LAND CLASSIFICATION OF THE STANDING STONE STATE FOREST AND STATE PARK ON THE EASTERN HIGHLAND RIM IN TENNESSEE: THE INTERACTION OF GEOLOGY, TOPOGRAPHY, AND SOILS

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Abstract—This paper summarizes the application of a land classification system developed by the senior author to the Standing Stone State Forest and State Park (SSSF&SP) on the Eastern Highland Rim. Landtypes are the most detailed level in the hierarchical system and represent distinct units of the landscape (mapped at a scale of 1:24,000) as defined by climate, geology, soils, topography, and vegetation. The area is highly dissected with local relief of about 1,000 feet. Mississippian and Ordovician strata are essentially level bedded; defining elevations were assigned. Suites of soils are common to the nine strata, and a group of landtypes was defined for each geologic strata/soils combination. Each of the 19 landtypes is described in terms of 9 elements. Additional information includes species suitability, site productivity, and operability for management activities. The maps aid the delineation of stands, streamside management zones, and "conservation" and other special use areas; the location of rare, threatened and endangered (RT&E) species; the design of harvests; and the modeling of future forest conditions. The landtypes are an integral element in modeling wildlife habitat, in siting game food plots, and planning other wildlife management activities. The maps are excellent training devices and extremely useful in explaining management plans to legislators and the public.

INTRODUCTION

The Tennessee Division of Forestry (TDF) has adopted a land classification system developed by the senior author (Smalley 1991b) as the basic theme of information for the management of its 15 State forests (SF). At least one SF occurs in each of eight physiographic provinces—Southern Appalachian Mountains, Ridge and Valley, Cumberland Plateau, Eastern Highland Rim, Nashville Basin, Western Highland Rim, Upper Coastal Plain, and Mississippi Embayment. In this paper we describe how the system was applied to the Standing Stone State Forest and State Park (SSSF&SP) located on the Eastern Highland Rim.

THE LAND CLASSIFICATION SYSTEM

Initially, the land classification system was developed for the 29 million acres of the Cumberland Plateau and Highland Rim/Pennyroyal Physiographic Provinces in parts of Alabama, Georgia, Tennessee, Kentucky, and Virginia (Smalley 1986, Smalley and others 1996). The system was adapted from Wertz and Arnold's (1975) Land System Inventory. The system can best be described as a process of successive stratifications of the landscape. Stratifications are based on the interactions and controlling influences of ecosystem components—physiography, climate, geology, soils, topography, and vegetation. Macroclimate does not vary much across both physiographic provinces, but microclimate varies because of local relief. Since the current species composition and structure of rim and plateau forests was more a function of repeated disturbances than an indication of succession and site potential, vegetation was relegated to a minor role in the development of the land classification system (Delcourt 1979). Application of the system to other physiographic provinces represents an extension of the original concept (Smalley 1991a).

EASTERN HIGHLAND RIM

The Eastern Highland Rim (Pennyroyal in Kentucky) (EHR) region covers about 11,440 square miles extending from Louisville, KY, through Tennessee, to Russellville, AL (Smalley 1983). In Tennessee the EHR includes the upland surrounding the Nashville Basin on the east and the knobby transition from the rim to the basin (Edwards and others 1974, Fenneman 1938, Springer and Elder 1980). It is bounded on the east by the ragged western escarpment of the Mid-Cumberland Plateau (Smalley 1982). The division between the EHR and the Western Highland Rim (Smalley 1980) is somewhat arbitrary, defined mostly on the basis of soils.

Compared with the National Hierarchical Framework of Ecological Units (Avers and others 1993, Bailey and others 1994, Cleland and others 1997), the EHR is equivalent to the Eastern Karst Plain Subsection (223Eb) of the Interior Low Plateau-Highland Rim Section (223E) of the Central Interior Broadleaf Forest Province (223) (Cleland and others 2007).

SPECIFIC LOCATION

The SSSF&SP is in Overton and Clay Counties (36°27' N, 85°27' W) along the western edge of the Eastern Highland Rim. It falls into two subregions—the Highland Rim Plateau and the Transition to the Nashville Basin (Smalley 1983) (fig. 1). Two land type associations are represented—LTA-A Strongly Dissected Plateau and LTA-E Tennessee Knobs.

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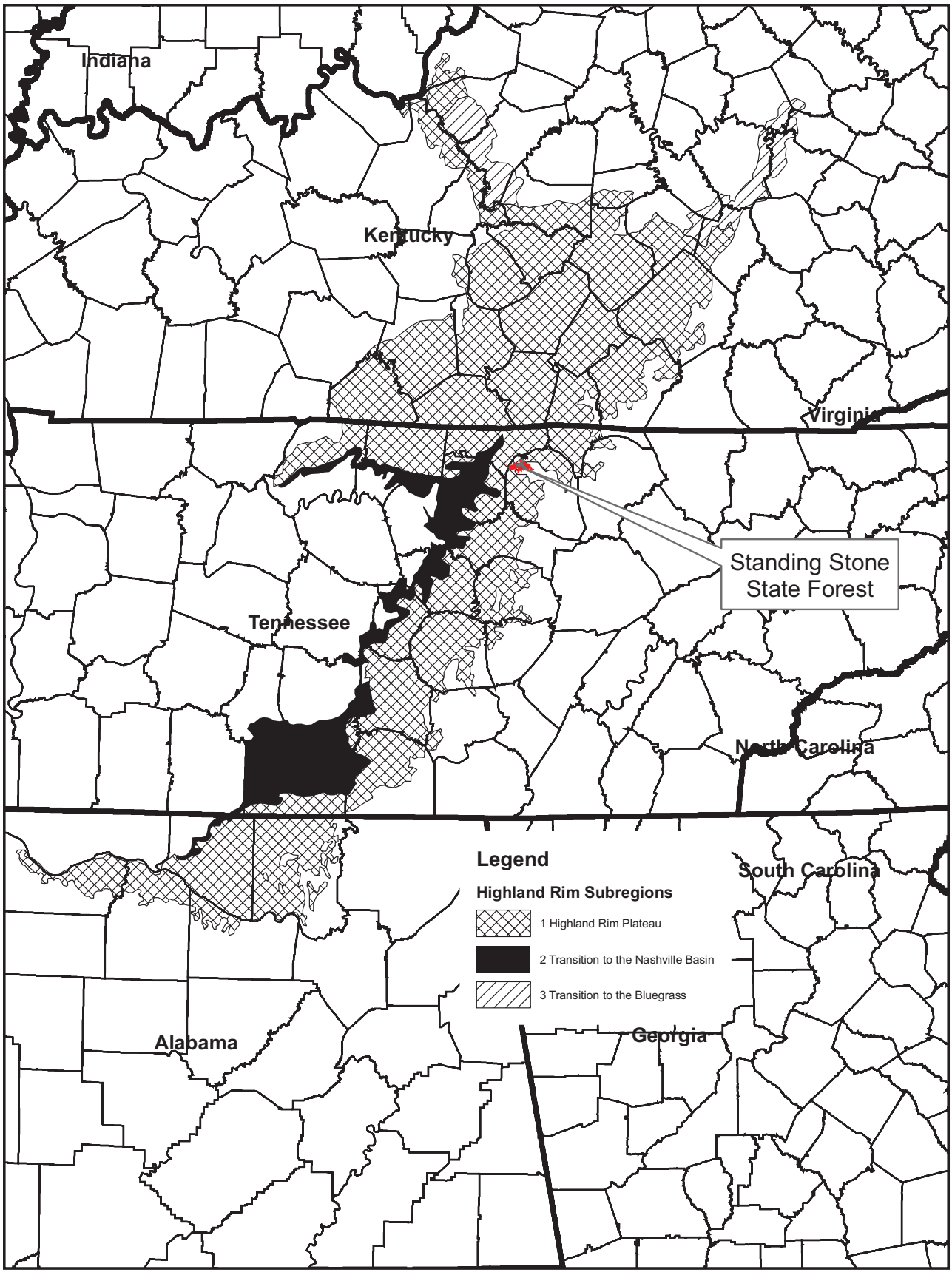

Figure 1—Location of Standing Stone State Forest and State Park in relation to the subregions of the Eastern Highland Rim.

The SSSF&SP lies between the communities of Hilham on the south, Timothy on the north, and Allons on the east. Livingston, the county seat of Overton County, is about 5 miles to the southeast and Celina, the county seat of Clay County, is about 6 miles to the northwest.

THE FOREST

The SSSF&SP consists of acreage purchased by the Resettlement Administration of the Federal Government beginning in 1935. In 1939 the U.S. Department of Agriculture leased the acquired land to the State of Tennessee, Department of Conservation, Division of Parks. The land was deeded to the State in 1955. In 1961, by agreement, the administration of 8,490 acres was transferred to the Division of Forestry (Standing Stone State Forest) and 855 acres (Standing Stone State Park) was retained by the Division of Parks. The cleared lands were eroded due to extensive row cropping and poor farming practices. The forests had been extensively logged (mostly high-grading) and burned. The park area was developed by the Civilian Conservation Corps in the 1930s and early 1940s. Recent surveys show the forest is 8,445 acres in extent, and the park is 865 acres for a total of 9,310 acres. Two in-holdings total 136 acres. The SSSF&SP occur on two U.S. Geological Survey quadrangle maps: Hilham and Livingston. The gross area mapped was 22,247 acres; 19,627 (88 percent) occurs on the Hilham quad and 2,620 acres (12 percent) occurs on the Livingston quad.

CHARACTERISTICS OF THE FOREST AND PARK

Geology

Stratigraphy was obtained from the geology maps for the Hilham and Livingston quads (scale 1: 24,000) (Wilson 1968, Wilson and Colvin 1968). These strata are essentially level-bedded, and defining elevations can be assigned (fig. 2). Most of the strata are of Mississippian age (estimated ≥325 million years BP). The Pennington Formation and Bangor Limestone (mostly limestones with some shale) occupy the highest parts of the landscape (east side of SSSF&SP) on Reynolds Mountain above an elevation of 1,440 feet. The nearly flat-to-rolling terrain in and around Allons on the Livingston quad and the higher ridges (mountains) on the Hilham quad are capped with the Hartselle Formation (primarily sandstone), locally known as Brotherton Bench. Elevation is between 1,300 and 1,440 feet. Below 1,300 feet is the Monteagle Limestone, and below 1,110 feet is the St. Louis Limestone and Warsaw Formation. Topography over these three strata is undulating to rolling combinations of ridges and slopes. The Fort Payne Formation occurs between 1,100 and 900 feet. Mill Creek (Hilham quad) has carved into the Leipers and Catheys Formations of Ordovician age as far upstream as the dam forming Standing Stone Lake. These two formations consist of calcarenite, some phosphate pellets, and fine-grained limestone (argillaceous, nodular, and shaly). These Ordovician rocks are visible only in the bed of Mill Creek; elsewhere they are covered with alluvium.

Topography and Drainage

The highly dissected nature of the area results in a local relief of slightly over 1,000 feet (fig. 2). Elevation of Reynolds Mountain just east of the forest boundary is 1,620 feet. Goodpasture, Wilson, and Cooper Mountains exceed 1,400 feet. Landforms range from broad ridges with rolling sideslopes to very steep lower sideslopes. Bottoms are fairly broad. The area is drained by Mill Creek and Right Fork and their tributaries. These streams empty into the Cumberland River (Cordell Hull Lake—pool level is 504 feet) near Butler's Landing in Clay County about 56 miles upstream from Cordell Hull Lock and Dam. Standing Stone Lake, an impoundment on Mill Creek has a pool level of 726 feet. The bottom along Mill Creek below the dam has an elevation of about 600 feet. Slopes, particularly those over the Fort Payne formation, are very steep. Sinkholes, some quite large and deep, are common.

Soils

The Tennessee General Soil Map (Scale 1: 750,000) (Springer and Elder 1980) shows the SSSF&SP to be in general soil association H21 (Bouldin-Rock outcrop-Ramsey) which is equivalent to land type association C-Strongly Dissected Margins and Sides of the Cumberland Plateau. This anomaly happens because soils formed from the Hartselle Formation are similar to soils occurring on the Cumberland Plateau. In reality the ragged western escarpment of the Cumberland Plateau lies several miles to the east. As stated earlier, the SSSF&SP is situated on the Eastern Highland Rim at the transition to the Nashville Basin.

Five soil associations are common to this geologic diverse area (McCowan 2005, Krantz and McCowan 2006). The Christian-Sengtown association consists of deep and very deep, rolling-to-steep well-drained soils formed in residuum from cherty limestone. Minor soils are Talbott, Minvale, and Waynesboro. The Nella-Talbott-and similar soils association consists of very deep and moderately deep, rolling-to-very steep well-drained soils formed in colluvium and residuum from limestone. Minor soils are Bouldin and Etowah. The Gilpin-Shelocta-and similar soils association consists of moderately deep and deep, rolling-to-very steep well-drained soils formed in residuum from cherty limestone and siltstone. Minor soils are Bouldin, Ramsey, and Lily. The Lonewood-Clarkrange association consists of deep and very deep, undulating-to-rolling, well-drained, and moderately well-drained soil formed in loess and residuum from sandstone. Minor soils are Lily and Ramsey. The Garmon-Newbern association consists of moderately deep-to-shallow, steep to very steep, well-drained, and somewhat excessively drained soils formed in residuum from calcareous shale. Minor soils are Humphreys, Ocana, and Christian. These soils represent four orders—Alfisols, Inceptisols, Mollisols, and Ultisols. The taxonomic classification of these soils is shown in table 1.

Climate

Surface weather data were obtained from the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center for weather station 405332, Livingston, TN, from 1971 to 2000 (National Climatic Data Center 2004). Average annual precipitation is about

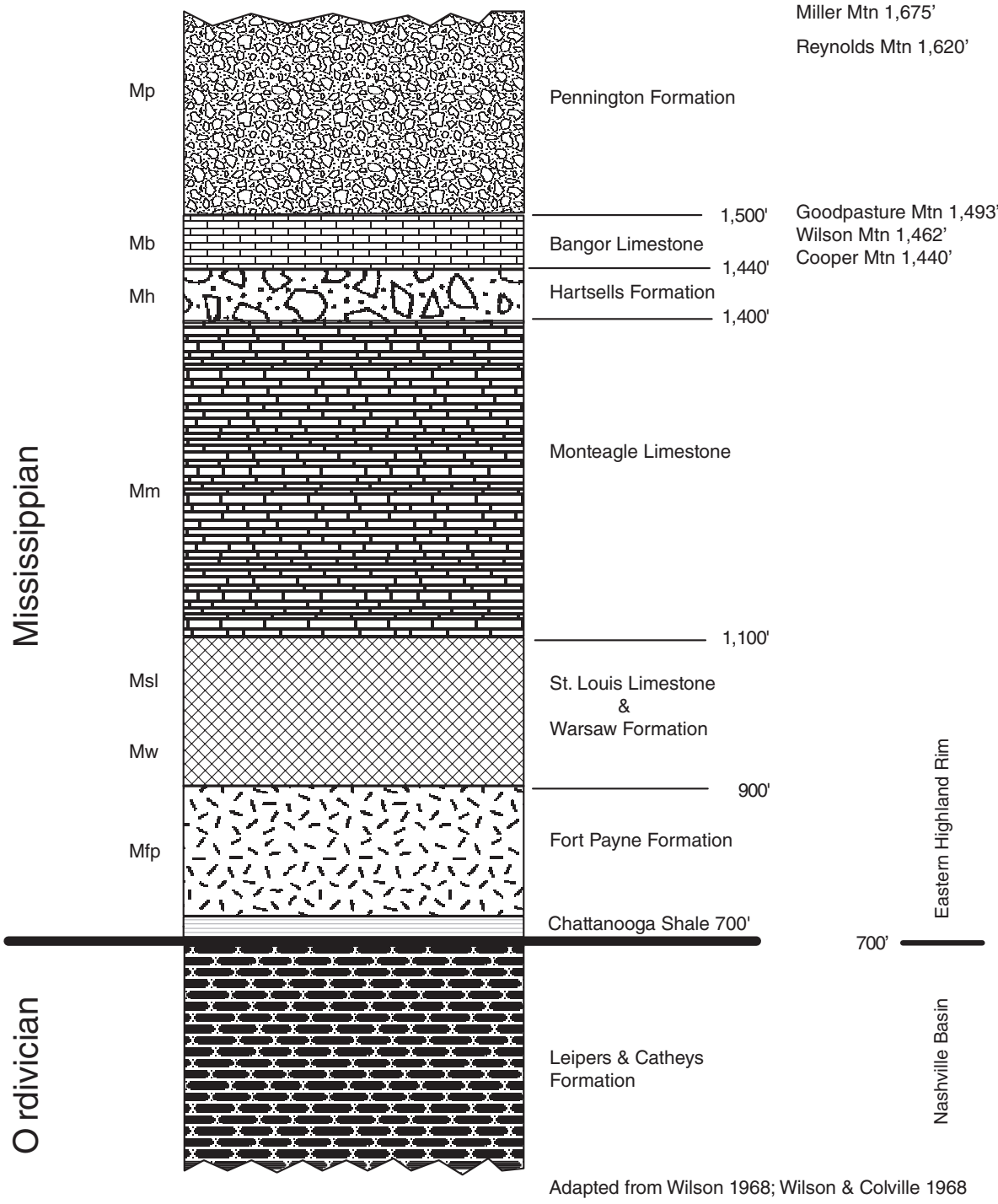

Figure 2_Stratigraphy of the Eastern Highland Rim in the vicinity of Standing Stone State Forest and State Park.

52.59 inches of which 34.41 inches fall in the April through October growing season. The average snowfall is 9.3 inches. The average winter temperature is 40.4 °F and the average daily minimum is 28.8 °F. The record low is –25 °F recorded on January 21, 1985. The summer average daily temperature is 73.1 °F; the average daily maximum is 85.1 °F.

Humidity, sunshine, and wind data are reported in the Clay County soil survey (Krantz and McCowan 2006). Average relative humidity in midafternoon is 57 percent. Humidity is higher at night and averages about 84 percent at dawn. Cloud-free days occur 64 percent of the time in summer and 43 percent in the winter. The prevailing wind is from the south. Average wind speed is highest, about 10 miles per hour from December to April.

Table 1—Taxonomic classification of soils common to Standing Stone State Forest and State Park

Order/Suborder/great group/series	Family/taxonomic class
Alfisols	
Udalfs	
Hapludalfs	
Talbott	Fine, mixed, semiactive, thermic Typic Hapludalfs
Paleudalfs	
Sengtown	Fine, mixed, semiactive, thermic Typic Paleudalfs
Inceptisols	
Aquepts	
Endoaquepts	
Melvin	Fine-silty, mixed, active, nonacid, mesic Fluvaquentic, Emdoaquepts
Udepts	
Eutrudepts	
Sullivan	Fine-loamy, siliceous, active, thermic Dystric Fluventic Eutrudepts
Ocana	Fine-loamy, mixed, active, thermic Dystric Eutrudepts
Hamblen	Fine-loamy, siliceous, semiactive, thermic Fluvaquentic Eutrudepts
Garmon	Fine-loamy, mixed, semiactive, mesic Dystric Eutrudepts
Newbern	Loamy, mixed, active, mesic Lithic Eutrudepts
Ochrepts	
Dystrudepts	
Ramsey	Loamy, siliceous, subactive, mesic Lithic Dystrudepts
Mollisols	
Rendolls	
Rendolls	
Gladeville	Clayey-skeletal, mixed, active, thermic Lithic Haprendolls
Udolls	
Hapludolls	
Barfield	Clayey, mixed, active, thermic Lithic Hapludolls
Ultisols	
Udults	
Fragiudults	
Clarkrange	Fine-silty, siliceous, semiactive, mesic, Typic Fragiudults
Hapludults	
Alticrest	Coarse-loamy, siliceous, semiactive, mesic Typic Hapludults
Lily	Fine-loamy, siliceous, semiactive, mesic Typic Hapludults
Lonewood	Fine-loamy, siliceous, semiactive, mesic Typic Hapludults
Christian	Fine, mixed, semiactive, mesic Typic Hapludults
Sequoia	Clayey, mixed, active, mesic Typic Hapludults
Paleudults	
Bouldin	Loamy-skeletal, siliceous, subactive, mesic, Typic Paleudults
Nella	Fine-loamy, siliceous, semiactive, thermic Typic Paleudults
Minvale	Fine-loamy, siliceous, subactive, thermic Typic Paleudults
Waynesboro	Fine, kaolinitic, semiactive, thermic Typic Paleudults

Source: Soil Survey Staff (2008). Official soil series descriptions. http://ortho.ftw.nrcs.usda.gov/ogi-bin/osdname.cgi. [Date accessed: September 15, 2008, verified November 20, 2008].

Vegetation

The Eastern Highland Rim forests are part of the broad oak-hickory forests (western mesophytic/oak-hickory forests) region described by Bryant and others (1993). Delcourt and Delcourt (2004) concluded that oak-hickory forests are prevalent on the more xeric sites with more mesic species, similar to those in the mixed mesophytic forests further east on the Cumberland Plateau escarpment and in the Cumberland Mountains, and occur on cool slopes and in the gorges along the escarpment into the Nashville (central) Basin in Tennessee. Species distribution on the SSSF&SP is governed by slope, aspect, soil depth, soil moisture, and geologic substrate. Considerable acreage is occupied by 50- to 70-year-old forests resulting from old-field succession.

LAND TYPES

Nineteen land types were identified and mapped on the extended area of SSSF&SP (table 2). Because of the close association of geology and soils, a group of land types was defined for each geologic strata/soils combination. Land types were numbered sequentially according to elevation—highest to the lowest.

Table 2—Land types of the Eastern Highland Rim occurring on Standing Stone State Forest and State Park

Land type number	Land type name	Acres	Percent of the total acres
	Land types over the Pennington Formation and the Bangor Limestone		
1	Broad limestone ridges	22	0.1
2	North-facing shaly limestone slopes	68	0.3
3	South-facing shaly limestone slopes	43	0.2
	Land types over the Hartselles Formation		
4	Undulating sandstone uplands	811	3.6
5	Narrow to moderately broad sandstone ridges	228	1.0
6	Shallow soils and sandstone outcrops	44	0.2
7	Depressions, flats, and sinkholes	39	0.2
	Land types over the Monteagle Limestone		
8	Narrow to moderately broad limestone ridges and spurs	1,286	5.8
9	North-facing limestone slopes	2,042	9.2
10	South-facing limestone slopes	994	4.5
11	Depressions and sinkholes	281	1.3
	Land types over the St. Louis Limestone and Warsaw Formation		
11	Depressions and sinkholes (see above)		
12	Narrow to broad limestone ridges and knobs	6,987	31.4
13	North-facing limestone slopes	1,675	7.5
14	South-facing limestone slopes	1,409	6.3
	Land types over the Ft. Payne Formation		
15	North-facing shaly slopes	2,632	11.8
16	South-facing shaly slopes	2,732	12.3
	Stream and creek bottoms		
17	Stream and creek bottoms with good drainage	837	3.8
18	Stream and creek bottoms with poor drainage	25	0.1
	Miscellaneous landforms		
19	Water—lakes, ponds, and streams	90	0.4
	Total	22,245	100.0

Land types 1, 2, and 3 are common to the Pennington Formation and Bangor Limestone. Land types 4, 5, 6, and 7 are common to the Hartselle Formation. Land types 8, 9, 10, and 11 are common to the Monteagle Limestone. Land types 11, 12, 13, and 14 are common to the St. Louis Limestone and Warsaw Formation. Land types 15 and 16 are common to the Fort Payne Chert. Land types 17 and 18 are creek and stream bottoms with good and poor drainage, respectively. All bodies of water (ponds, lakes, and streams) are assigned LT-19. Descriptions of the two most extensive land types are shown in table 3.

APPLICATIONS OF THE LAND CLASSIFICATION SYSTEM

Earlier research on the Cumberland Plateau showed that the land classification system divided the Prentice Cooper State Forest landscape into distinct ecological units with relative discreet plant communities (Arnold and others 1996). Additionally, the system grouped soils on the Catoosa Wildlife Management Area into landforms units having relative homogeneous chemical and physical properties (Hammer and others 1987). The utility of the system for all six SFs on the Cumberland Plateau has been reported (Smalley and others 2006). Plant community-landform relations have been studied at two locations on the Western Highland Rim (Clatterbuck 1996, Wheat and Dimmick 1987).

Cleland and others (2007) listed ecosystem mapping, resource assessments, environmental analyses, watershed analyses, desired future conditions, resource management, and monitoring as uses of the National Hierarchical Framework of Ecological Units system. These uses also apply to Smalley's system. Currently, TDF is focusing on ecosystem delineation, resource assessment, desired future conditions, and resource management and monitoring (Smalley and others 2006). Much more data need to be obtained before meaningful environmental and watershed analyses can be made.

Current Uses

Each SF is divided into compartments consisting of groups of stands averaging approximately 1,000 ± acres. Compartment plans are written to meet multiple use, broad landscape scale goals. The individual stand silviculture prescriptions are developed to be congruent with the overall compartment and forest level goals.

Stand delineation—Stands (silvicultural management units) are delineated at the same scale as the landtype maps (1:24,000). They have similar forest type and productivity and may range in size from 5 to 40 acres with the average being 23 acres. Stand delineation is the result of a combination of considerations. While the primary objective is to create

Table 3—Example of the information found in the land type descriptions

Description of Land type 12: narrow to moderately broad limestone ridges and knobs over the St. Louis Limestone and Warsaw Formation
Geographic setting: Deep to very deep, gravely silt loam to gravely clay soils on gently sloping to strongly sloping narrow to moderately broad ridges and knobs over the St. Louis Limestone and Warsaw Formation. Slope generally ranges from 5 to 12 percent on the moderately broad ridges but may be as much as 20 percent on the narrow ridges and knobs. Elevation ranges from 900 to 1,100 feet. Land types 8, 9, and 10 over the Monteagle Limestone occur above LT-12. Land types 15 and 16 over the Fort Payne formation occur below LT-12. This land type is dotted with artificial ponds, sinks, and depressions. There is no comparable land type in the guide for the Eastern Highland Rim (Smalley 1983). Land type 12 is the most extensive land type. Seventy-seven units were mapped; 75 (6,684 acres) on the Hilham quad and 2 (303 acres) on the Livingston quad. Altogether 6,987 acres were mapped constituting 31.4 percent of the total area.
Dominant soils: Christian, Sengtown, and Waynesboro. Sengtown and Waynesboro soils are very deep (>60 inches) and Christian soils are deep (40 to 60 inches). These soils developed in residuum or old alluvium from cherty limestone with some possible influence from shale and sandstone. Christian and Sengtown soils have mixed mineralogy; Waynesboro soils are kaolinitic. Sengtown and Waynesboro soils have a thermic temperature regime; Christian soils have a mesic temperature regime. Coarse fragment content ranges up to 35 percent, but usually is <15 percent.
Bedrock: shaly limestone, limestone
Depth to bedrock: ≥40 inches
Texture: usually gravely silt loam near the surface, but may lack the gravel in places; grades to gravelly loam and clay in the subsoil.
Soil drainage: well drained, moderately permeable
Relative soil water supply: medium
Soil fertility: moderate
Forest type: mixed oaks, hickories, maples, yellow-poplar, American beech, eastern redcedar, Virginia and shortleaf pines. An extensive acreage south of the forest has been cleared and is currently in pasture or hay.

Legend

Com p 03 Stands

Landtype ID, Landtype Description

1 Broad Limestone Ridges over the Pennington Formation
2 North-facing Shaly Limestone Slopes over the Pennington Formation
3 South-facing Shaly Limestone Slopes over the Pennington Formation
4 Undulating Sandstone Uplands over Hartselles Formation
5 Narrow to Moderate Broad Sandstone Ridges over Hartselles Formation
6 Shallow Soils and Sandstone Outcrops over the Hartselles Formation
7 Depressions, Flats, and Sinkholes over the Hartselles Formation
8 Narrow to Moderately Broad Limestone Ridges & Spurs over Monteagle Limestone
9 North-facing Limestone Slopes over the Monteagle Limestone
10 South-facing Limestone Slopes over the Monteagle Limestone
11 Depressions and Sinkholes in the Monteagle Limestone, St. Louis Limestone
12 Narrow to Moderately Broad Limestone Ridges & Knobs over St. Louis Limestone
13 North-facing Limestone Slopes over the St. Louis Limestone
14 South-facing Limestone Slopes over the St. Louis Limestone
15 North-facing Shaly Slopes over the Fort Payne Formation
16 South-facing Shaly Slopes over the Fort Payne Formation
17 Stream and Creek Bottoms with Good Drainage
18 Stream and Creek Bottoms with Poor Drainage
19 Water Lakes, Ponds, and Streams

Figure 3—Landtypes and delineated stands in compartment 03 on Standing Stone State Forest.

management units of uniform characteristics, many times other needs result in stand boundaries being drawn along roads to facilitate stand access or along streams to reduce stream crossings. Consequently, ridge land types (LTs-1 and 2) and upland hollows (LTs-14 and 15) may be split. Conversely, some individual units of a land type may cover 50+ acres. Stand size for various reasons is typically <40 acres and is primarily restricted to meet compartment goals, allow silviculture prescription on a stand by stand basis, accommodate physical boundaries, and meet certain standards for forest certification. Therefore, several stands may be defined within a single land type unit. Figure 3 shows delineated stands and land types. Note the close agreement between stand and land type boundaries.

An immediate benefit of the land type maps has been to reduce the time required to delineate stand boundaries. Heretofore, stand delineation required several weeks of work. With the availability of land type maps, the task has been reduced to a few days.

Management type determination is characterized by a single forest type, often an association of two or more species where hardwoods are dominant. Because of past abuses, the current forest type may not be the desired management type. The ancillary information about desired species and estimated productivity for each land type enables forest managers to formulate appropriate silvicultural strategies to achieve desired forest conditions.

Future Uses

Predictability of future forest attributes is invaluable to forest managers for making decisions that meet stated objectives and communicate management strategies. Land type information and models have been used to assess current and future forest ecological conditions (Druckenbrod and Dale 2004, Druckenbod and others 2006). Currently, the SF system is embarking on utilizing the U.S. Forest Service's Forest Vegetation Simulator (FVS) (Dixon 2002) and the Landscape Management System (LMS) (McCarter and others 1996, 1997, 1998) to predict future stand, compartment, and forest level conditions in both tabular and graphical forms. Land type information, primarily species composition and productivity, can be utilized in these models to show stand attributes over time. Graphical depiction will help communicate long-term forest management strategies and visual management issues to interest groups, such as, the general public, forest managers, forested landowners, SF users/visitors, State executive managers, and legislative representatives.

Figure 4 is a comparison of species composition and height growth of LT- 6 (low productivity) and LT-15 (high productivity) at ages 5 and 40 years after harvest using the LMS/FVS model. The species composition used for regeneration of each land type was derived from those listed in the description of land types. Site indices used in the LMS/FVS model were derived from site index estimates of these land types located on SSSF&SP. LT-6 is described as shallow soils and sandstone outcrops over the Hartselle Formation. Land type15 is described as north-facing shaly slopes over the Fort Payne Formation. Land type 6 supports poor site mixed oaks and some Virginia pine (*Pinus virginiana* Mill.). Whereas, LT-15 is a good north-facing slope that supports yellow-poplar (*Liriodendron tulipifera* L.), mixed oaks, and trends toward mixed mesophytic species. Height growth is depicted by the forest profile graphics in figure 4. The stadia lines on each side are 70 feet tall. These results illustrate the differences in initial species composition found on different land types, the change in species composition over time, and height growth for these land types.

Just by knowing the land type for each stand, one can roughly model each delineated stand in a forest and follow the stands through time. Treatments can also be applied to graphically examine visual aspects and/or management strategies. Figure 5 is a portion of Standing Stone depicting the visual character of several stands in a landscape view using LMS.

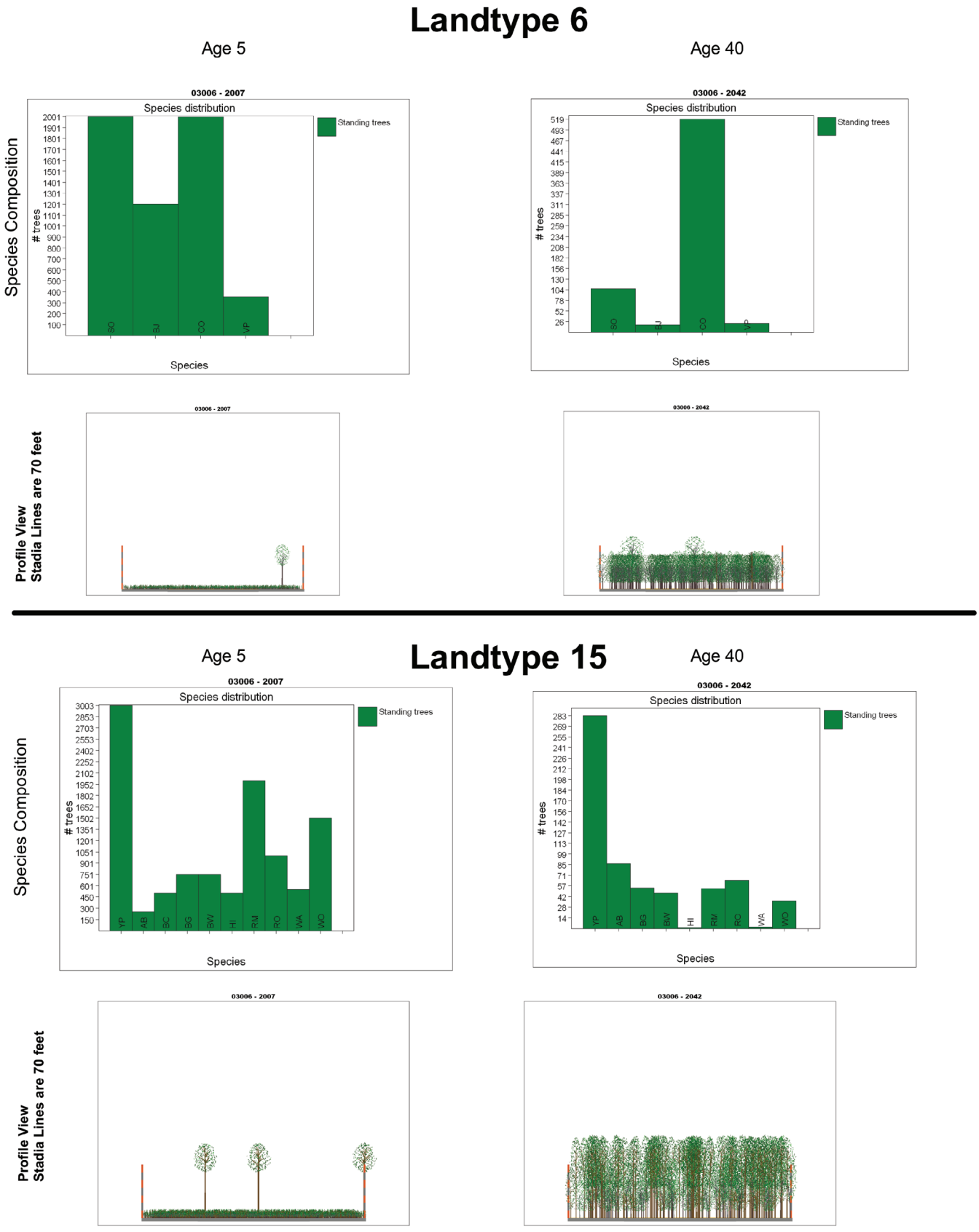

Figure 4—Comparison of species composition and height growth of LT-6 (poor site) and LT-15 (good site) at ages 5 and 40 years following harvest.

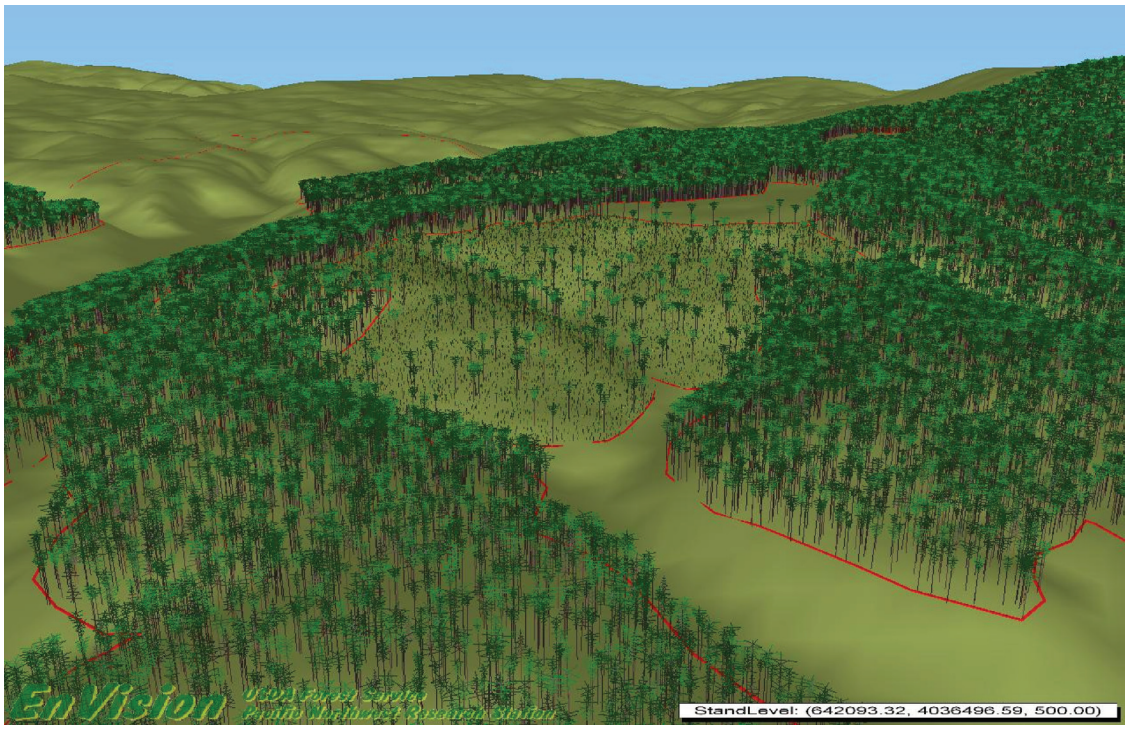

Figure 5—Graphical landscape view of a portion of Standing Stone State Forest using LMS to model stands using landtype information.

ACKNOWLEDGMENTS

We are indebted to W.H. McNab, C.J. Schweitzer, and W.K. Clatterbuck for their insightful suggestions and diligent review of this paper.

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