alkaline Hemlock–Hardwood (AHH), Montane Spruce–Fir (MSF), Pine–Hemlock–Hardwood and Cove communities, which together represent 21% of the land area in the park. The alkaline ecosystems (AHH, AHF, LAK) were concentrated in the Champlain Valley in the eastern part of the park and in some areas of the northwestern portions of the park underlain by alkaline bedrock.

According to the species Importance Values derived from ground data, plots classified as NH were dominated by sugar maple, beech, and yellow birch (Figure 3). These species were present as minor components in LSF plots where red maple, red spruce, and balsam fir had greater importance. MSF and PHH composition were similar to LSF, but MSF had a higher proportion of paper birch, and PHH had increased values for pine and hemlock. These findings are consistent with the NatureServe descriptions of these types. Composition of AHH was also generally consistent with the type description, although

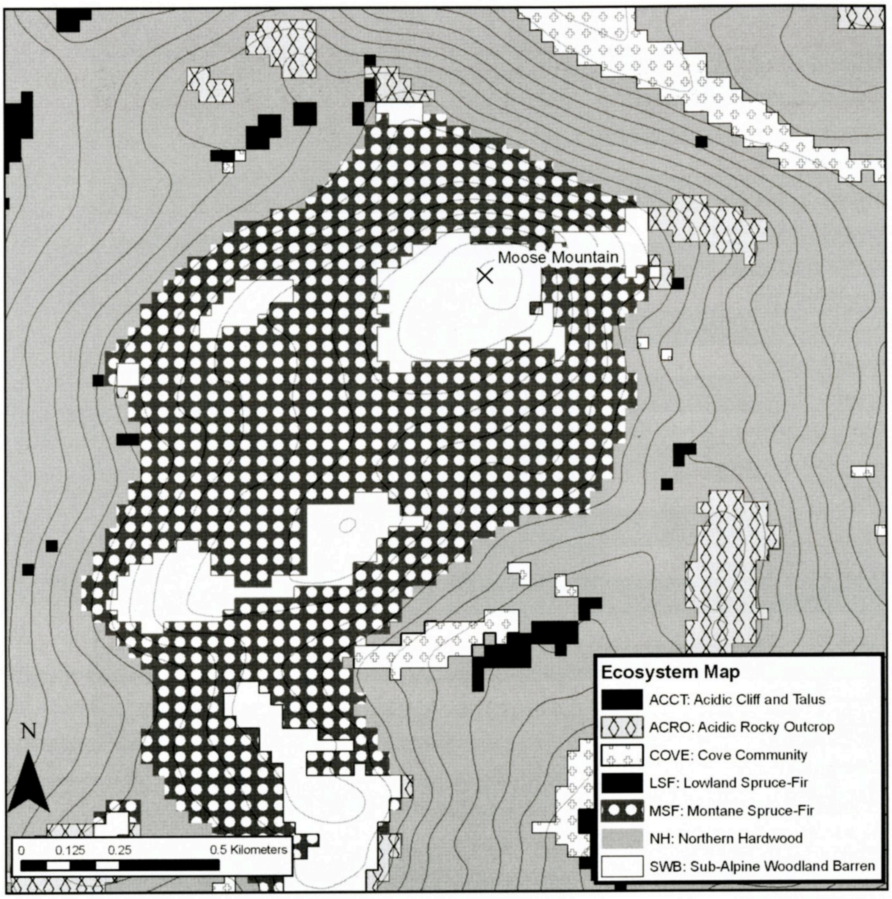


Figure 2. *Modeled ecosystems with topographic contours of Moose Mountain, central Adirondacks.*

these areas may better be termed Alkaline *Pine*–Hardwood forests due to the high percentage of pine. Data from the COVE, AHF, and ACRO plots did not match their descriptions as closely. This was reflected in the inability of discriminant analysis to distinguish these from other types (Appendix B). For example, 7 of 13 COVE plots were classified as NH, because they contained a high percentage of sugar maple, beech, and yellow birch. In general, the ability of the model to discriminate ecosystem types correctly increased with ground plot sample size. On average, discriminant analysis predicted the correct ecosystem 56% of the time, with correct classification rates ranging from 7% (COVE, n = 13) to 60% (LSF, n = 188). This was substantially better than random—when ecosystem codes were randomized, discriminant analysis classified only 30% of the plots correctly.

Discussion

As a projection of the Adirondack region in its most natural and undisturbed form, the ecosystems model can provide a number of benefits for land planning. As with any tool, models have limitations and are scale-dependent, and the ecosystem map is useful only at spatial scales of 1:62,500 or greater (for reference, 7.5 minute topographic maps are at the higher-resolution 1:24,000 scale). The power of this ecosystems map, therefore, lies within its application to park-wide planning to identify regions that are more biologically significant or that might host species of interest. For example, units with lower ecosystem richness or rarity could be managed primarily for recreation, while units containing a high proportion of rare

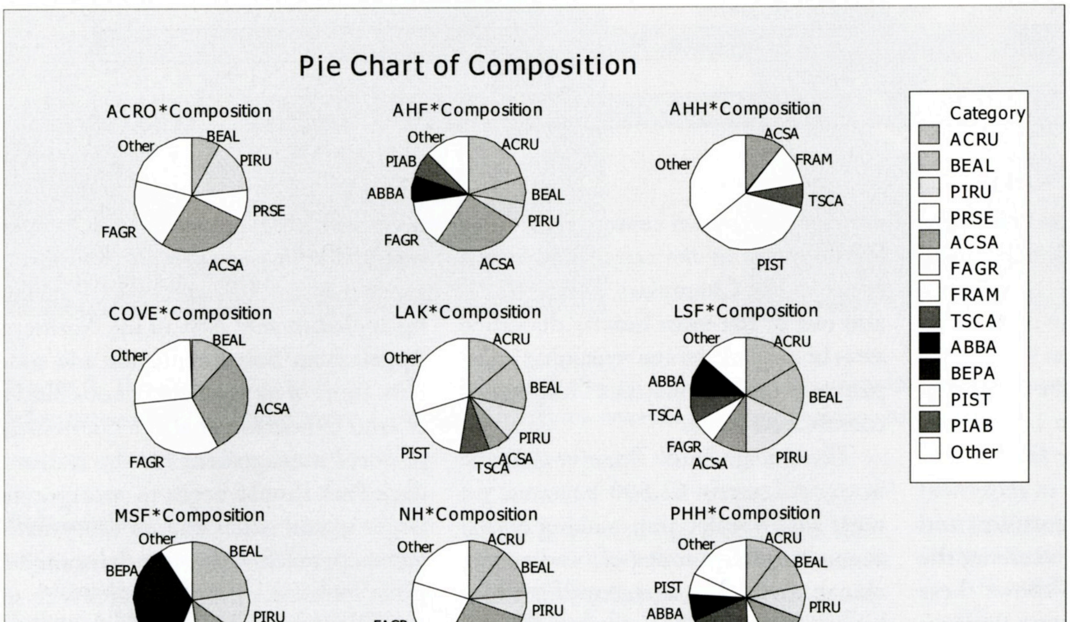


Figure 3. *Proportion of tree species of Importance Values by ecosystem type.*

Table 1. *Ecosystem codes and acreages.*

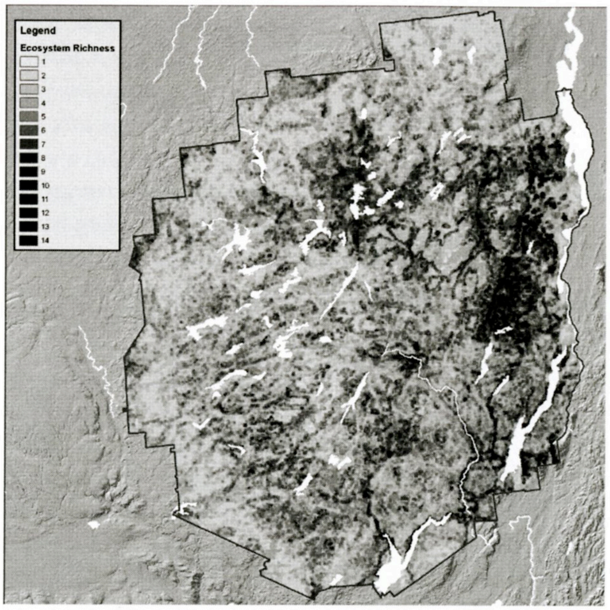
Ecosystem Code	Ecosystem Abbreviation	Ecosystem Name	Ecosystem Size (Acres)	Percent of Total Acres (%)
21	NH	Northern Hardwood	2,764,240	42.0
17	LSF	Lowland Spruce–Fir	1,552,135	23.6
28	WATER	Water Body	443,275	6.7
24	PHH	Pine–Hemlock–Hardwood	364,459	5.5
6	AHF	Alkaline Hardwood	281,143	4.3
19	MSF	Montane Spruce–Fir	245,184	3.7
7	AHH	Alkaline Hemlock–Hardwood	203,763	3.1
16	LAK	Lowland Alkaline	156,420	2.4
13	COVE	Cove Community	131,931	2.0
4	ACRO-WPRP	Acidic Rocky Outcrop–White/Red Pine	109,944	1.7
27	SWB	Subalpine Woody Barren	91,681	1.4
25	SAND	Sand Plain	58,322	0.9
30	DRY FLATS	Dry Flats	52,153	0.8
23	NH-S	Dry Northern Hardwoods	33,342	0.5
18	MAK	Montane Alkaline	33,192	0.5
15	DOF	Dry Oak Forest	19,685	0.3
1	ACCT	Acidic Cliff & Talus	18,039	0.3
26	SAND-PB	Sand Plain/Pine Barren	8,198	0.1
11	AKRO-MAK	Alkaline Rocky Outcrop/Montane Alkaline	7,267	0.1
3	ACRO-DOF	Acidic Rocky Outcrop–White/Dry Oak Forest	2,179	*
5	ACS	Acidic Swamp	1,555	*
10	AKRO-AHF	Alkaline Rocky Outcrop/Alkaline Hardwood Forest	641	*
29	WMSM	Wet Meadow/Shrub Marsh	337	*
2	ACRO	Acidic Rocky Outcrop	325	*
8	AKCT	Alkaline Cliff & Talus	174	*
14	CSF	Conifer Seepage Forest	30	*
12	ALPB	Alpine Barren	9	*
22	NH-N	Wet Northern Hardwoods	5	*
20	MSF-MAK	Montane Spruce–Fir/Montane Alkaline	4	*
9	AKF	Alkaline Forest	1	*
		Total	6,579,633	100.0

* = < 0.1%.

ecosystems might have protection as first priority (Adirondack Park State Land Master Plan 2001).

With this in mind, we created a map showing ecosystem richness for the Adirondack Park, defined as the number of ecosystems found within a 1-kilometer radius of each pixel center (Figure 4a). There is spatial variability in ecosystem richness, with large river corridors and the eastern Adirondacks receiving the highest scores. Figure 4b shows these scores summarized by Forest Preserve unit. Likewise, ecosystem rarity was calculated by assigning higher value to ecosystems with few pixels and then summing the values within a 1-kilometer radius of each pixel center (Figure 5a). While many of the rarest ecosystems occur in the Champlain Valley, this is also one of the most heavily disturbed areas of the park, so any remaining intact parcels in this area may be of heightened conservation value.

The average Forest Preserve unit size is approximately 42,800 hectares, yet most land use decision-making occurs at much smaller scales of biodiversity management. Management of land for biodiversity protection often focuses on small-patch ecosystems (e.g., individual wetlands, deer wintering yards, old growth forest patches) and local species assemblages. Less attention has been paid to ecosystem, park-wide, and regional land management. However, given that the Adirondack Park makes up approximately 20% of the Northern Appalachian/Boreal ecoregion and contains some of its most contiguous blocks of land (Anderson et al. 1999), natural resource management for the Adirondack Park should begin to incorporate larger spatial scales and an ecosystem-based approach. The ecosystems model makes possible a multiscale approach to managing ecosystems and species (Poiani et al. 2000), and provides a larger context by which land planners can assess biodiversity in the Adirondack region.



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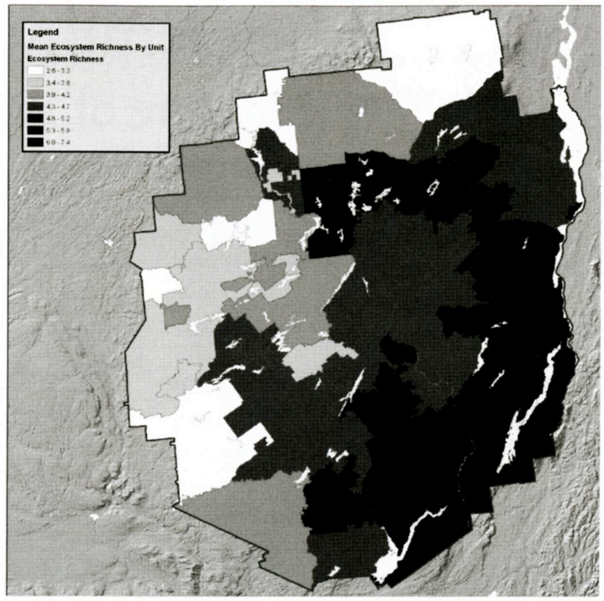

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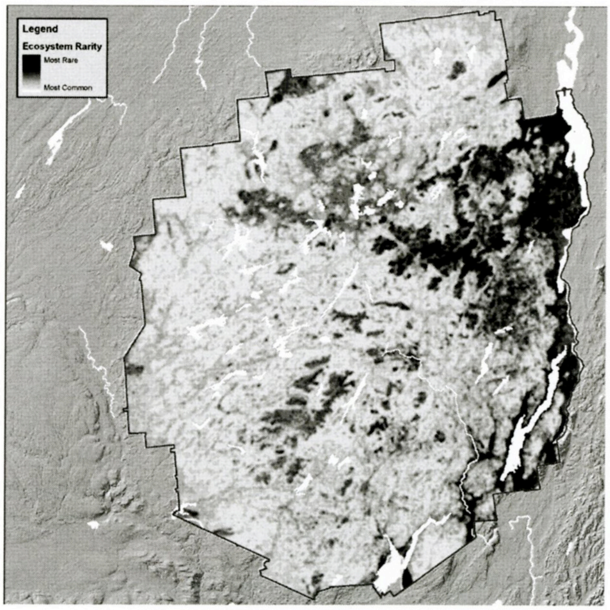
Figure 4. *Ecosystem richness. a) Richness calculated by counting the number of ecosystems within a 1-kilometer radius of each pixel center. b) Mean richness scores according to Forest Preserve unit.*



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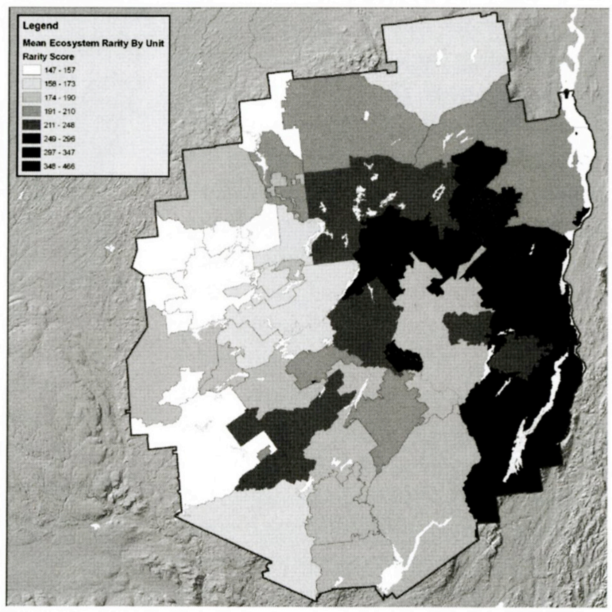

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Figure 5. *Ecosystem rarity. a) Rarity calculated by assigning higher values to rare ecosystems and then summing the values within a 1-kilometer radius of each pixel center. b) Mean richness scores according to Forest Preserve unit.*

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