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.

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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.

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, ELTand 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 complementarity 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 (mi^2& km^2) 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. Secondly, 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. Thirdly, 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.

LITERATURE CITED

Bailey, R. G. 1995. Descriptions of the ecoregions of the United States. USDA, Forest Service, Misccellaneous Publication 1391 (rev.), Washington, D.C.

Berg, T. M., Barnes, J. H., Sevon, W. D., Skema, V. W., Wilshusen, J. P., and Yannacci, D. S., compilers, 1989, Physiographic provinces of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 13, 1:2,000,000 scale.

ECOMAP, 1993, National Hierarchial Framework of Ecological Units. USDA Forest Service, Washington, D.C., 20 p.

Godfrey, A. E., and Cleaves, E. T., 1991, Landscape analysis: theoretical considerations and practical needs: Environmental Geology and Water Science, v. 17, no. 2, p. 141-155.

Myers, W. L., 2000, Landscape scale ecological mapping of Pennsylvania forests: Environmental Resources Research Institute, Pennsylvania State University, University Park, PA ER2002 17 p.

Sevon, W. D., 1997, Geologically correct topography of Pennsylvania: Geological Society of America Abstracts with Programs, v. 29, no. 6, p. A37-A38.

Sevon, W. D., 1998, Landform map of Pennsylvania: Geological Society of America Abstracts with Programs, v. 30, no. 1, p. 73.

Sevon, W. D., and Hoskins, D. M., 1999, Ecological forest management and the landform map of Pennsylvania: Geological Society of America Abstracts with Programs, v. 31, no. 7, p. 484.

Sevon, W. D., compiler, 2000, Physiographic provinces of Pennsylvania: Pennsylvania Geological Survey, 4th ser., Map 13, 4th ed., 1:2,000,000 scale.