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Land Type Associations Conference: Development and Use in Natural Resources Management, Planning and Research

**April 24 – 26, 2001
University of Wisconsin
Madison, Wisconsin**

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Proceedings

Land Type Associations Conference: Development and Use in Natural Resources Management, Planning and Research

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Edited by:
Marie-Louise Smith

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Posters

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I. LTA DEVELOPMENT

Landscape Ecosystem Classification Principles and Concepts

Burton V. Barnes[1]

Abstract

Examination of the latest views by ecologists on 21st century frontiers indicates that there is no higher priority than research and application of landscape ecology. Landscape ecology is the science of landscapes, understood concretely as spatial and volumetric ecosystems in their regional contexts. It's application provides the framework and substance for understanding and solving the most pressing human-caused problems of the 21st century and the management of landscapes and waterscapes. Ecosystem is another fuzzy ecological term like population and community—maybe an illusion? Therefore, advancing the theory and application of ecosystem classification and mapping requires a clear understanding of what a landscape ecosystem is—a real live chunk of earth space with characteristic composition, structure, and function—and the ability to articulate this reality to multiple publics. Advancing an ecosystem approach requires systematic classification and mapping of ecosystems throughout regional landscapes with defined protocols for distinguishing boundaries at all scales. Greater attention to the hierarchy of spatial scales, multiple-factor integration, and climatic factors at appropriate scales would increase our ability to understand changes in ecosystem composition, structure, and function in the light of climatic change and unexpected stresses. Ecosystem classification with genetic differentiation of plant populations in mind and the importance of collaboration with aquatic ecologists are emphasized. The new paradigm of landscape ecology needs to be reflected in the training and employment of ecosystem ecologists with strong field skills rather than environmentalists or disciplinary specialists. Theory is the most practical of all things, but Bottom Line: Ya Gotta Know the Territory!

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Towards National Landtype Association Data Standards

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Abstract

As landscape analyses become the norm for the next generation of National Forest planning, the need to achieve consistency in mapping ecological units at the landscape, or Landtype Association (LTA) scale, becomes imperative. Using an interdisciplinary team approach, we first make the case for national data standards. We then propose standards to reflect the scale, patterns, and processes of LTAs using four map unit themes: design, delineation, characterization, and validation. We aim for a balance between consistency and the practical need to recognize previous work and the diversity of landscapes across the United States.

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Introduction

Given the complexity of issues confronting land managers, the need for ecological maps as a planning framework (Cleland et al. 1997) is greater than ever. Over the past ten years in resource management, the value of characterizing and understanding ecological patterns and processes changing at the landscape scale has become firmly embraced. Yet implementation and use of mapping at landtype association (LTA) scale is still hampered by incomplete coverage and by a lack of consistency, both within regions and nationally. In this paper we review the definition of LTAs and their importance in forest planning. We then make the case for adoption of standardized methodology and elements of LTAs. Finally, we propose LTA data standards, organized among four map unit themes: design, delineation, characterization, and validation of map units.

This paper represents a portion of the work of a U.S. Forest Service interdisciplinary team (henceforth described as the "revision team") charged with updating manual standards and protocols to meet today's business needs and in accord with today's science. (The Natural Resources Conservation Service also has a representative on the team.) Forest Service Handbook 2090 (ecological unit standards) is under revision by this team, and will be incorporated into Forest Service Manual 1940. Thus standards in this paper may be further revised before this manual is finalized. While these standards will apply to Forest Service mapping efforts, the revision team seeks the cooperation and expertise of other agencies and organizations as we continue to work towards the ideal of a unified approach to ecological mapping. Their comments and input on this work are welcome.

Definitions

Landtype associations are landscape scale map units defined by multiple biotic and abiotic factors, including a dominant geomorphic process type, similar landforms, surficial and near-surface geologic formations, and associations of soil families and potential natural vegetation at the series level (Forman and Godron 1986, Bailey and Avers 1993, Cleland et al. 1997). In accordance with the national hierarchy of ecological units (ECOMAP 1993), climate should also be included when developing LTAs, although it is usually less important as a delineator than at broader scales. In this document, we include definitions of commonly used terms in ecological unit mapping (see Glossary) to avoid confusion and promote standardization of discourse.

Context of LTAs within the National Hierarchy

Landtype associations represent a middle, landscape scale in the national hierarchy of ecological units (Cleland et al. 1997). At broader scales (subsection, section, province, and domain), a regional concept applies; and landtypes and their phases are found at local (fine-resolution) scale.

Climate, geology, geomorphology, soil, and potential vegetation, as well as their associated processes, operate at all scales of the hierarchy. It's important to note, however, that the relative importance of individual factors varies with scale (Cleland et al. 1992) and with ecological province (broad-scale differences across the United States).

At macro-scale, sunlight and precipitation (climate), and patterns in gross physiography are used to delimit provincial boundaries. The separation of the tallgrass from the shortgrass prairie region based on precipitation levels is a good example. At meso-, or landscape scale (the focus of this paper) geomorphic conditions and processes mediate these climatic effects. Mountain building, bedrock differences, glaciation, and fluvial action temper, change, and mediate climatic effects. Rain shadows are created in some areas and rain forests in others. Limestone bedrock leads to increased site fertility, in turn increasing productivity and affecting plant community composition and structure. Deglaciation leaves behind moraines, galaciofluvial deposits, and other features with profound effects on resulting soil and vegetation. Finally, at a land unit scale (landtypes and landtype phases), differences in soil textures and drainage, and micro-topography strongly influence the plant communities we see on the ground.

Importance and Value of Landtype Associations

The chief value of landtype association mapping is the planning framework it provides. LTAs provide a context for organizing National Forest and other landscape-scale planning. Because they reflect mid-scale influences of local weather patterns, disturbance regimes, biological productivity and resiliency, and hydrologic patterns and function, they serve as an excellent coarse filter for organizing the landscape by capabilities and limitations.

Perhaps less appreciated is the relatively low cost—in dollars, personnel, and time—of developing LTAs. Whereas finer-scale landtype maps for a National Forest may take years to develop, LTAs can normally be developed in a year or less. In the rapidly changing contexts of resource management, the ability to quickly develop useful information is of great value. An initial emphasis on LTAs in no way diminishes the importance of landtypes. Indeed, LTAs can direct priorities for landtype and landtype phase mapping. Landtypes and their phases are nested within LTAs, and in turn are used to check and revise boundaries, and interpret conditions and processes occurring within and among LTAs. Mapping efforts may be increased in areas of complex nature or where more management activity is anticipated. Perhaps more importantly, LTAs, once established and in routine use, will help build the managerial support needed for a successful landtype mapping and interpretation program.

Finally, because LTAs are relatively broad landscape units, usually with visible differences, LTAs are readily summarized and communicated, both within the natural resource profession and with the public. This is of no small value in developing a Forest plan.

The Need for Standards

Data standards are badly needed for landtype association work. Without standard ways of delineating, building, classifying, and describing map units, communication across National Forests and administrative regions is hampered. In lieu of standards, LTAs become less defensible scientifically, because of lack of peer review, and legally, because adjacent entities, such as National Forests, will be inconsistent in addressing the same or similar resource management issues. Resource management problems are increasingly interrelated across broad landscapes. For example, it is no longer acceptable to evaluate rare or wide-ranging species' viability at only a local scale.

LTA data standards must be developed carefully, in an open, well-thought out process. Hastily developed standards that are unworkable in practice are just as limiting as a lack of standards. We have therefore incorporated peer review throughout the standards development process. In addition to the utility of applying national standards in mapping LTAs, the ultimate success or failure of data standards will depend on whether or not professionals support them as meeting their best interests. These interests can only be determined through thorough discussion, review, compromise, and editing.

In order to provide a common platform for data entry, storage, analysis, and reporting, the Forest Service is implementing a Natural Resource Information System (NRIS). The component of this effort that supports the national hierarchy of ecological units is known as "Terra" (subsequently referred to as "NRIS Terra" in this document). Extensive practical experience indicates NRIS Terra simply will not work without data standardization. Maintaining custom data structures for local data sets has proven prohibitive in cost and unworkable when combining data sets to answer questions across broad geographic areas. Because this lack of standardization means other agencies and partners must contend with a multitude of approaches to addressing the same kinds of data, cooperation and coordination are frustrated.

NRIS Terra supports data from the National Hierarchy very well. We recommend following NRIS Terra codes and protocols (for example, Haskins et al. 1998 for geomorphology). Standards developed through our effort should also facilitate the data stewardship intended by the NRIS effort.

Finally, in an era of downsizing and reduced budgets, standardization offers cost-cutting advantages. "Retrofitting" data sets to agree with each other to produce a landscape analysis, such as the Interior Columbia Basin assessment in the Pacific Northwest, is enormously expensive and time-consuming. In the competition for scarce data management dollars, strategies with simple, standardized approaches applicable to broad areas will survive. Lack of standardization will only increase the pressure to develop regional, centralized teams for planning. In this context, National Forest staff may lose funding and support if approaches to data standardization are not successful.

Developing Landtype Association Standards

National data standards and protocols are under development by an interdisciplinary Forest Service team. This paper outlines the standard protocols recommended by the team. For greater detail, see Forest Service Manual 1940, scheduled for completion in late 2001. For ease of communication in this paper, we organize data standards around four central map unit themes: design, delineation, characterization, and validation.

Map Unit Design

Before proceeding further we must first clarify some key concepts in mapping ecological units. These units, as at all levels of the National Hierarchy of Ecological Units, are map units. They are spatial and can be displayed in a geographic information system. Map units are sets of polygons with similar identity, and repeat across the landscape. Their occurrence is driven by predictable landscape patterns of geomorphology, soil, vegetation, and other relevant ecological factors.

In the context of landtype associations, elements are used to describe the map units. (Note that LTAs are also composed of finer-scale landtypes—each with its own assemblage of elements (ecological types)). We recognize five necessary elements to differentiate landtype associations: geomorphology, climate, geology (both bedrock and surficial), soil, and potential vegetation. Each of these elements represents a taxonomic unit (group of similar samples) developed through classification (the systematic process of developing these groups). The integration of these taxonomic elements

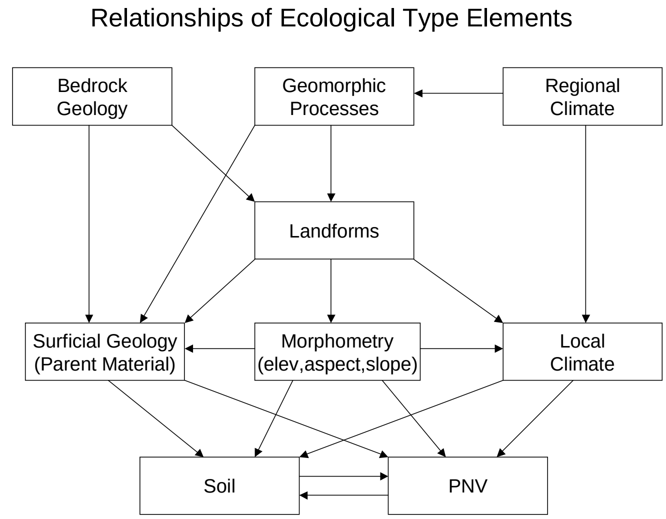

Figure 1.—Interrelationships of ecological elements important in characterizing ecological units.

through conceptual or numerical modeling is critical in mapping and interpreting LTAs.

At the LTA scale, map units may be constructed through aggregating finer-scale ecological units developed through a classification procedure, or by distinguishing land areas through the process of regionalization (Rowe 1980). In any case, the conceptual basis of LTA units is the integration of geomorphology, climate, bedrock and surficial geology, soils, hydrology, and potential vegetation. While the association of multiple factors is all important in identifying ecological units, all factors are not equally important at all spatial scales (Cleland et al. 1992). Different physical factors may predominate at different locations; for example, bedrock may be a strong influence where it is close to the surface, but surficial geology may be more important elsewhere.

Map Unit Delineation

Delineation of LTAs should proceed based on the ecological factors recognized during differentiation, using delineation criteria. The strategy we recommend includes integration of the elements within map units, and also making map units interlock within scales (e.g., nesting landtypes within LTAs).

Strategy Within Units

Within map units, geomorphology, geology, climate, soil, and potential vegetation are defined as inter-related; i.e., ecological processes unite them as a common ecosystem, rather than a mere association of elements (Fig. 1).

Strategy Between Scales—Top Down and Bottom Up

LTA map units are designed to nest within subsection boundaries (the next broader scale in the National

Hierarchy), and should in turn contain landtypes (the next finer scale in the National Hierarchy).

Two basic approaches for designing map units have emerged—top down (regionalization) and bottom up (aggregation). The top down approach conceptually separates broader ecological regions (subsections) into LTAs, using geomorphology, climate, bedrock and surficial geology, soils, hydrology, and potential vegetation. This method usually involves an interdisciplinary team synthesizing information and making judgments on where the combination of ecological factors changes in a way significant to management. LTA boundaries are placed at the approximate locations where these changes occur. Raised or shaded relief maps, orthophotos, satellite images, geologic maps, vegetation maps, and other tools aid the work. Geographic information systems aid this process where data are available.

One advantage of this method is its relatively quick development and inexpensive cost. A top down approach enables recognition of complex landscape patterns that may be less obvious at a finer scale. Thus, top-down stratification sometimes captures patterns and processes of landscapes more effectively than the bottom up approach used alone.

With the bottom-up approach, existing finer-scale units (landtypes and landtype phases) are aggregated into landtype associations. Landtypes and landtype phases are developed using more intensive ground data, so with this approach, quantitative data are available. An advantage of the bottom-up approach, therefore, is that the composition of the LTAs is known in greater detail. A disadvantage is that landtypes and landtype phases are expensive and time-consuming to develop. Also, broader scale patterns of landscape features are sometimes not recognized through aggregation.

As a standard methodology, we recommend an integrated approach employing both top-down and bottom-up strategies. The top-down approach should first be used to quickly stratify the landscape, based primarily on geomorphology and geology but tempered by considerations of climate, soil, and potential vegetation. LTAs will then not only serve as an immediate input to Forest planning, but also as a stratification for subsequent landtype level work. In turn, the initial top-down LTA work should be verified or refined using a bottom up approach with landtypes or landtype phases. The pattern of landtypes will serve to check the work, generating corrections where necessary. Information on the landtypes will also provide useful information on the composition of the LTAs. For example, plant species diversity within and across landscapes can be estimated, serving to map one aspect of biodiversity.

Importance of Factors

Geomorphology and geology are usually the prime environmental factors shaping the delineation of landtype associations. At this scale, geomorphic processes of mountain building (tectonics and volcanism), glaciation, fluvial action, and other processes temper the influence of climatic factors pre-eminent at regional scales. The resulting landforms and their geology (mountains with different bedrock geologies, glaciated landscapes differing by type of deposition, etc.) define LTAs. Other factors—climate, soils, and potential vegetation— are then used to refine these delineations.

LTAs should be mapped at 1:100,000 scale. This scale is broad enough to distinguish the landscape nature of LTAs while capturing sufficient detail for planning at National Forest scale.

Each landtype polygon should be attributed or somehow linked with an LTA code. In this way LTAs can also be displayed at landtype/landtype phase scale (1:24,000). Displaying this "membership" of landtypes within LTAs is useful when generating summaries and predicting effects. This relates multiple scales to each other—one of the main strengths of the National Hierarchy. For this reason, landtypes should be forced to fit (or "nest") within a landtype association.

While this nested spatial hierarchy applies to ecological units, the occurrence or interpretations of patterns or processes for particular phenomena may or may not follow this nested spatial organization. For example, habitats for mobile fauna and metapopulations, or natural disturbance regimes, may be networked among LTAs occurring within a subsection. Distinguishing and applying a nested versus networked spatial hierarchical organization to select ecological patterns or processes becomes possible by evaluating the phenomenon of interest and grouping (networking) LTAs when necessary.

Normally LTAs are mapped as units thousands to tens of thousands of acres in area. As with landtypes, LTAs may repeat within subsections, depending on regional patterns, although they will tend to repeat much less than landtypes. Delineating inclusions within landtype associations should be discouraged—these should be mapped as landtypes or landtype phases, at a finer scale.

Map Unit Characterization

The following guidelines describe how to characterize LTAs in most situations. The relative influence of the elements will vary somewhat with ecological province. Fig. 1 provides a conceptual view of how the elements are interrelated.

Geomorphology

At LTA scale, geomorphology means the process(es) shaping the landscape, as well as the morphometry of that landscape. The Forest Service publication A Geomorphic Classification System (Haskins et al. 1998) describes 10 process types, from fluvial to volcanic. These processes in turn generate patterns of landforms, such as the highly dissected Allegheny Plateau or the moraines and outwash plains of glaciated landscapes. Haskins et al. (1998) is the Forest Service standard for geomorphic process and landform terms, as well as morphometric measures. These are intended for all Forest Service land characterization efforts and are part of the NRIS Terra database.

A complete geomorphic characterization for an LTA map unit would therefore consist of three parts: 1) process, 2) dominant landscape(s), and 3) morphometry. Following is an example of these three components, respectively:

<u>Process.</u>—Glacial alpine ice erosion features and alpine ice contact depositional features, occurring with mass wasting flows and complexes;

<u>Dominant Landscapes.</u>—Mountains, foothills, and valleys; and

<u>Morphometry.</u>—Drainage density, slope gradient, elevation range, drainage pattern, and relief.

Geology

Both surficial and bedrock geology are needed to properly characterize the geology of a landscape. Surficial geology includes the kinds of unconsolidated material (e.g., colluvium, alluvium, residuum, or glacial deposits) covering the surface, and the original rock type(s) from which they eroded.

Bedrock geology is an important delineating factor for LTAs in many landscapes. It will tend to be less important where surficial materials cover bedrock to depths greater than 10 meters or so. Bedrock characterization means describing the lithology (rock type, such as sandstone, limestone, granite, basalt, etc.). In certain areas, such as the Sierra Mountains, the bedrock's structure (e.g., faulting) is also important. The list of appropriate geology terms resides in NRIS Terra as well.

Climate

At the landtype association scale, regional patterns of sunlight and precipitation are altered by landforms (typically mountains), or by large water bodies. Mountains feature elevational gradients that generate cooler temperatures and increasing precipitation with increasing elevation (orographic effect). Rain shadows are often created on the other sides of these mountains. Nationally accepted climatic classifications have yet to be devised, so climatic descriptors at this scale are likely to vary, as least for the near future. Trewartha (1968) is a good starting point; as it was used in Bailey's (1988, 1995) work, in turn the philosophical underpinning of the National Hierarchy of Ecological Units.

Soils

Soils should be characterized and classified at a level of detail that conveys important information at the scale of the LTA. The level of soil taxonomy used in classifying the soils may need to vary with the complexity of the landscape, but should be one of the higher categories of USDA Soil Taxonomy, such as the Subgroup level. Consideration must be used to balance the level of detail and the number of classifications used in characterizing the LTA. Patterns in soil texture and drainage are typically used to define and characterize LTAs. Soil attributes of LTAs will be described using the nomenclature of Soil Taxonomy (Soil Survey Staff 1999). Soil climate information (frigid, mesic, thermic, etc.) should be included in map unit descriptions.

Potential Natural Vegetation

Potential natural vegetation (PNV) is defined as the plant community with a vegetation structure that would become established if all successional sequences were completed without interference by man under the present climatic and edaphic conditions (including those created by man) (Tuxen 1956, Mueller-Dombois and Ellenberg 1974).

PNV is a taxonomic concept established to make scientific generalizations about basic land capability. Potential, rather than existing, vegetation is used in order to capture the productivity and capabilities of areas, and to provide a relatively stable characterization over time. We realize that in highly or frequently disturbed areas, potential vegetation may be a difficult concept to describe. In these cases, use the best practical approximation of potential conditions.

An emphasis on potential vegetation in ecological unit mapping in no way diminishes the importance of existing vegetation. Indeed, potential vegetation at LTA scale can be used to stratify the landscape and better organize existing vegetation mapping efforts.

The Forest Service will use PNV at the series level for LTAs. Names and codes for potential vegetation should follow those correlated and standardized at the Forest Service Regional level (e.g., Hall 1998). Examples include western hemlock series, sugar maple-red oak series, etc.

Supporting Characterizations

Although not mandatory, supporting characterizations, such as stream density and pattern, disturbance regimes, associated rare plants and animals, etc. are valuable and encouraged.

Map Unit Validation

Display Criteria

Display criteria are important considerations in communicating LTAs (or any map units, for that matter). The integration of five elements (geomorphology, climate, geology (bedrock and surficial), soils, and potential vegetation), while ecologically accurate, is difficult to display and communicate. In display criteria the user has considerable latitude; standards are not appropriate. Therefore, while geomorphology and geology should be used as the primary delineation factors for LTAs, a user may choose to display soils or potential vegetation. Design criteria will be driven by user analysis or communication needs. For example, on both the White Mountain (Fay, this symposium) and the Monongahela (DeMeo, this symposium) National Forests, LTAs were often grouped and displayed by broad vegetation types for ease of communication. This does not obviate the need to follow standards in delineating and attributing LTAs.

Bottom Up and Top Down Validation

Note that the bottom up process of aggregating landtypes into LTAs serves to validate LTAs by describing their composition more clearly (see Map Unit Delineation section above). In turn, a top down approach serves to test the validity of finer-scale landtypes.

Field Validation

Fieldwork can also be used to validate LTAs, although bear in mind the differences in scale between an LTA described at landscape scale and data collected at sites on the ground. Field data should sample the landscape adequately and be coordinated with the landtype development process.

Analysis Validation

Analyzing ground data can show differences (or lack of differences) in LTAs. For example, if a large, random sample of plant association plots in two nominal LTAs shows a similar plant community composition, perhaps they should be joined into one LTA map unit. Similarly, if breaks or discontinuities are found within an LTA, perhaps it should be split into two LTAs. Such an analysis tests the hypothesis that a similar geomorphology and bedrock influence should generate similar vegetation.

Peer Review

Rigorous peer review, both within the Forest Service and among other agencies (both state and Federal), partners, academia, and the public, is strongly recommended. (Of course, such review should examine adherence to these standards, as well as any supplemental Forest Service Regional standards.) Such efforts encourage standardization and correct errors. Especially important is edge-matching LTAs between Forests or other administrative units. Coordinated strategic planning among all the partners will greatly ease this process.

Glossary

Bedrock Geology.—Characteristics of the consolidated material at the earth's surface or that immediately underlies soil or other unconsolidated, surficial deposits, specifically: lithology (rock type), weathering, structure (e.g., fracturing or bedding), and stratigraphy (the rock-unit age and designation).

Classification.—The act and result of arranging facts or things into groups or classes of like individuals (Kimmins 1987). Classification permits confident statements to be made about all the members of a class based on the knowledge gained from analysis and interpretation of a limited number of samples.

Delineation.—The process of separating map units (repeating sets of polygons) using a consistent set of criteria.

Ecological units.—Map units designed to identify land and water areas at different levels of resolution based on similar capabilities and potentials for response to management and natural disturbance. These capabilities and potentials derive from multiple elements: climate, geomorphology, geology, soils, water, and potential natural vegetation. Ecological units should, by design, be rather stable. They may, however, be refined or updated as better information becomes available.

Elements.—As used in this paper, the components of a landscape that describe its ecological characteristics.

Geographic Information System (GIS).—A powerful computer set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a particular set of purposes. Spatial data in a GIS are characterized by their position, attributes, and spatial interrelationships (topology) (Burrough 1986).

Geomorphology.—The classification, description, nature, origin, and development of present landforms and their relationships to underlying structures, and of the history of geologic changes as recorded by these surface features.

Landtype Association.—Landtype associations are landscape scale map units defined by a dominant geomorphic process type, similar landforms, surficial and near-surface geologic formations, and associations of soil families and potential natural vegetation at the series level (Forman and Godron 1986, Bailey and Avers 1993, Cleland et al. 1997).

Map Unit.—Map units represent areas on the ground (polygons) distinguishable from one another based on certain biological or physical properties. Criteria for creating map units are determined by the mapping objective. Map units typically repeat across the landscape, thus consist of one to many polygons each comprised of the same set of biophysical properties. Ecological units are a specific type of map unit (NRIS Terra 2000).

Map Unit Characterization.—The description of the elements in a map unit. In regards to LTAs, this includes the "primary five" (geomorphology, geology, climate, soils and potential vegetation), but also often includes supporting elements, such as hydrology, disturbance regimes, etc.

Map Unit Delineation.—The criteria used to spatially differentiate between map units. At LTA scale, differences in geomorphology and geology are normally the primary delineation criteria between map units. Climate, soils, and potential vegetation also influence this delineation, however.

Map Unit Design.—What a map unit is intended to depict or display. In this paper, map unit design considerations include the interrelationships between elements, and how LTAs relate to finer scale units (landtypes/landtype phases) and broader scale units (subsections).

Map Unit Validation.—In this paper, the process of verifying the accuracy of ecological unit differentiation, delineation, and characterization.

Morphometry.—The measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms (i.e., relief, elevation range, slope aspect, gradient, shape, and position, dissection frequency and depth, and drainage pattern and density).

National Hierarchy of Ecological Units.—The US Forest Service's multiple-scale, multiple-element system of map units used to characterize the natural world and provide a framework for National Forest planning and management (Cleland et al. 1997). Other state and Federal agencies are also using the National Hierarchy, particularly at broader scales.

Surficial Geology.—The mode of deposition of unconsolidated deposits lying on bedrock or occurring on the earth's surface, and the rock type(s) from which those deposits are derived, known as "kind" and "origin," respectively.

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Landtype Associations: Concepts and Development in Lake States National Forests

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Abstract

Landtype Associations (LTA's) represent one spatial-scale of a hierarchical ecological land classification system developed by the USDA-Forest Service for use in land management planning, analysis, and monitoring and evaluation. The system is described in, "The National Hierarchical Framework of Ecological Units" (ECOMAP 1993). LTA's are the primary spatial-scale used in National Forest planning; information at this level also provides context for project-level activities and content for ecoregional assessments. Mappers in the Lake States have been refining LTA concepts and mapping to better reflect new understanding of landscape ecosystem concepts and spatial hierarchies. LTA's are landscape ecosystems, made up of clusters of interacting finer-scaled patches (Crow 1991). They have emergent properties which are not discernable by observing the function of an individual patch, but are apparent at the broader spatial-scale (Salt 1979). LTA's are conceptually identified based on differentiating criteria, and may be mapped by the "top-down" method of regionalization (Rowe, 1962). Broader-scaled ecosystems are subdivided based on dominant physical factors that control or mediate biotic structure and function at this level. LTA boundaries may be based on climatic, physiographic, or hydrologic features that correspond with changes in vegetative composition or productivity. Often the precise boundary location is difficult to identify, as the dominant environmental factors may occur along a gradient. In cases where ecological boundaries are not discrete, they may be placed along physiographic boundaries or aligned with finer-scaled boundaries of soils or vegetation.

Introduction

National Forests and state agencies in the Lake States are collectively updating a level of ecological land classification known as the Landtype Association (LTA). This paper presents an overview of concepts and mapping processes for the development of LTAs.

A general description of the land classification system is found in "The National Hierarchical Framework of Ecological Units" (hereafter referred to as the "Hierarchy") (ECOMAP 1993, Cleland et al. 1997).

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Direction has been given that this Hierarchy be used within the National Forest System as a basis for land management planning, analysis, monitoring, and cooperative efforts with other agencies and partners (Unger 1993). The Hierarchy is a "regionalization, classification, and mapping system for stratifying the Earth into progressively smaller areas of increasingly uniform ecological potentials for use in ecosystem management". It identifies eight hierarchical levels of land classification that have been demonstrated to be useful in land management and planning in the Forest Service (Bailey and Avers 1993). There may be other levels needed in the future, or by other land managers. Albert et al. (1986) stated that, "Management occurs at various levels, from continent-wide to site specific, and thus it is important to delineate ecosystems at a level and scale that is appropriate to the management intensity." Landtype Associations are a level of the Hierarchy that was developed primarily for use in National Forest planning and analyses. It also has applications in assessment and analyses at broader and finer-scales, and is useful to natural resource managers in many agencies and organizations.

Principles and Concepts

The objective of ecological classification and inventory is to distinguish, at various scales, land areas that differ significantly from one another in one or more ecological factors (Albert et al. 1986). This approach is intended to improve land-use planning, management, and monitoring by providing a basis for understanding ecosystem structure and function and the "inherent capabilities of land and water resources and the effects of management on them" (ECOMAP 1993).

Principles described in the Hierarchy include the application of ecosystem concepts, hierarchical structure and spatial-scales, dominant controlling or mediating environmental factors, partitioning gradients, and utilizing the top-down process of regionalization in conjunction with the bottom-up process of classification. This section presents a description of how these principles have been applied to LTA's.

Concepts of Ecological Units

The ecologist Tansley, in 1935, first used the term "ecosystem" to express the concept of abiotic and biotic factors interacting to form a system. Ecosystems are the combination of an ecological unit (expressing potential conditions) and the structure and processes that presently exist within the ecological unit (current conditions, or successional state). Both layers of information, together with information on types and rates of change, are essential for making management decisions.

Ecological units are identified through a systems approach that integrates ecosystem components and processes such as climate, physiography, soil, water, vegetation, and disturbance (Rowe 1991, Spies and Barnes 1985, Cleland et al. 1992, 1994, Uhlig and Jordan 1996). The ecological unit has been defined in the Hierarchy as "a land or water area that has similar capabilities and potentials for response to disturbance, including management". In a mathematical sense, the ecological unit is a weighted sum of physical component variables that predict vegetative composition and productivity, and also consider sensitive environmental conditions.

LTA's represent the landscape-scale of the Hierarchy; they are groupings of Landtypes or subdivisions of Subsections based upon similarities in geomorphic process, geologic rock types, soil complexes, stream types, lakes, wetlands, subseries or plant association vegetation complexes. Repeatable patterns of soil complexes and plant communities are useful in delineating map units at this level." (ECOMAP 1993). Forman and Godron (1986) have written that at this scale, "ecological units are defined by general topography, geomorphic process, surficial geology, soil and potential natural community patterns and local climate (Forman and Godron 1986). These factors affect biotic distributions, hydrologic function, natural disturbance regimes and general land use. Terrestrial features and processes may also have a strong influence on ecological characteristics of aquatic habitats" (Platts 1979, Ebert et al. 1991).

Landscape patterns become apparent at the LTA level, and patterning is an important ecological property of many LTA's. Landscape ecosystems have been described as a cluster of interacting finer-scaled ecosystem patches (Wertz 1972) (Crow 1991). The properties of these smaller, embedded ecosystems emerge in the context of the larger landscape. Salt (1979) has written, "An emergent property of an ecological unit is one which is wholly unpredictable from observation of the components of that unit. A corollary is: An emergent property of an ecological unit is only discernible by observation of that unit itself." Emergent properties depend in part on the spatial arrangement of Landtypes (LT's) and Landtype Phases (LTP's) within an LTA; these influence the exchange of energy and matter that occurs through fire or wind disturbance, propagate exchange, or animal transport.

Integration of multiple ecological factors

Ecosystems are made up of multiple factors; they include biotic and abiotic components in association with each other, and are differentiated by characteristics of structure or function. The ability of biotic components to exist on the Earth's surface is dependent on conditions of the physical environment, primarily material and energy supplies as solar radiation, moisture, and nutrient availability, and disturbance regimes. These major environmental gradients are modified locally by climate, physiography, hydrology, soils, flora, and fauna (Barnes et al. 1982, Jordan 1982, Cleland et al. 1985).

Biotic and abiotic factors differ in their relative level of influence on ecosystem structure and function at different spatial-scales and at different geographic locations. Information on associations among ecological factors at a given location is best gained through research and other ecosystem studies prior to classification or mapping. With this approach, the relative importance of different factors is recognized, their mutual associations and interactions are discovered, and appropriate factors are associated with specific geographic areas and spatial-scales.

At the LTA level in the Lake States, research studies have identified associations among many ecosystem components, including glacial features, mid-scale climatic variation, soil physical and chemical characteristics, hydrology, vegetative composition and productivity, nutrient cycling processes, regeneration, forest succession, and natural disturbance regimes of fire and wind (Barnes et al. 1982, 1984, Albert et al. 1986, Zak et al. 1986, Host et al. 1987, Denton and Barnes 1988, Padley 1989, Host and Pregitzer 1992).

Hierarchical structure of ecosystems

Partitioning the spatial variability of the environment into levels of scale aids in comprehending ecosystem complexity. Each level of scale has differences in dominant environmental factors, organization of ecological systems, type and degree of patterning, kinds of processes, and rates at which certain processes occur. Identifying these scales and their characteristics clarifies our thinking about ecological systems, and thus helps us better understand and predict the ways management will affect them.

Rowe (1980) has stated that to determine the effects of management on ecosystems, we often need to examine conditions and processes occurring above and below the level under consideration. Broader-scaled information provides context for management questions and helps identify roles and opportunities; finer-scaled information provides important detail. Selection of a spatial-scale for a primary level of consideration is based on the level of complexity or generalization appropriate to the management decision.

A nested spatial hierarchy provides this structure for selecting a primary scale appropriate to the level of decision, and for analyzing context and content

(Brenner and Jordan 1992). Small land areas can be grouped together into larger units based on common characteristics, or, conversely, larger units can be subdivided if sufficient information on differences within the unit is available (Allen and Starr 1982, O'Neill et al. 1986, Albert et al. 1986).

The concept of hierarchically organized ecosystems has been described as analogous to that of biological hierarchies: organelles, cells, tissues, organs, individuals, demes, and species are specific levels of biological organization, with lower levels nested within higher levels. Each of these levels has a specific function that can only be understood by observing the whole unit at the appropriate level of scale. Ecological systems have spatially explicit hierarchical characteristics; different levels of scale have different functions, and these functions are apparent only when the whole system is considered at specific scales (Allen and Starr 1982). A hierarchical approach to ecological systems allows us to develop and utilize those levels of spatial-scale where organization is apparent. These are the levels that contain the greatest amount of information pertinent to our management activities.

The selection of which and how many levels to develop in a classification hierarchy involves a degree of subjectivity, because hierarchies are often continuous, but there are certain spatial-scales with greater applicability to management questions (Allen and Starr 1982, Rowe 1991). The LTA level was developed to describe patterns and processes operating at the landscape level for application in land management assessment, analysis, and planning. Ecological organization at this scale is based on associations of mid-scale climatic regimes, patterns of landforms developed on glacial features, natural disturbance regimes, and vegetative alliances.

Dominant ecological factors

One or a few ecological factors often dominate ecosystem structure or function at a specific level of spatial-scale. At broad-scales, temperature, precipitation, and gross physiography control the composition of vegetative communities (e.g. the Rocky Mountains, or the Great Plains) (Spurr and Barnes 1980, Bailey 1987). At mid-levels of scale, solar energy and moisture inputs are modified by physiography, especially elevation and aspect in mountainous regions (Rowe 1980, Bailey 1988). At fine-scales, biotic distributions are influenced by soils, local topography, and floristic mediation (Bailey 1987, Cleland et al. 1994).

The dominant environmental factor controlling biotic distributions at the LTA scale in the Lake States is the glacial feature, because the source material and surface form of glacial deposits constrains other physical factors that control the distribution and growth of vegetation. Associations between vegetation and glacial features are usually readily observable from elevated vantage points such as airplanes or fire towers. In general, northern hardwood forests tend to occur on glacial moraines, mixed pine or oak forest on ice-contact features, and jack pine forest on outwash plains.

Secondarily dominant factors include hydrology, lake-effect climatic zones, bedrock outcrops, or, occasionally, landscape context that controls long-term past disturbance. At certain locations, these factors may be more dominant than glacial features. For example, the influence of a watertable at the land surface overrides the effect of parent material in determining vegetative composition.

Surficial geologic features are made up of interacting patterns of landforms, which have been characterized as combinations of "relief-topography (surface shape) and geological parent material (subsurface composition and structure)" (Rowe 1991). Other definitions of landform include, "physiography, geomorphology, terrain, and topography" (Pregitzer and Ramm 1984); "a three-dimensional part of the land surface, formed of soil, sediment, or rock that is distinctive because of its shape, that is significant for land use or to landscape genesis, that repeats in various landscapes" (Soil Survey Staff 1975). Some refer to landforms in the Lake States synonymously with glacial features like end and lateral moraines, till plains, outwash plains, outwash channels, deltas, beach complexes, lake plains, islands, and bedrock topography (Burgis 1977). Rowe (1994) has stated that "repetitive patterns in vegetation can be traced directly to repetitive patterns of topography associated with specific kinds of surficial materials of landforms." This definition, "repetitive patterns of topography," corresponds with historical concepts of land classification.

Our use of the term "landform" generally corresponds with the term "landtype". Landforms, then, are specific topographic portions of glacial features in the Lake States, such as post-glacial erosional valleys incised on the side of a moraine. Landtype Associations are repeating patterns of landforms, such as an end moraine. Such usage provides consistency with historical land classifications and with terminology used in the Hierarchy (ECOMAP 1993).

The lack of consensus on the definition of the term "landform" makes its application in LTA development problematic. There is a need for a geologic term that corresponds to the landscape-scale and LTAs.

Partitioning Gradients

Biotic distributions and ecological processes are controlled by gradients of solar energy, moisture, and nutrients. At finer spatial-scales, these gradients are modified by physiography, soils, hydrology, and biota (Cleland et al. 1985, 1994, Spies and Barnes 1985).

Some gradients change gradually, but there are instances where changes are abrupt, such as at a lakeshore or a cliff. Unfortunately, managing natural resources along a gradient is usually impractical or impossible, and mapped units are needed. A major goal and challenge of land classification is to partition environmental gradients so that map units are relatively homogeneous within their boundaries. Homogeneity is generally greater at finer spatial-scales, but some units are inherently more variable than others. A map unit boundary is the best estimate of the location where change along a gradient becomes important to management, but users must recognize that variability can be relatively high when diffuse gradients are present. Advances in technology will allow us to display "fuzzy" boundaries that show gradients as incremental degrees of change.

Regionalization and Classification

Regionalization (or ecosystem geography) is a process by which an area is subdivided based on dominant ecological factors whose effects in controlling or mediating biotic distributions are known (Rowe 1980, 1991; Bailey 1988, 1995a). Landscapes are partitioned by identifying their characteristics and differentiating them from surrounding areas using criteria relevant to the intended purpose, proceeding "from above" by division and subdivision. This method is useful in identifying and delineating broad-scale ecological units where macroclimatic zones or large physiographic features (e.g. mountain ranges) have strong and obvious associations with vegetation patterns. Regionalization often uses existing maps of the dominant abiotic factor or factors, which makes regionalization a cost-effective approach to ecological mapping when relationships between biotic and abiotic factors are known.

For finer-scaled units, classifications are developed from analyses of site-level data and mapped based on legends developed from classifications. Fine-scale units would be difficult to derive by regionalization because there is usually not information available at the appropriate spatial resolution.

LTA's in the Lake States have most often been developed through regionalization because previously mapped information on ecological factors is available (Russell and Jordan 1992). Information on surficial and bedrock geology, drift thickness, historic vegetation, wetlands, hydrography, and elevation, together with research information on associations of ecological factors and dominant factors, have provided the basis for regionalization.

Aggregation of finer-scaled units (LT's or LTP's) is may be another way to map LTA's. At present, these finer-scaled units have not yet been developed for most areas. If the aggregation method is used a top-down framework must be present. Highly patterned areas should in some cases be grouped into LTA's even though they contain very dissimilar LT's or LTP's. In these cases, patterning may be the dominant ecological factor that may be very difficult to identify through aggregation.

Associations of LTA's with Disturbance Regimes

While climate and landform influences exert fundamental constraints on forest composition, disturbances control temporal patterns of vegetative structure and composition, and regulate successional processes in a landscape (Huston 1994, Alverson et al. 1994). In pre-European settlement times, cycles of succession were initiated by the natural regimes of fire, wind, or flooding, or through actions of insects and disease. Knowledge of the spatial distribution of natural disturbances is important because managers often wish to emulate some aspects to help conserve biological diversity.

Some natural disturbances have been associated with glacial features in the Lake States. Whitney (1986) found that frequencies of catastrophic fires were greatest on outwash sand plains and were less frequent in forests on ice-contact sand hills. Similarly, composition of the Big Woods of Minnesota was related to fire history, which was in-turn related to glacial landforms (Grimm 1984). Rowe (1984) noted that landforms were associated with fire patterns, which interacted with insect population cycles. Wind is the dominant disturbance factor within glacial moraines; the most frequent and extensive wind disturbance is fine-scale gap-phase replacement (Whitney 1986, Runkle 1982). Catastrophic wind disturbance, infrequent in the Lake States, is sometimes followed by fire (Canham and Loucks 1984). Knowledge of these associations enables mappers to identify the dominant natural disturbance regime for LTA's.

Mapping Process

When LTA's are delineated, higher levels of the Hierarchy have usually already been mapped. Broad-scale dominant factors at the Subsection and higher levels of scale, particularly macro-climate, and gross physiography, will have already been identified. At the LTA level, the mapping process usually involves subdividing Subsections through the process of regionalization, using existing mapped information on the relevant ecological components. The follow discussion described this process.

Differentiating Criteria

Differentiating criteria are ecological factors that allow us to conceptually separate ecological units; they are the dominant controlling or mediating factors operating at a given spatial-scale. Differentiating criteria are not used alone, and the conceptual identification of an ecological unit will be based on corresponding changes among multiple abiotic and biotic components relevant at the particular scale and location of interest.

We make a distinction between differentiating criteria and delineating criteria. The latter refers to those relatively stable and fine-resolution environmental features that are used to draw ecological unit boundaries. Differentiating criteria are those factors used to conceptually formulate the ecological unit. Differentiating criteria for LTA's in the Lake States include, in general order of most frequent use, surficial geology, composition or productivity of historic vegetation (or some estimate thereof), hydrology, meso-climate, patterning of LT or LTP's, bedrock type, hydrography, and disturbance processes. In addition to these criteria, the Hierarchy (ECOMAP 1993) suggests that patterns of soil complexes and local landforms can sometimes be used as differentiating criteria for LTA's. It is further known that repeating patterns of associated ground-flora species groups, such as the Habitat Types described by Kotar et al. (1988) have been used to conceptually separate LTA's. Differentiating criteria are further described in the following sections.

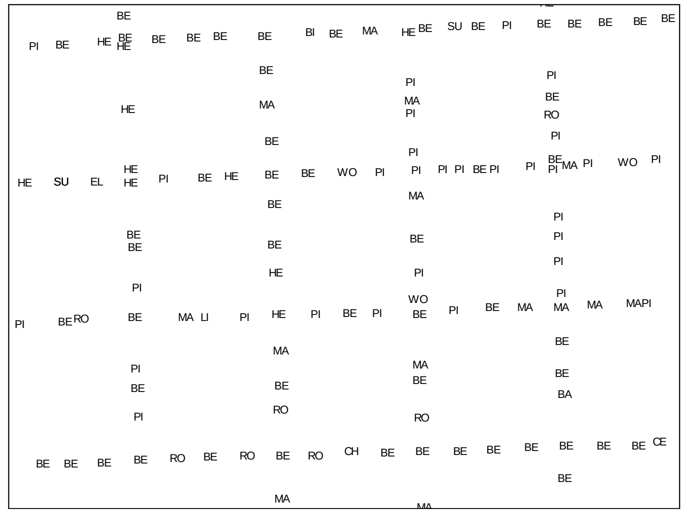

Figure 1.—Digital historic vegetation composition estimated from GLO survey maps and notes.

Glacial Features

Surficial geologic features associated with Pleistocene glaciation are the dominant abiotic factor correlated with vegetative composition and productivity, and other ecosystem functions, at the LTA level in the Lake States. Associations among glacial features, soil characteristics, and vegetative composition and productivity have been documented (Curtis 1959, Peet and Loucks 1977, Barnes et al. 1982, Jordan 1982, Spies and Barnes 1985, Albert et al. 1986, Host et al. 1987, Padley 1989, and Host and Pregitzer 1992). In Canada, Rowe (1971), and Rowe and Sheard (1981) have described similar associations. Ecosystem functions such as nutrient cycling have also been linked to glacial features and landforms (Padley 1989, Zak and Pregitzer 1990). Because of the strong association of glacial formations with other ecological characteristics and functions, they are most often used as the primary criteria in differentiating land areas at the LTA scale. The specific glacial formations generally used as differentiating criteria include terminal moraines, till plains, heads-of-outwash, outwash plains, lake plains, glacial outlet, dune/beach-ridge feature, and drumloid till plain.

At the landscape-scale, broad climatic zones used in developing Regional and Subregional level ecological units are modified by geology and topographic (landform) features (Bailey et al. 1994). Landforms modify the intensity and flux of solar energy and moisture, affect the flow of organisms, and determine the pattern of soil development and associated vegetation and animal populations. They provide the essential framework of the ecosystem, controlling such factors as soil moisture, temperature, and nutrients (Rowe 1971, Bailey 1988).

Historic Vegetation

Information on composition and productivity of historic vegetation is useful in conceptualizing and differentiating among LTA's. In most parts of the Lake States, historic vegetation can be estimated from information on early European settlement era forest composition available from General Land Office (GLO) survey maps and notes, see Figure 1. These data are generally of too coarse a resolution to serve as delineating criteria, but help provide the conceptual basis for separating the unit by providing information about vegetation at a time when effects of human disturbance were considerably less. The successional status of forests during early European settlement is more indicative of potential capability of ecological units than are today's largely human-induced successional conditions, and are useful for identifying correlative changes in vegetative potential as related to one or more of the abiotic ecosystem components.

Climate

At Regional and Subregional scales, climate is largely controlled by latitude and continental features. At the landscape-scale, climate is modified by geology and topography. For example, snowfall amounts and snowpack thickness tend to increase with elevation. Other climatic variations are due to the effect of the Great Lakes, with vegetation in the lake-effect along Lake Superior and the eastern shoreline of Lake Michigan reflecting strong influences of moisture inputs from lake humidity and temperature moderation. There may be other climatic variations due to topographic influences on air movement and humidity, such as orographic effects.

Climatic influences are difficult to differentiate because climatic changes usually occur along a diffuse gradient. Also, climatic data in the Lake States are not yet available at a sampling density suitable for analysis at the landscape-scale. Although there are several studies that demonstrate a process for identifying climatically distinct areas, most of these efforts were conducted at a broader scale. Methods will likely become available in the future to better differentiate climatic zones at the LTA level.

Bedrock Geology

Occasionally, a primary differentiating factor for a LTA may include the presence of, depth to, and type of bedrock. For example, limestone outcrops along the Niagaran Escarpment strongly influence composition of forest and ground-flora species where limestone is within plant rooting depth, or where it influences water chemistry in wetlands. Bedrock also influences the development of stream patterns. Bedrock-controlled terrain of large extent may be differentiated as a separate LTA, while smaller areas of bedrock outcrop are considered inclusions in other units.

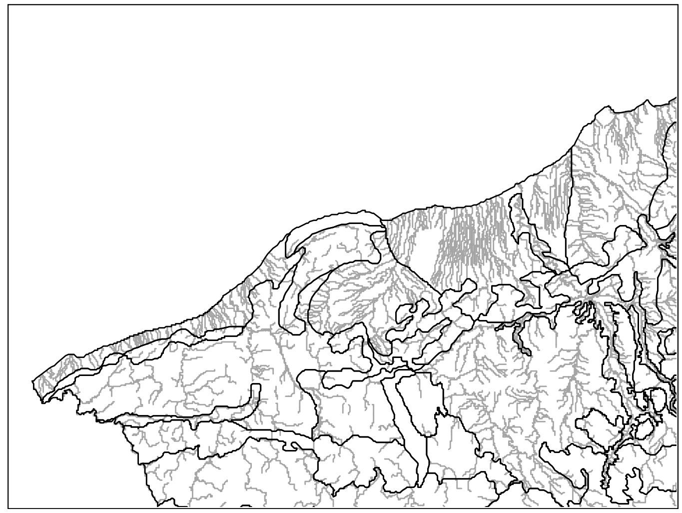

Figure 2.—The pattern of lakes and streams is often correlated with glacial features and LTAs.

Hydrography

Hydrography, or the pattern of lakes and streams that develops on the landscape, has shown a correlation with glacial features at the Subsection level, and in some cases at the LTA level as well, see Figure 2. Hydrographic patterns may be useful in differentiating LTA's in some areas. The pattern, density, and type of streams, lakes, and wetlands can often be related to glacial features. For example, the common occurrence of lakes in collapsed-outwash deposits and/or terminal moraines relates to processes and conditions during deposition, whereas parallel stream patterns and few lakes are found on former glacial clayey lakebeds.

In general, the process of regionalizing LTA's will involve the use of hydrography in differentiating glacial landforms. Aquatic features are usually not a dominant environmental influence at the LTA scale, and will generally not be the primary factor used in regionalization. The exception to this general guideline occurs when a water body is large enough to exert an influence on the surrounding terrestrial area that is believed to be greater than the influence of the terrestrial systems on the water body. Some examples include large lakes that create conditions of temperature moderation and humidity that influence ecological factors in the surrounding area, such as the occurrence of northern hardwood forests on old sand dunes along Lake Michigan.

Hydrology

Hydrology is an environmental factor sometimes used in conceptually separating units at the LTA level. The presence of regional watertables within rooting depth has a strong influence on vegetative composition and ecological processes at the landscape-scale. The effect of a shallow watertable, where present, may override the effects associated with the glacial feature. Watertable depth can affect processes of succession, type and frequency of disturbance, and rate of forest growth. Thus if an extensive land area is predominantly vegetated by hydrophilic species and contains hydric soils, it would be considered a unique LTA. If a landscape consists of an intricately patterned area of wetlands and uplands, the entire area could be identified as a single LTA based on the concept of LTA's as clusters of interacting ecosystem patches.

Disturbance Processes

In some instances, ecological processes are differentiating criteria used in conceptually separating ecological units. Processes that often operate at the LTA scale include natural disturbance regimes of fire, wind, and flooding. The landscape context of a LTA unit can sometimes govern the intensity, type, and frequency of natural disturbance events, and these events may have a long-term effect on vegetative composition and successional pathways. A number of local studies have documented associations between disturbance regimes and vegetation types, or among vegetation types and soils, landforms, or glacial formations (Maissurow 1941, Canham and Loucks 1984, Whitney 1986, Padley 1989, Webb 1989, Pastor and Broschart 1990, Frelich and Lorimer 1991, 1994, Mladenoff et al. 1993, Mladenoff and Pastor 1993). These associations of disturbance regimes and ecological units occur at all spatial-scales, depending on the geographic location and the type of disturbance process. Other processes associated with the landscape-scale are geomorphic processes (landslides), cycles of insect habitation, and diseases of vegetation.

Soil and Vegetation

Patterns of associated landforms, which are often equivalent to glacial features in the Lake States, are the primary differentiating factor at the LTA scale. Soils are derived from parent materials on the mantle of landforms, hence landforms often exhibit characteristic patterns in soil texture, morphology and drainage, as well as patterns in vegetation (Host et al. 1987, Cleland 1992). Although repetitive broad-scaled patterns of soil texture, drainage, and distribution of vegetative communities can be used to differentiate LTA's, these broad patterns are often not recognizable until after the LTA has been conceptualized based on the glacial feature. Soil characteristics and associated plant communities may become the primary delineation criteria at the LT and LTP levels of the Hierarchy. Soil patterns within LTA's are used to validate and characterize the conceptual unit, and to refine LTA boundaries from the bottom-up as LT's and LTP's are mapped and characterized. Similarly, plant communities including ecological species groups or Habitat Types develop in association with soil patterns within landforms, and therefore are not used as differentiating criteria at the LTA level, but are used as differentiating and delineating criteria at finer-scales.

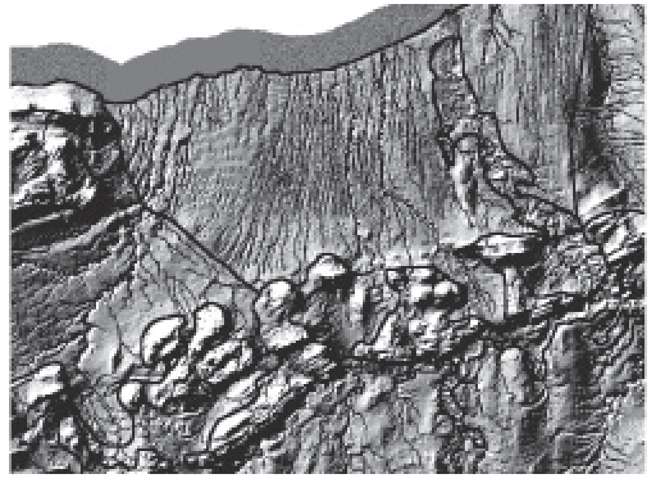

Figure 3.—Landform patterns are the primary delineating criteria.

Boundary Identification

After a LTA unit has been identified conceptually, based on primary differentiating criteria, units are mapped based on delineating criteria. Delineating criteria are those factors used to identify the specific location for placement of map unit. The delineating criteria are those relatively stable environmental features that help identify where a change in ecological potential has occurred. As discussed previously, some dominant controlling or mediating environmental factors occur along gradients, and some gradients can be quite diffuse while others are relatively discrete. Identifying the precise location at which to place a unit boundary can be difficult when the unit is conceptually based on features that occur along a gradient.

The process of identifying ecological boundaries follows that described by Rowe (1984), who recommended a multifactorial approach, beginning with factors that operate at broader spatial-scales. Climatic maps provide iso-lines that display gradients of solar radiation, temperature, soil moisture, and other factors related to ecologically important changes in forested ecosystems. If these climatic factors show a correlation with the mosaic of landscape patches that comprise vegetative structure at the spatial-scale of consideration, they may be useful in boundary placement. After subregions have been divided based on climatic differences, they are further subdivided based on features known to control the intensity of ecologically significant key factors at the next finer-scale. The correlation of biological indicators with glacial features or other physical factors provides information as to where to subdivide the landscape into ecological units. Boundaries of ecological significance that emerge show correlative changes in meso-climate, vegetation, soil, hydrology, landforms, and landform patterns.

Climatic Boundaries

Climatic boundaries are often the most diffuse of the environmental factors we wish to partition. While quantitative methods may be used to help identify climatically distinct areas (Rauscher 1984, Denton and Barnes 1988, Host and Polzer 1995), due to the coarse resolution of existing climatic data, most climatic zones identified through these methods have been at scale broader than the LTA. Sometimes, changes in vegetative composition may be indicative of climatic boundaries. Local expertise is sometimes useful in identifying locations where climatic differences occur. Because of the difficulties in gathering information on climatic boundaries, this factor is more often used as a differentiating criterion than a delineating one.

Physiographic Boundaries

At the landscape-scale in the complex, glaciated terrain of the Lake States, glacial features, comprised of landform patterns, are the primary delineating criterion. Landforms, with their control of radiation regime, and retention of water and other materials according to slope, aspect and geological substrate etc, usually afford good clues to boundary placement (Rowe 1991), see Figure 3.

Surficial geology maps that depict topographic features formed by Pleistocene glaciation are the most valuable source of information for identifying physiographic boundaries at the LTA scale. The spatial resolution of such maps is a consideration in deciding whether to utilize the boundaries as they appear on the map, or to use stereo-photographic interpretation or another finer-scaled land feature within the LTA to draw the boundary more accurately. Detailed surficial mapping that depicts landforms within glacial formations may be generalized to depict the LTA boundary. Detailed Pleistocene geology maps are available for many parts of Wisconsin on a county basis (Clayton 1984, Attig 1985, Mickelson 1986). These maps are an excellent source of information on glacial formations and the landform patterns that comprise them.

Hydrologic Boundaries

In areas where watertables are a dominant controlling or mediating influence on vegetation composition and productivity, maps of wetlands or hydric soils can be used to identify boundary placement. Such information can separate areas influenced by watertables from adjacent uplands. Host et al. (1996) used STATSGO information on drainage classes to identify areas with similar drainage characteristics. In eastern Upper Peninsula of Michigan, the National Wetlands Inventory maps were used as one piece of information in identifying and mapping LTA units where the dominant controlling environmental influence is a watertable within the rooting depth.

Distinguishing wetlands from each other can present a more difficult problem, but such a situation is rarely encountered. Here, corresponding changes in vegetation, landform, soils, or surface water drainage divides may indicate a difference in nutrient status, acidity, or oxygenation that will help identify boundaries.

Use of Finer-scaled Information to Locate Boundaries

Soils and vegetation are ecosystem components that vary at scales finer than the LTA, and are nested within the LTA. Maps and imagery displaying locations of these finer-scaled attributes are often used to identify locations of LTA boundaries. Soils maps from Order 2 surveys conducted by the Natural Resource Conservation Service (NRCS), or maps of LT's where available, are suitable sources for helping locate LTA boundaries. Satellite imagery or aerial photographs may be used to identify vegetative boundaries, although may boundaries are related to land-use rather than ecological potential. Maps of historical vegetation, if drawn at fine enough a resolution, are sometimes useful for identifying boundaries associated with potential vegetation.

Bedrock outcrops, or shallow-to-bedrock areas, are ecological features that often vary at finer-scales than LTA's in the Lake States. If the bedrock-controlled areas are mapped or can be identified on photographs at a fine enough resolution, they can provide an indication as to the location of ecological boundaries.

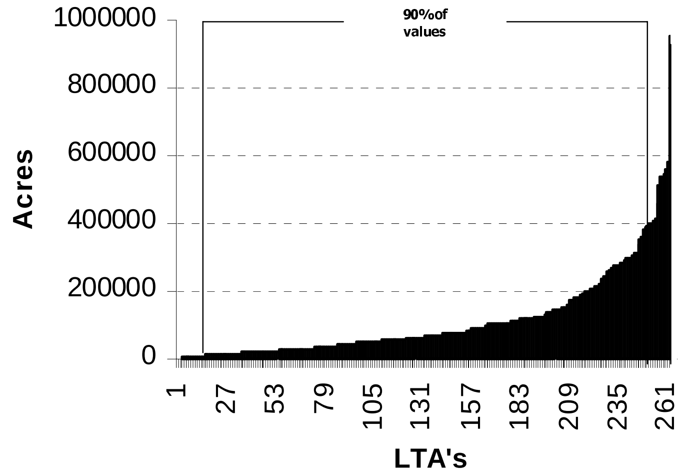

Figure 4.—Size distribution of LTA's that intersect Lake States National Forests.

Scale and Map Unit Sizes

The map scale used in displaying ecological units implies a certain level of perceived detail (Bailey 1988). It is chosen based on the intended use of the map; usually in mid-scale planning applications. Typical map scales for displaying Lake States LTA's range between 1:100,000 and 1:250,000. The map may be developed at a larger map scale than that used for display, to about 1:50,000. Maps should not be displayed at a scale larger than the one used for development.

The size of any given map unit will depend on its ecological characteristics at the LTA scale. Mapping landscape ecosystems involves identifying interacting clusters of heterogeneous finer-scaled ecosystems (LT's), or single large areas of relatively homogenous composition. Some landscape features are inherently smaller, while others are larger. We examined the size of LTA's and draft LTA's that intersect National Forests in the Lake States. The size distribution is shown in Figure 4. Sizes ranged from 1,432 to 950,650 acres, with 90 percent interval of the sizes between 9,665 and 385,972 acres. The 90 percent interval level corresponds well with the range of sizes recommended several years ago by the National Forests' LTA team; they suggested a minimum polygon size of 10,000 acres with exceptions to 3,000 acres for features with significantly different perceived function. The maximum size recommended was 175,000 acres, with exceptions to 300,000 acres for extremely homogenous areas.

Recommended Approach

In the past, LTA's in the Lake States have generally been developed by: 1) identifying the conceptual unit through visually examining paper maps for correlative changes in vegetation and abiotic factors, 2) preparing draft maps on paper, 3) field checking or sampling, and 4) revising draft maps and preparing a final version. Advances in spatial information and management tools can reduce the time and effort involved in LTA conceptualization and delineation, and also improve repeatability and documentation. The addition of ancillary information in databases or attribute tables can increase the utility of products. We recommend that new technologies be utilized while retaining the original concepts and procedural approach to developing ecological units.

The recommended approach includes the following steps:

1) *Assess information needs and sources.* Land managers primarily utilize LTA information for strategic planning and assessments (Almendinger, et al. 2000). In the Lake States, several organization have identified issues and information needs for regional, subregional, and landscape "LTA" scales (Jordan and Uhlig 1995, Seesholtz et al. 1995, Webster and Vasievich 1997). Managers should continue to be involved in the identification of the need for LTAs, and the attribute information to be acquired.

2) *Information assemblage.* All pertinent information should be gathered, including information on separate ecosystem components as well as existing maps of ecological units. The information should be of an appropriate spatial resolution to depict landscape ecosystems; thus, AVHRR satellite imagery at 1 km2 is generally too coarse, and aerial photographs at 1:20,000 are too detailed. Imagery and maps in the range of approximately 1:60,000 to 1:250,000 will often be useful. Electronic information that can be manipulated in a GIS environment is the most desirable. Digitized surficial geology maps, climatic classifications, DEM's, STATSGO, historic vegetation, hydrology, current vegetation and land use, and other GIS themes will be useful in analyses, syntheses, and display.

3) *Conceptual identification.* Conceptual units are developed through the process of rationalization, by examining the information themes while applying the differentiating criteris. GIS techniques can aid in synthesizing multiple information themes by identifying correspondence among vegetation and abiotic factors, aiding the mapper by displaying simple theme overlays, or 3-dimensional views of surficial formations with various information themes draped on them. For a more quantitative approachs, Host et al. 1966, Barnes, B. 2001, Zastrow, D.E. 2001, Cleland, D.T. 2001, Nigh, P.A. 2001.

4) *Drafting boundaries.* Boundaries between conceptual units are identified based on the delineating criteria. If GIS technology and information is available, boundaries from the most accurate piece of digital information can be used. If paper maps are being used, boundaries will be drafted onto overlays. Draft versions of ecological unit maps, are usually based on meso-climatic zones and/or physiography. The draft maps are refined by other pertinent ecological factors and fine-scaled information, where available. Rationale for boundary placements should be documented. (Zastrow, D.E. 2001, Nelson, D. 2001).

5) *Validation.* Techniques described earlier, such as utilizing vegetation information from classified Landsat TM imagery, can partially replace field work as a method for validating LTA units (Host et al. 1996). There will be a role for longer-term management studies where questions exist regarding boundary locations, or where there is a need to better identify important environmental factors and their mechanism of operation (Fay, S.C. and Sorgman, N.J. 2001, Hansen, D.S. and Almendinger, J.C. 2001, Drotts, G. and Provost, J. 2001, Hvizdak, D.J. 2001).

6) *Reporting.* After LTA's are mapped, there is a need to develop attribute tables that can be accessed in a GIS environment, that display data and descriptive information. Narrative, integrated descriptions are also needed to provide the average user with an understanding of the emergent properties, ecosystem linkages, and ecological processes operating in the unit. Additionally, there have been requests for management handbooks that describe capabilities, opportunities, and limitations of LTA's for various management activities. Wisconsin has developed the most extensive GIS-link LTA database in the Lake States (Zastrow, D.E. 2001).

7) *Revision.* Iterative revisions will be needed as more and better information becomes available from remotely sensed imageries, research and management studies, and agency inventory and survey projects. As mappers have opportunities to investigate individual units in detail, synthesizing information and conducting field examinations, new comprehension of ecological structure and function will emerge and boundaries will be refined and improved to better reflect units of equivalent ecological response.

Conclusion

LTAs provide the appropriate framework (context and content) for addressing biological, physical, and social issues in strategic planning and assessments. Land managers need to address these issues that are regional, subregional, and landscape- scale (i.e., biological diversity, forest health, climate change, and fire risk and management).

Although ecosystems change due to disturbances and biological processes, the basic physical components of LTAs are relatively stable. In the Lake States, the dominant environmental factor controlling biotic distributions at the LTA-scale are Pliestocene glacial features.

Regionalization is the dominant process for developing LTAs in the Lake States. Research has documented associations of glacial features with soil characteristics, vegetation composition and productivity, nutrient cycling, hydrography, and hydrology.

LTA maps have been developed for most of the Lake States using a common approach as described in this paper.

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Development of Wisconsin's Landtype Associations — A Layer within the National Hierarchical Framework of Ecological Units

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Abstract

The National Hierarchical Framework of Ecological Units (NHFEU) is an ecological classification system that divides landscapes into ecologically significant regions at multiple scales. Ecological types are classified and units are mapped based on the associations of biotic and environmental factors which include climate, physiography, water, soils, air, hydrology, and potential natural communities. In Wisconsin, the Provinces, Sections, and Subsections of the NHFEU have been used as large scale ecological units for resource assessment and planning projects. Wisconsin created the finer "landscape" scale Landtype Association (LTA) layer of the NHFEU. The development of this important layer of information supplies a spatially oriented, ecological classification tool that is available to a variety of landowners, land managers, and resource interest groups in Wisconsin and the Lake States. A partnership in Wisconsin developed the LTA layer of the NHFEU for the entire state. Many individuals representing a diversity of forest industries and councils, environmental and landowner interest groups, private interested persons and experts, and many agencies have provided information and assistance in the development of the LTA map. A group of volunteers (Wisconsin LTA Project Team) was formed to initiate the LTA drafting work and development of an annual work plan. A first approximation for the state of Wisconsin was completed in the fall of 1999.

Introduction

The National Hierarchical Framework of Ecological Units (NHFEU) is an ecological classification system that divides landscapes into ecologically significant regions at multiple scales (McNab and Avers 1994, and Bailey 1996). Ecological types are classified and units are mapped based on the associations of biotic and environmental factors which include climate, physiography, water, soils, air, hydrology, and potential natural communities. In Wisconsin, the Provinces, Sections, and Subsections of the NHFEU had been delineated and are being used as large-scale ecological units for resource assessment and planning projects. Wisconsin has delineated the finer "landscape" scale Landtype Association (LTA) layer of the NHFEU. The development of this important layer of information will supply a spatially oriented, ecological classification tool that is available to a variety of landowners, land managers, and resource interest groups in Wisconsin and the Lake States.

History

Within the state, LTA's had been developed primarily on National Forest Lands. The statewide development of Landtype Associations gained momentum in the mid-1990's. A workshop of field-level resource managers from a variety of agencies identified the need for such an agreement whereby a variety of ecological land classifications systems were available and being used by land managers (Steele et al. 1994). A critique of an exercise at the workshop pointed out that the lack of a common ecological language in these systems was a major barrier to communication and the sharing of information between land managers. In response to this concern, a cooperative effort led by the University of Wisconsin-Madison and the Wisconsin DNR Forestry program developed the Wisconsin Forest Accord.

The Wisconsin Forest Accord is a memorandum of understanding designed to focus future communication for statewide forest resource management using the Forest Habitat Type Classification System (Kotar et al. 1988 and Kotar and Burger 1996) and the NHFEU as a common language. Use of the Forest Habitat Type Classification System promotes a common language for interpreting site capability based on potential natural vegetation. The NHFEU divides the state into ecologically significant regions at multiple scales. The Accord further resolved to continue the development, evolution, and application of these ecological classification technologies. In July of 1994, representatives of more than a dozen public, industrial and private landowners signed on to the Wisconsin Forest Accord. The signing of the Wisconsin Forest Accord marked the first time nationwide that an entire state adopted uniform criteria to describe, evaluate and share critical ecological information between private landowners, county, state and federal agencies.

Since the signing of the Accord, workshops focused on the development of LTA's in Wisconsin were conducted. These workshops were intended to train interested agencies and individuals on LTA technical development procedures and the potential utility of this information.

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- USDA Forest Service - S&PF
- USDA Forest Service - National Forest
- Wisconsin County Forest Association
- University of Wisconsin - Madison
- University of Wisconsin - Stevens Point
- Menominee Tribal Enterprises
- WI Geological and Natural History Survey
- WI Department of Natural Resource

Figure 1.—Agencies represented on the WI LTA Project Team

CLIMATE	HABITAT
Mesoclimatic Regions	Common Forest Habtat Type
GEOLOGY	**HYDROGRAPHY**
Geomorphic Process	Surface Drainage Pattern
Geomorphic Surface	Total Perennial Stream Miles
General Topography	Total Intermittent Stream Miles
Bedrock Type	Total Open Water Area
Bedrock Depth	Total Wetland Area
Bedrock Description	Aquifer Depth
SOIL	**VEGETATION**
Common Soil Associations	Historical Cover Types
Soil Surface Texture	Historical Cover Type Description
Soil General Texture	
Soil Family Texture	
Soil Drainage	
Soil Parent Material	
General Soil Description	

Figure 2.—Primary data content for the WI LTA Database

From these workshops three distinct groups of participants were identified and include:

• **Guidance Team** – The group of managers and key leaders who oversee and support the activities of the project team. Guidance team members do not conduct the actual activities of the project, rather guide the efforts and support the project with needed resources.

• **WI LTA Project Team** – The group of technical and procedural experts who develop the project.

• **Interested Persons** – The largest group of individuals who express interest in the process or products under development.

From this workshop, a general understanding of the development procedures for the LTA layer occurred and the various agencies began identifying needed resources, including financial and technical expertise. In essence, a partnership in Wisconsin is developing the LTA layer of the NHFEU for the entire state. A variety of agencies and private individuals participate as partners in this effort and assist in the development of a LTA GIS layer.

Agencies represented on the WI LTA Project team are identified in Figure 1. In addition, many individuals representing a diversity of forest industries and councils, environmental and landowner interest groups, private interested persons and experts, and representatives of aforementioned agencies have provided information and assistance in the development of LTA's for Wisconsin.

Deliniation

The specific data used in the development of Wisconsin's LTA layer varies across the state depending on the best information available. The WI LTA Project Team gathered the best available ecological information for the development of the LTA's (Figure 2). The primary data source for the WI LTA Database were gathered from existing GIS layers or project team input. An automated process has been developed to annually update the WI LTA Database by GIS spatial overlays and new input data tables collect by the project team (Figure 3). The data depicted in the WI LTA Database originate from climate, soil, habitat, geology, hydrology and vegetation datasets.

Delineation of LTA boundaries for Wisconsin progressed north to south. The process included the following processing steps:

- Technical Expertise
- Digitizing
- Database Development
- Documentation

Wisconsin LTA's reflect the interrelationships of geology, landforms, hydrology/hydrography, soil associations, vegetative communities, natural disturbances, and climate. Since each factor varies in its susceptibility to change, LTA development proceeded from the most stable to the least. Draft LTA's, or LTA groups, were initially delineated within the NHFEU framework by identifying geomorphic patterns (surficial and bedrock geology, landforms, and hydrography) because these represent the most stable and the most recognizable features on the landscape and are the dominant environmental factor controlling biotic distributions and soil attributes. Plant-soil relationships, within the context of their relationships to climatic factors and geomorphology, refined the initial LTA's and provided for additional LTA development. Natural disturbance patterns, relative to all the other factors, provided the final refinement. As new data and ecological concepts are developed, LTA's will be further refined on a periodic basis. The WI LTA Project Team is in the process of developing a procedure for LTA validation.

Data Model

The WI LTA Project Team developed an annual process to create and update GIS data model and database for

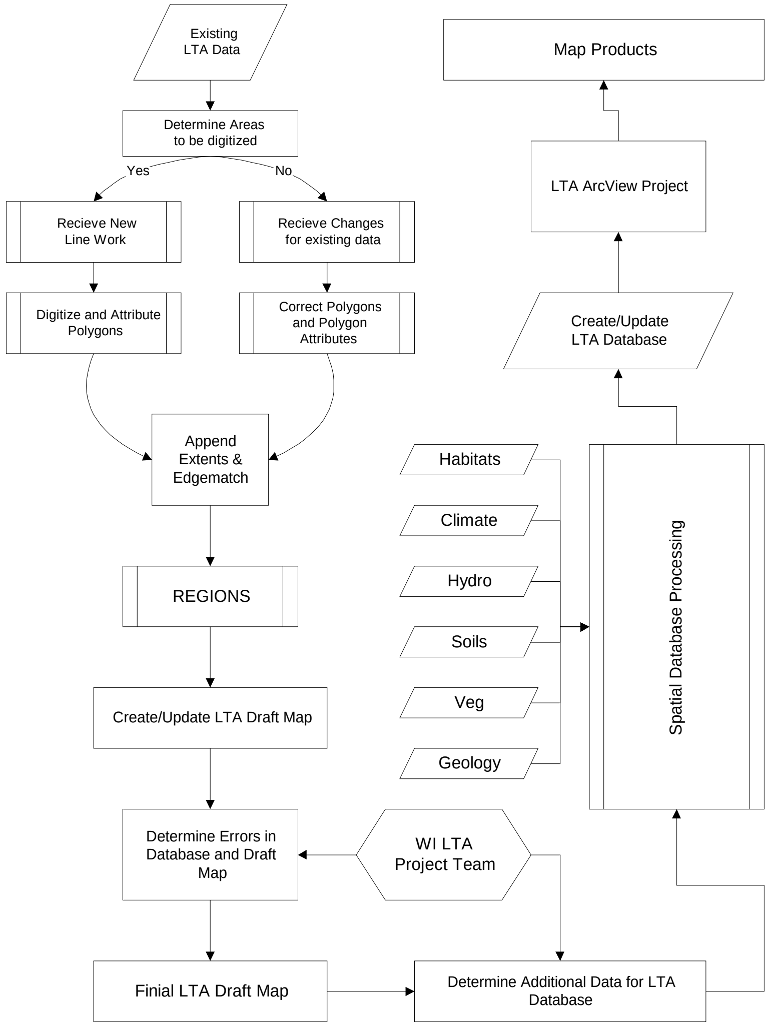

Figure 3.—Process used by WI LTA Project Team for LTA delineation

LTA's in Wisconsin. The purpose for data collection was to provide a technical description of the NHFEU, specifically the Landtype Association. This included descriptions of the line, polygon, region features and a set of related data tables. The WI LTA Database includes all digital spatial features and related tabular information. A subset of the WI LTA Database is the LTA Region Data Model. This is an ArcInfo data model utilizing a separate REGION for polygon features in each level the NHFEU. A general description of the data used for production of the database can be found in Figure 2.

The WI LTA Region Data Model is a spatial representation of the NHFEU including such features as the Province, Section, Subsection, Landtype Association and Landtype. This data set depicts the NHFEU in representing LTA's at 1:250,000 scale. The WI LTA Database is designed with the intent of making linkages to other statewide databases possible, as well as maintaining the integrity of the 1:250,000 scale data.

The WI LTA Database is now complete state-wide. Total expenditures for a robust state wide dataset to date has been about $100,000. The 2001 revision includes supplementary ecological classifications systems used by WDNR and other agencies.

Data distribution for Wisconsin LTA information is provided in a CD-ROM format entitled LTA Disk 2.1. This CD has a similar look to the USDA Forest Service "Ecological Units of the Eastern United States - First Approximation". The CD contains all GIS information and FGDC compliant metadata for the WI LTA Database and WI LTA Region Data Model. From this CD individuals are able to query, analyze, print maps and reports of the first approximation of LTA's for Wisconsin (Figure 4.)

LTA: 212Xd05

NAME: Jump River Ground Moraine ACRES: 950650 SQ MILES: 1485

DESCRIPTION: The characteristic landform pattern is undulating moraine and stream terraces. Soils are predominantly somewhat well drained silt loam over dense, acid sandy loam till. Common habitat types include forested lowland, hydromesic, and AH/AViO.

GRID CODE (Climate)	PERCENT	HABITAT 1	HABITAT 2	HABITAT 3	HABITAT 4	HABITAT 5	HABITAT 6
23	2.10517	Lowland	Hydromesi	AH/AViO			
24	8.23416						
31	6.52777						
33	6.87722						
36	47.213						
40	28.3745						
43	0.668304						

BTGW DESCRIPTION
Carbonates

DEPTH	DEPTH DESCRIPTION
0'-20'	Bedrock is between 100 feet and 50 feet of the land surface

PROCESS
Till and Glacial Meltwater Deposition

TOPOGRAPHY
Undulating

SURFACE
Till Plain with Outwash Terraces

PER. STRMS	INT. STRMS	OPEN WATER	MARSH ACRES	DPTH TO AQFR	SRF DRAINAGE
1041.25	328.399	6298.2	106847	0'-20'	parallel

DESCRIPTION	PERCENT	DEFINITION
Hydrographic	0.522664	Water
BF	0.344607	White Spruce, Balasam Fir, Tamarack, White Cedar, White Birch, Aspen
HH/P	76.7645	Hemlock, Sugar Maple, Yellow Birch, White Pine, Red Pine
NH/P	4.84384	Sugar Maple, Yellow Birch, White Pine, Red Pine
PW/PR	0.871154	White Pine, Red Pine
PJ/OX	0.165997	Jack Pine, Scrub Oak and Barrens
ABW/P	0.385773	Aspen, White Birch, Pine
NH/O	0.047462	Sugar Maple, Basswood, Red Oak, White Oak, Black Oak
SC	16.0545	Swamp Conifers - White Cedar, Black Spruce, Tamarack, Hemlock

SOIL ASSOCIATION
Magnor-Freeon-Almena-Lupton-Auburndale, Sconsin-Pa dus

SOIL DESCRIPTION
Somewhat poorly drained, moderately well drained, and poorly drai ned loamy and silty soils with a silt loam surface over non-calca reous sandy loam dense till, along with very poorly drained nonac id organic soils.

SURG TXT	GENERAL TXT	FAMILY TXT	DRAINAGE
SIL-MK	Loamy-Silty-Mucky	COL-FISI-SP	SPD-MWD-VPD

PARENT MATERIAL
Dense_Till-Organic

2001 April 9

Figure 4.—2001 LTA Report from LTA Disk 2.1

Summary

The WI LTA Project Team will continue to refine the "landscape" scale Landtype Association (LTA) of the NHFEU. Future progress will include capture of recent available GIS dataset such as soils and current vegetation. GIS applications and data training opportunities will be made available to field staff to include integration of the Federal Inventory and Analysis (FIA) data and other ECS models. This development and improvement of information will supply a spatially oriented, ecological classification tool that can be use by a variety of landowners, land managers and resource interest groups in Wisconsin and the Lake States

Acknowledgment

We thank all the participating individuals, agencies and partners for providing their time to accomplish the creation of the WI LTA Database through membership on the WI LTA Project Team. The development of the WI LTA Database was dependent upon their cooperation and is the foundation for the continued success for future development, application and validation of LTA's in the state of Wisconsin.

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General Ecosystem Survey of National Forest System Lands in Arizona and New Mexico

Wayne Robbie[1] and Shirley Baros[2]

Abstract

An ecosystem survey at the landscape scale was completed on 22 million acres of National Forest System lands in Arizona and New Mexico. Ecological components consisting of climate, soil, vegetation and water were simultaneously integrated through direct gradient analysis to develop a continuum of terrestrial and aquatic ecosystems. Soils were classified to subgroup categories of Soil Taxonomy and Potential Natural Communities were classified to the series (alliance) vegetation taxonomic category. Fluvial and lacusterine water bodies were categorized with respect to permanence, continuity and trophic states. A regional climate classification based upon seasonal distribution of precipitation and winter temperatures was used to differentiate weather regimes between the two states. Compensating factors of landform, slope and aspect that determine the spatial arranges of aquatic and terrestrial ecosystems were introduced during the mapping process. Mapping was completed on 1:250,000 scale USGS quadrangle sheets. Field documentation was completed to verify map components, accuracy of delineations and present conditions. State and transition of ecological systems were described through primary climax and disclimax classes. Terrestrial ecosystems consist of contiguous polygons and aquatic ecosystems were represented by line segments (stream) and polygons (lakes). Interpretations of site productivity, soil condition, erosion hazard and vegetation potential are presented. Multi-forest analysis to address distribution and extent of plant communities, disturbance regimes, productivity potentials and suitability for revegetation are used to prioritize treatment areas in the southwestern region.

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LTA Delineation for the Hoosier National Forest: Criteria and Methods

Andrey V. Zhalnin[1], George R. Parker[2], Guofan Shao[3] and Patrick Merchant[4]

Abstract

A GIS approach to delineate LTAs for the Hoosier National Forest (HNF) area is used. In our model we assume that the spatial distribution pattern of ELTs provide a theoretical foundation for LTA unit delineation. On the basis of ELT computer classification two approaches were applied: automated (moving window with area 4-12 km^2), and semi-automated (visual detection of areas of different ELT patterns followed by multivariate statistical analysis and clustering). The moving window method failed to provide a reasonable spatial clustering of analyzed areas into LTAs. Visual analysis resulted in 5 LTAs that were delineated using natural landscape features such as rivers or watershed boundaries (ridges) on the basis of spatial pattern differences between ELTs (mean ELT size and mean proximity index). In addition, we incorporated into the delineation process a soil parent material layer that greatly affects site conditions and vegetation of the area.

Introduction

An Ecological Land Type Association was defined in the National Hierarchical Framework of Ecological Units as a "groupings of Landtypes or subdivisions of Subsections based upon similarities in geomorphic process, geologic rock types, soil complexes, stream types, lakes, wetlands, and series, subseries, or plant association vegetation communities" (ECOMAP 1993). This ecological unit represents the landscape scale in the hierarchy and its mapping can help in forest or area wide planning and analysis of the watershed. LTA's reflect distinct landscape processes and ecological capabilities as reflected in patterns of ecological landtypes and ecological landtype phases.

LTA's will effectively define the landscapes associated within the Hoosier National Forest and surrounding area and help to define management areas. Management areas on the Hoosier National Forest are defined as an area with similar management objectives and a common management prescription.

Generally two approaches can be used to define LTAs: automated versus expert based classification. The first method is rarely used in the field of ecological unit mapping. A national map of vegetation ecoregions produced by Hargrove and Luxmoore (1998) is a good example of such an approach. The authors used a 1 km grid and nine variables that are important for vegetative growth and listed several advantages of the multivariate geographic clustering technique they used:

- Clustering is data-driven and empirical producing the same result every time, given the same data and a request for the same number of clusters, in contrast to regions drawn by expert opinion.

- Users control what data are included for consideration in the clustering process based on what is appropriate for their purposes.

- Finally, any eclectic combination of continuous variables can be combined to form homogeneous areas on a map.

On the other hand, expert-based classification can consider information that can not be incorporated into the computer-based classification due to the absence of GIS layers or statistically proven relations that can affect classification. For instance, the history of land use, stand composition and/or forest management practices could be included. In our work we tested both methods in attempt to delineate LTA units within the Pleasant Run unit of Hoosier National Forest.

Methods

The study area is located in south-central Indiana and underlain by Paleozoic sedimentary bedrock that becomes deeper from east to west (Gutshick 1966). Analysis was performed within the Pleasant Run unit of Hoosier National Forest that is situated within the Brown County Hills Subsection according to Bailey's (1994) Ecoregion classification (Figure 1). This unit encompasses 412,507 ha of land. Parent material of this area is early to middle Mississippian age siltstones and shales of the Borden group (Schneider 1966). Prevailing soils of this area are acid silt loams formed from weathered bedrock and a small amount of loess (Homoya et al. 1984). Typical relief consists of uplands dissected by creeks, steep slopes and narrow hollows.

Van Kley (1992, 1995) developed an ecological classification for the forest that includes five ELTs and twelve ELTPs for the Pleasant Run unit. Important factors affecting the classification were landscape

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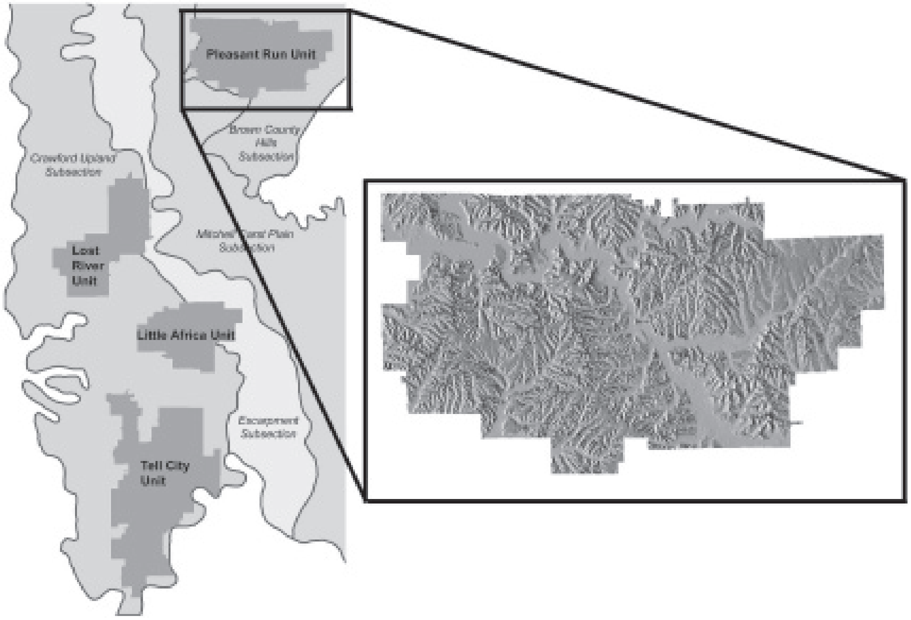

Figure 1.—A map of study area. Dark gray – four Hoosier National Forest units. Bailey's ecological region sections are shown in the background.

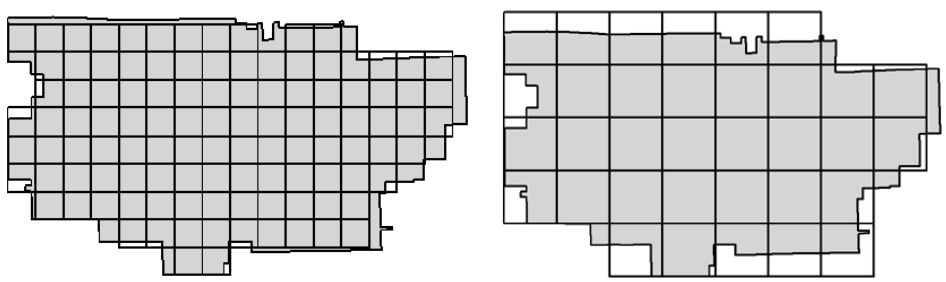

Figure 2.—Northern unit of Hoosier National Forest and grid resulted from area division into 4 (left) and 16 (right) km^2.

physiography and soil parental material at ELT level and physiography, horizon A depth and vegetation at ELTP level. ELTs for the HNF have been mapped using GIS tools (Shao 1999). Since the ELT map already reflects information on landscape physiography and soils, we accepted this map as a basis for delineation of larger units (LTAs) as a first approximation. A soil data layer was added due to the effect of limestone soils on vegetation pattern within the area.

Moving Window Analysis

We used Arc View GIS software for a Moving window analysis performed in several stages. starting from an arbitrary point in the left top corner of the map, the study area was first divided into uniform quadrats with an area of 4 or 16 km^2 using Avenue script for Arc View (Rho 2000), (Figure 2). Quadrat size was selected based on the LTA size specified in the National Hierarchical Framework of Ecological Units (Cleland et al. 1997). The guideline was to maintain an area large enough to capture spatial differences among quadrats and small enough to fit into landscape feature boundaries (rivers, ridges, etc.). All edge quadrats that contained less than 50% of area covered by the ELT map were excluded from analysis to eliminate distortions. The next step was to analyze each quadrat with the Patch Analyst extension for ArcView (Rempel et al. 2000) for differences in ELT spatial pattern. From a variety of spatial metrics suggested by the program, mean patch size (MPS) and mean proximity index (MPI)were selected as metrics that most reflected spatial differences between quadrats. Each metric was calculated for each ELT separately. Next we used multivariate statistic analysis (Principal component analysis) to extract quadrat clusters. The last step was to map clusters and visually analyze them as reasonable units.

Selected Area Analysis

In this type of analysis we assumed that it was most appropriate to consider the natural features of the landscape as LTA boundaries. Therefore at the first stage we visually analyzed the ELT map and defined areas

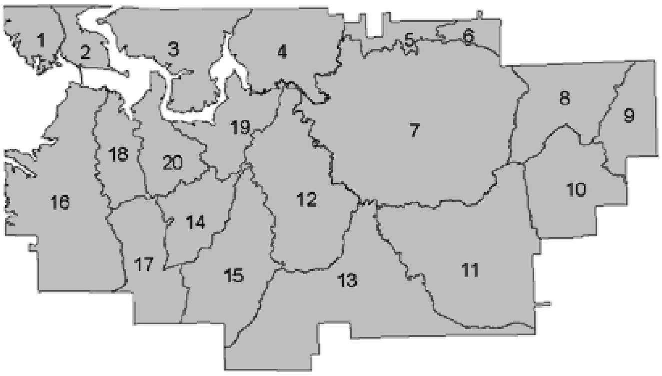

Figure 3.—Pseudo LTA unit boundaries for the Hoosier National Forest area. Numbers refer to temporary unit labels in analysis.

different in ELT spatial pattern and natural landscape boundaries (streams or ridges) to establish boundaries of pseudo LTAs (Figure 3). Areas covered with large water bodies were not included. The next step was to analyze each pseudo LTA with the Patch Analyst extension of Arc View (Rempel 2000) for differences in ELT spatial distribution. As in the moving window analysis we chose mean patch size (MPS) and mean proximity index (MPI). Again, each metric was calculated for each ELT separately. Then we used multivariate statistic analysis (Principal component analysis and Detrended Correspondence Analysis) as well as cluster analysis (Minimum variance, squared Euclidean criteria) to group pseudo LTA into final LTA units. In addition, we used a soil map to determine limestone areas and incorporate that information into the LTA classification.

Results

Moving Window Analysis

The two kilometer grid ultimately resulted in 109 cells to be analyzed for spatial differences. Results of multivariate and cluster analysis of the spatial metric (MPS) are shown in Figures 4 and 5. Both PCA and DCA did not reveal a pattern distinctive enough to form groups of similar spatial characteristics. Quadrats were either uniformly spread along the metric gradient or were clumped together. Results of cluster analysis are presented in Figure 5 as a map of quadrats where each of four clusters has a different pattern. Pseudo LTA boundaries are also shown to give an idea of areas naturally outlined by landscape features.

The four kilometer grid resulted in 34 cells. Results of multivariate and cluster analysis of this spatial metric (MPS) are shown in Figures 6 and 7. Again quadrats plotted along variability gradients did not reveal a distinctive pattern of grouping either on the PCA or the DCA graph. Results of cluster analysis are presented on figure 7. Quadrats did show spatial differences but results are hard to interpret and fit into the landscape.

Selected Area Analysis

In the first stage we defined 20 sub units (Pseudo LTAs, Figure 3). Spatial metrics for each subunit's ELT are presented in tables 1-2. We performed the same standard multivariate statistical procedure as in moving window analysis. Subunits 5, 6, 8, 13, 16, 17 and 18 were not included in multivariate analysis. Units 5 and 6 were added to unit 7, since they are small parts of larger units that lie outside the Hoosier National Forest boundary, and visually resemble unit 7. Unit 8 has a

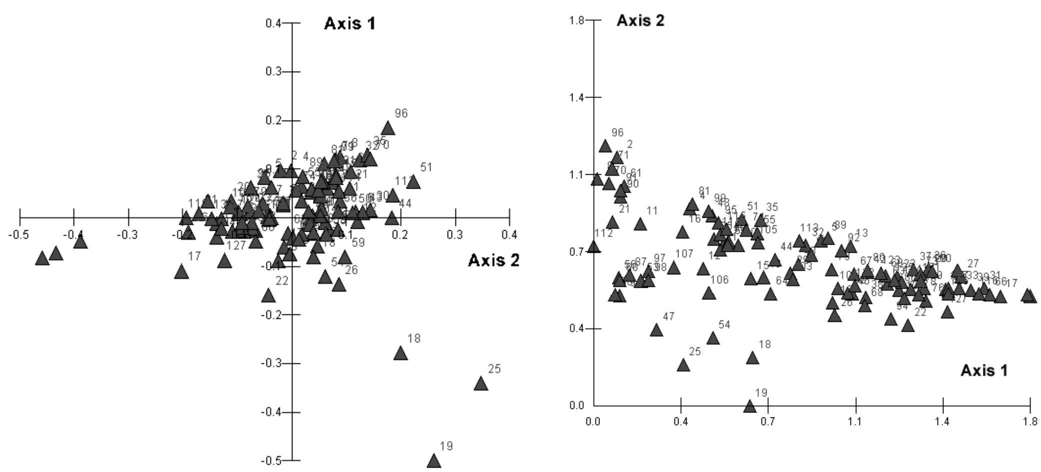

Figure 4.—Results of PCA (left) and DCA (right) statistics for 4 km² plots. Axes represent mean patch (ELT) size variability of 5 ELTs among quadrats.

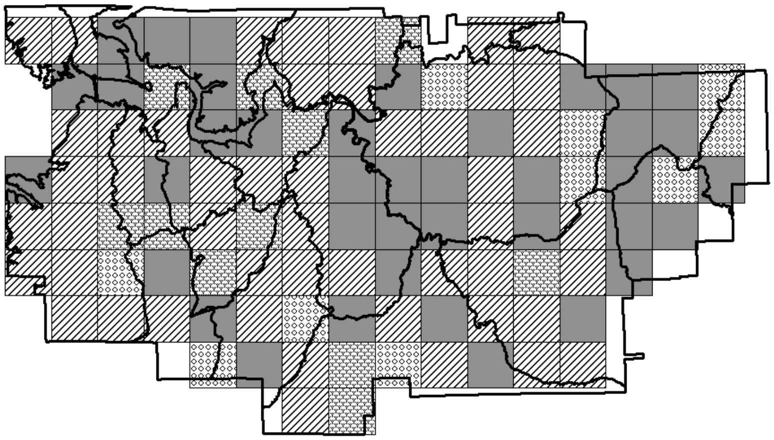

Figure 5.—Mapped analysis quadrats. Each cluster is marked with a different pattern. Lines represent subunit areas from Selected Area analysis and show natural boundaries of landscape features (rivers, ridges, watershed boundaries).

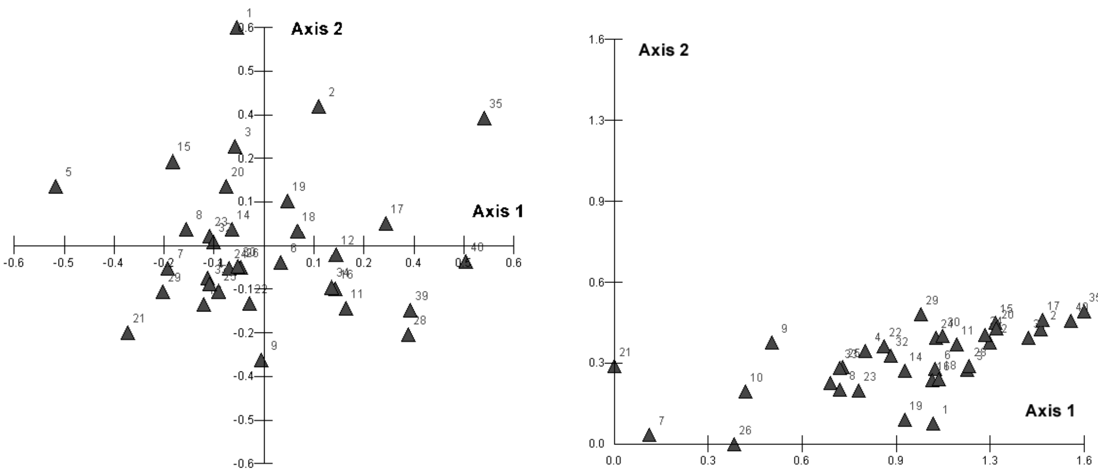

Figure 6.—Results of PCA (left) and DCA (right) statistics for 16 km^2 plots. Axes represent mean patch (ELT) size variability of 5 ELTs among quadrats.

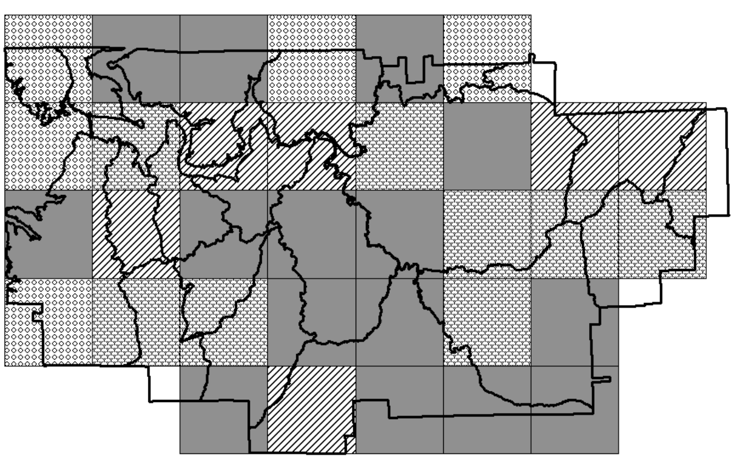

Figure 7.—Mapped analysis quadrats. Each cluster is marked with a different pattern. Lines represent subunit areas from Selected Area analysis and show natural boundaries of landscape features (rivers, ridges, watershed boundaries).

Table 1.—Results of mean patch size (hectares) analysis for subunit's ELTs

Subunit number	ELT Dry ridge	Dry slope	Mesic ridge	Mesic Slope	Bottom-land
1	0.61	4.44	1.32	3.36	15.35
2	2.03	3.54	12.38	3.18	1.35
3	2.67	6.72	21.84	6.13	3.89
4	1.85	7.55	—	4.72	15.27
5	1.5	4.22	2.72	2.49	58.38
6	4.88	6.92	3.89	2.5	8.47
7	2.07	4.96	31.49	4.27	10.96
8	—	1.17	223.46	1.32	16.07
9	1.62	1.11	13.41	2.49	9.69
10	1.51	1.94	24.9	2.42	9.3
11	1.76	6.36	11.44	4.34	29.56
12	2.57	2.43	11.4	4.37	14.44
13	2.23	2.89	21.24	3.37	11.99
14	2.3	3.49	21.25	2.8	7.03
15	2.68	3.99	13.12	2.33	3.29
16	3.92	5.52	13.22	3.64	3.45
17	3.97	3.49	24.44	4.59	5.83
18	3.42	2.53	18.97	8.68	2.6
19	1.02	5.85	39.83	8.03	3.18
20	2.35	6.06	18.31	3.59	1.42

Table 2.—Results of mean proximity index analysis for subunit's ELTs

Subunit number	ELT Dry ridge	Dry slope	Mesic ridge	Mesic Slope	Bottom-land
1	1.79	528.34	—	194.48	1280.41
2	33.54	90.65	15.24	391.20	118.23
3	32.12	384.21	31.36	209.48	131.37
4	18.94	619.71	0.00	396.80	2847.51
5	42.35	182.46	7.08	27.23	5845.78
6	92.06	759.42	35.01	109.25	77.89
7	106.91	554.97	354.94	428.45	3875.24
8	—	20.66	1315.86	26.00	2927.86
9	51.40	32.18	711.11	179.92	709.37
10	41.03	124.27	1125.99	203.83	713.18
11	26.37	379.64	5.04	392.87	1063.59
12	111.15	107.47	69.07	496.92	1689.90
13	51.08	153.74	93.43	319.80	1698.94
14	45.05	222.70	909.70	106.79	799.95
15	148.85	292.40	83.78	136.15	389.22
16	395.38	425.38	22.47	201.75	217.22
17	297.92	167.52	75.05	384.06	1751.34
18	310.66	124.77	2734.79	1427.38	318.78
19	9.85	173.23	5.40	774.10	216.14
20	81.52	476.34	132.12	190.73	114.87

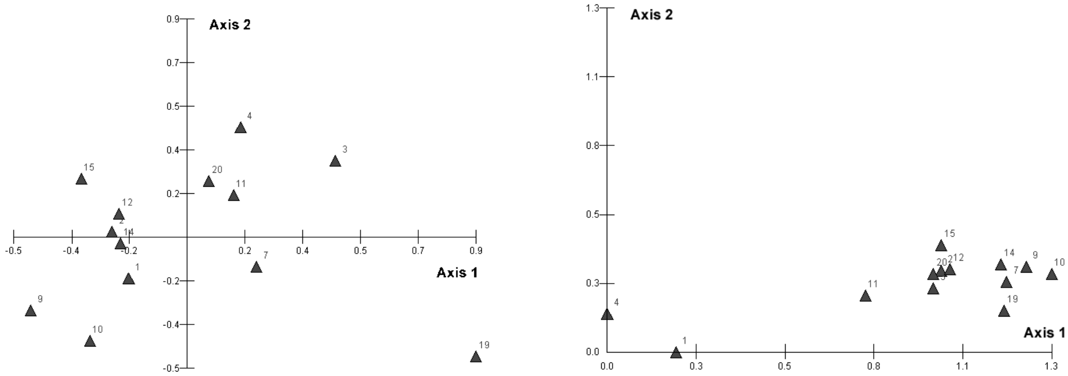

Figure 8.—Results of PCA (left) and DCA (right) statistics for LTA subunits. Axes represent mean patch (ELT) size variability of 5 ELTs among subunits.

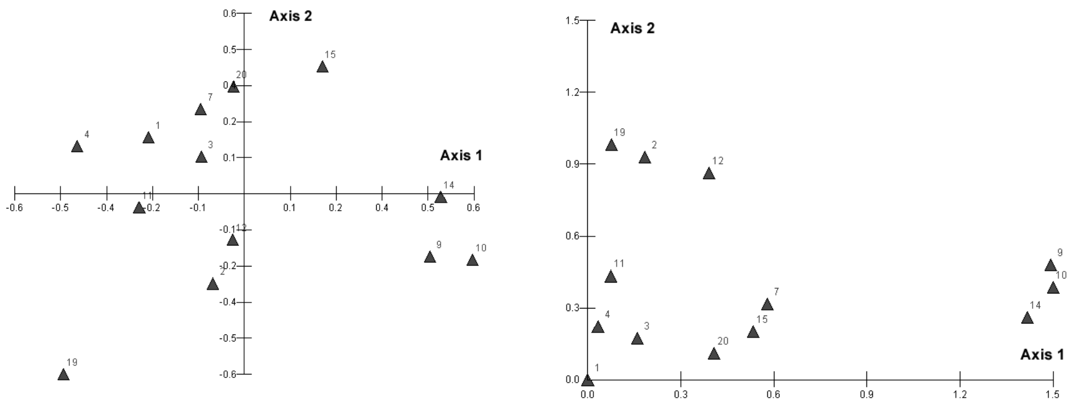

Figure 9.—Results of PCA (left) and DCA (right) statistics for LTAs. Axes represent mean proximity index variability of 5 ELTs among LTAs.

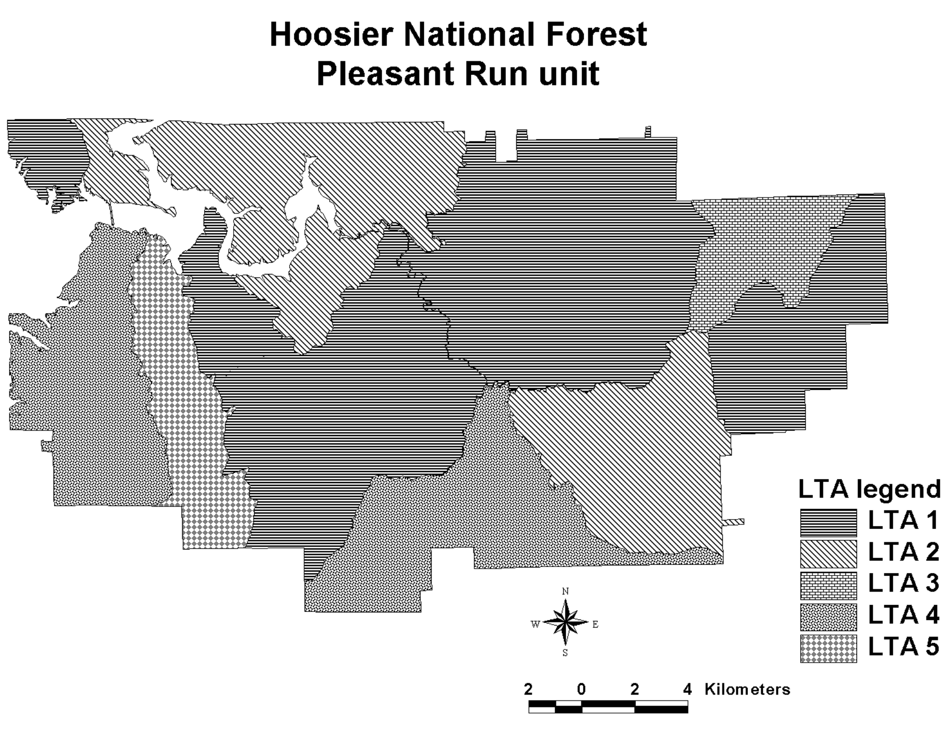

Figure 10.—Map of LTAs delineated for the Pleasant Run Unit of the Hoosier National ForesMAPPING.

Table 3.—Selected spatial metrics for the five LTA units within the area of the Northern unit of Hoosier National Forest

LTA	ELT				
	1	2	4	5	6
	– – – – – – – –	– – – – – –	Class area, acres	– – – – – –	– – – – – – – –
1	4119	14699	6166	13443	11348
2	1506	8659	1730	7741	5814
3	-	286	3309	322	947
4	1776	7151	1354	6496	4506
5	500	1858	1172	2148	1023
	– – – – – – – –	– – – – – –	Mean Patch Size*, acres	– – – – – –	– – – – – – – –
1	5.71	8.84	51.38	8.50	27.02
2	4.64	15.61	38.43	12.30	23.34
3	0.00	2.91	551.43	3.51	36.41
4	7.41	9.83	45.13	8.65	16.75
5	8.35	7.43	58.59	14.72	11.88
	– – – – – – – –	– – – – – –	Patch Size Standard Deviation	– – – – – –	– – – – – – – –
1	5.63	6.87	32.29	6.53	71.55
2	3.53	10.90	22.96	10.47	59.54
3	-	1.25	369.42	1.98	47.97
4	9.00	6.23	40.80	6.14	48.77
5	6.45	5.03	59.22	15.50	33.07
	– – – – – – – –	– – – – – –	Edge Density	– – – – – –	– – – – – – – –
1	47.43	104.20	29.44	102.65	53.28
2	34.00	91.88	14.69	91.07	50.88
3	-	34.74	68.47	33.17	49.81
4	47.68	109.81	13.17	109.52	49.21
5	40.04	96.14	29.37	102.69	36.52
	– – – – – – – –	– – – – – –	Interspersion Juxtaposition Index	– – – – – –	– – – – – – – –
1	56.40	91.36	76.09	91.46	71.86
2	57.63	81.87	78.19	81.98	68.66
3		80.07	99.93	80.36	94.28
4	55.91	80.09	81.68	79.51	62.68
5	52.67	86.81	56.04	89.17	52.82
	– – – – – – – –	– – – – – –	Mean Proximity Index	– – – – – –	– – – – – – – –
1	80.70	314.15	1027.06	312.93	2986.89
2	26.38	384.50	12.84	401.21	956.56
3	-	23.54	1423.00	22.56	556.11
4	152.82	279.44	128.27	293.16	1093.27
5	258.43	155.70	2894.44	820.82	746.87

unique pattern of ELT spatial distribution. Units 13 and 16, as well as 17 and 18 represent two groups of LTA that have a distinctive difference from the rest of the area due to the pattern of limestone soil occurrence that forms two LTAs. MPS and MPI metrics for each subunit are shown in tables 1 and 2.

The ultimate reasonable number of LTAs for the Northern unit of Hoosier National Forest is 4 – 5 units. Three of the subunits formed distinctive LTAs and did not need multivariate analysis. Therefore the quota for the remaining subunits is two LTAs. Multivariate analysis of MPS indicated that in general subunit variability forms two clusters: first – pseudo LTAs 1, 2, 9, 10, 12, 14, 15; second - pseudo LTAs 3, 4, 7, 11, 19, 20 (PCA statistics). Subunit 19 is "outlier" on the graph, but still can be considered closer to group 2 than to group 1 (Figure 8, left). Groups from DCA were not that distinctive: group 1 - 2, 3, 11, 12, 15, 20; group 2 - 7, 9, 10, 14, 19. Subunits 1 and 4 were not closely associated with the rest of the subunits (Figure 8, right). Results of multivariate analysis of MPI show more than two clusters: group 1 - 2, 12, 19; group 2 - 1, 3, 4, 7, 11, 15, 20; group 39, 10, 14 (DCA statistics, Figure 9, right). PCA statistics suggests two clusters: group 1 - 9, 10, 14; group 2 - 1, 3, 4, 7, 11, 20. Subunits 15, 19, 2 and 12 are dispersed throughout the scatter plot (Figure 9, left). Clustering showed similar results and will not be discussed here. These analysis were used to determine boundaries for two additional LTAs.

On the basis of visual and statistical analysis we ended up with five LTA units (Figure 10). For each unit spatial metrics were calculated again and the selected metrics that best reflect spatial variability are presented in table 3. Spatial metrics definitions (Elkie et al. 1999) are as follows:

• Class Area - sum of areas of all patches belonging to a given class.

• Edge density - amount of edge relative to the landscape area.

• Mean Shape Index - shape complexity. MSI = 1 when all patches are circular (polygons) or square (grids). MSI = sum of each patches perimeter divided by the square root of patch area (hectares) for each class.

• Mean Proximity Index - measure of the degree of isolation and fragmentation. Mean proximity index (MPI) is a measure of the degree of isolation and fragmentation of a patch. MPI uses the nearest neighbor statistic.

• Interspersion Juxtaposition Index - measure of patch adjacency. Approaches zero when the distribution of unique patch adjacencies becomes uneven and 100 when all patch types are equally adjacent.

Discussion

Results from the moving window analysis revealed a peculiar contradiction between window size that is necessary to capture spatial variability among ELTs and output resolution that would reasonably fit landscape features and represent ecological units at the LTA scale. Grid cells of 16 square kilometers captured differences in ELT spatial pattern quite well, but the cell boundaries did not agree with the landscape pre-determined boundaries of different LTAs. Smaller cells provided a better fit but were less precise in estimating spatial characteristics of ELTs. Multivariate analysis performed in order to group grid cells into meaningful clusters supported this idea. At the finer resolution spatial metrics of the ELTs were poorly grouped using both PCA and DCA statistics. Larger cells (16 km^2) showed better grouping that were hard to interpret. Generally this approach failed to be useful in reaching the ultimate goal - to delineate LTA boundaries due to above-mentioned contradiction.

The second approach was more tedious in terms of deciding where to draw a boundary as well as drawing or rearranging existing GIS layers (e.g. polyline river themes in Arc View). However, primary units were well matched to landscape topography with a mean area 21.9, minimum area 3.9 and maximum 73.6 km^2 and standard deviation 17.3 km^2. Multivariate statistics confirmed this approach by displaying better groupings that improved combining subunits. Final LTA units have the following statistics (spatially separated areas were considered) : mean area 39.78 km^2, maximum 103.65, minimum 5.80 and standard deviation of the area 31.54 km^2. Numerical values for the LTA areas are within the range for the landtype associations suggested by Cleland et al. (1997) within ECOMAP Framework (~ 4-40 km^2).

Conclusions

• The ELT unit map is a good starting point and conceptual basis for LTA mapping, which can be extended and modified with additional information later

• Human based delineation of analysis units performed better versus automated, moving window delineation at the spatial scale of ELT and LTA units

• Mean Proximity Index and Mean Patch Size metrics best reflected spatial differences among LTA analysis units

This is the first approximation of LTAs and the project is on-going. Additional GIS data on forest stand composition, soils , ground vegetation and hydrogeological settings for the area will be incorporated to describe LTAs more precisely and provide implications for management practices.

Subunits that were generated as an intermediate product can be rearranged into new LTAs according to updated information. Names of LTAs will be given after field sampling and based on prevailing vegetation, physiography and soils.

Acknowledgement

This research was supported by the USDA Forest Service.

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Land Type Associations using Digital Soil Maps and Landscape Topography

David W. MacFarlane[1], Craig Coutrous[1], James P. Dunn[1]

Abstract

Land Type Associations (LTA) are map units which aggregate landtypes into groups with similar ecological potential. They are one level in the ECOMAP hierarchy which maps ecological potential at different spatial scales. Ecological "potential" is a vague term which has made LTA mapping (and Ecomapping in general) a difficult task. We defined ecological potential as a direct function of physical landscape attributes which can be explicitly mapped. LTAs were derived from digital soil series maps provided by the Natural Resource Conservation Service (NRCS). Soil series map-units were aggregated into broad-scale groupings which reflect the similar parent material from which they were derived. Parent material groups were aggregated to form LTAs, which reflect both parent material and landscape topography. The Lower Kittatinny Valley (LTA:221Ba2), for example, is comprised of soil series derived from alluvial, glacio-fluvial and limestone till which dominate the lower portions of the Hudson-Kittatinny Valley. Hence ecological potential at the LTA scale is defined specifically by local or regional differences in soils and topography. Ecological potential was related to botanical inventories conducted within each LTA and aerial cover-type mapping.

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Predictive Community Mapping using Ecological Land Units in the Northern Appalachian Ecoregion

Mark Anderson[1], Charles Ferree[1], Greg Kehm[1], and Arlene Olivero[1]

Abstract

The Northern Appalachian Ecological Land Unit (ELU) dataset focuses on three primary factors that are important to the distribution and abundance of ecological communities in a region: elevation, geology, and landform. These three primary factors were modeled in a GIS and combined into distinct 90m grid cell units that each represent the intersection of a given landform feature occurring within a particular elevation range on a given bedrock type. (e.g. low elevation calcareous sideslope). The ELU dataset was then combined with EPA MRLC 30m land cover data and used to predict the general location and extent of particular ecological communities based on the current land cover (MRLC) and underlying diversity of abiotic ecological features (ELU). One hundred and fifty Northern Appalachian communities were linked to the ELU+MRLC type classes based on probability model factors, and the resultant community distribution maps integrated into TNC science and stewardship planning applications.

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Development and Applications of Landtype Associations in Missouri

Tim A. Nigh[1] and Walter Schroeder[2]

Abstract

The Missouri Ecological Classification System (ECS) Project is an inter-agency sponsored program to pursue development of an ECS for the state of Missouri. Using the USFS hierarchy we have completed development of ecological units statewide through the landtype association (LTA) level. We have also piloted the development of ecological landtypes for the Current River Hills subsection. LTAs have been used as a framework for ecoregional inventory, assessment and planning. Regional priorities were directed toward public and private land management activities using LTAs as a guide. Area level planning and management has also used LTAs as a framework for breaking large conservation areas into management units. ELTs have been used to direct land management strategies within LTAs.

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II. PLANNING, MANAGEMENT, AND RESEARCH APPLICATIONS

Policy Implications of Using Landtype Associations

Chester Joy[1]

Abstract

The General Accounting Office (GAO), is an independent, non-partisan agency of the Congress charged with reporting to committee chairmen and others on the effectiveness, efficiency, and economy of federal programs. In recent years GAO has reported and testified before committees on problems with accountability of federal land and resource management agencies including, notably, the USDA Forest Service. A central focus of GAO's work has been performance accountability – or agency accountability for making progress in accomplishing agency objectives – especially in relation to a framework of accountability GAO has developed related to implementation of the Government Performance Results Act of 1993 and other statues enacted in the last decade to foster accountability. Central to achieving accountability is the development of good performance measures. Useful measures of agency performance related to achieving desired or current conditions of ecological units such as LTAs. GAO's recent and ongoing work on multiagency efforts to address the problem of increasing threats from catastrophic wildfires raise questions about how LTAs can best be used to formulate useful agency performance measures, how well ecological unit delineation and condition characterization are being integrated into agency management decision-making, and how the research enterprise associated with them can best be applied in a timely fashion. Conference participants are encouraged to share with GAO their insights into how these questions can best be assessed.

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Use of Ecological Units in Mapping Natural Disturbance Regimes in the Lake States

David Cleland[1], David Shadis[2], Donald.I. Dickman[3], James K. Jordan[4], Richard Watson[5]

Abstract

We are conducting a review of the literature and mapping natural disturbance regimes across Province 212 in the Lake States using Subsections and Landtype Associations as initial polygons of investigation. The objective is to map landscape ecosystems at multiple scales based on their susceptibility to, hence potential for disturbance through wildfires. We are utilizing a number of sources of spatial and plot-level information. This includes General Land Office records of past fire locations and extent, maps of pre-European settlement vegetation, weather station monthly and daily data, surficial geology maps, remotely-sensed vegetation, FIA data on forest conditions, digital elevation models, and fine-scale NRCS soil surveys. We are using a hierarchical approach to mapping and interpreting landscape ecosystems. This approach enables assessment of interactions and spatial relationships (adjacency and nesting) among fire-dependent and fire-intolerant forest ecosystems, and their associated disturbance regimes. Currently we have identified five forest-replacement and two community maintenance (ground fire) classes based on the literature, and are attributing polygons into combinations of these classes. These classes range from very short (30 –75 years) to very long (>1,000 years) fire return intervals. Exploratory analyses of General Land Office data are underway within fire-prone ecosystems to determine if historical patch size and age, hence fire extent and return intervals, can be estimated based on recorded tree diameters and modern data on tree specie's diameter-age relationships. Density, extent, and possibly return intervals of historical and modern fires will be described for disturbance polygons. Final maps, interpreted in conjunction with information on current ecological and social conditions, will be useful for prioritizing fuel and fire management needs, and assisting land managers in developing plans and prescriptions for maintaining or restoring fire-adapted ecosystems.

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Use of LTAs as a Tool for Wildlife Management in Minnesota

Gary Drotts[1] *and Jodie Provost*[1]

Abstract

With the advent of an ECS in Minnesota and it's recent mapping completion to the LTA level, the Minnesota Department of Natural Resources, Division of Wildlife is in the process of assessing a direction for the utilization of all ECS levels into the assessment, planning, management and monitoring of wildlife populations and habitats. Examples to be demonstrated are:

1) Minnesota Wildlife Resource Assessment Project (MnWRAP) - Project will define species range and habitat relationships to the ECS subsection and LTA level and act as a core wildlife GIS/database reference source for Minnesota. Various uses of this application will be demonstrated;

2) Subsection Forest Resource Management Planning (SFRMP) - State timber management planning and other related forest resources are now be planned on a ECS subsection basis, however, not all wildlife specific needs may be addressed at this level. Various wildlife needs that can be addressed at the subsection and/or LTA level will be demonstrated; and,

3) Open Landscape Assessment in Northern Minnesota for Management of Brushland Wildlife Habitat. This project will demonstrate how the LTA level has been used to refine and document the distribution of open/brushland landscapes in Minnesota and act as a tool for the management of this wildlife resource.

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The History of White Pine in Minnesota and the use of Landtype Associations for Restoring White Pine Forests.

Dan Hanson[1] and John C. Almendinger[1]

Abstract

We use Landtype Associations (LTAs) to illustrate the paleohistory, historic distribution, and modern occurrence of white pine (*Pinus strobus*) in Minnesota. These topics are fundamental to restoring forest communities with white pine. Pollen diagrams from across the state were used to reconstruct the paleohistory of white pine in Minnesota. This is a story of invasion and westward migration during the middle and late Holocene, beginning about 7,000 years ago. We defined the set of LTAs where white pine was at least three percent of the Public Land Survey bearing trees as the historic habitat for white pine. Time-series maps illustrate the migration as these LTAs were invaded by potential seed zones for white pine. Maps of white pine bearing trees show that it did not occur uniformly across this region in the mid-1800s. Rather, there are clear centers of high abundance associated with particular LTAs. For each LTA, we calculated the relative abundance of white pine as a bearing tree and its relative abundance in a recent inventory (1990 Forest Inventory and Analysis). These calculations illustrate where white pine was formerly abundant and where it has suffered its greatest population declines. Bearing tree records were used in conjunction with a vegetation classification to better understand forest communities with white pine. The bearing tree records provide an understanding of how white pine associated with other trees on different LTAs. The classification provides a means of grouping LTAs into management units with similar white pine communities, potential for restoration, and ecological constraints.

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Land Typing for Bioregional Planning: A Perspective from the Niagara Escarpment, Ontario

Robert J. Milne[1], Michael R. Moss[2] and Lorne P. Bennett[2]

Abstract

Functional models of land units were used to classify land units of the central region of the Niagara Escarpment, Ontario, Canada. The Escarpment Slope Model (ESM) combines geomorphic processes with forest dynamics in Escarpment slope systems. This classification is comparable to the 'land types' of the U.S. system. The Escarpment Landscape Model (ELM) expands the scope of the ESM to consider geomorphic processes, forest dynamics and wildlife populations at the scale of the landscape. The ELM identifies land units at the scale of the 'land type association'. This functional approach to land classification is presented as an improvement on the current Ontario approach, the Ecological Land Classification (ELC) program.

Introduction

To be of value to environmental management beyond merely a characterization of land information, the development of mappable units at the level of land type association requires the identification of integrated land types based upon functional properties of such land units. Land types in the Ontario system are currently mapped as ecological land units. The Ontario approach is examined in the context of both the United States land type association procedures and the value of both of these methodologies for effective land and landscape management.

This examination will be centred on the development of an integrated landscape model for the Niagara Escarpment of Southern Ontario. This model identifies land units similar in scale to the 'land types' and 'land type associations' of the U.S. system. It is based on a functional approach to land systems, that recognizes the inter-relationships between landscape structural characteristics, surficial processes, forest dynamics, and bird associations; the latter being used to illustrate types of wildlife relationships. Originally, the integration of geomorphic processes and forest dynamics were established in a slope system model (Moss and Milne 1998). More recently, the role that these biophysical processes have on wildlife and habitat, such as the spatio-temporal response of avian populations to these processes, has been integrated into this model (Milne and Bennett 1998). The value of this approach to management illustrates the role of a 'land type', and 'land type association' base, to a range of management and stewardship goals which could include other wildlife groups as well as restoration, conservation and preservation goals for ecosystem sustainability.

Background

In Ontario, there is a long history of land 'typing' (Wiken and Ironside 1977). Such provincial procedures were incorporated into the Canadian Federal 'ecoregional' proposals, which achieved considerable international recognition in the 1970's and 1980's. The units in the system proposed by the Canadian Committee on Ecological Land Classification (CCELC) which correspond most closely with the U.S. 'land type' and 'land type association' are, respectively, ecosite and ecosection, i.e. units recognizable at a scale of 1:10,000 to 1:250,000. This version of ecological land classification is based on an inventory of land system component characteristics. More recently, the provincial government of Ontario has developed the Ecological Land Classification (ELC) program based on the work of the CCELC (Lee and others 1998). Comparable land units in this system are the ecosite and community series. The ecosite is defined as a part of an ecosection having a relatively uniform parent material, soil and hydrology, and a chronosequence of vegetation (Environmental Conservation Service Task Force 1981). This unit represents the recurring plant species selected for and maintained by varying ratios of different factors. The community series, comparable to the 'land type association', is based on the type of vegetation cover or the plant form that characterizes the community (Lee and others 1998).

However, the development of a functional land system model and related mappable land units must go beyond simply recording the characteristics. Ecosystems are dynamic, and the vegetation cover, for example, reflects this by directional change or flux in both structure and biodiversity. A land unit classification should recognize the underlying processes that drive these changes. Given this, the resultant map will provide a better understanding of the system and consequently enhance the impact of management decisions (Moss 1983).

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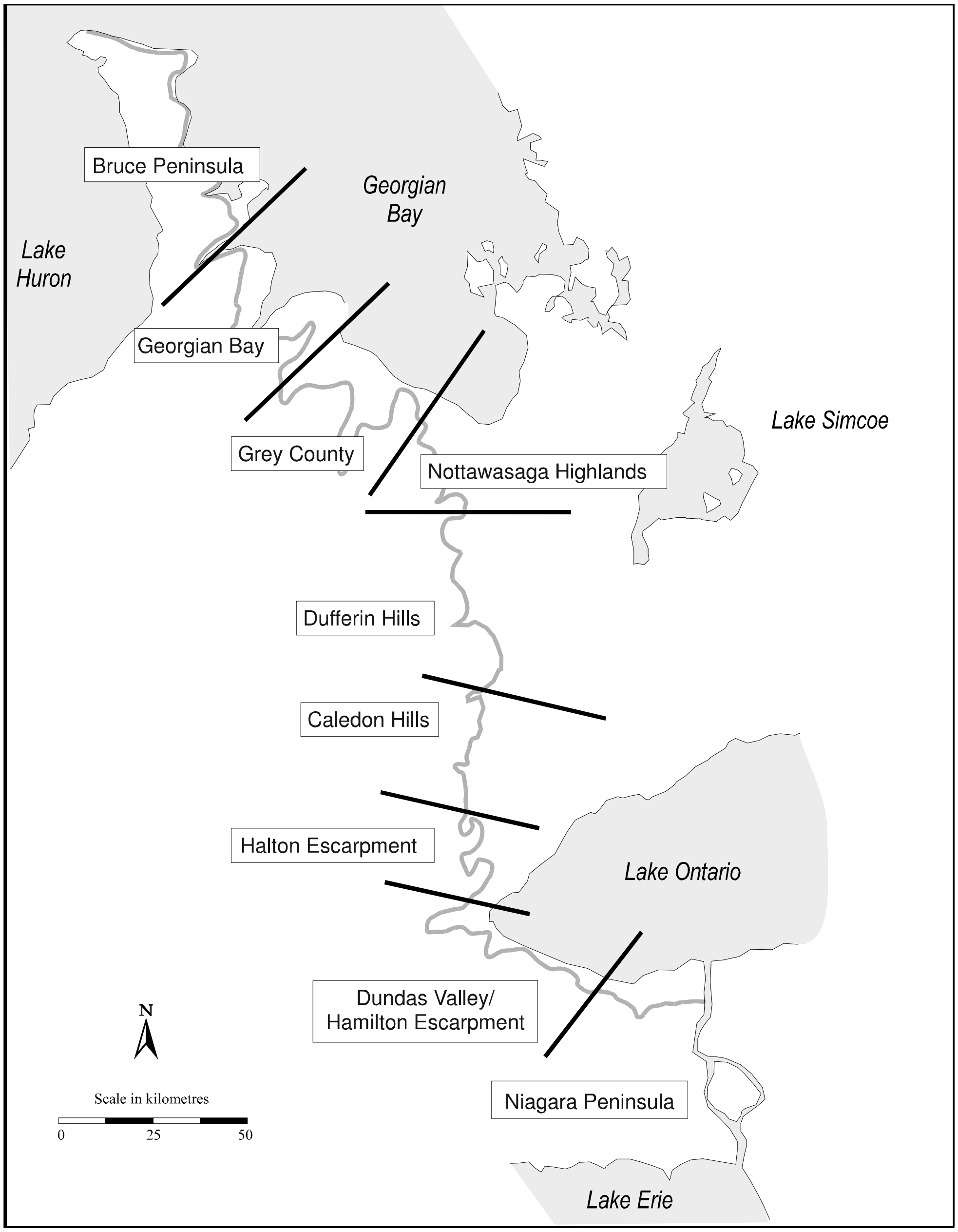

Figure 1.—Land Type Associations of the Niagara Escarpment, Ontario.

Niagara Escarpment

The Niagara Escarpment is the dominant landscape feature of Southern Ontario, extending for over 700 km from the U.S. border at the Niagara River to the head of the Bruce Peninsula in eastern Lake Huron (Figure 1). From the late 1950's, concerned citizen groups began to lobby for some form of preservation and controls on land use planning and development on the Escarpment. In 1973, the Niagara Escarpment Planning and Development Act was passed, establishing the Niagara Escarpment Commission (NEC) which published its Proposed Plan for the Niagara Escarpment in 1979 (Niagara Escarpment Commission 1979). Subsequently, in 1990, the Niagara Escarpment was designated a World Biosphere Reserve by UNESCO (United Nations Cultural and Scientific Organization). Later modifications to the Plan reflect an evolving land use management strategy that provides for the multi-use of this landscape for activities including agriculture, aggregate extraction, tourism, and natural heritage (Moss and Milne 1998).

Biophysical Models of the Niagara Escarpment

Over the past 25 years, the relationships between geomorphic processes and forest dynamics have been

Geomorphic Process	Slope Type	Disturbance Size (m^2)	Recurrance Interval (yrs)	Forest Dynamics (*Open Surface* — *Open Forest* — *Closed Forest*)
creep sheetwash	C	1-10	<1	Gap — End
rockfall	A B			Talus — Shrub
slump	B C	10-100	10-30	Scar — Shrub — Mixed — End
debris slide	C	100+	20-100	Scar — Shrub — Mixed — End
blockfall	A			Talus — Shrub

Figure 2.—The Escarpment Slope Model (ESM): the relationships between geomorphic processes and forest dynamics.

studied at a number of locations on the Niagara Escarpment; for example, in the Niagara Peninsula (Moss and Rosenfeld 1979), the Bruce Peninsula (Moss and Nickling 1980), and Blue Mountain (Milne and Moss 1988). From this work, a model of the Escarpment slope system has been developed based on the interactions of geomorphic processes and forest dynamics (Moss and Milne 1998). More recently, the slope system model has been expanded to include the avifauna component of the land system (Milne and Bennett 1998). In this paper, a model of the broader Escarpment landscape is introduced that extends the scope of the model beyond the main face of the Escarpment to include the uplands and valleys in order to provide a more thorough understanding of the complete Escarpment system.

Escarpment Slope Model (ESM)

The Escarpment Slope Model (ESM) identifies the interrelationships between physical and biological processes. Specifically, the model identifies the response of forest systems to the spatio-temporal complexity of geomorphic processes operating across the Escarpment slopes.

Geomorphic Processes

The lithology and structure of the Niagara Escarpment determine a number of specific geomorphic processes that currently modify surface form. These geomorphic processes range in magnitude from low energy, small magnitude events such as soil creep, sheetwash, and rockfall to much larger disturbances initiated by large debris slides and blockfalls. These larger disturbances occur over an area of at least several hundred square metres. As noted in Figure 2, the recurrence of these events also varies. The low energy events occur on a regular basis, whereas the more disruptive events occur less frequently and more irregularly as a result of variations in the magnitude of weathering and erosion processes.

Three slope types have been identified that are a function of landform and underlying lithology (Figure 3). Type A slopes are dominated by steep cliffs of massive limestone or dolostone; Type B are small cliffs, 2-3 metres in height and characterized by crevasses of various widths; and Type C are rounded slopes of glacial till or weathered bedrock that have a predominantly shale base (Moss and Milne 1998).

Forest Dynamics

The forest dynamics depend on the particular combination of slope processes and landforms. When disturbance is low, there is little disruption of the vegetation cover. Forest dynamics are typically by single tree replacement, creating gaps in the forest canopy that quickly return to a closed forest (see Figure 2). Larger gaps are formed when slumps and debris slides occur. In these cases, the forest cycle includes the establishment of a shrub cover which remains dominant if there is continual or frequent disruption. Sometimes these scars are sites of seeps where water enters the slope surface materials, promoting further movement of slope material and leading to a continuously exposed slope and a stressful high moisture environment. Some scars are eventually covered by a successional forest that returns to the locally dominant or forest cover, identified as the end phase in Figure 3. Larger debris slides can be governed by similar processes but they are more likely to exist as open scars for longer periods. These are often complex micro-environments, subject to

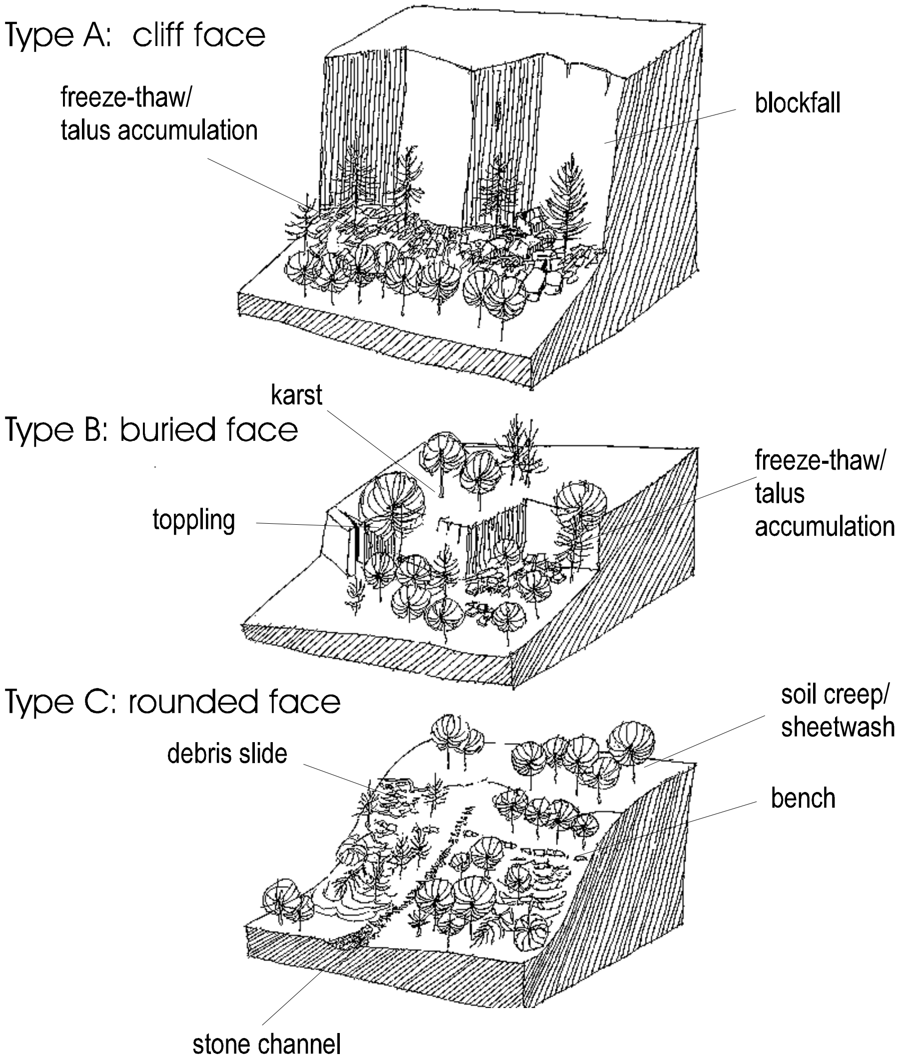

Figure 3.—The three major slope types encountered along the Niagara Escarpment.

moisture and temperature stresses that create many combinations of revegetation, and include slide re-initiation (Milne and Moss 1988).

The processes described above are more common on slope segments where the surface is primarily composed of clay, weathered shale bedrock, or glacial till. When the slope is located below limestone cliffs, as found with Type A slopes, a deep talus base develops. This type of slope is dominant in the northern sections of the Escarpment on the Bruce Peninsula (see Figure 1). Most faces have frequent rock falls in which small blocks of weathered bedrock are delivered to the base of the cliff. When rockfall is steady, a stressful slope environment is created that limits vegetation establishment and growth. These slopes usually have a dominant shrub layer, sometimes interspersed with individual trees which fluctuate in dominance depending on the frequency of talus accumulation. In some cases, large blocks are released from the face, initiating debris slides which disturb all vegetation in their path. Eventually a combination of shrubs and trees cover the large blocks and talus on the blockslide scar, although this successional process may be delayed depending on the environmental stress and the amount of rooting material covering the slope (Moss and Milne 1998).

Wildlife

The wildlife component of this model is useful in developing a better understanding of the interaction between wildlife and the biophysical processes and, more broadly, how these ecosystems function. Despite the volumes of research on wildlife management and land use, there has been little attempt to integrate wildlife ecology with research on biophysical processes. There is a strong literature base on the relationship between wildlife and vegetation, or more generally

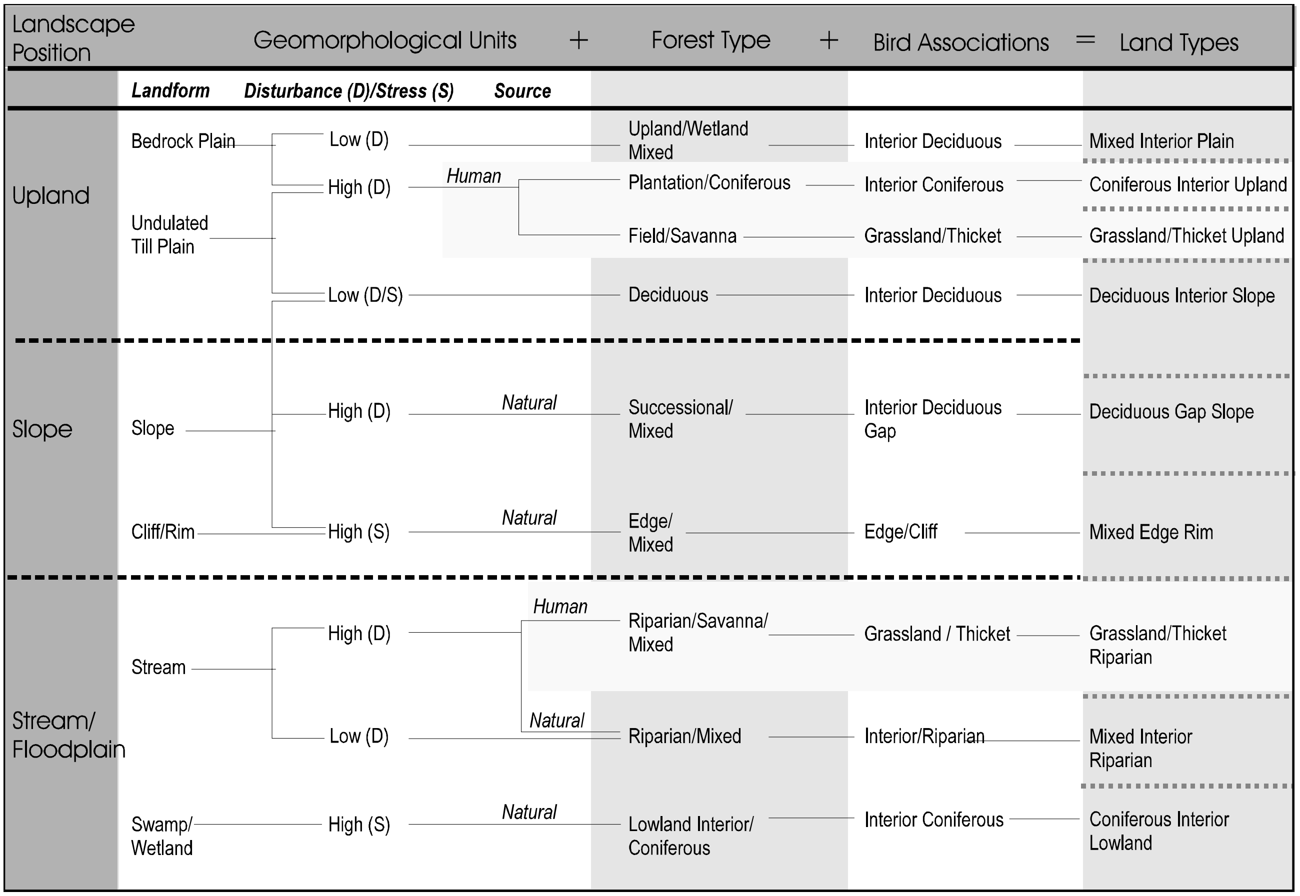

Figure 4.—The Escarpment Landscape Model (ELM) and land types of the central region of the Niagara Escarpment.

habitat, and there has also been more limited investigation of the relationship between vegetation and geomorphic processes (e.g. Parker and Bendix 1996). However, there has been little research on the relationship between wildlife and biophysical processes in slope systems.

Milne and Bennett (1998) found that the spatial pattern of avian species within the Escarpment forests varied depending on slope position and changes to forest habitat. Forest-interior species were found over most of the Escarpment. This would indicate that even though there may be variations in habitats on the slopes, such as small gaps created by landslides or stream valleys, forest-interior birds use the entire complex of forest habitats. However, specific habitats may be created by slope processes, for example, where there is talus accumulation or slope failure. These habitats attract species that are opportunistic, making use of temporary gaps in the forest cover. The overall combination of different slope units and systems creates irregular patterns in the forest ecosystems of the slopes which is reflected in the patterns of bird diversity. This suggests that these surficial, land unit processes are responsible for maintaining a high level of diversity of birds in forests on the Escarpment.

Escarpment Landscape Model (ELM)

The ESM described above can, however, be expanded to provide a more comprehensive model of the Niagara Escarpment landscape system. Where the ESM focused on the inter-relationships between geomorphic processes and forest dynamics on the different slope types, the Escarpment Landscape Model (ELM) has a broader spatial scope to include the bedrock plains and glacial till plains above the face as well as the stream valleys and lower plains within and below the scarp face. In some cases, the Escarpment slope gently grades to flat or hilly glaciated lower plains. In other areas, the base of the slope is actively being shaped by fluvial processes as streams cut deeply through glacial material and the Escarpment bedrock. It is the complex of these land units that make up the greater Escarpment landscape system. It is also these combinations of units that compose the larger land system units, the equivalent of the 'land type associations' in the U.S. system.

The slope model provides an understanding of the slope systems useful for management planning within the natural and protected areas of the Niagara Escarpment. However, land use decisions within the jurisdictional area of the NEC plan will often have a greater impact on the surrounding land types, the uplands and valleys included in the ELM, where human access is often greater.

ELM of the Central Escarpment

An Escarpment Landscape Model (ELM) for the central Niagara Escarpment is illustrated in Figure 4. This area is included in the Dufferin Hills and Caledon Hills land type associations identified in Figure 1. The Dufferin Hills unit of the Escarpment is dominated by Type C slopes, with rounded caps and deep glacial deposits. In contrast, the Caledon Hills unit has Type B slopes with small cliffs and extensive bedrock plains. Based on the relationships between wildlife, forest dynamics and geomorphic processes, a set of nine land units, comparable to 'land types', were identified that become the building blocks for the land type associations.

In this model, one of the distinguishing features of the land types are the processes that initiate change or control the structure of the system. One way to classify these processes is based on the level of disturbance and stress that the site experiences. At this scale of operation, the sources of disturbance are expanded from the ESM to include a differentiation between both human and natural disturbances. For this model, these levels are simply identified as high or low disturbance. High levels of human disturbance include land clearance and forest replacement. For example, there are a number of pine and spruce plantations found along the Escarpment which alter the vegetation structure of the forest from deciduous to coniferous. There are also sites where the land has been cleared for agriculture but has subsequently been abandoned and is returning to a natural forested state. In the earlier successional stages, these areas are a combination of fields, orchards and cedar stands. Areas in the uplands and valleys, rather than the slopes, often exhibit higher levels of human disturbance. By contrast, natural disturbances are greater where there are geomorphic events of high magnitude, more common on the Escarpment face.

Land Types

From the ELM, a set of 'land units' were established based on the combination of the geomorphic information, forest dynamics characteristics and bird associations. These are mappable units and are similar in scale to the 'land type' of the U.S. system (ECOMAP, 1993) or the 'ecosite' of the Ontario Ecological Land Classification system (Lee and others 1998). Each of these 'land types' cannot be described here, but a comparison of the upland sites within the area will be presented as an overview.

Figure 4 identifies four land units in the uplands differentiated by the level of disturbance and lithology. Where disturbance and stress are relatively low, two types of land units exist. On the bedrock plain, a mixed forest community, the Mixed Interior Plain land type, develops with small pockets of wetland forest interspersed with upland deciduous stands. Where there is poor drainage, silver maple, Acer saccharinum, red maple, Acer rubrum, and eastern white cedar, Thuja occidentalis, dominate, while the forests on the well-drained sites are primarily sugar maple, Acer saccharum, and American beech, Fagus grandifolia. The bird populations are typical of deciduous forest interior including Scarlet Tanager, Piranga olivacea, Wood Thrush, Hylocichla mustelina, Ovenbird, Seiurus aurocapillus, and Red-eyed Vireo, Vireo olivaceus. In addition, the small wetlands attract other species such as Northern Waterthrush, Seiurus noveboracensis, and Wood Duck, Aix sponsa. This pattern of habitats increases the overall species diversity for these areas. By comparison, the well-drained sites in the undulating glacial till areas, the Deciduous Interior Slope land type, are dominated by deciduous trees primarily sugar maple with white ash, Fraxinus americana, butternut, Juglans cinerea, and American beech. These forests are very similar to the slope forests that become established when there is little disturbance. The bird associations are also typical of deciduous forest interior as described above but the wetland species are absent.

In some areas, there has been considerable human disturbance, including both forest clearance and plantation establishment. These are identified as the Coniferous Interior Upland land type. Plantations are subject to various levels of management determined by the type of vegetation and the site dynamics. The plantation forests are typically red pine, Pinus resinosa, although there are some stands of white pine, Pinus strobus, jack pine, Pinus banksiana and white spruce, Picea glauca. The birds associated with these land types are typical of coniferous interior forests, quite different from the birds found within the native deciduous cover the plantations have replaced. The dominant birds include Yellow-rumped Warbler, Dendroica coronata, Pine Warbler, Dendroica pinus, Chipping Sparrow, Spizella passerina, and Red-breasted Nuthatch, Sitta canadensis. When the plantations have had little management or have been allowed to naturalize, a deciduous understorey replaces the coniferous cover. Where this occurs, other birds such as Mourning Warbler, Oporornis philadelphia, enter the system.

Other sites are in the process of reforestation following field abandonment. In general, these sites, the Grassland/Thicket Upland land type, are dominated by eastern white cedar, apple, Malus spp., hawthorn Crataegus spp., and shrubs such as raspberry, Rubus spp. The bird populations are dominated by field and thicket species such as Northern Cardinal, Cardinalis cardinalis, Song Sparrow, Melospiza melodia, and Field Sparrow, Spizella pusilla. The recovery of the vegetation cover at sites where human disturbance has been removed suggests these forests will eventually return to the dominant upland deciduous forest cover and corresponding bird species. The time scale for recovery will depend on the level of human disturbance.

Land Type Associations

Originally, the ESM provided the foundation for establishing a functional landscape classification for the Niagara Escarpment (Moss and Milne 1998). Land units along the length of the Escarpment were delineated by the slope type and related geomorphic processes. As a result, a set of nine planning units was identified along the entire length of the Niagara Escarpment (Figure 1). These units are comparable in scale to the 'land type associations'.

The ELM has provided a more detailed understanding of the ecosystem processes operating at the scale of the 'land type', and consequently, can be expanded to verify the pattern of the 'land type associations' as described here for the Dufferin Hills and Caledon Hills units. At the 'land type association' scale, unit identification is primarily a function of the dominant landforming processes and resultant landforms. At the lower level of the hierarchy, land types are more a function of local processes such as disturbance or stress.

From the model, two land type associations emerge that are primarily differentiated on the basis of landforming processes. These two associations include: (1) the Caledon Hills, where there is only a thin surface cover over a limestone bedrock, which forms an irregular plain extending back from the ridge/rim of the Escarpment and 2) the Dufferin Hills, where the glacial deposits form an undulating surface characterized by steep slopes and small valleys in glacial till. These two associations are composed of combinations of the land types identified in the model, but specific types will dominate within each association. For instance, the Mixed Interior Plain and Mixed Edge Rim land types are typical of the Dufferin Hills land type association, and the Deciduous Interior Slope and Mixed Riparian Interior are common in the Caledon Hills land type association.

By comparison, the Ecological Land Classification (ELC) system for Southern Ontario, at the scales of 'land type' and 'land type association', is primarily focussed on vegetation pattern and variation in the structure of the forest cover. With this focus, any variations in vegetation dynamics and patterns in habitat will be overlooked. This will have implications for land management. At the scale of the 'community series' of the ELC, an area may be mapped as deciduous forest cover. However, this will overlook the dynamics of the biophysical processes that are driving this system. For example, Figure 4 shows that some forest cover in the slope and upland units is deciduous, but forest gap replacement occurs more frequently in the Deciduous Gap Slope unit than the Deciduous Interior Slope. In response, bird populations will have a greater diversity in the Deciduous Gap Slope units where landslides are a component of the biophysical system. Consequently, these units could play a more critical role in foraging and nest sites for many species than sites situated in the Deciduous Interior Slope units. In turn, land and resource planning decisions should take these differences into consideration when planning land use on the Escarpment. 'Community series' maps within the ELC cannot identify such habitat processes. This clearly restricts its usefulness as a land use planning tool.

Summary

The land unit equivalents to 'land types' and 'land type associations' have been described for Ontario and specifically, the Niagara Escarpment, Ontario. These units were originally based on the Escarpment Slope Model (ESM), a functional approach that combined geomorphic processes with forest dynamics in Escarpment slope systems. This model has been expanded to include avian populations to illustrate the role of wildlife in these systems. The scale of the model was also increased to include adjacent land units above and below the Escarpment face and slope. This work has culminated in the Escarpment Landscape Model (ELM) which combined scales of land types and land type associations. The Ontario Ecological Land Classification (ELC) program was compared to functional models that were developed from research on the Niagara Escarpment. Unlike the Ontario approach, which is strongly based on vegetation cover, the Escarpment Landscape Model builds from the biophysical processes at the land type level to established land type associations based on functionally integrated land types. The ELM is comparable in scale to the planning units of the Niagara Escarpment Plan and is applicable for current land use planning issues in this region.

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Use of Landtype Associations and Landforms in Managing Pennsylvania's State Forests

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Abstract

The Pennsylvania Bureau of Forestry is committed to sustainable ecosystem management using a landscape based approach on 2.1 million acres of state forest land. The Bureau has relied on two major ecological delineation methods to help define landscape level units – ECOMAP and Landform Map. Landtype Associations (LTA) will serve as the basic large-scale management unit on state forest lands. Goals will be established for all LTAs based on its "landscape context" considering its biological character, the nature of all surrounding LTAs, and its landform context.

Introduction

The state forest system of Pennsylvania — two million acres of woodland in 48 of the Commonwealth's 67 counties — comprises 12 percent of the forested area of the Commonwealth. Pennsylvania's state forests represent one of the largest expanses of wildland in the eastern United States making them a truly priceless public asset.

Pennsylvania's state forests have been under formal management since 1955 with the development of *State Forest Management Plans* that focused on timber and water resources. These plans were followed by *State Forest Resources Plans* (1970) that evolved from the initial plans, to multiple-use plans, to detailed multiple-resource management plans (1985) including water, soils, minerals, fauna, flora, timber, and recreation. Our current planning effort, a fourth generation of plans, has evolved to an ecosystem management approach with a focus on the sustainability of forests to provide an array of values including the conservation of biological diversity, recreational opportunities, and forest products.

Sustainability is a complex idea involving economic, environmental and social factors. The term forest sustainability implies the following elements: the continued existence and use of forests to meet human physical, economic, and social needs, the desire to preserve the health of forest ecosystems in perpetuity, and preserving options for future generations while meeting the needs of the present.

Sustainability concerns the interactions between humans and forests. Forests are defined as ecosystems dominated by trees but with other components such as shrubs, herbs, mammals, birds, insects, microscopic creatures, soil, air, water, and the interactive processes that bind them together. Forest managers must consider ecosystem integrity constraints when prescribing actions to provide forest uses and/or values. The Pennsylvania Bureau of Forestry believes that sustainability can best be met by using an ecosystem management approach to forest management.

Sustainable ecosystem management rests on the understanding of environmental geography. Coordinated management at a landscape level is essential for implementing ecosystem management. Landscapes are mosaics of interacting communities or ecosystems. Landscape patterns change in time and space, reflecting both the impact of human activity upon the system, as well as natural changes such as climate. Ecosystem management, focusing on landscape context, is the strategy that best ensures that the viability of forest systems can be maintained while, concurrently, providing benefits to society.

Although many agree that "landscape" level planning and management are key components for managing forest ecosystems, there is no widely accepted definition of what constitutes a "landscape." The Pennsylvania Bureau of Forestry has relied on two major ecological delineation efforts to help define and delineate landscape level units in the Commonwealth and on state forest lands. These efforts include the U.S. Forest Service's National Hierarchy of Ecological Units (ECOMAP) (Bailey1995) and the Pennsylvania DCNR Bureau of Topographic and Geologic Survey's Landform Mapping project (Sevon 1998).

Pennsylvania ECOMAP

The goal of ECOMAP for Pennsylvania is to provide a geographic spatial framework, based on ecological parameters, which can be widely used by agencies and organizations throughout the Commonwealth.

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Pennsylvania's ECOMAP effort is directed toward coordination and building consensus. It builds upon the work of a consortium of agencies led by the U.S. Forest Service, in which Pennsylvania has participated. An eight-level hierarchy of ecological units forms the basis for the framework. In essence, a standardized classification and mapping system stratifies the earth into progressively smaller areas of increasingly uniform ecological potential. These units provide a means of integrating research, inventory and monitoring information from multiple disciplines and organizations for assessments across political, administrative, and jurisdictional boundaries.

The Pennsylvania ECOMAP consortium endorsed and adapted the concepts of the U.S. Forest Service *National Hierarchical Framework of Ecological Units* (ECOMAP 1993). The Forest Service, in cooperation with the Bureau of Forestry, brokered the delineation of ecological units within the Commonwealth and across state boundaries through the first five levels of the hierarchy as follows: domain, division, province, section, and subsection.

Section and subsection units for Pennsylvania were configured for compatibility with the long-standing and widely recognized physiographic provinces and sections of Pennsylvania (Sevon 2000). The Bureau of Forestry recognizes ECOMAP subsections within Pennsylvania as "Ecological Regions."

The Bureau of Forestry coordinated the delineation of the lower levels of the hierarchy, ecological landtype (ELT) and landtype association (LTA), on, and adjacent to, state forest lands. These two levels, ELT and LTA, bear directly on resource management and planning.

An ELT is a contiguous sector of terrain that exhibits relatively uniform influence on the landscape context. LTAs are complexes of complementary landscape components (ELTs) that combine through spatial adjacency. ELTs are instances of a specific landscape setting, whereas LTAs are extensive areas (typically thousands of acres) of terrain having composite characteristics that are more or less distinctive in the regional context. The LTA level is considered a landscape level because it represents the scale at which natural resource management plans and operations become more specific.

Four major considerations have shaped the conceptualization of both LTAs and ELTs for Pennsylvania. The first of these is ecological specificity, whereby the framework should be useful for segregating differing ecological conditions. The second is determination of landscape context, whereby the framework should assist resource planners in recognizing where and how allowances need to be made for vicinity influences. The third is extendibility, whereby the framework should be applicable to other northeast states. The fourth is its complementary nature with contemporary technologies of geographic information systems (GIS). The intent is to capture components of spatial information that are not easily extracted from GIS databases in an automated manner, so that combining the ECOMAP delineation with common GIS layers should enhance the value of both.

The approach used was to first delineate ecological landtypes (ELTs) in terms of landform components, because this level constitutes the building blocks of landscapes that must have substantial consistency across regions. The landtype association (LTA) level has a different nature in that its elements are logical aggregations of ELTs that have commonality in their particular setting. Thus, a given ELT can only belong to one LTA.

Landscape scale ecological mapping reflects floral and faunal propensities, but not necessarily existing biotic composition. ELT typology is designed to be transferable among regions with very different geological histories. Topographic position is the strongest consideration for delineating ELTs across Pennsylvania. Although many organizations are using soils and/or vegetation to delineate ELTs, statewide data on soils and vegetation is limited. Thus, ELTs were determined by analyzing topographic maps in conjunction with supplemental information (e.g., remotely sensed images, soil maps, and hydrologic maps).

ELTs are grouped into the following families: Crests, Uplands, Slopes, Terraces and Plains, Valleys, Hills, Wetlands, and Water. Differences in soil and geology are expressed in landform, because resistance to erosion principally determines topography. Environmental properties thus enter indirectly into topographically delineated ELTs. However, these properties will not be adequately expressed through ELTs unless supplemented by overlay analysis using geographic information systems (GIS) to build tables of environmental factors such as slope steepness and aspect.

LTAs tend to have considerable individuality relative to their environmental implications. LTAs should segregate substantial differences due to underlying soil and geology. Placement of divisions between LTAs is crucial for management purposes but oftentimes nebulous in the field. To help resolve this apparent quandary, we introduced the concept of *caplands* and *cuplands*. Caplands are the generally convex to level upper landscape surfaces that receive precipitation and direct it downward as runoff to small intermittent or headwater flowpaths. Cuplands are generally concave to level valley areas that concentrate moisture as channelized flow and near-surface groundwater.

Caplands extend from crests and uplands down to the base of footslopes flanking valleys. Cuplands consist primarily of valley floors or valley bottoms, floodplains, and wetlands. Hydrologic processes change at the interface between caplands and cuplands from being dominated by runoff and erosion to favoring infiltration and deposition along with collection in major watercourses and basins. Not surprisingly, this is also a juncture where habitats change with regard to moisture dependent species versus those that tolerate dryer conditions.

This gives process rationale for LTA separation. LTAs are primarily either caplands or cuplands. When delineating LTAs, resource managers avoided partitioning drainages longitudinally. It was preferable to contain headwater drainages in capland LTA's. Separation should occur where they meet cupland LTAs. If it proved necessary to partition crests or uplands, it was done at saddles or where drainages appear to meet from opposing directions.

Both ELTs and LTAs were delineated by Bureau of Forestry field foresters using a standard protocol (Myers 2000). ELTs and LTAs were delineated and attributed on mylars overlaying standard 1:24,000 scale USGS topographic maps. Mylar overlays were checked by Bureau of Forestry central office staff for completeness and consistency. The mylars were scanned, digitized, rectified, edge-matched, and attributed through a contract with the Pennsylvania State University (PSU). Dr. Wayne Myers, PSU, reviewed and, when necessary, revised ELT and LTA coverages to insure adherence to protocols and to provide quality control.

The LTA will form the basis of the Bureau of Forestry's landscape management approach on state forest lands. Scope for consideration of the human dimension is greatest at the LTA level. Geology, orography, prevailing winds, viewsheds, watersheds, connectivity, insularity, infrastructure, and land-use history determine interactions among LTAs.

Landform Map

The Landform Map of Pennsylvania is a project of the Pennsylvania Geological Survey. The project originated in 1994 as a response to a request by the Pennsylvania Bureau of Forestry. The Bureau of Forestry desired an updated and smaller scale version of the 1:2,000,000 scale Physiographic Provinces of Pennsylvania (Berg and others 1989). A recompilation of that map at 1:50,000 scale refined all boundaries and created several new sections. The map was digitized at 1:100,000 scale. Recognition of the potential for production of a much more detailed landform map and a strong indication of interest in such a map from the Bureau of Forestry prompted work on the Landform Map to commence early in 1997. The first version of the map, completed early in 1998 increased the number of landform subdivisions from 16 to 65. The utility of this effort was recognized immediately and work commenced on further refinements in the map.

The Landform Map of Pennsylvania is a detailed subdivision of the physiographic provinces within Pennsylvania. The 2000 version has 653 subdivisions. The map has been digitized and attributed. Subdivision classification adheres broadly to the scheme proposed by Godfrey and Cleaves (1991) and is: Province, Section, Region, District, and Area.

Landform subdivisions on the current map have been interpreted using 1:50,000-scale topographic maps with 20-foot contour intervals (an existing county map series). Use of maps of this scale and detail allowed interpretation of the topography of Pennsylvania at a level never before attempted (Sevon 1997, 1998).

Criteria for subdivision include:

1. Subdivision must have a topographic identity that distinguishes it from an adjacent subdivision.

2. Subdivisions should have readily definable boundaries, but arbitrary boundaries are acceptable where necessary.

3. Subdivision must be large enough to show on a 1:500,000-scale map.

The landform map comprises:

1. A digital map with:

   a. Landform boundaries and identification numbers for each landform.
   b. Topography in selected metric intervals or in digital-elevation image.
   c. Public road network.
   d. Stream network.
   e. Names of selected cities.

2. A digital database with the following descriptive items:

Unit number; Province; Section; Region; District; Area; representative 7.5-minute quadrangle; county; area, dominant topographic form; land use (15 categories); boundaries; underlying rock type; geologic structure; surficial sediment; drainage pattern; drainage density); elevation (maximum, minimum); slope (maximum, minimum, mean); relief (maximum, minimum, mean); detailed descriptions of landform and boundaries; and soil temperature.

This digital coverage along with its database is an essential component for landform analysis and further subdivisions. The map and data should be useful for evaluating habitats for birds, mammals, and flora. It also compliments the Pennsylvania ECOMAP effort (Sevon and Hoskins 1999).

Landscape Scale Management on State Forest Lands

The central purpose of ecological mapping is to facilitate understanding of landscape organization in terms of ecological implications for resource management. Landscape scale ecological units are those involving visual range along with processes for near-surface movement of organisms and substances across the terrain. The landscape scale typically involves substantial acreage (1,000-5,000 acres). Because this is the scale of strong spatial interplay among ecosystem elements, it is also the scale natural resource managers must be most concerned about when assessing offsite influences and consequences.

The Pennsylvania Bureau of Forestry has been planning for and managing large-scale land units for over 30 years. Traditionally, state forest lands have been zoned and divided into management units called compartments. State Forests lands are assigned a management zone that subjects the area to specific management criteria and/or restrictions. Compartments are permanently identifiable geographic units using physical features such as roads, trails, rights-of-way, streams, and ridge tops as compartment boundaries. As a general rule, compartment acreage ranged between 500 and 3,000 acres.

Compartments were examined on a regular schedule. The compartment examination schedule provided for the orderly examination of all state forest lands within the 15-year management period. The schedule consisted of a table listing the compartments in numerical order with a corresponding column for entering the year of examination. One-fifteenth of the compartments were examined each year.

Each stand or area otherwise classified was examined visually. The area examined was of sufficient size to allow the examiner to determine reasonably the present condition of each classified stand or other area and to make recommendations on management needs for the next fifteen years. Such determinations and recommendations included timber management, habitat management, recreation management, and infrastructure condition/needs. Recommendations were made based on various stated resource objectives. Accomplishments and/or changes in the compartment were noted, kept in a compartment file, and in some instances sent to the central office for updating maps and databases.

Although the compartment has served as the Bureau's basic large-scale management unit for over 30 years, it has several shortcomings in terms of using an ecological approach to forest management. First, the boundaries of compartments are based on convenient physical features that usually have little biological or ecological implication. Second, all compartments are considered similar in that the goals and objectives are the same for each and are distributed evenly across all compartments regardless of its biological/ecological potential. Third, a compartment is considered an entity unto itself with little consideration to its location on the landscape.

The management of state forest land is based on State Forest Resource Management Plans that are goal driven. Traditionally, Bureau of Forestry program areas have developed regional, compartment, and resource/use goals. These goals were based on scientific knowledge, legal mandates, public input, and constraints. In the current planning effort goals are being developed on several scales including statewide, ecoregional (ECOMAP subsection), individual state forest, landscapes (LTAs), and resource/use. Although new management plans will be based on multi-level goals, they will focus on landscapes and landscape goals.

Because of the limitations related to compartments, as stated above, the Bureau is switching its basic large-scale unit of management to the LTA. We believe that the LTA is better suited to a landscape scale ecological approach for state forest land management. However, it should be noted that landscapes are contextual in nature rather than fixed parcels of land. Therefore, LTAs will be analyzed and considered in their "landscape context".

The landscape scale (LTA) is often referred to as the intersection of ECOMAP's top-down / bottom-up approach to ecological classification. LTAs must fit into a larger scale ecological unit, Section and Subsection, but they are usually formulated based on finer scale ecological units, usually ELTs. Following this concept, landscape (LTA) goals will be formulated based on stated fine-scale resource/use goals and broad-scale ecoregional goals.

Each LTA will be analyzed as to its potential contribution to stated ecoregional goals such as connectivity and its potential contribution to stated resource/use goals such as biodiversity conservation, timber management, flora management, water resource management, etc. In considering its contribution, each LTA will be examined first in terms of its biological/ecological character such as its make-up of compartments, ELTs, forest communities, aquatic communities, infrastructure, etc. Second, each LTA will be examined in relation to the nature and/or character of all surrounding LTAs to determine its potential complementariness and/or clash. Third, each LTA will be examined in its landform(s) context denoting the specific characterizing landform attributes, such as rock type, elevation, relief, slope, etc. Program area staff in conjunction with field staff will formulate initial landscape goals using this "landscape context" approach.

LTAs will be examined on a regularly scheduled basis as described above for compartments. Recommendations based on ground examinations will be formulated for each LTA. Recommendations will be recorded and reviewed. Any changes in forest community types, infrastructure, habitat, etc., will be documented and changes made to appropriate GIS coverages and/or databases. Recommendations for changes in LTA goals will be forwarded to central office staff for consideration and approval/modification.

The Bureau of Forestry believes that the use of LTAs as a large-scale management unit on state forest lands will have several benefits. The first is its potential application to other land holdings in the state, regionally, and across the country. The delineation of LTAs is based on standard protocols that can be applied regardless of land ownership. Second, LTAs are ecologically based delineations as opposed to traditional compartments. Third, LTAs will be viewed in their landscape context allowing for the character of the LTA and surrounding LTAs to play a major role in setting goals.

Perhaps the greatest benefits to using LTAs in terms of their landscape context is flexibility and adaptability as opposed to having standardized goals and objectives that apply across the landscape regardless of the landscapes ability to accommodate them. The landscape context approach, using LTAs, focuses on natural ecosystem processes as opposed to forcing systems into regimented standards. Bureau of Forestry resource managers (field and central office staff) will be better able to apply their knowledge and skills using this approach.

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Clay Lake Plain Ecosystem Project

Robert DeVillez[1] and Randy Wilkinson[2]

Abstract

This project sought to implement an innovative strategy for identifying ecological units, Land Type Associations (LTA's) within a landscape; define NIPF planning objectives; and target landowners within the LTA units for contact. Landowners were provided information on the role of their parcel in the landscape and factors affecting management activities. Information developed and presented included: current land cover; land type association descriptions; soils information; pre-European settlement conditions; common and unique birds and mammals; natural features; and native plant and watershed information. Landowners and consulting planners were provided the information through public meetings, mailings, tours and personal contact. NIPF landowners were encouraged to develop and implement ecosystem plans through the USDA – State of Michigan Forest Stewardship Program. In addition to the $30,000 the State of Michigan Stewardship Committee allocated for the Clay Lake Plain Ecosystem Project they earmarked an additional $11,250 in funds for developing forest stewardship plans within the Clay Lake Plain area. As of April 6, 2001, 145 landowners with over 26,140 acres of land are under Stewardship Management Planning. This represents seven percent of the NIPF lands within the project area.

Sponsors

On July 15, 1994, the Michigan Department of Natural Resources entered into an agreement with the Upper Peninsula Resource Conservation & Development Council (501c-3 nonprofit association), to initiate the forest stewardship program known as the Clay Lake Plain Ecosystem Project. Supporting sponsors included the U.P. RC&D Forestry Committee, the Chippewa County Soil Conservation District, MI Department of Natural Resources - Forest Management & Wildlife Divisions, USDA agencies - Natural Resources Conservation Service and the Forest Service, Michigan Technological University Remote Sensing - GIS lab and the Eastern U.P. Planning & Development Region.

Project Goals & Products

Since the 1980's, resource personnel from the MDNR, Natural Resources Conservation Service, (NRCS), Farm Service Agency, (FSA), and the citizen committees of these organizations, have had numerous discussions on the unique qualities and opportunities the proposed project area affords. The project area fits in extremely well with the ecosystem approach to resource management and the objectives of the Forest Stewardship Program. Selection of the project area was based on several unique qualities the area offers for such a study. The goals for the Clay Lake Plain Ecosystem Project were to implement a strategy for identifying sub region ecological units within the Eastern Upper Peninsula; define these units and management activities and target educational, technical and financial assistance needs, and to incorporate existing knowledge about biodiversity and functions of ecosystems into Forest Stewardship management plans. The Clay Lake Plain Ecosystem Project on private lands complements another ongoing project by the Eastern U.P. Partners in Ecosystem Management a committee of state, federal and industrial forest landowners efforts to plan and manage their lands with an ecosystem approach. To guide and promote this effort, the Clay Lake Plain Ecosystem Advisory Committee was organized through the RC&D Council and the Chippewa Soil Conservation District. Members represented landowners, interest groups and public interests or agency personnel. Objectives of the proposal were well received and the committee soon was functioning to achieve the project objectives.

Geographic Information Services, (GIS), were contracted through Michigan Technological University. Base data that was provided or obtained for use in the project included: soils data, land use cover information, presettlement conditions and land type association (LTA) data based upon U.S. Forest Service work on the National Hierarchical Framework of Ecological Units.

While the GIS work was underway, the Advisory Committee developed a mission statement and a set of ecosystem project planning objectives that they felt would conserve the uniqueness of the E.U.P. Clay Lake Plain Ecosystem. The Advisory Committee spent considerable time defining the unique qualities of the area and evaluating objectives that would maintain these qualities.

The project mission statement and planning objectives that were identified for use in developing ecosystem based management plans within the area were:

To promote a cooperative effort to maintain and or enhance the biodiversity of sustainable ecosystems on private lands in the Eastern Upper Peninsula through information and education.

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Ecosystem Project Planning Objectives

Plans should address the following:

- Grassland nesting species and cover.
- Wetland areas for dependent species.
- Riparian areas: stream bank corridors and shorelines.
- Best management practices to sustain forests and forest dependent species.
- Evaluation and maintenance of drainage systems.
- Non-game and game species.
- Presettlement land cover.
- Habitats for diversity.
- Water quality issues.
- Impact of development on habitats.
- Recreational opportunities.
- All adjacent landowner uses.

The Advisory Committee next made suggestions for the make-up of the LTA information sheets and development of the public outreach activities. Randy Wilkinson, U.P. RC&D Coordinator, and Bob DeVillez, DNR CFM Forester assembled the information for the LTA information sheets. The DNR Wildlife Biologist, MI Natural Features Inventory staff, USDA Natural Resources Conservation soil scientists and U.S. Forest Service plant ecologists, assisted them in technical areas. Ecosystem information covered in the LTA sheets include:

- LTA - Legend & Description
- Ecological Significance
- Acreage & Cover Type Breakdown
- Soil Association
- Native Plant Information
- Common & Unique Birds & Mammals
- Watershed Information

As the Clay Lake Plain Ecosystem data was being assembled and edited, the Committee and advisors discussed methods of outreach to landowners. The first outreach activity included the development of an Ecosystem Project Informational Brochure. Major points of the brochure were a definition of ecosystems, ecosystem mapping, land cover display, planning objectives, ecosystem management examples and sources of planning and implementation assistance.

Discussion followed on methods of public and planner stewardship information. Consulting foresters and planners were contacted and provided information and materials. Public outreach included news releases, direct mail of the brochure to targeted landowners, public meetings, presentations to sportsman clubs and updates by Advisory Committee members to other organizations of which they are members. Distribution and updates were also provided through SCD newsletters, Farm Services Agency mailings and County Fair display materials. Response to these efforts was well received by landowners, organizations and the news media. The Advisory Committee discussed the fact that a method of information dissemination needed to be developed that would not require continued use of resource specialist's time. It was decided to develop a short, (12 - 15 minute) video covering ecosystem management, stewardship principles and the Clay Lake Plain Ecosystem Project. It was hoped this would allow for continued information efforts by numerous agency and Advisory Committee members. A contract was approved with a local video production firm for development of the video, spot announcement and 100 copies of the video.

Project Outcomes

Outreach Results:

Through the efforts of the committee, technical advisors and sponsors, the following is a summary of some of the Clay Lake Plain Ecosystem Project outreach efforts.

Public Town Hall Meeting

600 targeted mailings. 82 people attended evening informational meeting. News releases were also utilized as a tool.

Presentations

Presentations were made to agencies, organizations and the general public. Included in this are presentations to Natural Resources Conservation Service staff, DNR staff, wildlife or special purpose committees, State Stewardship Committee, RC&D Councils, local and state forestry association groups, Great Lakes land type association groups, MI Society of American Foresters and the Soo Sustainable Community Committee. The purpose of these meetings was to inform and update membership on the project and solicit assistance in getting information out about the project.

Tour

Approximately five weeks after the public town hall meeting, a field tour was arranged and held on an active stewardship landowner property. Targeted audience was the people who attended the public meeting. Twenty-three people attended, including staff, 3 planners and members of the State Stewardship Committee. Several landowners that did not attend did contact landowners advisory committee members for additional information.

Video development

This informational effort was started after the town hall meeting. Delays in the production resulted in not having the video available during the outreach effort. The video will be used now for future outreach and stewardship efforts. Final public results will not be known on this effort until several months after the final report is complete.

A 30-second spot commercial was developed from the 13 1/2 minute video. The commercial was placed with TV-6 Marquette, TV 9 & 10 Cadillac/Traverse City and Bresnan Cable Co. The cable coverage includes the central U.P., Marquette, and Escanaba to Newberry and Sault Ste. Marie. Bresnan also donated 75 commercial spots on ESPN, *CNN*, TNN and Discovery. In total to date, 176 spots have been contracted for.

Cost of Project

Major costs for the Clay Lake Plain Ecosystem Project included approximately $17,500 for mapping, printing, personnel and materials. Of this $6,000 were for GIS support, $9,000 for reports, brochures, education meeting and map display. Targeting and data base work costs were approximately $9,500 of which $6,600 was for video production. Meeting and training expense was approximately $500. Administrative and miscellaneous expense was approximately $2,300. Over $24,000 of in-kind services by the Advisory Committee, technical committee and technical staff time was utilized during the 2 1/2 year project time. Actual mapping and data work did not get started until Sept. of 1994. Total project grant costs were approximately $27,500. Final costs will be included as an attachment to the report to the grant provider, the Department of Natural Resources.

Evaluation

Several methods of evaluation were used during this project. In data gathering, selection of information, and public outreach, the experience and opinions of the landowner advisory committee were used. Technical information was limited to that which the advisory committee felt was of landowner interest.

During the final portions of the project and video review a short evaluation form was developed and presented to the Advisory Committee, consultants and technical staff familiar with the overall project. These written evaluations showed a couple of interesting items. Everyone felt that the information gathered was useful to landowners. Advisory committee members felt that information on native plants, as well as common and unique birds and mammals was of more interest to landowners than the resource data such as soils, possibly because this information *is less* readily available. The Advisory Committee felt that the most successful methods of public information on this project were the public meeting, word of mouth, and one-on-one group contact. As stated, the effects of the commercial and 13 minute video will not be known for several months yet. All evaluations stated that the project value to the landowners was worth the cost of the project (grant) and matching volunteer and staff time.

In the eyes of the Clay Lake Plain Ecosystem Advisory Committee, the project has been a very successful one that has far exceeded the objectives of the grant agreement. The five stated goals of the grant agreement have been met.

As part of the evaluation, the Advisory Committee compiled a landowner profile and listing of activities that landowners have accomplished that meet the Ecosystem Project Planning Objectives. The information was gathered from the required assessment form that is part of the Stewardship Plan and USDA cost sharing accomplishments by landowners in the project area.

The Clay Lake Plain Ecosystem Project landowner, on the average, owns 180 acres, and the range was from 18 acres to 1,620 acres. The majority of the landowners have owned the property for ten years or less. They predominantly reside in the Upper Peninsula of Michigan and are absentee landowners. They have full title to the properties that are under a warranty deed rather than land contract. They have had no past contact with professional resource people and rarely have received any cost sharing. The majority has never had a written management plan, nor have they cut or sold timber from their property. Landowners, priorities for the resource values of the property are primarily for wildlife and recreation.

Accomplishment of Ecosystem Project Planning Objectives, encouraged by the Advisory Committee, on lands within the project as of April 6, 2001 includes the following:

Grassland Nesting and Cover:	100 projects for 230 acres
Wetland Created:	31 projects for 640 acres
Reforestation Projects:	86 projects for 445 acres
Timber Management:	87 projects for 5,220 acres
Other Wildlife Habitat Improvement:	3 projects for 155 acres

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Human Preference for Ecological Units: Patterns of Dispersed Campsites within Landtype Associations on the Chippewa National Forest

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Abstract

Forest Service landscape architects sought a method for determining if people showed a preference for certain landscape-scale ecosystems and if ecological classification units could be used in visual resource management. A study was conducted on the Chippewa National Forest to test whether there was a systematic relationship between dispersed campsite locations and landtype associations (LTA) (most National Forests allow "free-choice" camping; sites with repeated use are inventoried and monitored as "dispersed campsites"). A statistically significant pattern exists in dispersed campsite locations as a function of LTA's. End moraine and sand plain LTA's contain the most campsites, while people apparently show little inclination to pitch their tents in the peatlands and ancient lakeplains. The test reinforces many conclusions from existing landscape preference research, such as people's preference for water bodies (Kaplan and Kaplan 1989, Herzog 1985, USDA 1974, Ellsworth 1982). The findings also indicate that landscape scale management of visual resources using Ecological Classification and Inventory units may be appropriate and that LTA's could be used as a forest planning unit that "links" the social and natural environment.

Introduction

The Research and Management Context

Existing Visual Resource Management Systems

Patterns in human preference for different landscapes in the Forest Service *Scenery Management* and *Visual Management Systems* are established through criteria of landform, rock-form, vegetation types, and bodies of water.

Although descriptions or analysis of characteristic succession or disturbance patterns, and associated visual changes to the landscape, are not discussed at length in the systems, the criteria used to identify the most visually scenic landscapes are very similar to the criteria used to inventory and classify ecological units in the Ecological Classification and Inventory System (USDA 1974 and 1996).

Predictable Human Adaptation to Environments

Anthropologists have long recognized a connection between human cultural adaptations and the biophysical environment. In 1911, for example, Ellen Church described the vast area of steppes and deserts extending across Europe and Asia and the associated diverse ethnic groups of Negroes, Hamites, Semites, Indo-Europeans, and Mongolians, who all developed the behavioral adaptation for nomadic herding as their main occupation. People tend to take customs, social organization structures, and economic tendencies with them when migrating (Church, 1911) and, as described by Alfred Crosby (1992) in his description of the European Colonial invasion of the Americas, they will modify the composition,structure and function of a newly encountered ecosystem to create landscapes with which they are familiar. Those ecosystems in the Eastern United States which failed to support the European, agrarian model fell into public ownership; hence most eastern National Forests share common features of non-arable land such as steep topography, infertile soils, cold climate, or a high proportion of wetlands.

Studies in visual perception by environmental psychologists such as Steve and Rachel Kaplan (1989), also indicate that human response may be psychologically or physiologically affected by adaptation to the environment. Humans tend to prefer the environments in which their survival is most likely or those that include features or characteristics that meet certain psychological needs, such as "making sense, stimulation, and complexity". They believe that the more "regular" and predictable patterns in human visual preference are the psychological perceptions of landscapes they have identified through their research (Kaplan, 1979).

The Purpose for a Dispersed Campsite Analysis on the Chippewa National Forest

Land management agencies are increasingly adopting ecologically based methods for planning and carrying out management activities such as timber harvesting. But how well do systems developed for the biophysical environment relate to forest resources such as recreation and scenery, which are more human-focused and

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perceptual in nature? Landscape architects, recreation planners, and other personnel within these agencies who address people-forest interactions face the question of how to best incorporate ecological classification systems into existing recreational and visual planning systems, like the Scenery Management System. Research and past planning experience as described above supports the relationship between people's preferences for landscapes and the presence of certain biophysical features. If this relationship could be shown to occur in patterns, and extended to ecological classification units like landtype associations, then landscape architects and recreation planners could link their planning systems with ecological classification systems to provide a common foundation and language for resource planning.

Forest Plan revision efforts for the Chippewa National Forest adopted landtype associations as planning units for new management prescriptions. Landscape architects involved in the project decided to inventory, analyze, and set draft visual management goals for the forest using landtype associations as the planning unit to improve consistency and integration with other resources. After completing the inventory stage of the process, they wanted to "test" whether or not they might be "on the right track," in terms of whether or not people show a preference for landscape scale areas on the Chippewa Forest. The following statistical analysis of dispersed campsite locations by landtype associations was conducted to determine whether or not a pattern existed in campsite locations (indicating a preference of some landtype associations over others) or if people preferred all landtype associations equally for dispersed camping.

Methods And Materials

Why Use Dispersed Campsite Locations?

USDA Forest Service camping regulations allow "free choice" camping outside designated, developed campgrounds. People may choose where they would like to camp, within specified distances from roads, trails, rivers and lakes, unless the management prescription for an area (e.g. a Research Natural Area) specifically prohibits camping. This activity is called "dispersed camping." Forest Service personnel monitor where people choose to camp, and sometimes, like on the Chippewa Forest, they will note the locations where repeated use occurs. Since the general public, or at least those that engage in dispersed camping, choose where they want to camp based on their own likes and dislikes, the locations of the dispersed campsites give some indication of environmental preference. As managers, Forest Service personnel do not know whether or not the choice is based on visual, access (closeness to road, etc.), activity association, or some other factor; however, the locations, and any *patterns* in the locations, do give some indication of the landscapes in which people like to camp.

Gathering Data and Setting Up the Test

The boundaries of the Chippewa Forest landtype associations (LTA's) were established prior to the dispersed campsite test by a team of ecologists, soil scientists, and other personnel in cooperation with scientists from other agencies and forests. 405 dispersed campsites were located on the Chippewa National Forest using a global positioning system. Two of the dispersed campsites occurred next to Leech Lake and fell within the Leech Lake LTA. Given the extreme size of Leech Lake, (87,644 acres) and that the lake comprises almost the entire landtype association, the Leech Lake LTA (and the two dispersed campsites) were excluded from further analysis. The Cass Lake (15,900 acres) and Lake Winnibigoshish (56,764 acres) were also excluded from the test, again, due to the extreme sizes of the lakes and that the LTA boundaries followed the lakeshore boundaries and did not include dry land on which dispersed camping could occur.

Results

The Kolmogorov-Smirnov Goodness of Fit test was used to determine whether or not a pattern existed in dispersed campsite locations. H_0, the null hypothesis, was that people prefer all landtype associations equally; the number of dispersed campsites within a LTA related to the percent area of the forest the LTA comprised. For example, if a LTA comprised fifty percent of the forest area under consideration, then fifty percent of the dispersed campsites were found within the LTA. H_1, the suggested alternative hypothesis, was that the number of dispersed campsites within an LTA did not relate to the proportional area of the Forest an LTA comprises and people do not prefer all ecosystems equally for dispersed camping. Table 1 shows the data used in the test and Table 2 indicates the results of the test.

The largest value in /Sx-Fx/ (16.72) is greater than T.95 (7.2) and therefore H_0 is rejected (Table 2); people do not prefer all landtype associations equally for dispersed camping and some sort of pattern exists in the locations. The bar graph in Figure 1 illustrates the differences between the actual and expected number of dispersed campsites. The Bemidji sand Plain shows the greatest difference between expected and actual numbers of dispersed campsites. The Marcell Moraine shows the next highest difference between expected and actual numbers with *more* than the expected number of dispersed campsites. The Black Duck Till Plain and Bena Dunes and Peatlands also have high differences with *less* than expected numbers of dispersed campsites. The Itasca and Sugar Hills moraines have slightly more than the expected number of sites while the other Till Plains (Hill City and Guthrie) have slightly less than expected.

Table 1.—Data for Kolmogorov-Smirnov Goodness of Fit Test for Dispersed Campsite Locations on the Chippewa National Forest by Landtype Association

H_0: People prefer all ecosystems equally; the number of dispersed camping sites relates to the percent area of a forest an LTA comprises.

H_1: People do not prefer all ecosystems equally; the number of dispersed sites does not relate to the area of a forest and LTA comprises.

LTA	Acres	% Land Base	Dispersed Sites	Expected % (FX)	Sample % (SX)	/Sx-Fx/
Agassiz Lake Plain	75,295	5.24%	1	0.25	5.24	4.99
Bena Dunes/Peatland	200,413	13.95%	9	2.47	19.19	16.72
Bemidji Sand Plain	93,009	6.47%	102	27.65	25.66	-1.99
Black Duck Till Plain	283,018	19.70%	36	36.54	45.36	8.81
Deer River Peatland	57,660	4.01%	0	36.54	49.37	12.83
Guthrie Till Plain	72,874	5.07%	17	40.74	54.44	13.70
Hill City Till Plain	47,892	3.33%	4	41.73	57.77	16.05
Itasca Morain	186,142	12.95%	59	56.30	70.73	14.43
Marcell Morain	142,450	9.91%	110	83.46	80.64	-2.81
Rosie Lake Plain	227,368	15.82%	49	95.56	96.47	0.91
Sugar Hills Morain	50,776	3.53%	18	100.00	100.00	0.00
Total	1,436,897		405			

TO = 16.72 > T95 = 7.2
Reject Hï

Table 2.—Actual versus expected numbers of dispersed campsites on the Chippewa National Forest by landtype association

Landtype Association	Expected No. of Campsites	Actual No. of Campsites	Difference
Agassiz Lake Plain	0.05240111	0.002469136	-0.049931976
Bena Dunes/Peatland	0.13947625	0.022222222	-0.117254024
Bemidji Sand Plain	0.06472907	0.251851852	0.187122786
Black Duck Till Plain	0.19696471	0.088888889	-0.108075820
Deer River Peatland	0.04012814	0	-0.040128137
Guthrie Till Plain	0.05071623	0.041975309	-0.008740922
Hill City Till Plain	0.03333016	0.009876543	-0.023453612
Itasca Morain	0.12954443	0.145679012	0.016134584
Marcell Morain	0.09913724	0.271604938	0.172467700
Rosie Lake Plain	0.15823542	0.120987654	-0.037247765
Sugar Hills Moraine	0.03533726	0.044444444	0.009107186

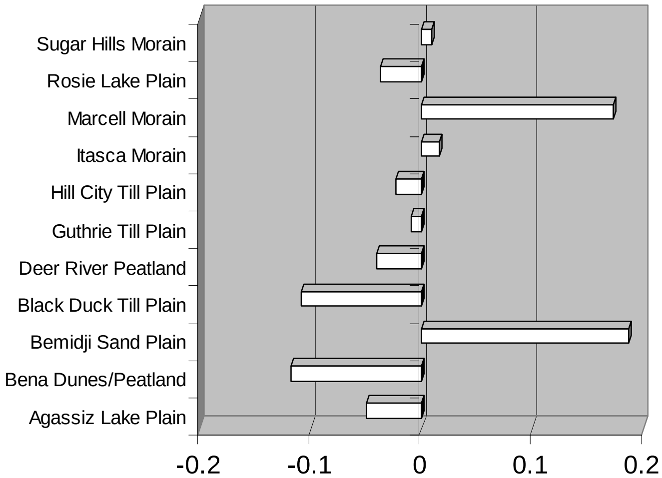

Figure 1.—Difference among expected versus actual dispersed campsite locations on the Chippewa National Forest by landtype association.

Far less than the expected number of campsites also occur within the Deer River Peatland and Agassiz Lake Plain.

Discussion

The patterns in dispersed campsite locations, and the characteristics of the associated LTA's, are generally consistent with what could be expected based on results from existing research in visual preference and perception. The landtype associations with more than the expected number of dispersed campsites have characteristic hydrologic patterns and vegetation that people typically rate highly in visual preference and perception studies. LTA's with both rolling and nearly level terrain have more than the expected number of campsites, which mirrors the mixed results for topographic preference in several studies. And, while some studies that indicate preference for characteristic community structure and disturbance patterns do exist, Forest Service management techniques, such as harvesting timber and wildfire prevention, make connections between the study results and existing research problematic. Ultimately, however, the results of the dispersed campsite analysis generally support the use of landtype associations as a planning unit for scenery management and encourage the use of multiple scales of ecological classification units in land management planning for both the natural and social environment.

Hydrologic Features

The results of the dispersed campsite location analysis on the Chippewa National Forest indicate that the single largest determinant in campsite locations may be the "recreation quality," quantity, and distribution of hydrologic features. Kaplan and Kaplan (1989) state that, from their experience with visual perception research, the presence of water so greatly influences visual preference and perception studies, that images with hydrologic features are not used unless the study focuses specifically on water bodies. People show such an overwhelming desire to look at, and possibly be near, water, that the use of images with hydrologic features skews research results unless *all* the images in the study include water features. The results of the dispersed campsite study support the Kaplan's assertion given that the campsite distances from hydrologic features range between 4 meters to 20 meters.

In addition, the results of the dispersed campsite study, and the patterns in campsite locations, also support existing research on the types of hydrologic features people prefer. Thomas Herzog found that people most preferred hydrologic features in mountainous settings followed by large lakes, rivers and then swamps (in Kaplan and Kaplan, 1989). John Ellsworth and William Hammit looked at differences in preference for rivers, marshes, and bogs, and found that images of open water bodies with clear, reflective surfaces rated highly (in Kaplan and Kaplan, 1989). Characteristic hydrologic features occur in patterns and vary between landtype associations on the Chippewa Forest. For example, very large, clear lakes that are distributed widely across the landscape are more common in the end moraine, sand plain, and till plain landtype associations. Sand plains also tend to have sandy beaches and lake bottoms that people could find more favorable for swimming and sun bathing. Sport fisheries for walleye and other species are also best in these lakes. Lakes occur less frequently in peatlands and lake plains and are more likely to have "encroaching" wetland vegetation surrounding the perimeter and mucky bottoms. These characteristics could discourage swimming, sun bathing, and other recreation activities along the lakeshore.

Generally, those LTA's with more than the expected number of campsites (Bemidji Sand Plain and Marcell Moraine) contain hydrologic features that provide great fishing and shoreline recreation opportunities. Those LTA's with less than the expected number of campsites, like the Black Duck Till Plain and Bena Dunes and Peatlands, have relatively fewer lakes, lakes with less favorable fishing opportunities, and larger scale wetlands and forested wetlands. Dispersed campsites in these LTA's tend to occur along rivers.

Topographic and Geologic Features

The conclusions from studies in visual preference and perception of landforms appear somewhat variable. Brush (1981) found that people prefer more mountainous landscapes. In 1987, Herzog found that people prefer mountains, canyons, and desert rock formations equally (in Kaplan and Kaplan, 1989). The results of the dispersed campsite analysis also show preference for different terrain and geologic features. The Chippewa Forest is relatively flat. More than the expected number of dispersed campsites occurred in the more rolling terrain of the Marcell Moraine and the more level terrain of the Bemidji Sand Plain.

Characteristic Flora

Forest composition may affect preference ratings due to people's expectations for what should occur in the landscape (Yarrow, 1966 in Ribe 1989). Several studies indicate a higher preference for hardwood species over conifers (e.g. Ribe , 1989.) Klukas and Duncan (1967, cited in Ribe 1989) found that people in Minnesota prefer mature pines to a deciduous forest. During the development of the current Forest Land and Resource Management Plan for the Chippewa Forest, people voiced a concern for maintaining and promoting the "North Woods" character of the landscape. This character was defined, in part, by the presence of large white pine, red pine, and northern hardwood forests (USDA, 1986).

Overstory and ground flora composition also occurs in patterns between different landtype associations (LTA's). Red and white pine forests, with large diameter "character trees," characterize the Bemidji Sand Plain landtype association. Northern hardwoods forests are typical for the end moraine LTA's, such as the Marcell, Itasca, and Sugar Hills associations. In general, the results of the dispersed campsite study are consistent with existing research and public comments during the development of the current Forest Plan; those LTA's with more than the expected number of campsites have characteristic vegetation patterns that coincide with what people describe as the desired "North Woods" character for the landscape.

Community Structure

Community structure, in the following discussion refers to both the vertical structure of a forest and the age structure of the community. Several studies indicate that people prefer mature forests with large diameter trees (e.g. Brush 1979). Kaplan and Kaplan (1989) attribute the apparent dislike of younger forests to a "blocked" appearance. They assert that people like to feel as if they can negotiate freely throughout a space and the multitude of stems in a young stand appears restricting and possibly dangerous.

Timber management activities within the National Forest and cutover logging make correlations between the results of the dispersed campsite analysis and community structure somewhat problematic. Characteristically, without management by people, some forest communities may have a more "blocked" appearance than others. For example, jack pine trees tend to have relatively small diameter trunks and grow in dense "thickets" following catastrophic crown fires. In Michigan expansive outwash plains covered by primarily jack pine forests are classified as one landtype association (USDA, 1993). Cedar, tamarack, or other forested wetland areas on the Chippewa Forest currently have the dense or "visually impenetrable" appearance that people may not like due to logging practices early in the last century; these areas are not typically managed for timber currently, however they have not developed the "large tree character" people prefer. Forested wetlands are characteristic of several landtype associations that have less than the expected number of campsites, such as the Deer River Peatland and Rosy Lake Plain. Over time, the community structure of these landtype associations, and their appearance, may change.

Disturbance Patterns

Fire repression efforts and timber harvesting practices make any connections between dispersed campsite locations and characteristic disturbance patterns difficult. Regardless of the type of disturbance causing the event, the presence of downed woody debris negatively affects visual preference ratings (Ribe, 1989). People do not like the appearance of a burned landscape (e.g. Brush, 1979, and Ribe, 1989). However, studies also show that people like the appearance of some landscapes after ground cover recovery (USDA, 1994). Studies by Buhyoff and Leuschner (1978), Buyoff, Wellman, and Daniel (1982), and Buyoff, Leuscher, and Wellman, (1979) found that the visual results of insect infestations decreased visual preference.

The Bemidji Sand Plain, with more than the expected number of dispersed campsites, is a fire-dependent community, although large-scale, catastrophic crown fires may not be common. Currently wildfires are suppressed and the timber is managed for conifer saw logs (USDA, 1986). Many of the landtype associations with less than the expected number of campsites, like the Deer River Peatland and Agassiz Lake Plain, are primarily forested and open wetlands that could experience flooding, insect infestations, windthrow, and possibly some fires. These areas are typically not managed for timber production due to their wetland character.

Conclusion

The landtype associations on the Chippewa National Forest with more than the expected number of dispersed campsites (end moraines and sand plains) have characteristic hydrologic and vegetation patterns that typically rate highly in visual preference and perception studies. Those landtype associations with less than the expected number of dispersed sites are characterized by large-scale wetlands and relatively few lakes. Systems like the Forest Service Scenery Management System use similar criteria to evaluate landscapes as those used in ecological classification systems (ECS). Human uses occur in patterns, such as dispersed campsite locations, that relate to ecological boundaries like landtype associations. Ecological classification can be used to inventory, analyze, and manage social environment factors and provide a "link" between humans and other species.

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Land Type Association Applications on the White Mountain National Forest

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Abstract

Four Land Type Associations along a steep elevation gradient have been used since the early 1980's. Applications include support for delineation of Bicknell Thrush and Canada Lynx habitat, identification of commercial forest zones for land use planning, support for visual quality mapping, and identification of softwood forest community potential in major valleys. Successful use depends on easily observed land units, and being the only or best way to address a land management problem.

Introduction

The successful use of land type associations (LTA's) for land use planning or other purposes depends on at least two factors: 1—They must be observable, discernable features on the landscape easily recognized by a variety of users and; 2—They must either be the best or only way to resolve or address a land management issue. The reason they must be observable without depending on subtle or detailed technical distinctions is to overcome the inertia of relying on other potentially less suitable approaches because they are more familiar. The reason they must be the only or best approach is because it strengthens the usefulness of the method. An inability to meet these criteria leads to an intermediate level of land classification that may not be used.

The White Mountain National Forest has had LTA's since the early 1980's. There are four—Mountaintop, Upper Mountain Slope, Mountain Slope, and Valley. Each one is based on a unique set of ecological land types, so it is a completely "nested" system. All lie within the White Mountain Subsection. This subsection distinguishes itself from nearby subsections by its generally higher elevations and steep environmental gradients. The land type associations generally follow changes in elevation. The Mountaintop LTA lies generally above 3,000 feet, and includes low growing balsam fir forest on shallow till soil resulting from intense continental ice sheet scouring. The Upper Mountain LTA lies in the 2500-3000' zone characterized by moderately tall balsam fir, red spruce, and paper and heart-leaved birch on deep alpine ablation tills. The Mountain Slope LTA is the classic northern hardwood forest of sugar maple, beech and birches on deep, well-drained ablation till soil in the 1000-2500' elevation. The Valley LTA is a spruce, fir, hemlock and white pine forest on outwash sands, washed-till and slack water sediments at elevations generally beneath 1000'.

Applications

Use of LTA's includes long-term land use planning, and support to bolster the analysis of individual issues. Our experience is LTA's are not used for small, individual project purposes. Some examples of our applications are as follows. All include spatially referenced applications across the 800,000-acre White Mountain National Forest. The acreages represented by each LTA are as follows: Mountaintop: 200,000; Upper Mountain: 160,000; Mountain Slope: 270,000; and Valley: 160,000 acres.

Mountaintop Association

The Bicknell Thrush is a sensitive species that resides in alpine and sub-alpine communities at high elevation in New England. Its status has lead to interest in better definition of habitat throughout its range. On the White Mountain National Forest, alpine and sub-alpine communities have significant human use including hiking, camping and in some locations alpine ski areas. These human uses mean analyses must be conducted to estimate the effects on this species in accord with its conservation plan.

Initial estimates of habitat include the upper reaches of the Mountaintop LTA, especially where it intersects with the alpine zone. Since these lands are not routinely inventoried for vegetation for other purposes, the Land Type Association is a good mechanism for initial habitat identification. Since the time this need arose, a study including 250+ plots to listen for the thrush, and characterize habitat more definitively, has refined habitat estimates, and highlighted site specific conditions that provide more, or less, suitable habitat.

An alternative application is with respect to aesthetics and recreation. The visual management system in the U.S. Forest Service relies partly on something known as "variety class". Variety class relates to the occurrence of landform, vegetation form, water form and rock form. In essence, where there is more variety, there is greater scenic and recreation attraction. The Mountaintop LTA has a combination of ledges, water flowing over ledge and boulders, softwoods and paper birch, and distinct breaks in terrain—all combining to provide distinctive variety bolstering the recreation opportunity. In creating a forest-wide inventory of visual variety class, therefore, land type associations provided a useful mechanism to support this inventory need.

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Upper Mountain Slopes

Two examples are available to illustrate potential uses of this LTA. First, the Canada Lynx is a threatened species for which there is now a conservation plan. Similar to the Bicknell thrush, there is a need to identify its likely habitat. While there are a number of factors involved, one is the occurrence of softwood forest at high elevations where there were historic sightings. The Mountaintop and Upper Mountain Slope LTA's provide a good, first approximation of potential habitat. Clearly, there are other ways to make this identification, such as remote sensing, but given the timing of the need, and the benefits of field checking from the ecological land type inventory that support the land type associations, this was a useful way to define potential habitat. Timber inventory is infrequent at these elevations. In addition, disturbance patterns are an important feature of lynx habitat, especially the occurrence of 5-acre or greater areas of blow-down. Characterization of disturbance patterns by land type association revealed that blow-downs of this size are uncommon in this association.

Secondly, the distinction between commercial forestland, and non-commercial land, was made during the 1986 land management planning process. Land type association was the first step in doing this. The distinction is between the Mountain Slope and Upper Mountain LTA's. The steepness of slope in the Upper Mountain Association raises road-building costs about 25% greater than the Mountain Slope due to cut and fill slopes. The size and value of the timber is substantially less in the Upper Mountain, making road building even more of an issue. The steepness of the slope makes clear-cutting the only viable harvest method for rubber-tired skidder, but openings this size on these steep slopes at upper elevations are very visible and do not meet visual quality objectives. And finally, the remoteness from roads and other evidence of human use, plus the visual variety class, makes these lands highly suitable for dispersed recreation purposes. The Mountaintop and Upper Mountain Slope land type associations, therefore, are not part of the commercial forest base on this Forest. It is the Mountain Slope and Valley LTA's that initially comprise the commercial forest zone, though other factors ultimately affect these places, and not all of it is designated as commercial forest zone. Admittedly, this all seems like common sense, but the point is that the associations are a systematic way to reach this conclusion that can be displayed spatially across the whole National Forest.

Mountain Slopes

Quality northern hardwood timber production is one of the goals of the White Mountain National Forest. The Mountain Slope LTA defines the main boundary of this forest community. These are lands, in contrast to Mountaintop and Upper Mountain Slopes, where timber values are relatively high, and road costs are lower. From this perspective, this makes these lands suitable for commercial harvest purposes. In the continuing discussion about use of National Forest System lands, the LTA provides an ecological basis for delineation of this important forest community. Development of a forest-wide wildlife management strategy depends on knowing the distribution of major forest communities, and their succession patterns. This LTA is where much aspen and paper birch is grown to support wildlife needs, therefore, it helps to assess the possible distribution of these succession communities. And finally, as a sidelight, the ecological land types that underlie this LTA are the means used to separate those places within this LTA where even and uneven-age management is applied. Certain ecological land types may be managed for a lower Q-factor, meaning more, larger trees that contribute to timber values, and the creation of a "large tree" image in the visual management program.

Major Valleys

The major valleys are where the impacts of human activity on forest composition are most visible. A mosaic of forestry, agriculture, fire and human habitation has meant the original red spruce, balsam fir; eastern hemlock and white pine forest is heavily intermixed with red maple, aspen, paper and yellow birch. There is an interest in restoring some of the original softwood forest composition. One of the reasons is that even a few softwoods in a hardwood stand contributes significantly to songbird diversity, which in turn contributes to the overall biodiversity of the forest. It is estimated some thirty-five-songbird species are added to a hardwood forest when even a few softwood stems are included. A second reason is that it is generally believed that softwoods grown on softwood sites will produce larger, more productive trees of better quality. This is not only a factor in timber production, it also means that larger, better nesting sites are available, and that white pine may be better represented in the supra-canopy. The Valley land type association is a useful way to delineate the boundary of these softwood sites. While timber inventory is an alternative approach, especially where there is some softwood representation in the under-story, the fact remains that much inventory is done in the winter when the under-story is not visible, and in many instances there is little, or no, softwood represented.

Future Uses

The applications we have made so far are routine kinds of uses in land management planning. We have a couple possible ideas for future uses.

The White Mountain National Forest in cooperation with the U.S. Forest Service Northeast Research Station (Durham, NH) and The Nature Conservancy is starting to apply a computer generated landform analysis to its landscape. The goal is to apply a completely systematic approach to distinguishing different ecological conditions on the landscape. The Nature Conservancy model will be the approach. The outcome will be compared to an already spatially referenced ecological classification to "fine-tune" the computer approach. One reason to try this computer-generated approach is to permit a rapid ecological classification of similar nearby mountainous lands where it is presently absent. A second reason is to potentially derive a useful way to classify landscapes related to the nature and distribution of soil mineralogy, an important consideration on landscapes where soil acidification is an issue.

Another possible use also relates to acid deposition. Limited research is beginning to show some affiliation between landscape position and base cations such as calcium and magnesium. Calcium is a significant factor in the structure of a forest, and regulation of its growth. It also has been shown in places to be a precursor, along with other pre-disposing factors, in forecasting areas of forest health concern. In this sense, differences in forest canopy, soil and stream water calcium along an elevation gradient may prove to be important. At this point, red spruce at high elevations on shallow till soils already demonstrate some forest health concerns. This may mean that on a forest-wide basis, land type association may be one of the delineators of forest health risk, along with other considerations such as insect, disease, drought and land use.

Use of Landtype Associations as a Coarse Filter for Ranking Quality of Indiana Bat Habitat on the Monongahela National Forest, West Virginia

Thomas DeMeo[1]

Abstract

Landtype associations (LTAs) were used to rank Indiana bat (*Myotis sodalis*) habitat for landscapes of the Monongahela National Forest, West Virginia. A panel of expert biologists identified hibernacula, swarming habitat, maternity habitat, roosting habitat, and foraging habitat (in this order, from most to least important) as the elements related to life stages of concern in maintaining viable Indiana bat populations. LTAs were then ranked by their suitability for each of the habitat elements. Weighted by the relative value of the habitat element, rankings (scores) were quickly developed for each LTA. Results identified large areas of the Monongahela National Forest with little likelihood of use by Indiana bats. Dry oak forest was predicted as the most favorable forest type. Subsequent summer field investigations (1997-2000) led to the capture of only three Indiana bats among hundreds of other species Forest-wide. Results may mean Indiana bats are using summer habitat elsewhere, populations are so low they are evading detection, or that incorrect methods were used. The latter seems unlikely given the extensive nature of the sampling. In evaluating Indiana bat habitat, this coarse filter works well in directing surveys toward landscapes where they are most relevant, but should be coupled with fine-scale approaches in developing comprehensive management recommendations.

Introduction

The Indiana bat (*Myotis sodalis*) was listed by the US Fish and Wildlife Service as endangered in 1967. Populations have shown a 60 percent decline since the 1960s. More recent data show a population decline from about 500,000 bats in the early 1980s to 353,000 bats in the mid-1990s. Indiana bats are considered "exceptionally vulnerable to disturbance by humans and to local habitat changes" (NatureServe 2001).

Indiana bats occur in the central and part of the southern United States. They are virtually extirpated in the northeast US. The core area of the population occurs in Kentucky, Indiana, and Missouri. These three states account for a little less than 75 percent of the known population, and are the location for nine priority one hibernacula (those with more than 1,000 bats).

In the mid-1990s concerns for Indiana bats intensified in National Forests of the northeastern United States. One of these Forests was the Monongahela in West Virginia. Although nearby Hellhole Cave was an important hibernaculum, Indiana bat habitat and occurrence throughout the 906,000-acre national forest had not been surveyed. Because few Indiana bats have been documented on the Forest, populations here are probably peripheral to the species as a whole. An effective strategy for addressing potential impacts of timber, road, and other projects was needed.

Purpose And Objectives

The National Environmental Policy Act requires assessment of the impacts of proposed projects on federally-administered lands. Regarding wildlife species of concern, this often means field inspection of sites to determine species occurrence and habitat relationships.

Because field survey resources of time, funding, and personnel are increasing limited, more efficient sampling strategies are needed. Expensive, time-consuming inspections in areas with little likelihood of occurrence can divert resources from important habitats deserving of careful evaluation.

The purpose of this effort was therefore to provide a quick, defensible coarse filter method to rank the suitability of landscapes as Indiana bat habitat throughout the Monongahela, and predict where bats would be most likely to occur.

This strategy in no way reduces the importance of fine-scale surveys; rather, it should help direct the effort to areas of more important habitat and where management impacts are more likely to occur. Because little data on Indiana bat occurrence existed on the Monongahela, and because a landscape approach to the problem of identifying potential impacts was needed, a predictive model using an expert system was employed.

Study Area And Methods

Landtype associations were selected as a way to stratify the Monongahela landscape. Landtype associations are landscape scale units delineated by geomorphic process type, similar landforms, geology, soil subgroups, and potential natural vegetation series (Forman and Godron 1986, Bailey and Avers 1993, Cleland et al. 1997). The Monongahela is comprised of 26 landtype associations, but for ease of understanding and communication, these can be grouped within four broad vegetation

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zones: mixed mesophytic, northern hardwoods, red spruce, and dry oaks (DeMeo et al. 1995).

Mixed mesophytic forests are characterized by sugar maple, Acer saccharum, and red oak, Quercus rubra, typically at elevations below 900 m in the Allegheny Mountains (Core 1966). Northern hardwoods occur at higher elevations (900 to 1150 m), are generally less productive, and are characterized by American beech, Fagus grandifolia. Red spruce, Picea rubens, forest occurs at the highest elevations (1150 to 1240 m) and is characterized by cold soils and a relatively short growing season. Dry oaks, in contrast to the other three types, predominate in the eastern (Ridge and Valley) portion of the Monongahela, which has a markedly drier climate, thus limiting forest productivity. Vegetation there is characterized by white, Quercus alba, and chestnut oak, Quercus prinus, with scarlet, Quercus coccinea, and black oaks, Quercus velutina, on drier sites, and the "dry pines" (table mountain, Pinus pungens, pitch, Pinus rigida, and Virginia pine, Pinus virginiana) on the poorest sites (DeMeo 1999).

Methods feature an iterative process of successive refinement. This approximation can be thought of as a set of hypotheses to test and refine as our understanding improves.

A panel of experts were assembled at two meetings in November and December, 1997. Participants had a high level of experience in bat biology, with particular emphasis on the local area. (See Appendix for participants list.) The panel identified the following as key habitat needs of the Indiana bat at different stages of its life cycle: (1) hibernacula, (2) roosting habitat, (3) foraging habitat, (4) maternity habitat, (5) swarming habitat.

Using a scale of 1 to 5, with 5 representing the greatest value, we can rank these items as to relative importance to contributing to viable populations of Indiana bats on the Monongahela National Forest (Table 1). Following is a discussion of each habitat need and the rationale for the ranking assigned.

Table 1.—Preliminary ranking of habitat elements contributing to Indiana bat population viability, Monongahela National Forest, West Virginia.

Hibernacula	Rank
Habitat Element	5
Roosting habitat	2
Foraging habitat	1
Maternity habitat	3
Swarming habitat	4

Hibernacula

Winter survival is critical for bat population viability. Moreover, suitable caves for hibernacula are a relatively uncommon landscape feature, particularly since Indiana bats prefer a cave temperature range of 39-46 degrees F (Agency Draft Recovery Plan 1997). We rank this component highly, since there are known caves of value to Indiana bats within the Monongahela NF boundary (Stihler 1997).

Craig Stihler (pers. comm.) of the West Virginia Division of Natural Resources has ranked West Virginia hibernacula in four categories: Category I, 1000 or more Indiana bats; Category II, 100-1000 bats; Category III, 50-100 bats; Category IV, less than 50 bats. These ratings were used to develop the hibernaculum rating for each LTA in the model.

Roosting Habitat

In summer, Indiana bats roost in trees, mainly along streams (NatureServe 2001). Maternity habitat, where females raise young, is a type of roosting habitat, but important enough to be considered a separate habitat requirement. (See maternity habitat section that follows.)

Roosting habitat consists of snags and live trees with exfoliating bark, including hickory (*Carya*) species, some oak species, and older sugar maples. Tree structure, however, is probably more important than species per se (Agency Draft 1997). Ideal roosting habitat depends on four factors: (1) whether the tree is dead or alive (dead preferred); (2) the amount of loose bark; (3) the tree's exposure to the sun; and (4) the tree's location relative to other trees, water sources, and foraging areas (Agency Draft 1997). Tree cavities are sometimes used as well (Gardner et al. 1991, Kurta et al. 1993). Most of the Monongahela landscape has forests in the 60-90 year age class. Many areas include residual trees (notably chestnut oak and sugar maple) not cut during the 1880-1920 logging era. The panel perceived roosting habitat as important, but less limiting than hibernacula, maternity habitat, or swarming habitat. Roosting habitat is abundant on the Forest, with great abundance in the Ridge and Valley Section (because of oak and hickory abundance), and less consistent abundance in the Allegheny Mountains Section.

Foraging Habitat

Foraging habitat receives a lower rank still, because the bats appear to use a wide variety of habitats for foraging; i.e., they are habitat generalists. At this point in the model-building, our ability to differentiate foraging habitats on the Monongahela is poor. While our current understanding is that Indiana bats use both riparian and upland habitat, work done elsewhere stresses the value of riparian habitat (Agency Draft Recovery Plan 1997). Excellent foraging habitat has been identified as woody vegetation within 30m of a stream (Cope et al. 1978). Notably, streams and associated floodplain forest are prefered foraging habitat for pregnant and lactating bats (Agency Draft Recovery Plan 1997).

A couple of points must be made. One is that "riparian" in the above documents refers to relatively broad, low energy streams associated with sycamore and elm. This type of riparian zone is less characteristic of the Monongahela landscape than in the Midwest, where these findings were developed. The second important consideration is that in Midwestern landscapes there tends to be more contrast between riparian zones and the surrounding landscape. Riparian corridors there are often narrow wooded corridors along streams in a matrix of agricultural fields. This great contrast between riparian zones and the surrounding matrix may increase the value of riparian zones for bats (just as they appear to for songbirds). In the Monongahela landscape, with much less agriculture, there may be less contrast between riparian zones and the surrounding landscape, particularly with first and second order, high-energy streams.

In Kentucky and Virginia, male Indiana bats have been documented using upland oak-hickory forest (Kiser and Elliott 1996, Hobson and Holland 1995). From Missouri, there is some indication bats prefer a mix of riparian, upland, and pasture edge habitats (LaVal et al. 1976, LaVal and LaVal 1980). A mix of upland forest, old fields, and pastures was suggested by Clark et al. (1987) and Gardner et al. (1991). (In West Virginia, the state's largest Indiana bat hibernaculum (Hellhole Cave) occurs in such a landscape.) Research also suggests bats use forest roads as travel corridors (Hobson and Holland 1995).

In conclusion, because Indiana bats on the Monongahela are thought to use a wide range of habitats for foraging, we perceive this part of the life cycle as least limiting to their viability, and give it the lowest rank (1). For now, we will rank LTAs featuring broad riparian corridors as slightly greater in value as foraging habitat.

Maternity Habitat

Maternity habitat, where females raise the young either singly or in colonies, can be considered a special case of roosting habitat. As with roosting habitat in general, live and dead trees with exfoliating bark are preferred. Clawson (1996), working in Missouri, found a significant correlation of large-diameter (greater than 30.1 cm) trees with maternity colonies. Large trees are apparently important as roosting sites during the maternity period.

With maternity habitat, however, there appears to be an additional emphasis on trees receiving direct sunlight (Callahan et al. 1997, NatureServe 2001). Warmer (southern and western) aspects also are preferred, because cool temperatures can delay development of fetal and juvenile young (Racey 1982).

While Indiana bats are adaptable, maintaining a variety of roost sites from year to year is important (Kurta et al. 1993, Callahan et al. 1997), since the bats' maternity colonies show site fidelity (Humphrey et al. 1977, Clark et al. 1987, Gardner et al. 1991).

Maternity habitat is associated with riparian floodplains (Humphrey et al. 1977), although recent research in Illinois indicates female Indiana bats may be using uplands for maternity colonies much more than previously thought. Of 51 trees used for maternity, Garner and Gardner (1992) found 38 were on upland sites.

The panel ranked maternity habitat next in importance after hibernacula and swarming areas. Clearly, ability to reproduce successfully is critical to species viability. Consideration of maternity habitat in West Virginia presents special challenges, however. A study by Stihler (1996) on the Fernow Experimental Forest, Monongahela NF, documented 69 Indiana bats, of which only 5 were females. Moreover, the females were captured late in the season, suggesting no maternity colonies occurred in the area.

No maternity colonies have been documented in West Virginia, and while they may occur on the Monongahela, it is equally plausible the bats are not using this area for maternity colonies at all. Until our understanding is refined, this item is ranked relatively high, in consideration of the importance of maternity colonies for species viability across its range.

Swarming Habitat

These are staging areas surrounding hibernacula, where bats feed and mate prior to hibernation (Cope and Humphrey 1977). The swarming period is important, since bats need to replenish fat supplies prior to hibernation. Maintaining adequate habitat buffers around Indiana bat hibernacula is therefore a component of good bat management. The panel gave this a high rank, not as important as hibernacula, but clearly more important than roosting or foraging habitat. The appropriate radius around hibernacula for staging areas is uncertain; reported distances range from 2.66 to 3.5 miles (Stihler 1996, Worthington 1998). For now, a distance of 3.5 miles is assumed, based on Stihler's telemetry work at Big Springs Cave, near Parsons, WV (Stihler 1996). While this study involved only four Indiana bats, it is the only fall swarming data available for the Monongahela National Forest. This estimate will be revised as new data become available. As with maternity habitat, roosting trees are important (Agency Draft 1997). Swarming areas are therefore ranked highly (4), because of their association with hibernacula.

Value of Landtype Associations as Habitat

The Monongahela has been delineated into 26 landtype associations (LTAs) based on physiography, climate, and vegetation (DeMeo et al. 1995). Table 2 contains a ranking of the LTAs as to their value to provide habitat for each of the five life-cycle components. Each also contains a brief justification for the ranking. Note cave rankings are those provided by Stihler (pers. com.) (See preceding "Hibernacula" section.)

Calculation of Habitat Scores

If we now weight (multiply) each of the above scores for each LTA by the importance values described at the beginning of the document, we can obtain a ranking of the estimated relative value of each LTA as Indiana bat habitat. For example, consider LTA Aa01 (North Fork Mountain/River Knobs):

Habitat Element	LTA Element Ranking		Ranking	Score
Hibernacula	3	*	5	15
Roosting	5	*	2	10
Foraging	3	*	1	3
Maternity	4	*	3	12
Swarming	3	*	4	12
Overall Rating (Sum)				52

In this way, the ratings for the LTAs emerge as follows:

LTA	Rating	LTA	Rating
Aa01	52	Bc01	22
Aa03	69	Bc02	3
Aa04	21	Bc03	49
Aa06	70		
Ba01	3	Bd01	39
Ba02	41	Bd02	38
Ba03	44	Bd03	29
Ba04	30		
Ba05	24		
Ba06	28		
Ba07	4		
Ba08	3		
Ba09	15		
Ba10	47		
Ba11	46		
Ba12	4		
Ba13	30		
Ba14	42		
Ba15	29		

Revision of Maternity Habitat Scores

At a review of the model by an interdisciplinary group in December 1997, the suggestion was made to consider how air temperature would affect female Indiana bat dispersal from caves to summer maternity sites. Craig Stihler (pers. com.) suggested that evening temperatures in April and May would be the most useful in ranking areas, with warmer areas presumably better habitat. In Missouri, for example, a higher density of maternity colonies were found in areas exposed to direct sunlight (Callahan et al. 1997).

Accordingly, National Oceanic and Atmospheric Association (NOAA) weather data for 1986-1997 was used to generate the average minimum temperatures for April and May. Data from 18 weather stations on or near the Monongahela National Forest were employed. These data were used to rank landtype associations (LTAs) by evening temperatures. Although weather stations are not always at locations representative of larger areas, we feel the approach is valid, since our goal is to rank LTAs by temperature, not determine precise estimates for each LTA.

The range of average minimum temperatures for April-May was 34.8 to 42.9 degrees F. The maternity habitat suitability scores were adjusted as follows: LTAs with average minimum temps within the first third (34.8 to 37.5 degrees F) were decreased by one, since these temperatures were the coldest in the 8.1 degree range from 34.8 to 42.9 degrees F. (For example, LTA Ba02 assigned average temperature was 37.0 degrees F, so its maternity habitat score was reduced from two to one.)

Maternity habitat scores for LTAs with temperatures in the high range (40.2 to 42.9 degrees F) were increased by one, and those in the mid-range (37.5 to 40.2 degrees) were not changed. Scores were not decreased below 0 or increased beyond 5, the original limits of the scores.

To our knowledge, research thus far has not addressed the question of critical temperature thresholds for Indiana bat dispersal and maternity sites. As this information becomes available, we will use it to refine the model. Revised total scores for LTAs, reflecting changes in maternity habitat scores, are as follows:

LTA	Rating	LTA	Rating
Aa01	55	Ba12	4
Aa03	69	Ba13	33
Aa04	24	Ba14	45
Aa06	73	Ba15	29
Ba01	3	Bc01	25
Ba02	41	Bc02	3
Ba03	41	Bc03	26
Ba04	27		
Ba05	24		
Ba06	25	Bd01	33
Ba07	4	Bd02	38
Ba08	3	Bd03	29
Ba09	12	Ba11	43
Ba10	50		

Table 2.—Landtype Association (LTA) ranking based on habitat values for each of the five life-cycle components of the Indiana bat, Monongahela National Forest, West Virginia.

M221A Northern Ridge and Valley Section		
M221Aa Northern Ridge and Valley Subsection		
Aa01 North Fork Mountain/River Knobs LTA		
Hibernacula	3	Some limestone formations, but relatively few
Roosting	5	Abundant hickories
Foraging	3	A general ranking, since foraging habitat not presently well-differentiated
Maternity	4	Dry oaks, adjacent pastures.
Swarming	3	Parallels ranking for hibernacula
Aa03 Germany Valley LTA		
Hibernacula	5	Hell Hole cave, the only hibernaculum designated critical habitat for Indiana bats in West Virginia, falls within this LTA. The only category I cave on the Mon.
Roosting	3	This LTA mostly pastures.
Foraging	3	
Maternity	5	Mix of pastures and dry oak forest.
Swarming	5	Parallels ranking for hibernacula.
Aa04 Potomac Riparian LTA		
Hibernacula	0	Unlikely in riparian zone.
Roosting	4	Sycamores and elms.
Foraging	4	Riparian LTAs ranked slightly higher as foraging areas.
Maternity	3	Some pastures and hickories, including snags.
Swarming	0	
Aa06 Cave Mountain LTA		
Hibernacula	5	Two known hibernacula (albeit not on NF) that were historically category I.
Roosting	5	Abundant hickories, chestnut oak.
Foraging	3	
Maternity	4	Good woodland/pasture mix.
Swarming	5	Not as good as Germany Valley.
M221B Allegheny Mountains Section		
M221Ba Northern High Allegheny Subsection		
Ba01 Cheat-Shavers-Back Allegheny Mountain System, Frigid Soils LTA		
Hibernacula	0	High elevation, no limestone.
Roosting	1	Virtually no oaks/hickories.
Foraging	1	Cool microclimate.
Maternity	0	Cool microclimate.
Swarming	0	
Ba02 Cheat Mountain Slopes LTA		
Hibernacula	4	Two known Cat. III caves; one known Cat. IV.
Roosting	2	May have scattered snags and sugar maple.
Foraging	3	Presumed average value.
Maternity	2	Moderately high elevation (3000-3800 ft)
Swarming	2	
Ba03 Upper Tygart Valley LTA		
Hibernacula	3	One known Cat. III cave.
Roosting	3	Fair amount hickory.
Foraging	3	Average value.
Maternity	4	Lower elevation, pasture mix.
Swarming	2	
Ba04 Tygart Valley River Riparian LTA		
Hibernacula	1	Hibernacula unlikely; no limestone.
Roosting	4	Sycamores/elms.
Foraging	4	Riparian areas ranked slightly higher.
Maternity	3	Woodland/pasture mix; thermal cover may be lacking.

Continued

Table 2—continued

Swarming	1	
Ba05 Middle Mountain System LTA		
Hibernacula	1	Hibernacula unlikely; non-limestone.
Roosting	3	Lower slopes will have oak/hickory, but mostly northern hardwoods.
Foraging	3	
Maternity	2	Mostly moderately high elevations.
Swarming	1	
Ba06 Spruce Knob System LTA		
Hibernacula	2	Hibernacula possible in small pockets.
Roosting	2	Hickory limited, mostly northern hardwoods.
Foraging	3	Few non-forested areas.
Maternity	1	Higher elevations.
Swarming	2	
Ba07 Dolly Sods LTA		
Hibernacula	0	High elevation, no limestone.
Roosting	1	Practically no hickory, few large snags.
Foraging	2	Colder climate, lack of large trees.
Maternity	0	Cold climate, lack of thermal cover.
Swarming	0	
Ba08 Allegheny Plateau Block Red Spruce-Frigid Soils LTA		
Hibernacula	0	High elevation, no limestone.
Roosting	1	Virtually no hickories.
Foraging	1	Cool microclimate.
Maternity	0	Cool microclimate.
Swarming	0	
Ba09 Burner Mountain-Laurel Fork VA System LTA		
Hibernacula	0	Lack of limestone.
Roosting	3	Some hickory at low elevation elevation.
Foraging	3	Few non-forested areas.
Maternity	2	Some areas in this LTA are at low elevation.
Swarming	0	
Ba10 Allegheny Sideslopes LTA		
Hibernacula	4	Two known cat. II caves, one cat. IV.
Roosting	3	Some hickories.
Foraging	3	
Maternity	2	Some low elevation sites.
Swarming	3	
Ba11 Northern Allegheny Mountain LTA		
Hibernacula	4	Limestone in Sinks of Gandy area.
Roosting	2	Mostly northern hardwoods.
Foraging	3	Some large pasture areas.
Maternity	1	Higher elevations.
Swarming	4	
Ba12 Canaan Valley LTA		
Hibernacula	0	High elevation, no limestone.
Roosting	1	Practically no hickory, many areas open.
Foraging	2	Colder climate, lack of trees.
Maternity	0	Cold climate, lack of cover.
Swarming	0	
Ba13 Cheat River LTA		
Hibernacula	1	Hibernacula unlikely; no limestone.
Roosting	4	Sycamores/elms.
Foraging	4	Riparian areas ranked slightly higher.
Maternity	3	Woodland/farmland mix; cover lacking.
Swarming	1	

Continued

Table 2—continued

	Ba14 Cheat River Hills LTA		
	Hibernacula	3	Possible in limestone adjacent to Mauch Chunk layer.
	Roosting	3	Hickories moderately abundant.
	Foraging	3	
	Maternity	2	Moderately high elevations.
	Swarming	3	
	Ba15 Allegheny Front Foothills LTA		
	Hibernacula	1	Lack of limestone.
	Roosting	4	Oak/hickory well-represented.
	Foraging	3	
	Maternity	3	Climate more like ridge and valley.
	Swarming	1	
M221Bc Southern High Allegheny Subsection			
	Bc01 Allegheny Plateau LTA		
	Hibernacula	1	Lack of limestone.
	Roosting	2	Mostly northern hardwoods.
	Foraging	3	
	Maternity	2	Moderately high to high elevations.
	Swarming	1	
	Bc02 Allegheny Plateau Red Spruce-Frigid Soils LTA		
	Hibernacula	0	High elevation, no limestone.
	Roosting	1	Virtually no hickory.
	Foraging	1	Cool climate.
	Maternity	0	Cool climate.
	Swarming	0	
	Bc03 Cloverlick System LTA		
	Hibernacula	3	One known Cat. III and one Cat. IV cave.
	Roosting	3	Oak-hickory fairly abundant.
	Foraging	3	
	Maternity	3	Some low elevation sites, good farmland mix.
	Swarming	4	
M221Bd Eastern Allegheny Mountain and Valley Subsection			
	Bd01 Allegheny Mountain System LTA		
	Hibernacula	1	Limestone lacking.
	Roosting	3	Oak-hickory fairly abundant.
	Foraging	3	
	Maternity	3	Some low elevation sites, good farmland mix.
	Swarming	4	
	Bd02 Beaverlick-Brushy System LTA		
	Hibernacula	2	Some limestone, although tends to be more like chert or mixed with shales (not conducive to cave formation).
	Roosting	4	Oak-hickory well-represented.
	Foraging	3	
	Maternity	3	Lower elevation sites, some farmland mix.
	Swarming	2	
	Bd03 Slabcamp-Little Mountain System LTA		
	Hibernacula	1	Limestone lacking.
	Roosting	4	Oak-hickory well-represented
	Foraging	3	
	Maternity	3	Lower elevation sites, some farmland mix.
	Swarming	1	

Table 3.—Summary of bat mist net capture, summer 1997, Monongahela National Forest, West Virginia.

Area	LTA	No. Net Locations	No. Bats	Indiana Bats	LTA Model Score*
Location	Ba14	11	37	0	42/18*
Lockridge	Bd01	10	106	0	39/15
Indian Run	Ba14	12	44	0	42/18
Burner Settlement	Ba09	12	12	0	5/12
Lower Glady	Ba10	11	27	0	47/18
Big Ditch	Bc01	11	35	0	22/16
Cabot Gas	Ba09	3	1	0	15/12

*Total model/Summer model scores

Summer Habitat Suitability

Another suggestion from the December 1997 meeting was to evaluate summer habitat only, since maternity sites appear to be selected independent of hibernacula locations. In this approach we therefore use only the roosting, foraging, and maternity components of the model (omit hibernacula and swarming scores). This approach is thought to illustrate the summer habitat potential— the period when most management activities, such as logging, occur.If this approach is taken, the ratings become:

LTA	Rating	LTA	Rating
Aa01	28	Ba12	4
Aa03	24	Ba13	24
Aa04	24	Ba14	18
Aa06	28	Ba15	23
Ba01	3	Bc01	16
Ba02	10	Bc02	3
Ba03	21	Bc03	15
Ba04	21		
Ba05	12		
Ba06	7	Bd01	15
Ba07	4	Bd02	20
Ba08	3	Bd03	20
Ba09	12		
Ba10	18		
Ba11	7		

Use of Ratings

From this it can be seen that the highest ratings are in the Ridge and Valley. This agrees with the map exercise of the November meeting. These ratings can be used to prioritize where field surveys or fine-scale data collection occur, with the caveats 1) that field verification of the model will be necessary, and that 2) the model is subject to revision over time as our understanding improves. Guidelines can be developed to indicate the appropriate level of field sampling effort. The guidelines can be considered hypotheses, to be tested with field data and other information as it becomes available. Following is a suggested set of possible guidelines.

Year-Long Habitat Model (Includes hibernacula, maternity, roosting, foraging, and swarming habitat):

Rating	Surveying Recommendation
< 10	No consideration necessary.
10-40	Conduct similar analysis at landtype (LT) scale for each project EA. Field work may or may not be necessary.
41-50	LT scale analysis, mist-netting.
>50	LT scale analysis, mist-netting, mitigation measures.

Summer Habitat Model (Includes roosting, foraging, and maternity habitat only):

Rating	Surveying Recommendation
< 10	No consideration necessary.
10-20	Conduct similar analysis at landtype (LT) scale for each project EA. Field work may or may not be necessary.
21-25	LT scale analysis, mist-netting.
>25	LT scale analysis, mist-netting, mitigation measures.

At this time one model is not recommended over another, but provided fall/winter sites were well-protected, it seems reasonable to use the summer model. As additional field data are obtained and analyzed, the above would be revised in an iterative process (as well as used to refine the model itself).

Model Validation

Clearly, field data are needed to validate this model, so that it can be revised as our understanding of Indiana bat habitat improves. Bat mist net data collected on the Monongahela during summer 1997 are summarized in Table 3.

Although 275 bats were captured during the summer, none were Indiana bats. This suggests the Monongahela National Forest may be providing suitable habitat that is not being used. Extensive subsequent sampling in 1998-2000 revealed only two adult Indiana bat males and one juvenile Indiana bat on or near the Monongahela National Forest (USDA Forest Service 2000).

Perhaps the largest problem in sampling Indiana bats is that Indiana bats are highly mobile and migratory (USDA Forest Service 2000). Another consideration is that mist netting as a method may not be adequate to locate Indiana bats, although it appears to be the best current method available. Another possibility is that the bats are using habitats other than the mixed mesophytic and xeric oak sites evaluated above. To test this hypothesis, bat sampling on northern hardwood sites is recommended. Further evaluation of other mixed mesophytic and dry oak sites also is recommended. Finally, other methods of identifying bats, such as identifying their calls with electronic equipment, are being pursued.

Conclusion

Effective modeling of Indiana bat habitat will require both coarse filter and fine filter strategies. Methods outlined in this paper are intended to prioritize surveys and refine our understanding of Indiana bat habitat. The model was effective in identifying much of the Monongahela National Forest as habitat of little value for Indiana bats. Removing the need to field sample these areas saves considerable resources to survey areas of more valuable bat habitat. To this end, coupling this work with a fine-scale bat modeling process, such as the Romme model (Romme et al. 1995) or Gardner's model (Gardner et al. 1991), is the logical next step in refining this work and making it more effective.

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Land Type Associations of Weber County, Utah

DeVon Nelson[1] and Jeff Bruggink[2]

Abstract

A land type association inventory was made primarily to support county planning and as an example of ecological land classification to planners and others who could benefit from information gathered by this approach. The inventory was made by visually delineating, describing and interpreting 13 land type associations on satellite imagery using personal knowledge and field observations supplemented by existing resource reports. The inventory proved to have limited application to the present, residential level of planning in the county but has considerable promise as the bridge between the current widespread use of land classification on National Forest lands and its possible use on lands of other jurisdictions.

The County

Weber County is one of five counties which make up the Wasatch Front in northern Utah. Eighty percent of the people in the state live in this 90 by 20 mile strip at the foot of the Wasatch Mountain Range along the east sides of the Great Salt Lake and Utah Lake. Of the 29 counties in the state, Weber ranks 27th in size at 371,840 acres and fourth in population with about 193,000 people. The population grew 14 percent between 1990 and 1997, the source of the growing development pressure on the land. Ogden, the county seat with a population of 77,226 people, is the largest of 20 communities in the county (US Census Bureau 2000). Like most of Utah, Weber County is highly urbanized with 95 percent of the people living in towns of over 2,500. Manufacturing is the largest single category of employment (electronics, medical equipment, airbags, armored cars), but Hill Air Force Base in adjacent Davis County is the single largest employer. Natural resource-related work such as mining, logging and farming produce less than 3 percent of the county's income. Seventy-seven percent of the land in the county is privately owned (Weber County Public Land Advisory Council 1997). This contrasts with the statewide ownership pattern where federal land ownership is 68 percent.

Archaeologists have found signs of early hunter-gatherers in the marshes and along the stream channels on the eastern shore of the Great Salt Lake dating back nearly 10,000 years (Madsen, 1980). There is evidence that Western Shoshoni people raised crops, fished the streams, and hunted antelope, deer and buffalo in what is now the western part of the county from about 1300 until the early 1800s when trappers reached the area. The first European to see the Great Salt Lake is thought to have been Jim Bridger, one of William Henry Astor's trappers, in 1824. In 1846, one of the last of the mountain men, Miles Goodyear, chose a spot on the Weber River near present day Ogden to build a fort for trading and supplying immigrants. A year later, he sold his interests in the Weber County area to the Mormons who had arrived in the Salt Lake Valley about 40 miles to the south of his fort in 1847. With the arrival of the Mormons, settlement began in earnest. Irrigation systems for farming were constructed; towns were established; an infrastructure of roads, canals, schools, etc. were established (Sandier and Roberts 1997). The arrival of the railroad in 1869 brought a major outside influence to the county. Ogden became the main railroad center for the intermountain west, contributing to its industrial growth. The Defense Department made large investments in the Weber County area in the 1930s and 1940s. Ogden lost its status as a major railroad center in the 1980s but other forms of business and industry keep the area growing (Miller 1980).

Planning in the County

The grid pattern of city layout was brought here from the midwest by the pioneers. Planning to reduce conflicts between kinds of development began county-wide in the 1940s. In the 1960s and 1970s, the county and cities worked together on federal grants to prepare comprehensive/master plans to guide orderly development, efficient public services and architectural continuity. Ogden and Roy, the second largest city in the county, established planning units of their own in the late 1970s, giving the county responsibility to support the smaller towns and unincorporated parts of the county. In the 1990s, the county worked with people in Ogden Valley on a plan to help them retain the character of the area and the water quality. Studies of water quality and road access to the valley led to a minimum three acre lot size. The county planning unit is now beginning a project in the western part of the county. Need for housing, a proposed inter-county highway, an outdated general plan and a shortage of sewage treatment facilities in the western part of the county prompted the current planning effort (Barker 2001). The expected output is a general growth plan which will capture the residents' vision of a desired future and the goals, policies and ordinances which will lead to that vision. Waste water treatment is a major concern because of the shallow water table in much of the western part of the county and the nearly overloaded treatment system in that area (Grier 2001).

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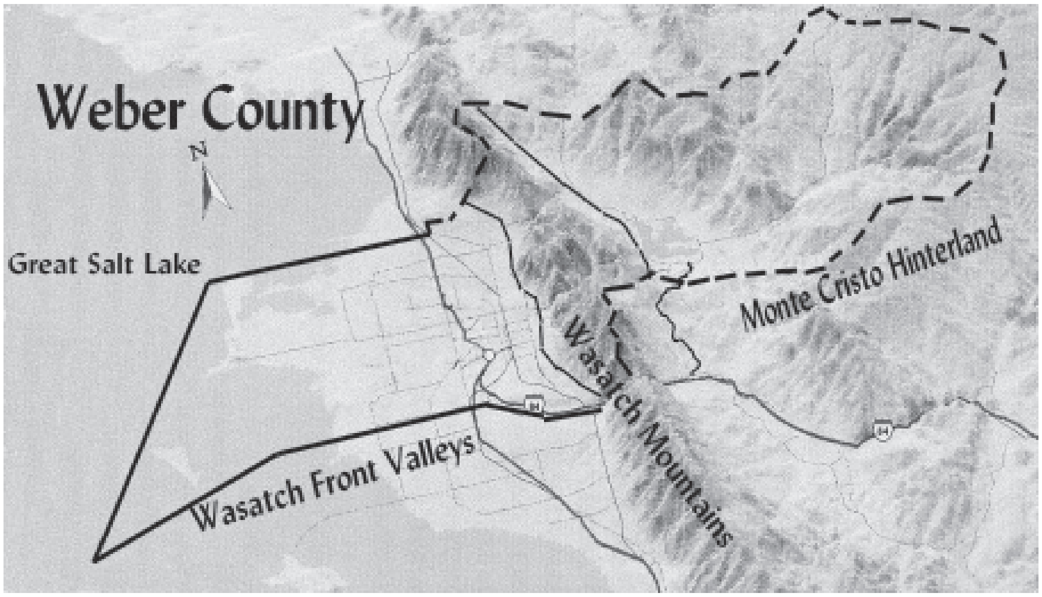

Figure 1.—Subsections mapped in Weber County

The Lands in the County

There are three main kinds of land based on physiography. The narrow Wasatch Mountain range extends from north to south in the middle of the county. Valleys and high ridges lie "behind" the mountains to the east and a long, gently sloping plain reaches westward from the mountains to the Great Salt Lake. Other northern Utah counties have similar land patterns. In the national scheme of things, the three kinds of land areas outlined here, according to a recent report sponsored by the Forest Service (Nelson 1994) are called "Subsections." See Figure 1.

Two subsections, the Monte Cristo Hinterlands and the Northern Wasatch Mountains are in the Overthrust Mountain Section (M331D) of the Southern Rocky Mountain Province. Locally, these are in the "Rockies." The lands to the west are in the Wasatch Front Valleys subsection of the Bonneville Basin Section (341 A) of the Intermountain Semi-Desert and Desert Province (McNab and Avers 1994). Most call this the Great Basin. The three subsections were the framework for identifying the thirteen Land Type Associations (LTAS) described in this report.

Weber County is drained by two major rivers. The Ogden River flows through the central part of the county from east to west and is a major tributary to the larger Weber River. The Weber starts in the Uinta Mountains to the southeast and enters the Front part of county from the south. It then flows north through a heavily urbanized valley about four miles to its junction with the Ogden River. From here it goes west to empty into the Great Salt Lake.

Wasatch Front Valleys Subsection

Over 95 percent of the people and 17 of the 20 communities in the county are in this approximately 11 miles by 13 miles "Front" subsection where the slopes are flatter, elevations are lower, and the climate warmer and dryer than the other two subsections. This part of the county is sometimes called "the lower valley." More about this subsection and an example LTA description in it are given in the Results section of this paper.

Northern Wasatch Mountains Subsection

The Northern Wasatch Mountains subsection rises abruptly along a fault line that marks the eastern edge of the lower valley. Many environmental differences accompany this physiographic break, The precipitation, for example, jumps from about I0 to 16 inches on the low, western slopes to over 40 inches on the crests of the Wasatch, a horizonal distance of about two miles but a vertical shift of nearly 5,000 feet (Nelson 1994). The geologic materials shift as radically, going from the young, unconsolidated sediments in the western valleys to steeply sloping quartzite and limestone rocks on the western face of the mountains (Stokes 1988). Slope gradients jump from less than 5 percent in the Front valleys to over 60 percent in the mountains. The mountains have small Douglas-fir stands on their north aspects and ridge tops and oakbrush and mountain maple on western and southern slopes. Oakbrush and mountain maple form solid stands on the eastern slopes. Snow Basin, a ski area on the east facing slopes will be an important venue for the 2002 Olympics. See Figure 2.

Figure 2.—A landscape in the Northern Wasatch Mountains Subsection. The area shown is a venue for the 2002 Winter Olympics.

Monte Cristo Hinterlands Subsection

The third subsection, the Monte Cristo Hinterlands, east of the Wasatch Range, is the upper watershed of the Ogden River. Most people in this subsection live in Ogden Valley, an elongated, north-south area of stream terraces and fans along the eastern side of the Wasatch Mountains (Muir and Winkelaar 1974). A series of relatively harsh, west-facing foothills rise to the west of this valley. Pineview Reservoir sits along the west edge of the subsection at the head of Ogden Canyon, one of three access routes to the Ogden Valley area from the "lower valley." A series of ridges and canyons cut by tributaries to the Ogden River lie to the east of the Ogden Valley. A series of broad ridges and subdued uplands form the rim of the Ogden River watershed. Compared to the Wasatch Front Valleys Subsection, the hinterlands are colder, wetter, and have much less land suitable for development. The growing season in the Ogden Valley, the only arable land here, is about 50 days less than it is for the Front Valleys, which are 6 miles to the west and about 400 feet lower (Soil Conservation Service 1968; Soil Conservation Service and Forest Service 1974). Outside of the Ogden Valley, nearly all of the hinterlands support brush and tree cover whose main uses are recreation, watershed and grazing land. The scenery, hunting, hiking, and winter sports opportunities bring many people to the area. Figure 3 is an example landscape in this subsection.

The Survey

Purpose of the Survey

The initial rationale for making the LTA survey is as follows:

1. Planning. A planning project in the western part of the county was beginning about the time the LTA survey began. This provided an opportunity to determine the possible role of this rather general survey in land use planning at the local level.

2. Demonstration. A subsection map of the state of Utah was recently completed by the Forest Service. Ecological land classification has been used for nearly three decades on National Forests here but it has received very little attention from other resource management agencies. This LTA survey could be an example to demonstrate the land classification concept to state and county officials.

3. Information. Over the years, considerable information on various resources has been produced by state and federal agencies. Although the information is readily available, some of it remains unknown to local planners and others dealing with the land. An LTA survey provides a set of recognizable land units that the available information can be tied to, making the information more relevant and visible to potential users.

4. Communication. The LTA survey provides land units which are the common ground for discussions about the land use issues. The survey can be an orientation tool for those getting acquainted with the county.

5. Learning. The survey map and description can be used to teach anyone who is interested in the lands of Weber County.

How the Survey Was Made

The survey was made by a combination of top-down and bottom-up activities with as much field checking as conditions permitted. The bottom-up tasks consisted of

Figure 3.—A landscape in the Monte Cristo Hinterland Subsection showing the Pineview Reservoir

collecting published reports and maps and then using these materials to guide the mapping of units and preparing map units description.

Mapping

The mapping was mainly a top-down task. Using information from the soil surveys, geologic maps and observations from driving surveys as a rough guide, the authors sketched out map units on a transparent overlay on a satellite image of the county (Landsat TM,Oct. 30, 2000; Bands 4, 5, 3). Criteria from the imagery used to delineate units were the type and density of the drainage pattern, local relief as expressed by the vegetation and shadow patterns, expressions of land use (e.g. visible roads, fields and structures) and tonal differences showing distribution of water and general slope aspects. USGS topographic maps (7 1/2 minute quads) were helpful in identifying land units in the Wasatch Front Valleys subsection because few natural surfaces remain intact and the key distinctions among these floodplains, fans and terraces are related to slight elevational differences. We visited as many units as we could in the field. We changed some unit boundaries as a result of these visits.

Descriptions and Interpretations

We drew mainly on the collected information to write the LTA descriptions. The soil association descriptions for the general soils maps in the two soil surveys were especially helpful for this task (Soil Conservation Service, 1968; Soil Conservation Service and Forest Service 1974). Our comments on management were based on field observations and on conversations with planners and other knowledgeable persons. We also used a map entitled "Selected Critical Facilities and Geologic Hazards, Weber County, Utah." by the Utah Geological Survey and Earthquake Preparedness Information Center (1995). Visual interpretation of the satellite imagery helped us describe the vegetation and physiographic features such as drainage patterns. We also used a landslide map of the state (Hardy 1991), the 7 1/2 minute quad topographic maps for elevations and the Forest Service ranger district map (USDA Forest Service 1994) for land ownership. An earlier land type association report on the Ogden Valley (Muir and Winkelaar 1974) was helpful at both mapping and description stages. We used three sources of geologic information (Eardley 1944, 1962; Stokes 1988).

Soils reports were particularly useful because, in addition to soil descriptions and extensive interpretations, they cover many other facets of the environment including vegetation type, geologic material, climate and physiographic information. A problem with these reports is that they contain too much detail for the level of mapping undertaken here, thus requiring considerable time to sort out what was needed. For example, five LTAs were identified in the Wasatch Front Valleys subsection but over 100 soil units were mapped in the same area. We tried to keep the subsection and LTA descriptions simple with the assumption that the referenced reports could be used for more detailed needs.

Results

The inventory resulted in a report entitled the "The Lands of Weber County, Utah." The two parts of this report are the map and the descriptions of the subsections and their land type associations.

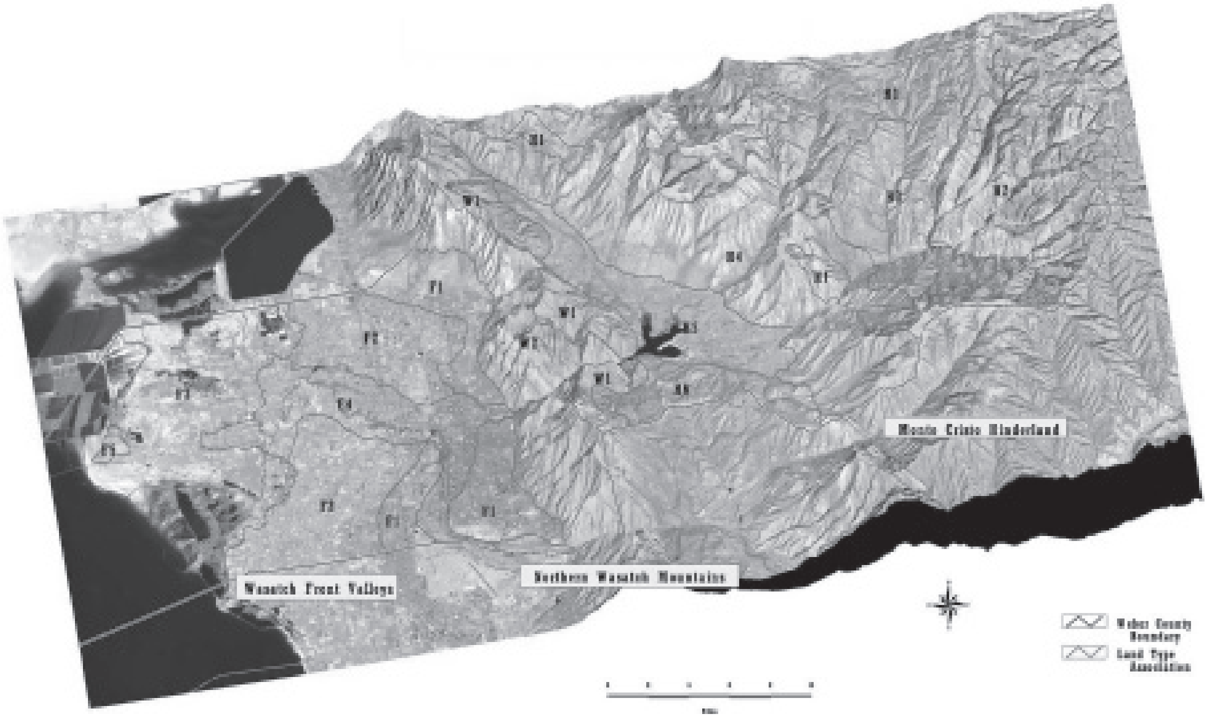

Figure 4.—Land type association map of Weber County

The Map

The Intermountain Region of the Forest Service's GIS Unit used our subsection and land type association delineations to produce an attractive poster showing the lands of Weber County as we saw them. The base map is of an oblique, vertically exaggerated, false color infra-red version of the landsat image used to map the LTAS. An attractive, laminated version of the map at a scale of 1:32,000 with a legend giving thumbnail descriptions and interpretations of the LTAs was prepared for key county officials. Figure 4 is a small scale, black and white version of this map poster.

Subsections and Land Type Association Descriptions

The narrative part of the Weber County LTA report consists of the descriptions and interpretations of the three subsections and thirteen land type associations. Space only permits presentation of examples of this material here.

Subsection Description: The Wasatch Front Valleys

This part of the county is called the "lower valley." The area is almost entirely a series of gently sloping stream and lake terraces and large fans of rock and earth at the mouths of the several canyons along the front. Large deltas formed at the mouths of the Ogden and Weber River canyons when the mountain glaciers melted. Remnants of these deltas have been covered with younger material which washed in from the adjacent mountain slopes. The distance between the foot of the mountains (LTA W2) and the Great Salt Lake is 8 to 10 miles but the elevation difference is 600 feet, giving an average slope of less than one-half percent. Within these long terraces and benches the most visual features are the valleys with their bluff-like side slopes cut by the two rivers. Discontinuous sections of benches formed by now extinct Lake Bonneville are visible along the foot of the mountains. The exceptions to the depositional landscapes mentioned above are Little Mountain and Fremont Island. The first is a broad hill with outcrops of tillite, a very old glacial deposit, in the western edge of the county. Fremont Island is about 4 miles off shore. It is the third largest island in the lake and tops out at 700 feet above the lake.

Other than the wetland along the Great Salt Lake in a wildlife refuge, this western part of the county is almost completely agricultural, residential, urban or industrial land. About 95 percent of the county's population live here, and the bulk of the interstate highway system and railroads cross this unit. This side of the mountains frequently has temperature inversions in winter, causing a layer of cloud of vehicle exhaust and industrial gasses to blanket the valleys of the Wasatch Front.

Four kinds of land related to landform, age and location of sediment deposits were mapped as land type associations within this subsection. We mapped Little Mountain and Fremont Island as LTA F5 to cover the only areas with exposed bedrock. An "F" for Great SaIt Lake "Front" is used as a prefix to the LTA numbers to

Figure 5.—Land Type Association F3, Low Terraces, in the foreground, the more populated Land Type Association F2, Mid Level Terraces, in the middle and the Wasatch Mountains forming the skyline

help distinguish them from other LTAs in the county. Elevation in relation to the Great Salt Lake controls much of the land use and management opportunities in this part of the county. For example, experience has shown that when the lake rises from its average of 4,200 feet to 4,204 feet, significant damage to structures from flooding can be expected. The historical high was reached in 1987 at 4,211.85 feet; the low in 1963 was 4,191.3 feet. In LTA F5 Little Mountain reaches 4,664 feet and Fremont Island's summit is 4,995 feet. Fremont Island seems to loom over the lake and nearby flatlands.

Land Type Association Description: LTA: F 3 Low Terraces.

General description.—This is a combination of flood plains of the two rivers in the county and the lowest lake terraces. Slow moving, meandering streams and drainage ditches cross the area in several places.

Materials.—Fine textured fluvial and lacustrine sediments.

Elevation.—4,202 to 4,220 feet.

Slopes.—Less than 3 percent gradients.

Precipitation.—13 to 16 inches

Mean Annual temperature.—47 to 52 degrees F.

Frost-free days.—150 to 175.

Soils.—Deep, stone-free loams to silty clay loam, mostly poorly drained with some moderately well drained areas. Most soils are saline or alkaline and have a water table within 5 feet of the surface. In the western part, the land surface has many small depressions. There are many free flowing springs in this unit according to topographic maps. Much of the area is salt crusted mud with little vegetation.

Vegetation.—Salt tolerant grasses and greasewood. Russian olive seems to be well adapted to the area. Cattails and other marsh plants are in the wetlands. Isolated cottonwood trees are along the Weber River.

Land use.—Pasture for cattle is the most extensive use. Patches of irrigated row crops are in the higher, eastern part. There are a few houses in higher areas or built-up sites. Department of Wildlife Management manages Ogden Bay Waterfowl Management Area (2 1,000 Acres) and the Harold Crane WNM (I 1,000 acres). Seasonal hunting and birdwatching are important uses. Several private duck hunting clubs are next to the WNIAS. ATV use is increasing. There are two processing plants here: Western Zirconium and IMC Kalium. The latter uses extensive evaporation impoundments in the northeast arm of the Great Salt Lake.

Management concerns.—Flooding by the Weber River and the Great Salt Lake, High sedimentation rates for the Weber River. The liquefaction hazard. Swarms of summer mosquitos. The Great Salt Lake Comprehensive Management Plan (Great Salt Lake Planning Team 2000) identifies these management issues: Vulnerability to flooding by the Weber River and the Great Salt Lake, high sediment for the Weber River, loss of agricultural land habitat required for certain species of birds due to residential housing development. See Figure 5.

Use of the LTA Inventory

Weber County planners are beginning to gather information for the 10 year growth plan for the western part of the county. This area is covered by four of the five LTAs identified in the Wasatch Front subsection. The LTA inventory has been introduced to the planners but it is too early to determine what its effect will be. The following is what we have learned so far:

1. The survey provides a synoptic view of the county. This gives planners an idea of where the next demands for assistance may come from and the limitations of existing plans. For example, the development requirements for the Ogden Valley (LTA H5) that were just prepared may not be appropriate for the expansion of houses along the streams in the South Fork Valley (LTA H3) in that same subsection. This perspective also appeals to the county officers who have seen the final map.

2. LTA delineation was marginally useful to planning. It did substantiate the boundaries used for more detailed data collection. For example, the terrace level separating the well drained soils of LTA F2 and from the imperfectly and poorly drained soils in LTA F3 became different categories in their detailed data collection efforts.

3. The information we accumulated for the LTA survey was, or will be, given to the county planning team. The team appreciated several key documents we have given them, including the Soil Conservation Service's soil survey reports and the Great Salt Lake Comprehensive Management Plan. References to other information sources is expected to be helpful also. It is not certain the team would have found these documents on its own.

We aggregated a considerable amount of information in the LTA descriptions which should be helpful. For example, getting information out of the soil survey report because of format and the spaghetti-like map can be daunting. Our identification of issues and possible hazards should alert the planners to information and expertise needs beyond the scope of the LTA survey. Our findings should help substantiate zoning and regulations related to the natural resources. The planner mentioned that a person had asked for a development permit on a flood plain. The person denied that flooding had occurred in the area. Our LTA F4 may help support decisions regarding development in the flood plains.

4. The Weber County planner we work with has been fully occupied with starting the new planning project and has not had time to discuss planning experiences in lands the county has in common with adjacent counties. The LTA survey may be an instrument to get such discussions started.

5. The hierarchical approach was intellectually interesting to local planners but did not have any impact on the current planning process because (a) selection of planning areas over the years has been based on perceived needs and local development pressures. Selection of areas is more of an evolutionary process than an analytical one and (b.) The subsections are accepted, facts of life for people in the county. It is "nice" to have them documented and described but their existence was never questioned.

6. Although the survey has not been used to provide the context for site studies, we have used some site work experience to describe the LTAS.

Conclusions

The survey was made too late to have any effect on long term, county-wide planning, and it is too early to assess the LTA inventory's value to the planning task now underway. A few observations are worth noting at this time, however.

We had no illusions that an LTA survey could satisfy the natural resource information needs of a residential planning project. Chances are that no survey, regardless of intensity, could meet every resource information need where high investments on a site by site basis are made. The information gathered in making the survey and its use as a means to get one's bearings in a subtly complex landscape along with its role in identifying potential land use issues and its application as a means to extrapolate experience from adjacent counties, all suggest the LTA survey is best used as a *pre-planning* tool in this Weber County example.

There is good potential for using the framework of units to give site investigations an ecological context. Making the survey generated a small library of descriptions, maps, and references which will improve our ability to respond to land use questions scattered around the county. It can provide a framework for extending information and experience gathered at a site. This function of the inventory is especially relevant to the site specific work done by the county's Public Land Advisory Council.

The LTA inventory will be a useful example of land classification. The concept of a hierarchy of land units is not widely known in Utah outside of the Forest Service and Utah State University. Over the years, key state and federal agencies have been urged, with minor success, to participate in a statewide land classification. The emphasis was on land classification as an information gathering tool and as a means for greater cross-boundary coordination. The Weber County LTA survey will be a useful tool to illustrate the land classification concept and its possible applications in local land management issues. The inventory can be used to reach out to the counties. A positive response here would be very gratifying in itself, but in addition, we may spark an interest in land classification in the state and other federal agencies with resource management responsibilities.

Three common checks on the validity of a land classification are (1) relevance to the issues at hand, (2) visibility to the decision maker and (3) "mappability" by the people making the classification. Using these criteria, we have to say that the inventory had limited application to the current planning project as an information source but does have relevance as orientation and communication tools. One of the strengths of the inventory is that the LTAs are readily visible to the county commissioners and department heads. Little explanation was required to make them understandable. For the most part, the LTAs in the final map were fairly obvious and could be consistently delineated. A mapping problem arose in only one situation. We expected to be able to map a mountain crest LTA in the Northern Wasatch Mountain Range Subsection but we could not consistently delineate it using the satellite image we had. Such a unit is visible on the ground and may eventually be separated at the land type level.

Low unit cost may be a fourth test of a successful LTA inventory. Land classification methods evolved originally to meet resource information needs on large areas of undeveloped land quickly and inexpensively (Davis 1969). It required approximately 6 person weeks to complete the inventory. Because much of the labor was volunteered, we have to estimate the cost at about $1500 per week for labor and materials. If these figures are used, it works out to be less than two and a half cents per acre. We believe we are safe in saying that this criterion is satisfied.

We broke new ground by making a county level LTA inventory. This kind of survey is not uncommon on National Forest land nor are more general subsection maps new to the state. We know such inventories are widely used in other parts of the country. In Utah, detailed, individual resource maps, e.g. soils, vegetation and geology, cover much of the state and are essential for some uses but their number, diversity, and detail can lead to confusion among planners and local officials if the need is for an overview of a large land area. This inventory was aimed at the gap between the generalizations of the subsection maps and the detailed, heavy single resource inventories. It will take some time to determine the value of land type associations to local planning but we now have an example we can use to reach out to this vital level of government.

Acknowledgements

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Updating the USDA-NRCS Major Land Resource Areas in Wisconsin using National Hierarchical Framework of Ecological Units Landtype Associations

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Abstract

A national effort is underway to update Major Land Resource Areas (MLRAs) by 2002. The criteria for delineating MLRAs have been revised to differentiate them based on soil material kind and age, soil moisture and temperature regime, native vegetation, and landforms. Less emphasis is being placed on landuse at this level, but will be a consideration in subdivisions of MLRAs referred to as Common Resource Areas (CRAs). In Wisconsin, the National Hierarchical Framework of Ecological Units (NHFEU), at the Landtype Association level, was used as a significant source for this update. Landtype Associations (LTAs) are delineated using the same basic criteria as MLRAs, but at a much finer scale along with a few additional criteria, such as disturbance regimes. With the completion of this project, MLRAs in Wisconsin are now meshed with the NHFEU with LTAs serving as the common thread. This is significant in that not only do the two land classification systems mesh in Wisconsin, which partially satisfies a related national goal, but also a wealth of soil data will be readily accessible to the NHFEU. Soil survey areas are currently being set up around MLRAs where each MLRA will have its own soil legend linked to the National Soil Information System (NASIS) database. MLRAs will be subdivided into CRAs and STATSGO (State Soil Geographical Database) is slated for update, all within the MLRA framework and with LTAs potentially serving as a basis. With MLRAs, CRAs, STATSGO, and soil survey map units meshed with the NHFEU in Wisconsin, each NHFEU strata could be linked to the same national soil survey database. Equally important, MLRAs will have a significant link to NHFEU ecological data beyond the standard NRCS databases. This will benefit all users of these two land classification systems.

NRCS Framework

Major Land Resource Areas represent a hierarchical level within the USDA Natural Resources Conservation Service (NRCS) Framework of land resource categories. The NRCS Framework is designed to address agricultural potential and soil capabilities. It provides NRCS a basis for making decisions concerning national and regional agricultural issues and serves as a framework for organizing and operating resource conservation programs. It identifies needs for research and resource inventories and provides a broad base for extrapolating the results of research within national boundaries (Agricultural Handbook 296 and National Soil Survey Handbook).

Like the USDA Forest Service's National Hierarchical Framework of Ecological Units (NHFEU), the NRCS Framework is hierarchical in nature consisting of Land Resource Regions, Major Land Resource Areas, and Common Resource Areas.

<u>Land Resource Region (LRR):</u> The highest level within the NRCS Framework. These approximate broad agricultural market regions having related patterns of soil, climate, water resources, and land use. LRR's are most useful for national and regional planning. LRR units are comparable in size to Provinces within the NHFEU.

<u>Major Land Resource Area (MLRA):</u> Subdivisions of LRR's reflecting associations among soils, climate, water resources, vegetation, physiography, and land use. MLRA's are important in statewide agricultural planning and have value in interstate, regional, and national planning. MLRA units are comparable in size to Sections and Subsections within the NHFEU.

<u>Common Resource Area (CRA) or Land Resource Units (LRU):</u> The lowest level within the NRCS Framework reflecting a particular pattern of soils, climate, water resources, and land use. These generally represent a geographic area having a characteristic land use pattern where conservation treatment needs are similar. CRA or LRU units are comparable in size to Subsections or Landtype Associations within the NHFEU.

Interagengy Memorandum Of Understanding

In 1995 a Memorandum of Understanding was signed by nine federal agencies (NRCS, FS, EPA, BLM, USGS, NPS, F&WS, NBS, and ARS) to integrate the major resource mapping frameworks into a common interagency spatial framework for defining ecological units of the United States. This interagency framework will be based on naturally occurring and recognizable features such as soil, geology, geomorphology, climate, water, and vegetation. Guides for this work will include the NRCS Framework, the NHFEU, and the EPA Ecoregion Framework along with other frameworks depicting biological and physical components of the environment, as appropriate.

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The resulting interagency framework is not intended to replace the three major frameworks already in place. Rather, the interagency group recognizes the differences and function of these frameworks and each will continue to play an important role within their respective agency program and administration. Commonality and refinement of these frameworks will be the basis for evolution of the common interagency spatial framework and related databases

Each of the three major frameworks incorporate associations among soil, geology, geomorphology, climate, water, and vegetation into their respective hierarchical system. Yet each produce very different land resource maps which do not nest well with one another, hence lack much common ground. To complicate the matter even more, NRCS delineations regard land use as important delineating criterion while EPA includes both land use and water quality, none of which are criteria within the NHFEU. Through the signed MOU, the nine federal agencies agreed to establish some commonality among the major frameworks through revision and update of their own framework.

Updating Major Land Resource Areas

NRCS is in the process of updating MLRA's. The last revision took place around 1978. In the spirit of the 1995 MOU, along with increasing involvement of NRCS staff in ecosystem planning, NRCS has slightly altered the criteria defining MLRA's. Primary distinguishing characteristics for MLRA's will be soil material kind and age (includes surficial geology), soil moisture and temperature regimes, native vegetation, and landforms. While land use is still a consideration, its role will be emphasized more at the CRA level. The project timeline goal is to complete the update of MLRA's by March 2002 with preliminary line work due April 15, 2001 and draft descriptions due July 2001.

The intended reference base for updating MLRA's includes CRA/LRU delineations, STATSGO delineations and associated data, and National Resource Inventory (NRI) data. In Wisconsin, each reference criterion is limited in application for updating MLRA's. CRA/LRU's have not been developed statewide. STATSGO units only represent soil associations derived from varying vintages of general soil maps and is also scheduled for update. NRI data is basically point data and has limited application for delineating MLRA's. Neither reference ensures establishing common ground with other frameworks. A need existed for an alternative reference.

Landtype Associations

In Wisconsin, Landtype Associations (LTA) were used to update MLRA's for several reasons. LTA's represent ecological resource associations incorporating the same factors that define both MLRA's and the proposed interagency framework (soil, geology, geomorphology, climate, water, and vegetation). Among the three major frameworks, LTA's represent the finest scale of ecological resource mapping available having statewide coverage. LTA's were developed by a multi-discipline, multi-agency team that included NRCS soil scientists. LTA delineations are digitized with a supporting database. Attributes within the LTA database, such as soil associations and geomorphology, can be readily grouped to aggregate LTA's into MLRA's. The bottom line is the groundwork for MLRA revisions exists in the form of LTA's.

MLRA Update Progression

Several MLRA revisions have been recommended over the years in Wisconsin. By aggregating LTA's into MLRA units and incorporating the highly detailed LTA line work, the revised MLRA's now represent the landscape more accurately. This process provided a quick method of updating MLRA's while at the same time provided for a high level of accuracy not otherwise possible. Also, MLRA lines coincide precisely with LTA lines establishing common ground between the NRCS Framework and the NHFEU. This is in accordance with the 1995 MOU. With LTA's associated with MLRA's, LTA data will become a significant source of information needed to update MLRA descriptions.

Common Resource Area Development

With the revision of MLRA's completed, NRCS will eventually develop Common Resource Areas (CRA). The term "Common Resource Area" is a proposed alternative name to be used in place of "Land Resource Unit" (LRU) currently being used. LRU's are aggregates of STATSGO units and historically have had wide use only in the southwestern portion of the Nation. Common Resource Areas are more widely accepted because they are to represent geographical regions where conservation treatment needs are similar. Landscape conditions, climate, human considerations (land use), and other natural resource concerns will be criteria used to determine CRA units. Each CRA will have several Benchmark Management Systems (conservation practices templates) associated with it based on land uses within a logical geographic framework. These templates then will be included with the NRCS Field Office Technical Guide (FOTG).

Landtype Associations could play a significant role in the development of CRA's. Each LTA exhibits a characteristic land use pattern even though land use is not a delineating factor within the NHFEU. This land use association, as land use on the local level, generally follows resource patterns characteristic of LTA's. This natural association readily lends itself to developing characteristic conservation practices templates specific for each LTA. With LTA's digitized statewide and already associated with MLRA's, LTA delineations could serve as a base for CRA development.

STATSGO Update

NRCS will soon be updating the State Soil Geographic Database (STATSGO). STASGO is a statewide spatial database representing soil associations derived from detailed soil surveys. The update will incorporate recently completed soil surveys and will establish a link to the National Soil Information System (NASIS). NASIS is a soil database from which soil attribute queries, reports, and interpretations can be generated and managed.

NRCS detailed soil surveys and STATSGO information were key factors in the development of Landtype Associations. Since LTA's reflect soil associations relative to landscape patterns, STASGO units could be tied in with LTA's either on a one-to-one basis or as sub-units to LTA's. This association would benefit the NHFEU by providing a means for linking LTA's directly to NASIS.

Results

The linkage between the NRCS Framework and the NHFEU is the Landtype Association. The LTA enables a direct correlation from the NHFEU to the NRCS Framework by creating a common ground between the two systems. A standardization of a spatial data model drives the update process for both frameworks. Each framework utilizes boundaries of the LTA to delineate every level for each framework. The data model then enables use of database information to be shared between both systems and other database mentioned above.

Utilizing NHFEU LTA's to update MLRA's, and potentially CRA's and STATSGO within the NRCS Framework, is enabling NRCS to complete the update in Wisconsin well within the prescribed timeframe (Figure 1). The resultant MLRA map has a higher degree of detail that is more representative of the landscape than would have been possible to achieve otherwise. This approach establishes common ground between the NRCS Framework and the NHFEU, which will benefit resource managers under either framework through better coordinated data sharing and effective communication of management concepts.

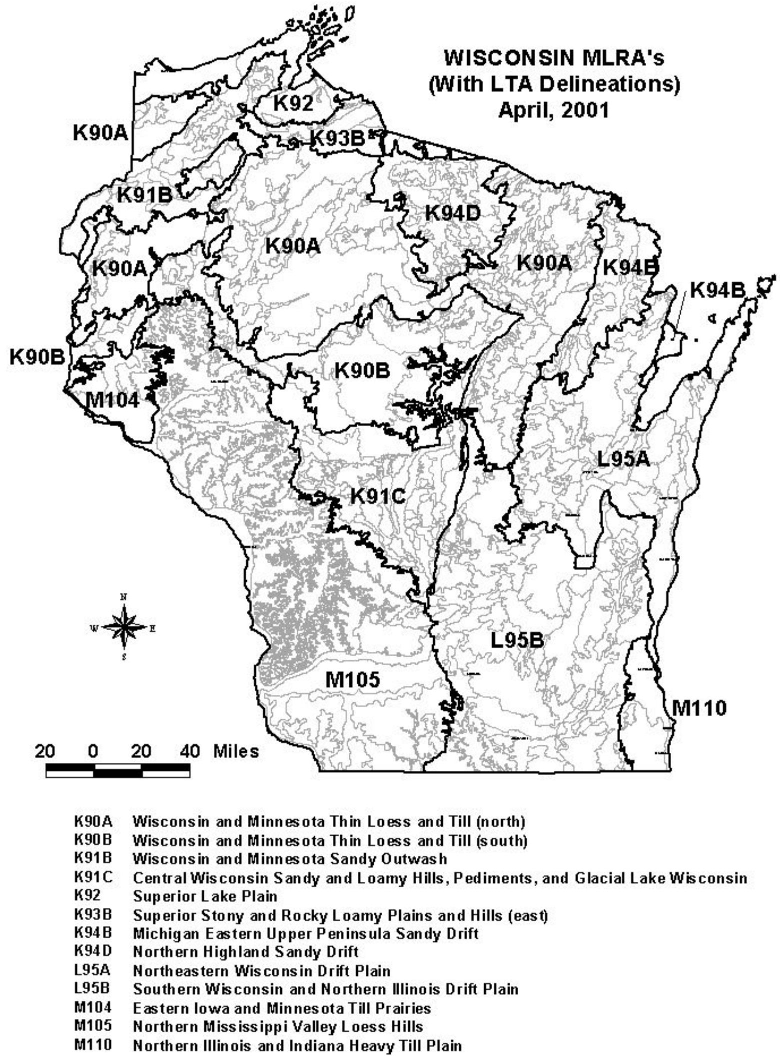

Figure 1.—Revised Wisconsin MLRA map with LTA delineations nested with MLRA's.

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Land Type Associations Conference: Summary Comments

Thomas R. Crow[1]

Introduction

Holding a conference on Landtype Associations in Madison seems appropriate given the amount of research and application on ecological classification that has taken place here and elsewhere within the region. In fact, a previous conference held at the University of Wisconsin, Madison, in March 1984 on ecosystem classification entitled "Forest Land Classifications: Experiences, Problems, Perspectives" provides a useful framework for summarizing the current meeting and, more specifically, a benchmark for assessing the advances in the development and application of ecosystem classification.

In the proceedings of the 1984 conference, Bailey presents six problems related to ecosystem classification and mapping that needed resolution in order to successfully implement a classification system. I think it is worthwhile revisiting these problems in light of what we heard at the current conference on Landtype Associations. Are these problems still relevant or have we moved beyond what was perceived by Bailey in 1984 as major impediments to implementing ecosystem classification?

Problems of Terminology and Criteria for Recognition

According to Bailey (1984), there is not a universally shared understanding of terms such as "ecological land unit" and "ecosystem." As a result, ecosystem classification is not being applied uniformly across the landscape, nor are same criteria being used in development and application, and the basic concepts underlying land classification can vary substantially.

The keynote speaker for the Landtype Associations, Burton Barnes, addressed these problems. There will always be those who view ecosystems as abstractions that are defined only by the interactions among their components and therefore difficult to identify in reality. The take-home message from Barnes, however, is that ecosystems are in fact tangible, identifiable, volumes of air, land, water, and vegetation. Following the lead of Rowe (1992), "landscape ecosystems" are described as real geographic chunks of the earth's skin. The concept of a hierarchical, multiple-factor framework for distinguishing, regionalizing, classifying, and mapping landscape ecosystems is gaining the day. We saw many examples of this at the conference. Sure there were some differences, and there will always will be, but there were many fundamental similarities in the conceptual basis among the classifications presented at this conference.

The work of Barnes and his students on the Huron Mountain Club, the Sylvania Wilderness, the McCormick Experimental Forest, and the University of Michigan's Biological Station has been invaluable in illustrating the process of identifying and characterizing landscape ecosystems. This work was extended to larger scales when Albert et al. (1986) published a classification and map of regional ecosystems of Michigan and Albert (1995) did the same for the three Lake States. The evidence is overwhelming – ecosystems can be identified and characterized at many different spatial scales.

What Role Should Land Use Play in Delineating Units?

This problem relates to the use of relatively permanent characteristics such as soil, landform, and climate, as the basis for delineating regional and landscape ecosystems as opposed to using existing vegetation to characterize the extent of units assuming that existing vegetation better reflects land use.

The role of land use in delineating regional and landscape ecosystem was not an issue at the Land Type Association Conference. In fact, land type associations provide a useful tool for considering land use. For example, Devon Nelson demonstrated the utility of land type associations as the basis for land use planning in Weber County, Utah. Steve Fay illustrated the use of land type associations for forest planning on the White Mountain National Forest in New Hampshire. And Dan Devlin showed us the use of landforms in managing landscapes on Pennsylvania's State Forests. The point here is that land use is not an independent variable used to define landscape ecosystems, but it can be a dependent variable in which land use patterns are related to landscape ecosystems as defined by their climate, landform, soil, and vegetation. Clearly, we need more demonstrations that illustrate the use of ecosystem classification in addressing important environmental and social issues such as those related to land use.

Insufficient Knowledge of Ecological Processes Limits Our Ability to Make Robust Environment Predictions

The basic argument here is that our knowledge of ecological processes for most ecosystems is insufficient to allow reliable predictions of ecosystem responses to

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management actions (Bailey 1984). This statement is probably as valid now as it was in 1984. But how does this statement relate to ecosystem classification? Does this lack of knowledge preclude identifying and characterizing ecosystems? I think not. There will always be more to learn about ecological processes, but again, I consider ecosystem classification to be a useful tool — in this case a research tool – that can be helpful in studying ecological processes. Specifically, it provides a basis for stratifying landscapes into similar ecosystems so that differences among systems can be reduced when studying processes.

This point was perhaps best demonstrated in Dave Cleland's paper in which Subsections and Landtype Associations were used as the basis for mapping natural disturbance regimes in the Lake States and in Gary Drotts' and Jodie Provost's presentation in which species ranges and habitat relationships were defined for selected wildlife species within the framework provided by Subsections and Landtype Associations. The application of multi-factor, integrated, hierarchical ecosystem classifications for the purpose of studying ecological processes such as nutrient cycling, forest dynamics, and forest growth is a largely untapped but potentially useful area of application. It is just a matter of time, for example, before modelers use Subsections or Landtype Associations as a framework to parameterize forest growth models. It seems so intuitive; I am surprised that it has not been done already.

Existing Classifications Systems Usually Emphasize the Terrestrial System

This is as much problem in 2001 as it was in 1984. According to Bailey (1984), most land classifiers do not understand aquatic systems and most aquatic classifiers to not understand terrestrial systems. Amen to this statement. We have the aquatic camp and the terrestrial camp – each doing their own thing and waiting for the other camp to come around. As we all recognize, aquatic and terrestrial systems are closely linked and approaches to classifying ecosystems should be capable of recognizing the integrated nature of terrestrial and aquatic ecosystems.

A few small steps have been taken in linking terrestrial and aquatic systems through classification (e.g., Baker et al. 1998, Crow et al. 2000), but more effort in this area is warranted.

The Problem of Wildlife

Although ecosystem classification is presented as a means for integrating both physical and biological factors existing in the landscape, integrating wildlife into the classification process has proven difficult (Bailey 1984). This may be true when considering the factors using to recognize and delineate units, but it is not true when considering the application of ecosystem classification. At this Conference, we heard about the application of Landtype Associations for ranking the quality of Indiana Bat habitat (Tom Demeo) on the Monongahela National Forest in West Virginia, for evaluating habitat of the Kirtland's Warbler in Michigan (Burt Barnes), and as a tool for wildlife management in Minnesota (Gary Drotts and Jodie Provost).

Abundant examples exist of applying ecosystem classification to wildlife questions. Integrating wildlife into the classification process may still be a problem, but as an applications tool, ecosystem classification has many uses in wildlife management.

The Relationship Between Delineated Units is Difficult to Assess

Much progress has been made in understanding relationships between landscape ecosystems during the past 20 years. This work has included the movement of organisms through landscapes, the flow of water and water borne materials, the fluxes of carbon and nitrogen between landscape ecosystems, the dispersion of seeds and other propagules among ecosystems, as well as the long distant transport of pollutants such as ozone in the lower atmosphere. The importance of context, adjacency, and proximity when considering ecological processes and characterizing the composition of a landscape ecosystem is now widely recognized. Much of this progress has been accomplished as part of the emerging discipline called landscape ecology (Pickett and Cadenasso 1995).

At the beginning of this Conference, you were encouraged to both communicate and demonstrate the utility of Landtype Associations. Is it not enough to simply classify, and as a tool, the classification is only a beginning. As was pointed out, your work is in the vanguard of applied ecology, but the linkages between ecosystem classification, critical natural resource issues, and decision-making are not obvious to most managers, planners, and policymakers. Not only do you have the responsibility for developing the classification, you are also responsible for demonstrating its value to help solve critical natural resource problems that are important to the public. Until this is done, your job is unfinished.

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III. POSTERS, MAP GALLERY, & INTERACTIVE EXHIBIT ABSTRACTS

Application of Land Type Associations in Michigan's Northern Lower Peninsula to Guide Landscape Management of State Forests

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Poster Abstract

The land type associations (LTAs) classified for Section VII (Northern Lacustrine-Influenced Lower Michigan) are employed to provide Michigan Department of Natural Resources' foresters and biologists the landscape and historical context in which they are managing state forests. LTAs developed by Michigan Natural Features Inventory (Corner and Albert, 1999) incorporated the following data layers for delineation: glacial landform, slope class, soil texture, drainage class, and presettlement vegetation, based on interpretation of vegetation notes collected during the 1816-1856 General Land Office survey (Comer et al., 1995). A comparison of presettlement vegetation and current land cover was derived for each LTA. Present vegetation is based on Michigan Resource Information System (MIRIS) land cover types. Total areas of presettlement communities within each LTA and MIRIS cover types within each LTA were obtained by executing cross-tabulations of layers in Geological Information System (GIS). Maps of state forest management compartments are overlain in GIS with the LTA layer in addition to rare species' locations and presettlement vegetation. Studies of vegetation change by LTA contextualize management spatially and temporally. In addition to description of biotic change by LTA, information on abiotic factors that influence management options and constraints are elucidated, including; soil types, soil texture, drainage class, slope class, bedrock geology, glacial landform, hydrology and disturbance regime. Providing information embedded within LTAs in conjunction with details on rare species' locations and presettlement vegetation allows for consideration of such questions as: How is potential management is likely to impact threatened species at scales greater than the stand? What are potential areas of focus for restoration management? And, What are appropriate management scales and intensities?

Development of Landtype Associations in Minnesota

Dan S. Hanson

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Poster Abstract

This paper describes the data and methodology used to create Landtype Association (LTA) map for Minnesota. The state was divided into six geographic areas based on groups of subsections. A team of volunteers was assembled for each area. Team members represented a cross section of natural resource management and inventory disciplines from a variety of organizations. LTAs were delineated by visually interpreting a variety of land surface information including: geomorphology, bedrock geology, topography, wetlands, hydrography, public land survey bearing trees, pre-European settlement vegetation, Landsat satellite imagery, soil associations, county soil surveys, and local knowledge of the landscape from individuals. Interrelationships of features were examined by overlaying thematic maps and observing how patterns coincide. Because multiple features were used to define LTAs, the feature(s) with the sharpest transition between adjacent LTAs are selected for boundary lines. Geomorphology map units were commonly used as LTA boundaries because they often integrate many of the individual features that show coincident pattern. LTA boundaries were delineated on mylar printouts of the Geomorphology of Minnesota data based on USGS 1:100,000 scale tiles. The mylars were then used as a basis for the capturing the LTA boundaries in digital format. Once the LTA coverage was complete, each polygon was assigned a code based on guidelines in the National Hierarchical Framework of Ecological Units. The LTA coverage, considered the first approximation, is available to the public via the DNR web site. Brief descriptions of the central concept and key characteristics for each LTA is in progress. A multi-agency work group has been formed to oversee periodic revisions.

Landtype Association Application to Forest Plan Revision on the Chequamegon-Nicolet National Forest

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Poster Abstract

The revision process for the ten year old Chequamegon and Nicolet National Forest Land and Resource Management Plans involved combining the two existing broad-scale Forest plans, as the Forests are now one administrative unit. A common framework was needed to provide an ecological context for developing a range of alternatives that would address biological diversity related issues, such as, distribution of old growth areas, ecosystem restoration, habitat linkages, range of natural variability and landscape patterns. The framework must also be applicable when addressing the identified revision issues related to access and recreational opportunities, special land allocations and timber production. Landtype Associations (LTA) provide the landscape-scale, ecological framework for land allocation in the revised 1.5 million acre Forest plan. LTA delineations are based on patterns of glacial landforms, topography, local climate, soil complexes and associated patterns of vegetation and succession. LTA polygons were assigned Management Area themes based on ecological potential, history of natural disturbance and management, existing condition and social concerns. LTA characterizations were used in the development of Management Area prescriptions that describe the theme, landscape setting, desired future composition and structure of plant communities and disturbance regimes at the landscape and site level. While LTAs serve as the basis for initial Management Area boundary placement, adjustments were necessary to map existing and potential special management designations like Wilderness, Wildlife Management, and Semi-Primitive Non-Motorized Areas, whose boundaries often follow roads or survey lines. The resulting Management Area map reflects these adjustments for social values, while retaining the integrity of the LTA boundaries where active management is intended to encourage plant communities to succeed to a desired future condition.

A Case Study: Mid-scale Hydrologic Relationships Derived from the Analysis and Application of Land Type Associations Developed for the Helena National Forest

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Poster Abstract

Land Type Associations (LTAs) were developed on the Helena National Forest following the criteria outlined in the Forest Service's National Hierarchical Framework of Ecological Units. Hydrologic features, patterns and processes associated with a diverse range of LTAs were subjected to spatial and tabular data analysis using geographical information systems. The relationships emerging from the analysis were validated through field observations and the systematic sampling of representative valley segments within the LTAs.

As a result of this analysis and validation process we were able to demonstrate relationships between LTAs and drainage and stream densities, valley segment patterns, flow regime patterns, elevational influences, stream order, nutrient regimes, water storage, release and response characteristics, woody debris dependency and recruitment capability, disturbance regimes and land use patterns. The LTAs reflect local orographic weather patterns within a broader climatic context defined at broader scales. The Land Types, which comprise the LTAs, are used to define classes of valley segments, which have predictable valley bottom and stream characteristics.

Practical uses include assessing cumulative hydrologic effects related to management scenarios, predicting habitat potential and response to management scenarios for fisheries and other riparian dependent species, providing a framework for discussing watershed structure, composition and function, predicting watershed response to increased peak flows, duration of peak flows, and sediment, addressing watershed resiliency and susceptibility to disturbances, helping to facilitate development of desired future conditions and determining approximate reference conditions.

Defining the hydrologic implications of LTAs is essential to effective land and watershed management planning. Analysis of such relationships is needed to develop realistic desired future conditions (DFCs). Such DFCs must consider the terrestrial and aquatic inter-relationships associated with the various LTAs.

Developing an Ecological Land Classification for the Allegheny National Forest: a Top-down, Bottom-up Approach.

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Poster Abstract

The Allegheny National Forest (ANF), in partnership with the Pennsylvania State University and Clarion University, is developing an ecological land classification to guide management and planning actions. A top-down, bottom-up approach consisting of digital mapping and field sampling of vegetation, soils, and landforms was used to develop a classification system at the land type association (LTA) and ecological land type (ELT) scales. The first approximation LTA/ELT classification was based on physical characteristics such as soils and topography that were integrated into a multi-layered GIS base map. First approximation LTA/ELT units were used to stratify vegetation-environment sampling efforts throughout the forest. Vegetation-environment data were analyzed by a range of multivariate statistical procedures (e.g., agglomerative and divisive clustering, ordination) to identify arboreal and herbaceous plant species groups and their relation to site characteristics. Stepwise discriminant function analysis (SDFA) was used to identify a set of biological and physical site variables that best distinguished first approximation mapping units. There was moderate correspondence between vegetation data and first approximation LTA/ELTs suggesting that vegetation composition was not strongly associated with mapping units. A second approximation LTA/ELT classification, refined and simplified using vegetation-environment data, is currently being validated. Our approach to ecological land classification on the ANF is adaptive and integrated, continually using new data from the field to refine mapping units in an ecologically relevant manner.

Map Gallery Abstracts

Northern Highland – American Legion State Forest: Management Opportunities by LTA

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LTA map depicting how LTA's are being used where ecological potential and management opportunities exist to restore a variety of plant communities including red pine, white pine, and hemlock for the Northern Highland – American Legion State Forest in northern Wisconsin. This map was produced for the master planning activities of Wisconsin's Northern State Forests.

ECOMAP in forest resource planning and management in New Jersey

James P. Dunn and Craig Coutrous
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Maps products displayed to demonstrate the various applications of ECOMAP in forest resource planning and management in New Jersey.

Landtype Association Map of Minnesota

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The Landtype Association (LTA) map for Minnesota was completed in 1999. This first approximation was created by natural resource professionals from Beltrami County, UPM-Blandin Paper Company, Chippewa National Forest, Koochiching County, Minnesota Center for Environmental Advocacy, Minnesota Department of Agriculture, Minnesota Department of Natural Resources, Natural Resources Conservation Service, Potlatch Corporation, Superior National Forest, and U.S. Fish and Wildlife Service. LTAs were delineated at a scale of 1:100,000 by visually observing how patterns coincide among a variety of physical and biological land surface characteristics. Geomorphology units were commonly used for LTA boundaries because they often integrate many of the individual features that show coincident pattern. A digital vector cover is available on the Minnesota Department of Natural Resources (MNDNR) web site.

Wisconsin Major Land Resource Area Map 2001

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This map shows the updated USDA-NRCS Major Land Resource Areas (MLRAs) in Wisconsin, along with potential Common Resource Areas. Incorporated in this map are the NHFEU Landtype Associations (LTAs) which served as a basis for updating MLRAs. As a result of this project, Landtype Associations provide common ground for both the NHFEU and MLRA land classification systems through which both systems can benefit from each other's databases for landuse assessments and applications. Common Resource Areas are subdivisions of MLRAs delineated according to common patterns in soils, climate, water resources, and land uses. They are important for local planning purposes and have common management concerns or landuse prescriptions.

Landtype Associations of the Western Upper Peninsula, Michigan

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LTAs were initially developed within the 1.5 million acre Ottawa National Forest in the early 1970s and served as an ecological-based, spatial context for the Ottawa, N.F. land management plan during the 1980s. To achieve the goals of the Great Lakes Ecological Assessment (GLEA), a landscape scale ecological unit (LTAs) needed to be developed for the entire Province 212 of Michigan, Minnesota, and Wisconsin. In 1995, LTA development was underway throughout the Province except for the remainder of the western Upper Peninsula of Michigan. As requested by the GLEA, a team of local experts was formed and work began on the LTAs of the entire western Upper Peninsula of Michigan in January, 1997. On January 30, 2000, a final working draft report and map was distributed throughout the Lake States. Digital map copies are available upon request.

Wisconsin Landtype Associations 2001

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This map depicts subregional and landscape ecological units developed according to the classification scheme of the National Hierarchical Framework of Ecological Units (Avers et.al., 1994). The map presents an iteration of Landtype Associations which nest within and refine successively larger ecological units. The map can be applied to landscape level assessment, analysis, and planning. The Landtype Associations were developed, mapped, and described in participation with a variety of agencies, organizations, and individuals. Development of ecological units is an ongoing process which will progress as additional information becomes available, and from peer review and comments by users of this map. The map will be reviewed annually. The map and descriptive legend are available through the Wisconsin Department of Natural Resources. A variety of agencies and private individuals participated as partners in the development of the LTA layer. Agencies include the Wisconsin Dept. of Natural Resources, the Natural Resources Conservation Service, the USDA Forest Service (State and Private Forestry and National Forests), the Wisconsin County Forest Association, the University of Wisconsin (Madison and Stevens Point), Menominee Tribal Enterprises, and the Wisconsin Geological and Natural History Survey.

Development and Applications of Landtype Associations in Missouri

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The Missouri Ecological Classification System (ECS) Project is an inter-agency sponsored program to pursue development of an ECS for the state of Missouri. Using the USFS hierarchy we have completed development of ecological units statewide through the landtype association (LTA) level. We have also piloted the development of ecological landtypes for the Current River Hills subsection. LTAs have been used as a framework for ecoregional inventory, assessment and planning. Regional priorities were directed toward public and private land management activities using LTAs as a guide. Area level planning and management has also used LTAs as a framework for breaking large conservation areas into management units. ELTs have been used to direct land management strategies within LTAs. This poster will describe the development and use of LTAs in Missouri. It will be paired with a computer demonstration

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Landtype Associations of Eastern Upper Michigan

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Draft Landtype Associations (LTA's) were updated from older maps in eastern Upper Michigan. Updates were made using spatial data in GIS, overlaying old LTA maps with surficial geology, soils, Digital Elevation Model (DEM), hydrography, original vegetation, and current vegetation themes. The conceptual basis of each LTA, and its boundary placement, were reviewed according to protocols established for the Lake States National Forests. Where LTA concepts were not reflected, new units were differentiated based on combinations of geology, historic vegetation, soils, hydrography, and elevation changes. The most spatially accurate layer, current vegetation, was used in delineating boundaries. Some boundaries were quite discrete, while others reflected a gradual change in ecological gradients.

The updated LTA map has been reviewed by the Forest Service, and will be released as a second draft for general review after minor modifications. It is available electronically in draft form from the author. The work was sponsored by the Forest Service, Eastern Region.

Draft Landtype Associations for New Hampshire

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A preliminary map of Landtype Associations (LTA's) was developed to support the state of New Hampshire's 1995 Forest Resource planning process. A group of New Hampshire scientists and resource professionals used the broad ecological approach described in the National Hierarchical Framework of Ecological Unit (ECOMAP)(Avers et al. 1994). Each LTA was classified based on similarities in geomorphic process, geologic rock types, soil complexes, hydrologic features, sub-regional climate, and potential natural community patterns. The draft map is available in digital form from GRANIT, the state GIS center housed at the University of New Hampshire.

Interactive Display Abstracts

New Jersey ECOMAP

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An exhibit will demonstrate the utility of various levels of the National Hierarchy Framework of Ecological Units. A hands on GIS platform will be employed to display and access sets of geospacial data for Subsections 221Ba and 221Bd to the ELT level. Specific examples of management applications, stewardship planning and watershed assessments will be available for demonstration.

An Ecological Characterization of the Greater Yellowstone Area with a Demonstration of Landtype Association Level Interpretations

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In 1998 an interagency cooperative effort (NRCS, USFS Region One) was initiated to utilize the Landtype Association, Subsection and Section levels of the National Ecological Mapping Hierarchy to develop a comprehensive ecological characterization of the Greater Yellowstone Area (GYA). This GIS-based interactive exhibit will provide an overview of the methods, datasets and products developed. A detailed ecological characterization of the GYA will be presented and will include comprehensive descriptions of landscape level ecological unit features and attributes as well as a method for characterizing the ecological features of component watersheds. The products shown will also demonstrate the use of Landtype Association mapping to model general basin morphometric properties (i.e. valley bottom settings, drainage density, stream channel and riparian habitat types) of landscapes and their component watersheds. It then expands the displays and discussion to represent how LTA's can be applied to model and pre-map interpretations such as susceptibility to erosion, sediment transport regimes, and fisheries habitat potential. This presentation will include: Map posters, a demonstration of the Interagency GYA CDROM; a demonstration of the Region 1 LTA CDROM publication which includes GIS coverages and electronic documentation of map unit descriptions; and a demonstration of the valley-bottom mapping, watershed classification, and erosion/sediment production spatial modeling tools. Methods for the development of the map units (Section, Subsection, Landtype Associations) will also be covered and copies of the CDROMS will be available.

FR Map – Custom ArcView Mapping using the NHFEU (LTA)

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FR_Map is a Division of Forestry mapping package customized using ESRI's ArcView GIS Software. It allows the user to automatically generate a color, poster-size map of any unit at any level in the National Hierarchical Framework of Ecological Units (NHFEU) system. Maps of NHFEU units (LTAs) can be automatically generated in a color, page-size format. A wide variety of backdrops can be used for mapping. These include: land cover (from the Wisconsin Statewide Landcover initiate — WISCLAND) using a forestry colorization; United States Geological Survey (USGS) Digital Raster Graphics (DRGs); a hillshade derived from 30m horizontal resolution Digital Elevation Model (DEM) data and boundaries of the NHFEU system units. FR_Map includes custom extensions to perform the following tasks: label a variety of predefined features; save, load and modify image legends; automatically generate tables of appropriate scale for the various subject themes and modify environment variable files for data sharing.

IV. ROUNDTABLE DISCUSSION AND SUMMARY

Roundtable Discussion and Summary

Connie Carpenter[1]

Abstract

The conference roundtable discussion resulted in the identification of a variety of needs regarding the ECOMAP program in the Northeastern Area. These include:

- ♦ Provide training on existing applications of LTAs to natural resource managers.
- ♦ Develop new applications of LTAs.
- ♦ Provide guidelines to standardize mapping and attribution of ecological units and database development.
- ♦ Support efforts to further clarify the relationships between spatial patterns contained in LTAs and ecological processes operating at the landscape scale.
  Market the use of LTAs to other states and disciplines (wildlife, conservation, forest health, fire risk-mapping, naturalists).
- ♦ Inform decisionmakers of the benefits of using LTAs.

Roundtable Discussion Group Outcomes

Group I

Question 1.—What do we feel confident about Land Type Association Development and Use?
(bullets reflect flip chart summary: moderator explanation)

- Multiple Scales/Nesting Hierarchy: It is important that LTAs are part of a nested hierarchy so what can apply up and down the scales.
- Good landscape level framework: LTAs are good landscape level framework; this level has very relevant application for resource management decisionmaking.
- Repeatability (or not): It appears that most LTA projects are taking the same approach in development, with geomorphology being an overriding differentiating criteria that is refined using soil and vegetation information. We are not sure how much others believe in the repeatability.
- Information management template: LTAs are an effective and cost saving template for resource information management.
- Cost effective (or not): They help identify and prioritize issues, thus saving time and money.
- Resource management priorities: LTAs are a good framework for identifying resource management priorities.
- Their use in land use and forest planning: LTAs have excellent potential for land use and forest planning.
- Their use encourages cooperation among divergent interests.
- LTAs are a communication tool.

Question 2.—What areas need further exploration; in what areas are further research and management testing needed?

- We need to apply, demonstrate, advertise and market LTA use.
- Applications (some applications worth pursing include fire disturbance potential, land use planning, information management and cost effectiveness).
- Repeatability of mapping (at a given scale?).
  - › Scale (of mapping?).
  - › Who should develop standards?

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- Standards would help:
  - › ensure and communicate repeatability
  - › establish mapping scale
  - › address size limits
  - › identify differentiating criteria
  - › Standards should be flexible
- Linking science to management to policy.
- We need more information management research.
- Geomorphic conditions need to be clearly tied to processes that they are a surrogate for.

Question 3.—What issues and opportunities do ECOMAP partners want to focus on first?

- Identify and pursue key applications and market them.
- ECS applications to stewardship plans.
- Identify key applications and act on them: demonstrate/advertise/market them.
- Provide clear documentation: Provide documentation that is clear about the science and art of mapping LTAs.
  - › Metadata
  - › Science and art.
- Provide clear interpretations.
- Develop communication tools such as:
  - › Website (supporting interactive displays).
  - › Newsletter.
  - › Conference.
- Integrate terrestrial and aquatic ecological classification.
- Establish an Ecological Classification System/Forest Inventory and Analysis linkage.
- Need more partners
  - › NPS and interpretive opportunities.
- Soil survey updates and ECS
- National coordination

Group II

Question 1.—What do we feel confident about Land Type Association Development and Use?

- They capture patterns at the landscape level and processes.
- Enough people are doing this we could work on standardizations.
- They are able to depict capabilities at the landscape level.
- There are strong benefits to having states work on land type associations mapping and development.
- Pleased with the similarities among independent efforts.
- National standards seem achievable if they are appropriate, not prescriptive.
- They already seem to have a level of acceptance for mid-scale planning.
- Current applications are strong.
- They are better for some studies than township and county boundaries that are currently used.
- There is tremendous potential for stratifying studies (e.g. biological studies of anticipated versus actual population densities, and wildlife research).
- We can improve land type association mapping and applications over time and we want to.
- There is good interagency and state/federal acceptance of them.
- They have practical uses in identifying hydrological relationships.

Question 2.—What areas need further exploration; in what areas are further research and management testing needed?

- Unclear on the objectives of pulling together across large areas.
- Need to examine if we really captured and validated processes (hydrologic relationships etc.).
- How do hydrologic relations interact up and down the hierarchy?
- Demonstrate the relationship among ecosystem components within land type associations.
- Need to learn how to look at functions and processes.
- Need to learn how to transfer information on functions and processes to users.

- Need a standardized data model linked to the national hierarchy structure.
- A relational database behind the model, and a repository at the national level perhaps a FGDC (Federal Geographic Data Committee) issue.
- Need national standards for mapping at regional and LTA level.
- What is TERRA?
- Keep the system dynamic.
- No clear leadership in the Eastern United States.
- Development and interpretation right now is an agonizingly slow process, we need to get something out there for people to use.
- Develop management interpretations.
- Seek broad national standards and consistency across the province level.
- Link Land Type Associations to the Montreal Process Indicators.
- Once you have Criteria and Indicators (C&I) for a unit you can establish performance measures.
- Support modeling approaches and testing.
- Repeatability issues.
- Standardize names/nomenclature.
- Need to get it out to the field.

Question 3.—What issues and opportunities do ECOMAP partners want to focus on first?
(list developed by voting for items in Question 2, items grouped after conference)

- Need to get the technology out to the field (***11 votes).***
- Develop management interpretations (***10 votes***). Need to learn how to transfer information on functions and processes to users (***1 vote***). Development and interpretation right now is an agonizingly slow process, we need to get something out there.
- Standardized data model linked to the national hierarchy structure, relational database behind the model, and repository at the national level perhaps FGDC. ***(7 votes).*** Standardize names/nomenclature (***1 vote***). What is terra.
- Need to learn how to look at functions and processes ***(7 votes***). Haven't demonstrated relationship among ecosystem components within land type associations. (***1 vote***).
- National standards for mapping. Regional standards and LTA standards ***(5 votes***). Keep the standards dynamic so you don't stifle integration of new concepts and technogical innovation. No clear leadership in the Eastern United States (states currently developing own standards and guidelines) (***1 vote***). Seek broad national standards and consistency within Provinces of the Hierarchy. Support modeling approaches and testing. Address repeatability issues.
- Need to examine if we really captured and validated processes (***3 votes***).
- How do hydrologic relations interact up and down the hierarchy. (hydrologic relationships etc.) ***(2 votes***).
- Support modeling approaches and testing. (***2 votes***)
- Unclear on the objectives of pulling together across large areas.
- Link Land Type Associations to the Montreal Process Indicators. Once you have Criteria and Indicators for a unit you can establish performance measures.

Consensus Issues And Opportunities To Focus On First

Priority I

Get information on the value and uses of Land Type Associations out to the field.

How

a) Identify and support champions, (e.g. overcome time limitations etc.).
b) Institute technology transfer training opportunities.
c) Get federal seed money to develop training.
d) Develop strategies to meet the needs of the following target audiences:
   a. *Senior managers*: inform them of the environmental and economic benefits of using LTAs so they provide needed staff time and budgets.
   b. *Managers in the field*: provide examples of improved decisions and operating efficiency so they benefit from using Land Type Associations and support staffing and funding decisions that give development and interpretation higher priority.
   c. *Non-industrial private forest land owners*: Provide information on land Type associations so land owners are aware of the big picture and the contributions of their actions.
e) Establish a web site.
f) Establish a user forum.

Priority II

Develop management applications of LTAs.

How

a) Get federal seed money to states to interpret Land Type Associations
b) Establish demonstration projects of LTA applications (e.g. field people use the units in a planning application).

Priority III

Provide National Standardization for mapping, attribution, and data storage.

How

a) Formalize state-federal cooperation on TERRA, the USFS corporate database for terrestrial ecological classification data.
b) Conduct tests of an automated approach to Land Type Association Mapping.
c) Develop a spatial data model.
d) Identify the appropriate data depository for Land Type Association Maps and attributes.

Written Comments Submitted

Question 1.—What do we feel confident about Land Type Association Development and Use?

- That they will continue to be used. That geomorphology will and should continue to be a major delineating factor. That more and more people and agencies will see the need for them and their utility.

- If the development relies upon a hierarchical approach with multifactor delineation criteria then:
  › Approach provides a consistent mapping/inventory strategy across regional and national landscape.
  › Provides a means for a lasting base inventory.
  › Helps identify and describe important ecological structures, functions and processes.
  › Helps increase understanding across broad regional areas.
  › Can assist other resource inventories — establish interrelationships.

Question 2.—What areas need further exploration; in what areas are further research and management testing needed?

- Stress the importance of standards for Land Type Associations. Otherwise, they will not be defensible and scientifically repeatable. There is too much reinventing the wheel.
- Problems in size/area of LTAs: e.g. Lake States 10,000 to 300,000 acres; New Jersey minimum of 500 acres. Are New Jersey LTAs really land types?
  - › If we don't have size standards we won't be able to communicate.
  - › Small LTAs are too small to be landscapes.
- Emphasis now is on different delineating criteria for different scales. Need more emphasis on ecological processes.
- Where does present land use delineation come into play? For example, intensive oil and gas development of hundreds to thousand of acres. These areas are impacted for many years. Some impacts may last for many decades.
- Document the history of land type association mapping and use that includes information from other countries.
- Research needs might include learning more about disturbance regimes. Also, in areas whose disturbance regimes cross LTAs, should that change LTA boundaries or should it be an overlay?
- Other research management testing needs include looking at threatened and endangered plants and animals.
- Desperately need further quality control (correlations documentation, map matching, reporting, data base) approached between LTA inventory areas.
- Validating interrelationships or management interpretation: hydrologic response, wildlife/fish habitat qualities, site potentials, etc.
- Identifying appropriate management interpretations at appropriate scales.
- Identify/approve/implement LTA standards across the nation.

Question 3.—What issues and opportunities do ECOMAP partners want to focus on first? How?

- It would seem like a good idea to try to work with and help non-Forest Service partners to put these LTAs to good use. It seems important that the LTA not be a Forest Service product. However, the issues and opportunities I see revolve around forest planning, forest plan revision as well as smaller scale planning efforts.
- Also need to highlight appropriate/optimal use of LTAs in watershed analyses. When are LTAs and when are watersheds the better base map to use for analysis?
- Need a common definition of terms
- Common acceptance of a hierarchical inventory approach with appropriate scales and applications of management interpretations.
- Resolutions of difference between landscape inventory approaches (EPA-Bailey) so there is more unity in landscape mapping and inventory.
- How?
  - › Need multiagency/landowner agreement (National, Regional, Local).
  - › Need working groups to begin to resolve difference in *ideals,* get strategy approaches, standards, etc.
  - › Need to make our successes more visible.
  - › Need to incorporate other resource specialists in development of interrelationships/ interpretations. This will broaden the support group.
  - › Need to reach out and get the most skilled personnel to help with working groups regardless of grade and location.
  - › Need to have higher priority for national funding.

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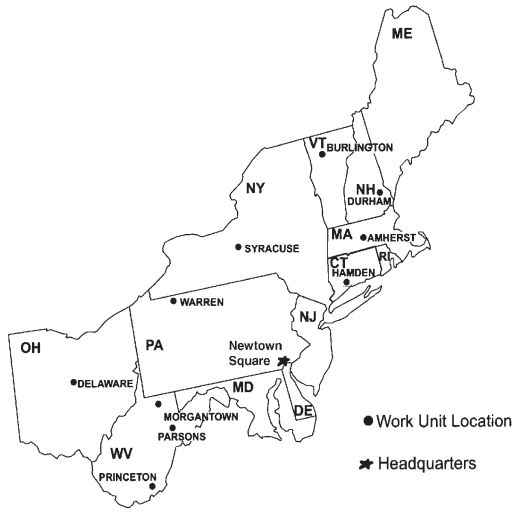

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