DEVELOPMENT OF AN ECOLOGICAL CLASSIFICATION SYSTEM FOR THE COOPER CREEK WATERSHED OF THE CHATTAHOOCHEE NATIONAL FOREST: A FIRST APPROXIMATION

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Abstract--The 2004 management plan for the Chattahoochee National Forest states that many future resource objectives and goals have an ecological basis. Assessment of resource needs in the Cooper Creek watershed area of the southern Appalachian Mountains of north Georgia were identified with awareness of ecological constraints and suitability. An interdisciplinary team of resource specialists developed a land-classification system for the watershed that identifies and maps 28 recurring land and water units with unique ecological characteristics. The classification will provide a basis to plan and implement management activities that are appropriate, cost effective, and consistent with views and concerns of a larger community of stakeholders.

INTRODUCTION

The Chattahoochee National Forest (CNF) extends across about 750,000 acres in Appalachian Mountains and Ridge and Valley physiographic provinces in northern Georgia. Beginning in 1911, tracts later designated as the CNF were purchased under the Weeks Act for control of wildfires and management of lands forming watersheds of headwater streams of navigable rivers. These lands, once in a forested condition maintained for thousands of years by natural- and Native American-influenced disturbances, were highly altered at the time of USDA Forest Service acquisition, resulting from subsistence agriculture practices of early European settlers in the 1800s and extensive commercial logging. Loss of the American chestnut [*Castanea dentate* (Marshall) Borkh.] in the 1920s, extensive planting of eastern white pines (*Pinus strobus* L.) through the Civilian Conservation Corps program in the 1930s, and most recently the gradual demise of eastern hemlock [*Tsuga canadensis* (L.) Carrière], have resulted in additional changes of species composition. Also, nearly 100 years of suppressing both natural- and human-caused fires has resulted in additional changes of vegetation species composition. The present CNF consists of a mosaic of forest stands with varying histories of disturbance, which are slowly changing with age toward a species composition compatible with the physical environment under a reduced disturbance, low-intensity management.

Vegetation management in the CNF provides products, services, and benefits desired by society at local and regional scales. The current forest plan of 2004 was crafted with input from many stakeholders to meet a range of objectives and goals, with a strong emphasis on ecosystem restoration and basing management goals on ecologically sound information with considerations of social needs and economic limitations. Planning for management activities in the CNF is done at a landscape scale typically formed by large single or multiple watersheds called project areas, which are appropriate for assessment of the effects of vegetation management activities on multiple resources, particularly actions with an ecological basis. Project areas are used to identify resource management opportunities to meet Forest Plan objectives using the traditional approach of describing current conditions of vegetation based on stand-level data. If the current vegetative species composition, structure, and age distribution is unlikely to meet the desired

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Citation for proceedings: Holley, A. Gordon; Connor, Kristina F.; Haywood, James D., eds. 2015. Proceedings of the 17th biennial southern silvicultural research conference. e–Gen. Tech. Rep. SRS–203. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 551 p.

future conditions, resource managers then propose actions that accelerate development of the stand toward that condition. Resource management objectives of the current Forest Plan bring together goals that were largely not attainable with traditional methods where emphasis was given to increasing yields of a few timber species with high commercial value. Now, desired future stand conditions often include restoration of a prescribed fire regime that in turn requires consideration of the biological potential of the area, which may be based on experience of the forester or by reference to a previously developed site classification.

Classification of land units based on ecological principles involves identifying physical properties of the environment that combine to define the productive potential of sites associated with temperature, moisture, and fertility gradients (Barnes and others 1982). The ecological potential of terrestrial sites is expressed by the vegetative community that would be present resulting from natural disturbances such as from climate, fauna, fire, insects, disease, and non-European humans. In 1992, the Forest Service adopted a policy of taking an ecological approach to management of national forests (Salwasser 1992) and developed a hierarchical framework of ecological units appropriate at a range of scales from national assessments, to regional inventories, and local land management projects (table 1) (Cleland and others 1997).

Relatively little information is available for application of an ecological-based classification to support project-level management actions in the CNF. Griffith and others (2001) mapped ecoregions in Georgia using a national hierarchy adopted by the U.S. Environmental Protection Agency primarily for water quality issues, which later provided a framework for describing the natural vegetative communities (Edwards and others 2013). Ecological mapping at the mid-scale subregion-level (suitable for state-level planning) was done by Cleland and others (2007) based on the Forest Service hierarchy.

The Forest Service national framework was the basis for an ecological classification developed for the Oconee National Forest in the Appalachian Piedmont of north-central Georgia (McNab and others 2012). These broad scale classifications are appropriate for state-level assessments but do not provide detail needed for planning at the watershed or project levels.

Although ecological studies have not been done in the Cooper Creek project area, relevant information is available from investigations of vegetation and environments in nearby areas. Ike and Huppuch (1968) found throughout the mountains of north Georgia that composition of species of arborescent vegetation was associated with features of soil and landform that defined a moisture gradient. Moffat (1993) working in watersheds east of the Cooper Creek project area (primarily in White County with smaller areas of Union and Towns Counties) reported 10 vegetative communities were related to a temperature and moisture gradient defined by elevation, slope position, and landform. Graves and Monk (1985) found that composition of understory vegetation and some tree species were related to soils derived from differing geologic substrate. Chafin and Jones (1989) found differences in composition of vegetation in high-elevation boulder fields compared to coves. These and other studies in nearby areas of the Southern Appalachians have demonstrated that vegetation is a biological integrator of environmental conditions and is responsive to varying but relatively stable physical properties of sites. However, vegetation can be an imperfect indicator of specific environment conditions because species composition and dominance may vary in response to the type and intensity of disturbance and the time since disturbance (Clinton and Vose 2000).

This report describes the development of an ecologically based method for identifying and grouping areas of land in a small area of the

Table 1--USDA Forest Service national hierarchy of ecological units[a]

Planning and analysis scale	Ecological units	Purpose and general use	General size range
Ecoregion	Domain Division Province	Broad applicability for modeling and sampling; national planning	Millions to tens of thousands of square miles
Subregion	Section Subregion	Strategic, multi-agency analysis and assessment	Thousands to tens of square miles
Landscape	Landtype association	Watershed analysis	Thousands of acres
Land unit	Landtype Landtype phase	Project and management area planning	Hundreds to tens of acres
	Site	Field sampling	Ten to less than one acre

[a]From Cleland and others 1997.

southern Appalachian Mountains of northern Georgia where certain management goals are best suited ecologically. The objectives of our paper are to: (1) describe the rationale and process used to develop an ecological-based classification, and (2) provide a tabulation of the ecological units identified. The scope of this study was limited to national forest lands of the Cooper Creek watershed assessment area in the Blue Ridge Ranger District of the Chattahoochee National Forest, in the Southern Appalachian Mountains, near Blairsville, GA. We consider this study as a pilot project for small-scale ecological unit delineation in the Blue Ridge Mountains using a broad base of disciplines, but without field data collection. The primary goals of the project were to: (1) determine if such an approach is feasible, and (2) develop a foundation for implementing ecosystem management. The methods we used deviated from those recommended by the agency for development of an ecological classification because of limited resources. Lessons learned from the modified process will serve as a foundation for future refinement and development of our classification.

METHODS

Study Area

The Cooper Creek watershed assessment is an area of about 34,000 acres extending across three large watersheds (Cooper, Young Cane, and Coosa Creeks) near Blairsville, GA (fig. 1), where management goals were identified based on being ecologically sustainable, appropriate or providing desirable benefits to both local and regional user groups (Unpublished office report on file at the Supervisors Office, Chattahoochee National Forest, Gainesville, GA.). Included in the assessment area is the Cooper's Creek Wildlife Management Area, administered in cooperation with the Georgia Department of Natural Resources, Wildlife Resources Division, which occupies 30,000 acres in Fannin and Union Counties. Physiography of this area is mountainous with broad intermountain valleys; elevations range from 1,978 to 4,330 feet. Bedrock geology is mostly Precambrian metamorphic formations consisting mostly of gneiss and schist. Climate is hot continental with temperature averaging 34.9 ^{o}F (range 22.7 ^{o}F to 47.1 ^{o}F) in January and 72.5 ^{o}F in July (range 60.9 ^{o}F to 84.0 ^{o}F). The frost-free period ranges between 140 to 180 days. Average annual precipitation ranges between 59 and 83 inches with highest amounts along the Blue Ridge watershed divide crest. Rainfall steadily decreases to the north into a 'rain shadow' of atypically low rainfall near Blairsville, GA. Precipitation is generally evenly distributed annually, although mild drought is common in the fall. The dominant soil orders are Ultisols and Inceptisols; moisture regime is udic and temperature regime is mesic. Soil depths range from shallow to deep; texture classes are typically loamy or clayey. Forest vegetation is

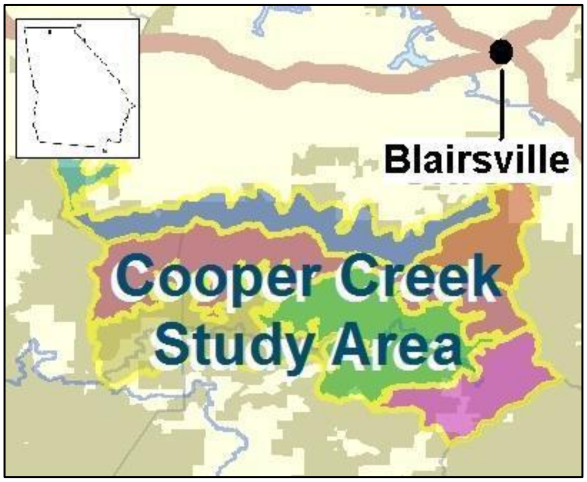

Figure 1--The study area in the Cooper Creek and adjoining watersheds of the Chattahoochee National Forest southwest of Blairsville, GA. Colored polygons within the study area show ecological units delineated at the landtype level in the Forest Service national hierarchical framework. Areas of national forest beyond the study area are shaded tan. The black dot on the inset map shows the general location of the study area in the southern Appalachian Mountains of north Georgia.

predominantly deciduous hardwoods throughout, varying from xerophytic species [oaks (*Quercus spp*) and hickories (*Carya spp*)] on ridges and slopes and mixed mesophytic species [yellow-poplar (*Liriodendron tulipifera* L.), sweet birch (*Betula lenta* L.), red maple (*Acer rubrum* L.)] on lower slopes and in valleys. Above about 3,000 feet elevation, species composition on cool north-facing slopes gradually changes to include yellow buckeye (*Aesculus octandra* Aiton) and basswood (*Tilia americana* L.) in coves and sweet birch on slopes and ridges. Conifers include shortleaf (*P. echinata* Mill.) and Virginia pines (*P. virginiana* Mill.) on ridges; eastern white pine occurs throughout. Eastern hemlock was a common former component of riparian areas along streams and in stands on lower slopes until recently, when almost total mortality resulted from effects of the hemlock woolly adelgid (*Adelges tsugae*). Its presence today is limited to isolated areas where insecticide and biological control methods have been used to conserve small populations of hemlock trees. Until about 1920, American chestnut likely occurred throughout and was a major component of most oak stands, particularly on middle and upper slopes. Almost all stands were heavily logged during the late 1890s and burned during the 1830 to 1930 mountain farmstead era (Brender and Merrick 1950). Natural- and human-caused fire has been controlled in the study area since about 1920, with the exception of a few areas where fire has been re-introduced through the prescribe fire program on selected landscape-scale burn units ranging in size from hundreds to low thousands of acres since the mid-1990s.

Classification Framework and Ecological Units

We used the Forest Service hierarchical framework of ecological units (Cleland and others 1997) as the basis for our classification (table 1). The national framework is based primarily on climatic factors appropriate at each level, with increased emphasis and importance of progressively localized physiographic, geologic, and edaphic factors that modify the effects of temperature and precipitation (Bailey 1983). National- and regional-scale ecological units had been identified and described at the ecoregion and subregions levels, which were identified and mapped using successive stratification of large somewhat heterogeneous units into smaller, relatively homogeneous units (Cleland and others 1997). Stratification into ecologically uniform areas becomes increasingly difficult at lower levels in the hierarchy because ecotones between units represent gradients of compensating environmental factors that are not clearly seen or measured. An important consideration in development of the classification was delineation of landscape units easily recognizable and of sufficient size for use by resource managers.

In the Cooper Creek study area, we identified and delineated ecological units by successive stratification of previously mapped landtype associations (LTAs) into smaller landtypes (LTs), which were subdivided into smaller and more homogenous landtype phases (LTPs) (table 1). Time and funding resources available for this study did not allow collection of field data for developing quantitative relationships between vegetative communities and environmental factors, such as elevation and aspect. Instead, land-stratification criteria were based on personal knowledge of biological relationships provided by a multidisciplinary team that included silviculturists, a botanist, soil scientist, fisheries biologist and wildlife biologist using the display on-screen and tabular results of iterative geographic information system (GIS) analysis of basic and inter-related data layers. Available sources of field vegetation data at the stand level included conventional forest cover, age and wood production-based condition data [Forest Service databases included Field-Sampled Vegetation (FSVeg) and its precursor Continuous Inventory of Stand Conditions (CISC)] and permanent inventory plots installed by the Forest Inventory and Analysis (FIA) branch of the Forest Service] for national assessment of timber resources. Evaluation of these two sources of data revealed the FSVeg/CISC data were not suitable for delineation of ecological units or identification of potential vegetation because it had been collected mainly for silvicultural purposes. The FIA data set consisted of about seven field plots in the study area, and therefore was too small to be used for analysis. Until other data become available, we use vegetative communities described by Edwards and others (2013) as the description of natural communities associated with the ecological units. Another decision was not to nest the smallest land units (LTPs) within LTs or LTAs, which would have increased the number of classification units in the classification to an unwieldy size. Therefore, the same LTPs may occur in all LTAs and LTs.

Utilization of a GIS was essential for implementing conceptual models of ecological relationships developed by the interdisciplinary team using digital elevation data sets. The topographic position index (Guisan and others 1999) was used with a digital elevation model to group areas within the landscape into categories of landform, ranging from convex ridges, nearly linear slopes, to concave valleys. This index, when combined with aspect and slope gradient, provided a means of subdividing the landscape into units of similar ecological potential (related to moisture gradient and solar radiation) represented by a distinctive vegetative community of characteristic species composition. Development and refinement was an iterative process where concepts developed by the team were implemented and displayed via GIS, evaluated and revised. Verification of ecological relationships was done through several field visits to representative sites for evaluation of predicted and actual conditions, followed by refinement of the model and additional field verification.

RESULTS

Landscape Scale Ecological Units

LTAs had been tentatively mapped in the Southern Blue Ridge Mountains Subsection (M221Dc) as part of the Southern Appalachian Assessment (SAMAB 1996). LTAs in this subsection were identified to account primarily for environmental variation associated with physiography and differential climate related to landform, primarily cooler climates at higher elevation and precipitation related to orographic effects from mountain ranges. The Cooper Creek study area occupied parts of two LTAs: M221Dc17 and M221Dc18. We made mostly minor adjustments to the boundaries of these two previously mapped LTAs as a result of on-screen review of GIS analysis.

Land Unit Scale Ecological Units

A total of seven LTs were identified in the two LTAs that accounted for environmental variation at a smaller scale related to elevation, landform, and predominant aspect. For example, Duncan Ridge North LT and Duncan Ridge South LT together account for areas of mid-elevation in the study area but are distinctly different in predominant aspect, terrain sheltering and landform. Individually, these LTs stratify the project area into landscapes that differ ecologically. The other LTs were mapped to account for similar variation at other locations.

We identified 28 LTPs in the study area (table 2). LTPs are smaller parts of LTs with increased environmental uniformity resulting from elevation (primary versus secondary ridge, secondary versus minor ridge), landform including terrain sheltering (exposed versus protected slope), and aspect (cool versus warm slope). Using a GIS, the conceptual models of combinations of elevation, landform, aspect, and relative slope position were mapped as LTP ecological units throughout the Cooper Creek study area (fig. 2).

DISCUSSION

Management Interpretations

Identification and classification of ecological units from our study using expert knowledge methods were more detailed compared to results reported by Moffat (1993), who used multivariate analysis of extensive field data from the Chattahoochee Game Management Area, which forms headwaters of the Chattahoochee River, east of the Cooper Creek study area. Moffat (1993) found four groups of land units: one riparian unit along large streams and three units associated with elevation zones. Excluding the sparsely sampled riparian and high-elevation sites, Moffat (1993) reported 4 subunits within the low- and middle-elevation zones that were related to moisture gradients, resulting in a total of 10 ecological units in his study area. Our results differed from Moffat (1993) primarily in the combined low- and middle-elevation zones where we identified three moisture gradients associated with each of three ridge types: primary, secondary, and minor. Additional ecological variation present in our study area, but not recognized by Moffat (1993), included eight types of slopes and three types of coves (table 2).

The 28 ecological units in our classification system will provide basic information for natural resource planning and management at the landscape scale in the Cooper Creek project area. Examples of anticipated uses are listed below:

1. Planning-LTPs offer an ecological based foundation for organizing, assessing and integrating information from stakeholder groups with common goals of a sustainable supply of forest resources.
2. Restoration-LTPs are a source of information on those parts of the Cooper Creek landscape where prescribed burning can be appropriately and economically used for limiting the spread of eastern white pine to areas where it was not historically present.
3. Recreation-LTP mapping allows direct analysis of the capability for managers to substitute camp sites in non-riparian Ecological Classification System (ECS) units for currently over-used sites in riparian areas.
4. Silviculture and wildlife habitat-LTP descriptions contain the information on physical site components that allow informed prediction of species composition of regeneration following planned disturbance resulting from silvicultural activities such as timber harvest. Maintaining oaks and diversity of habitat structure is important for many species of wildlife, particularly neotropical migratory birds.
5. Water quantity and quality-LTPs provide information on water yields with different vegetative covers and the effects on water quality and watershed health resulting from hemlock mortality in riparian zones caused by the hemlock woolly adelgid.

Lessons Learned

An important component of this study was to develop a context for estimating resources needed to complete ECS throughout the CNF, and to identify efficiencies, barriers, and opportunities for breakthroughs in future studies. Some of the more important lessons we learned include:

1. Mapping concepts of higher-level ECS units must also be considered when delineating small scale units. This project was very near the Hot Continental and Humid Subtropic Division boundary which is also coincident with: the Broadleaf-Coniferous Forest-Meadow Province of

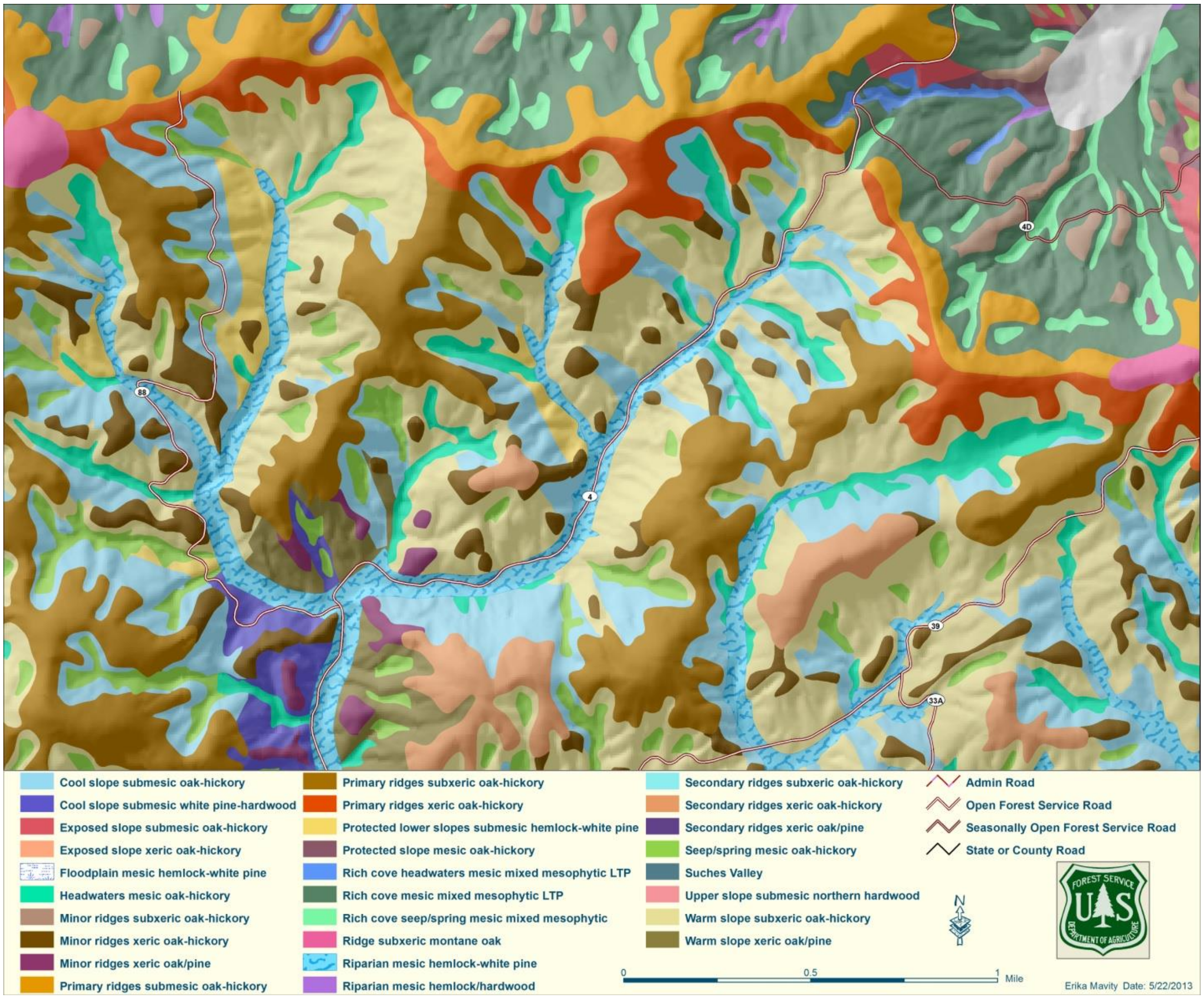

Figure 2--Twenty eight landtype phases accounting for environmental differences associated with variations of elevation, landform, aspect, slope position, and other environmental variables in the Cooper Creek project area of the Chattahoochee National Forest, in north Georgia. This graphic illustrates how the GIS applied the conceptual model to classify the landscape in a selected part of the project area.

the Appalachians and the Southeastern Mixed Forest Province of the Piedmont. These high-level units have a wide ecotone along their boundary extending both into the mountains and out into the Piedmont. The concept of ECS is that delineation of lower-level units refines the boundary of higher-level ones, but it is necessary to recognize that small-scale units such as LTPs may better belong to a much higher level of the hierarchy. In our case, mountainous landform and its ability to modify climate caused the Division and Province boundary to be placed south of the mountains. But the ecotone extends into the mountains. This can cause either relocation by refinement of the higher-level unit boundaries or the delineation of a rather large transitional unit within the mountains. Correctly understanding ecological behavior in the transition zone is challenging.

2. Learning the inefficiencies of classifying a small part of a larger area - be it a watershed, a mountain ridge, or a county - when their boundaries are not nested within existing ECS unit boundaries. We mapped portions of two LTPs. Inefficiencies arose because the

Table 2--Preliminary non-hierarchical ecological units occurring at the landtype phase level of the ecological classification system in the Cooper Creek study area of the Chattahoochee National Forest, Union County, Georgia

Vegetative community[a]	LandType Phase ecological unit name[b]	N. units	Mean size (acres)	Median elevation	Relative slope position[c]
			acres	*feet*	
Rich cove forests	Rich cove mesic mixed mesophytic	48	53	2,701	25
	Rich cove headwaters mesic mixed mesophytic	30	7	2,808	58
	Rich cove seep/spring mesic mixed mesophytic	147	3	2,696	37
Acidic cove forests	Cool slope submesic white pine-hardwood	88	15	2,316	24
	Protected lower slopes submesic hemlock-white pine	49	10	2,814	31
	Riparian mesic hemlock-white pine	37	70	2,646	65
	Floodplain mesic hemlock-white pine	2	395	2,525	63
	Suches Valley	1	153	2,966	34
Low to mid elevation oak forests	Primary ridges subxeric oak-hickory	12	118	2,999	8
	Primary ridges xeric oak-hickory	18	47	3,007	9
	Secondary ridges subxeric oak-hickory	10	41	2,841	7
	Secondary ridges xeric oak-hickory	41	34	2,989	6
	Minor ridges subxeric oak-hickory	246	3	2,691	7
	Minor ridges xeric oak-hickory	359	3	2,782	10
	Warm slope subxeric oak-hickory	206	23	2,877	23
	Exposed slope xeric oak-hickory	16	33	2,218	18
	Secondary ridges xeric oak/pine	9	12	2,503	6
	Minor ridges xeric oak/pine	149	4	2,429	8
	Warm slope xeric oak/pine	71	24	2,323	22
Low to mid elevation oak	Cool slope submesic oak-hickory	238	12	2,831	23
	Exposed slope submesic oak-hickory	125	12	2,658	23
	Primary ridges submesic oak-hickory	25	93	2,835	8
	Protected slope mesic oak-hickory	142	14	2,614	22
	Riparian mesic hemlock/hardwood	29	8	2,364	71
	Headwaters mesic oak-hickory	256	6	2,748	59
	Seep/spring mesic oak-hickory	420	3	2,787	38
Montane oak	Ridge subxeric montane oak	54	23	3,624	15
Northern hardwood	Upper slope submesic northern hardwood	9	8	3,700	32

[a]Based on information in Edwards and others (2013).
[b]These units may occur in any of the landtype associations or landtypes within the study area.
[c]Relative slope position of 0 indicates a ridge and 100 is a Valley.

total range of variability was not known. In our case, the range of variation should have been considered for at least the Georgia portion of the Southern Blue Ridge Mountain Subsection as the proper context of the variation in any of the variables used in classification. LTP concepts may change as the entire LTA landscape is considered. Such an approach would have facilitated using adjective descriptors (low, medium, high) both accurately and in a way that would be more useful into the future.

3. Delineation of smaller units is more difficult and thus more time-consuming than larger scale units because large-scale units rely on coarse and often

easily observable differences, such as mountain versus piedmont landforms. Boundaries of small units are often associated with subtle environmental gradients that are likely to be neither easily observable nor easily understood and described. Also, small scale units are usually discontinuous and are bordered on all sides by a different unit. This hypothesized difference should be observable when the ECS is applied in the field. If that difference is not observable in the field, it jeopardizes credibility of the classification by other users.

4. Correlating existing vegetation with potential vegetation is difficult because of the unknown influences of past land use and effects of disturbance. For example, ecological units that are hypothesized to be similar may show a wide variation of the existing vegetation growing on that unit based on past land use. For example, a middle-slope cool-aspect submesic oak-hickory unit might have significant component of cove hardwood cover or even southern yellow pine. The many successional vegetation communities appropriate for one ecological unit also introduce a complexity to interpreting existing vegetation by the user.
5. The scale of units particular users will want or find most useful can be expected to vary by purpose. For example, a prescribed-fire planner may need general information about blocks of hundreds to thousands of acres, but a silviculturalist may need detailed information about individual stands. Consideration of needs is related to choices made about map display, map scales, and even description detail.
6. Appropriate use of the delineated units required a narrative context. It was not difficult to predict questions that would arise from the use of the units. So we developed an introduction chapter that was designed to be the first and best source to answer these typical questions. It was also intended to be a beginning point for future ecological classification studies on the CNF.
7. It is likely that a GIS analysis of topographic data will result in questionable artifacts of information that form a hypothesized small ecological-classification unit. Many artifacts probably originated from scale-related mapping errors of the original data layers. When the data layers are merged using GIS, the resulting polygons represent illogical ecological units with no apparent biological relationship. We learned that considerable judgment is needed to decide which of the two or more adjacent ecological units represents the proper assignment for each artifact.

In conclusion, the Cooper Creek ecological classification system was a multiphase project to develop a useful tool for improving our ability to plan and implement project-level resource management activities to achieve desired future conditions with a minimum investment of human and economic resources. Because development of an ecological classification is an iterative process of testing and refinement, strengths and weaknesses of this first approximation will be identified and addressed through application, evaluation, and revision. This ecological classification may be viewed as a planning and management tool with many handles for working in collaboration with the Forest Service to achieve common goals of management and sustainable utilization of water and land resources in the Cooper Creek watershed and elsewhere on public lands of the Chattahoochee National Forest.

An unresolved issue was our inability to devise a hierarchical relationship for the ecological units of the Cooper Creek watershed, similar to that developed by Moffat (1993) for a neighboring watershed. Without a hierarchical framework, the 28 ecological units form a single group that appears overly detailed for easy understanding by unfamiliar users. Lack of field data suitable for a quantitative analysis was one reason why we did not develop a hierarchy of units, which would have subdivided the 28 units into groups based on environmental factors of varying ecological importance, such as elevation zones and included moisture regimes. Absence of a hierarchy, however, does not affect the validity and usefulness of the current configuration of the classification for project planning. Development of a hierarchical framework is an opportunity for future study of ecological relationships in the watershed.

ACKNOWLEDGEMENTS

This project would not have been possible without the vision and support of Mr. Ray M. Ellis, retired staff officer for natural resources, Chattahoochee-Oconee National Forests, who provided an understanding and experience with the landscape elements of an ecological classification system (ECS) and the perspective needed by land managers to integrate data into decisions. District Ranger Andrew Baker coordinated the field review of the ECS. Forest Service personnel Denise Bailey, Danny Skojac, and Kurt Steele reviewed an early draft of the manuscript. Questions about the ECS should be directed to the project Team Leader, Dick Rightmyer; Henry McNab, was responsible for the manuscript.

LITERATURE CITED

Bailey, R.G. 1983. Delineation of ecosystem regions. Environmental Management. 7: 365-373.

Barnes, B.V.; Pregitzer, K.S.; Spies, T.A.; Spooner, V.H. 1982. Ecological forest site classification. Journal of Forestry. 80: 493-498.

Brender, E.V.; Merrick, E. 1950. Early settlement and land use in the present Toccoa Experimental Forest. The Scientific Monthly. 71(5): 318-325.

Chafin, L.G.; Jones, S.B, Jr. 1989. Community structure of two southern Appalachian boulderfields. Castanea. 54(4): 230-237.

Cleland, D.T.; Avers, P.E. McNab, H. [and others]. 1997. National hierarchy of ecological units. Chapter 9. In: Boyce, M.S.; Haney, A., eds. Ecosystem management applications for sustainable forest and wildlife resources. New Haven, CT: Yale University Press: 181-200.

Cleland, D.T.; Freeouf, J.A.; Keys, J.E., Jr. [and others]. 2007. Ecological subregions: sections and subsections of the conterminous United States. [1:3,500,000] [CD-ROM]. Sloan, A.M., cartog. Gen. Tech. Rep. WO-76. Washington, DC: U.S. Department of Agriculture Forest Service.

Clinton, B.D.; Vose, J.M. 2000. Plant succession and community restoration following felling and burning in the Southern Appalachian Mountains. In: Moser, W.K.; Moser, C.E., eds. Fire and forest ecology: innovative silviculture and vegetation management. Proceedings of the 21st Tall Timbers fire ecology conference. Tallahassee, FL: Tall Timbers Research Station. 21: 22-29.

Edwards, L.; Ambrose, J.; Kirkman, L.K. 2013. The natural communities of Georgia. Athens, GA: The University of Georgia Press. 675 p.

Graves, J.H.; Monk, C.D. 1985. A comparison of soils and vegetation over marble and schist along tributaries to Panther Creek, Stephens County, Georgia. Castanea. 50: 146-163.

Griffith, G.E.; Omernik, J.M.; Comstock, J.A. [and others]. 2001. Ecoregions of Alabama and Georgia. [1:1,700,00]. Reston, VA: U.S. Geological Survey. [Color poster with map, descriptive text, summary tables, and photographs].

Guisan, A.; Weiss, S.B.; Weiss, A.D. 1999. GLM versus CCA spatial modeling of plant species distribution. Plant Ecology. 143: 107-122.

Ike, A.F.; Huppuch, C.D. 1968. Predicting tree height growth from soil and topographic site factors in the Georgia Blue Ridge Mountains. Georgia Forest Res. Pap. 54. Macon, GA: Georgia Forestry Commission. 11 p.

McNab, W.H.; Stephens, R.B.; Rightmyer, R.D. [and others]. 2012. A preliminary test of an ecological classification system for the Oconee National Forest using forest inventory and analysis data. In: McWilliams, W.; Roesch, F.A., eds. Monitoring across borders. 2010. Joint meeting of the Forest Inventory and Analysis (FIA) symposium and the Southern Mensurationists. e-Gen. Tech. Rep. SRS-157. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 77-86. http://www.srs.fs.usda.gov /pubs/40775. [Date accessed: May 10, 2013].

Moffat, S.O. 1993. Landscape ecosystem classification for the Chattooga Ranger District, Chattahoochee National Forest, Georgia. Clemson, SC: Clemson University. 83 p. M.S. thesis.

Salwasser, H. 1992. From new perspectives to ecosystem management: response to Frissell *et al*. and Lawrence and Murphy. Conservation Biology. 6: 469-472.

SAMAB [Southern Appalachian Man and the Biosphere]. 1996. The Southern Appalachian assessment summary report. Report 1. Atlanta, GA: U.S. Department of Agriculture Forest Service, Southern Region. 118 p.