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Sustaining the Landscape: A Method for Comparing Current and Desired Future Conditions of Forest Ecosystems in the North Cumberland Plateau and Mountains

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SUSTAINING THE LANDSCAPE:
A METHOD FOR COMPARING CURRENT AND DESIRED FUTURE CONDITIONS OF FOREST ECOSYSTEMS IN THE NORTH CUMBERLAND PLATEAU AND MOUNTAINS

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ACRONYMS

CPC	Current prevailing condition
DFC	Desired future condition
EPA	U.S. Environmental Protection Agency
ESD	Environmental Sciences Division
NIPF	Non-Industrial Private Land Ownership
TTNC	Tennessee Chapter of The Nature Conservancy

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ABSTRACT

This project initiates an integrated-landscape conservation approach within the Northern Cumberlands Project Area in Tennessee and Kentucky. The mixed mesophytic forests within the Cumberland Plateau and Mountains are among the most diverse in North America; however, these forests have been impacted by and remain threatened from changes in land use across this landscape. The integrated-landscape conservation approach presented in this report outlines a sequence of six conservation steps. This report considers the first three of these steps in two, successive stages. Stage 1 compares desired future conditions (DFCs) and current prevailing conditions (CPCs) at the landscape-scale utilizing remote sensing imagery, remnant forests, and descriptions of historical forest types within the Cumberland Plateau. Subsequently, Stage 2 compares DFCs and CPCs for at-risk forest types identified in Stage 1 utilizing structural, compositional, or functional attributes from USFS Forest Inventory and Analysis data. Ecological indicators will be developed from each stage that express the gaps between these two realizations of the landscape. The results from these first three steps will directly contribute to the final three steps of the integrated-landscape conservation approach by providing guidance for the generation of new conservation strategies in the Northern Cumberland Plateau and Mountains.

1. BACKGROUND AND RATIONALE

Traditionally, biological conservation has focused heavily on the protection of often small, isolated land parcels within a larger matrix of unprotected, developed areas. Both conservationists and scientists alike now recognize the need for sustainable management of landscapes outside of preserve boundaries not only to maintain species whose habitats are not contained within preserve boundaries, but also to maintain the biodiversity, structure, and function of ecosystems at a regional or landscape scale (e.g., Lindenmayer and Franklin 2003). This recognition is leading to a new ecosystem approach advocating the sustainability of integrated landscapes, comprising both natural areas and areas of human land use (McCormick 2003).

In this context, *sustainability* may be defined as "the capacity of forests, ranging from stands to ecoregions, to maintain their health, productivity, diversity and overall integrity, in the long run, in the context of human activity and use" (Helms 1998). This interpretation of sustainability should incorporate both underlying ecological principles for managing the land (Dale et al. 2000) and the regional-scale concept of *functional conservation areas*. These areas maintain "focal ecosystems, species, and supporting ecological processes within their natural ranges of variability" (Poiani et al. 2000).

In order to successfully implement an ecosystem approach toward the sustainable management of functional landscapes, policy makers must have a clear conception of the *desired future conditions* (DFCs) for that landscape and the gaps that separate that landscape from its *current prevailing conditions* (CPCs). DFCs enable future generations of a society to maintain or adapt cultural practices and also sustain the ecological integrity of the land (USDA Forest Service 1999). For these reasons, DFCs differ from the historical range of ecosystem variation on a landscape as they reflect both cultural values and the realities of integrated landscapes. Furthermore, the attributes of historical vegetation are, at best, estimates. Instead, DFCs must express a potential overlap between acceptable natural and human realizations on the landscape. The quantification of DFCs and CPCs rely on *ecological indicators*, which serve to synthesize the conditions and dynamics of ecosystems into readily accessible and objective measures (Dale and Beyeler 2001). For example, fragmentation may serve as an indicator of disturbance to forests at a landscape scale (Dale and Beyeler 2001). Recent reports have begun to identify and interpret ecological indicators within the United States (e.g., The Heinz Center 2002; USDA Forest Service 2003; EPA 2003). Collectively, these reports highlight both the benefits and current challenges to managing ecosystems at a landscape scale.

This report outlines the first steps of an integrated-landscape conservation approach for the Cumberland Plateau in Tennessee (Fig. 1). The vegetation of the Cumberland Plateau is generally considered part of the mixed or central mesophytic forest region (Braun 1950; Hinkle et al. 1993; Runkle 1996). This globally-outstanding region contains the most diverse temperate forests in North America and is viewed as requiring critical habitat protection and restoration (Ricketts et al. 1999). Within the Cumberland Plateau in Tennessee, Noss et al. (1995) estimated that approximately 95% of old growth forests have disappeared and that 60 to 70% of the mixed mesophytic forests have been converted to non-forest use. Non-industrial private forest (NIPF) land ownership accounts for 72% of the timberland ownership in the Cumberland Plateau in Tennessee (Schweitzer 2000). In light of these statistics, this region represents a logical and timely choice for an integrated-landscape conservation approach by The Nature Conservancy. Additionally, the predominance of NIPF ownership within this region suggests that conservation initiatives designed for this ownership group could have far-reaching impacts on the sustainability of forests in the Cumberland Plateau. These initiatives could be implemented through strategically-determined pressure points that influence market-based drivers for this ownership group.

Fig. 1. Aerial view of Northern Cumberland Plateau near Jamestown, TN, displaying a matrix of forest-types and land uses.

This report details a methodological approach capable of delineating gaps between CPCs and DFCs at the landscape scale for the Northern Cumberlands Project Area. This project area includes over 2 million acres and extends into both Kentucky and Tennessee (Fig. 2). Additionally, this area has been identified as an area of high biodiversity significance in within the Cumberland Plateau (The Nature Conservancy 2003) and is the focus of conservation action for the Tennessee Chapter of The Nature Conservancy (TTNC). The study outlined by this report first generates a suite of indicators using remote sensing data, enabling an assessment of the gaps between CPCs and DFCs at the landscape scale for the Northern Cumberlands Project Area. As a result, these gaps will be used to select indicators that identify at-risk forest types within the Northern Cumberlands Project Area. Secondly, this study then focuses on any at-risk forest type by determining finer-scale indicators of the structure, function, or composition requisite to the sustainability of each forest type. The results of this study should not only advance the science of functional conservation areas, but also provide The Nature Conservancy with the information necessary to evaluate pressure points leading to a more sustainable use of the Cumberland Plateau.

The methods described in this report achieve the first three of six landscape-conservation steps outlined by The Nature Conservancy for the Northern Cumberlands Project Area (Trianosky 2003):

- Develop a comprehensive ecological description of DFCs
- Describe the CPCs on the landscape and within forest types
- Delineate the gap between CPCs and DFCs
- Develop silvicultural prescriptions necessary to attain DFCs
- Conduct a socio-economic analysis
- Implementation

The first three steps of this integrated-landscape approach address the need for a scientific assessment of the ecological condition of the landscape. In turn, the latter three steps outline the need for new strategies that will influence the landscape through pressure points. The two-stage approach outlined for these first three steps focuses first on developing ecological indicators of landscape condition and, secondly, ecological indicators of forest type condition, to which pressure points may be targeted. Steps four through six of this integrated-landscape conservation approach will require the expertise of a forester or forest economist to devise and implement policies promoting sustainability. The indicators under development in this study will serve as a way to quantify the difference between the current conditions and desired future conditions of the Northern Cumberlands Project Area. These indicators are a necessary step to describe the intended influence on pressure points, as any pressure points will likely target changes in specific values of indicators.

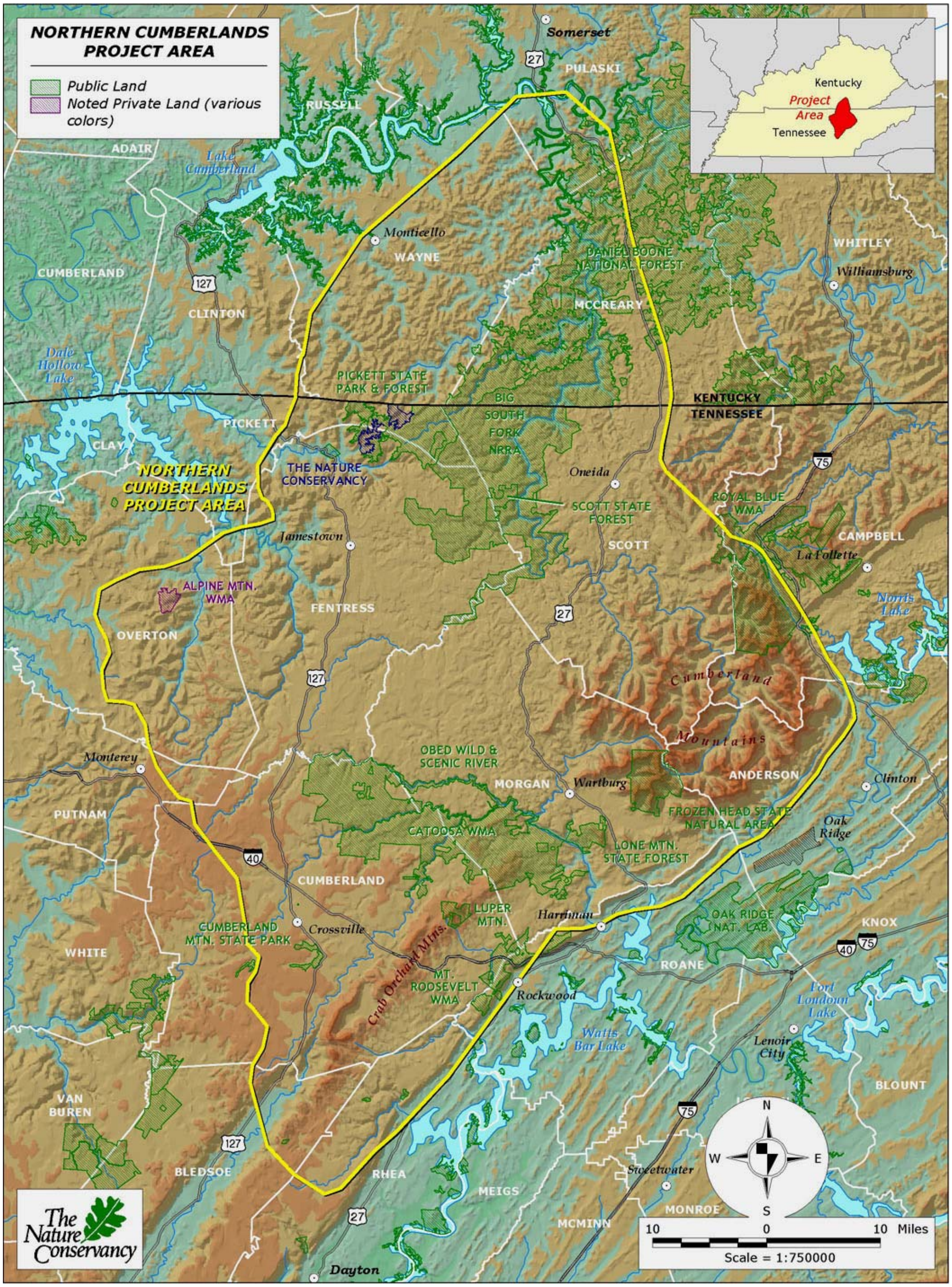

Fig. 2. Map of the Northern Cumberlands Project Area (Courtesy of The Nature Conservancy).

2. RESEARCH APPROACH

The successful completion of this study requires the close coordination of expertise, data resources, and effort from the Tennessee Chapter of The Nature Conservancy (TTNC) and the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory. The steps to develop and implement DFCs for the Cumberland Plateau have been outlined by TTNC (Trianosky 2003). The expertise of ESD is well suited to assist TTNC in accomplishing the first three of these steps as summarized below.

2.1 SIX STEPS TO DEVELOPING TARGETED STRATEGIES TO ATTAIN DFCs

2.1.1 Develop a Comprehensive Ecological Description of DFCs

The characterization of DFCs should include parameters drawn from extant old-growth or functional forests that are limited in number, measurable, and supported by scientific research. DFCs should also account for both the range of structural, compositional, and functional conditions in these forests as well as acceptable ranges of spatial variation for core and secondary conservation areas. These DFCs should highlight landscape attributes such as connectivity, ecotones, core conservation areas, and underrepresented forest types in core conservation areas.

2.1.2 Describe the CPCs on the Landscape and within Forest Types

CPCs should not only be evaluated using the same suite of parameters that characterize DFCs, but also be capable of translation into forestry terminology. CPCs should describe current trends or 'trajectories' in forest dynamics at both the landscape and forest-type scale, the homogeneity of forest conditions and forestry practices, and the decision processes that lead to these management practices.

2.1.3 Delineate the Gap between CPCs and DFCs

The gaps between CPCs and DFCs should be determined using a limited number of parameters that describe CPCs and DFCs (i.e. using ecological indicators). The spatial location and characteristics of such gaps could be characterized for specific forest types or for the landscape as a whole. Accordingly, these gaps should provide guidance for the management of particular forest types or the demarcation of additional conservation areas.

2.1.4 Develop Silvicultural Prescriptions Necessary to Attain DFCs

Silvicultural prescriptions should be developed that direct individual forest types and the landscape as a whole toward the DFCs identified in the first three steps. Particularly, these prescriptions should address those aspects of the CPCs that exhibit the largest gap from DFCs. Accordingly, these prescriptions need to be sufficiently broad in scope and should avoid solutions that must be implemented on a stand-by-stand basis. These prescriptions should also be developed independent of the current forest-products economy in this region to enable a full consideration of possible initiatives.

2.1.5 Conduct a Socio-economic Analysis

Conducting a socio-economic analysis of the region encompasses the dual goal of identifying not only the social, cultural, and economic drivers that create the CPCs on the Northern Cumberlands Plateau but also key pressure points that will re-direct these conditions toward the DFCs. Similar to the consideration of silvicultural prescriptions in step 4, the evaluation of pressure points should not be limited to a particular component of forest product production. Instead, all aspects of this process, from harvesting practices to consumer preference of forest products, should be investigated for leveraging the landscape toward the DFCs.

2.1.6 Implementation

This final step of the integrated-landscape conservation approach will affect the production and utilization of wood in the Northern Cumberland Plateau by influencing the economic structure at pressure points identified in step 5. This step may draw upon extant strategies or create novel approaches to exert influence on wood product production; however, a key to the success of any initiative will be the ability to harness the momentum of this marketplace to move the landscape toward DFCs. Possible strategies could include legislation for incentives that would promote the sustainability of the landscape, development of new forest products or new markets for forest products, or support for sustainable industries in the Northern Cumberland Plateau.

2.2 LANDSCAPE-SCALE ASSESSMENT

The integrated-landscape approach method in this report utilizes a two-stage approach to assess CPCs and describe DFCs first using landscape metrics (e.g., O'Neill et al. 1988) and then finer-scale estimates of forest structure, composition, or function by forest type. These two stages may be viewed as successive iterations through the first three steps outlined above (Fig. 3). Although the results of this process are providing The Nature Conservancy with scientific results to guide strategy development, a central result is also an evaluation of this integrated-landscape conservation method, leading to recommendations for future methodological refinements and improvements for later stages. The necessary steps of this two-stage approach to an integrated-landscape conservation method for the Cumberland Plateau are outlined as follows.

2.2.1 Step 1 Plan of Action

Stage 1 of this integrated-landscape conservation approach focuses on DFCs that may be determined from landscape metrics. ESD is working with TTNC to investigate landscape metrics that indicate the acceptable ranges of spatial variation for forest types in the Cumberland Plateau. Additionally, ESD is also identifying landscape metrics that relate landscape connectivity, ecotones, core conservation areas, and forest types by building upon our recent work at Fort Benning, Georgia (Olsen et al. in press). To assess DFCs for the Cumberland Plateau using landscape metrics, ESD is mapping forest-type distributions using three categories of published studies. Historical references (e.g., Killebrew and Safford 1874; Foley 1901; Foley 1903) provide the earliest information on species composition within the Cumberland Plateau. Scientific estimates of presettlement vegetation (e.g., Braun 1950; Küchler 1964; Hinkle 1978; Nowacki and Trianosky 1993) from extant remnant forests or forests with minimal anthropogenic disturbance should enable a finer spatial resolution of forest types in the Cumberland Plateau. These reconstructions will draw on a large amount of published scientific research on vegetation in the Cumberland Plateau (Appendix A). Finally, recent modeling methods that project species distributions across the landscape (e.g., Iverson and Prasad 1998; Prasad and Iverson 2003; Hargrove and Hoffman 1999) are being considered to augment forest type distribution for regions less studied.

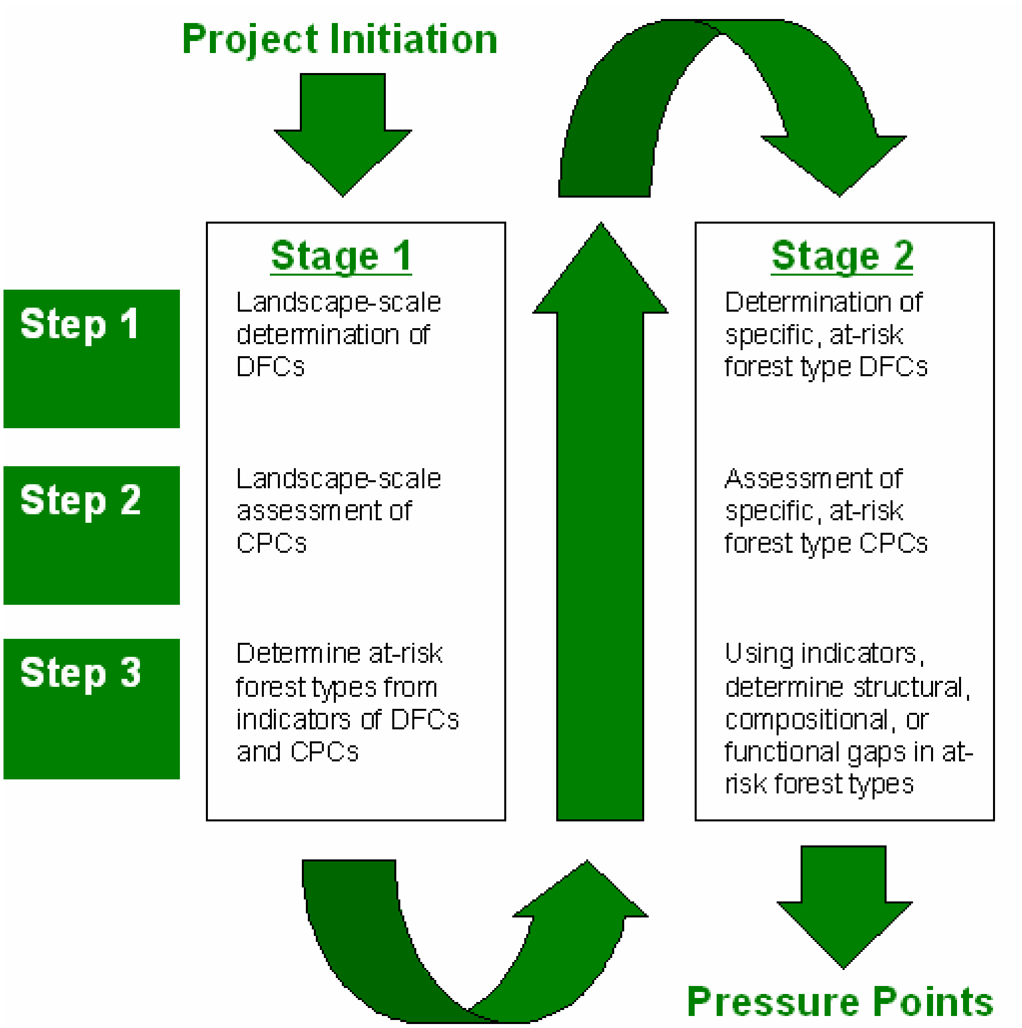

Fig. 3. Flowchart outlining a two-stage research approach to assess landscape-scale and forest-type gaps between DFCs and CPCs.

A key question in this stage is the appropriate spatial resolution of our approach. If feasible at a fine scale, potential natural forest types for the Cumberland Plateau will be distributed across the project area by topography and soils using data of physical attributes (e.g., 250K Digital Elevation Models, 250 K Soils, and EPA Reach Files 1 and 3) currently held by TTNC and classified into ecological land units (see Map 12 of The Nature Conservancy 2003). The spatial accuracy of these forest type distributions could be tested using a withheld, independent estimate of potential natural vegetation. Strittholt and Boerner (1995) successfully employed a similar, rule-based model to distribute natural forest types across south-central Ohio.

2.2.2 Step 2 Plan of Action

To assess CPCs for the Cumberland Plateau landscape, this study is utilizing Landsat 7 ETM imagery from the summer and winter (2000-2002). This imagery is already held by the TTNC and has been mosaicked and color matched, but not yet classified. TTNC also holds earlier Landsat 5 imagery that could be used for temporal comparison in later stages of analysis. Similarly to step 1, this step is also utilizing other data resources held by the TTNC to characterize the distribution of forest types on the Cumberland Plateau in relation to physical attributes (e.g., 250K Digital Elevation Models, 250 K Soils, and EPA Reach Files 1 and 3) and social attributes (e.g., public and private land ownership, 100 K road coverage, and Census data). Hence the unsupervised classification of the Cumberland Plateau is being developed using this Landsat data. A field ecologist will be subcontracted to provide an initial groundtruthing of forest cover types within the project area.

Once complete, both user and producer accuracy assessments of forest-cover classifications will be considered for the distribution of current forest types across the landscape. This analysis will utilize Forest Inventory and Analysis data collected by the USDA Forest Service (Miles et al. 2001). This dataset provides a recent, systematic survey of forests in the Cumberland Plateau and Mountains. While more traditional accuracy assessment of the current forest types would likely provide greater confidence in these classifications, this project will rely on the Forest Inventory and Analysis data as it is also a comprehensive source of stand-level information on forests in the Cumberland Plateau and Mountains. This data will also avoid the need for field-based ground-truthing during this stage. Forest types classified from the Landsat imagery will be compared with U.S. Forest Service forest types or individual site records to enable linkages between these data sets.

2.2.3 Step 3 Plan of Action

Landscape-scale metrics of DFCs and CPCs are being measured by TTNC using available geospatial software programs FRAGSTATS (McGarigal and Marks 1995; Berry et al. 1998; Raines 2002; Tinker et al. 2003) and ATtILA (Ebert 2001). Examples of landscape metrics from FRAGSTATS that may be suitable for indicators in the Cumberland Plateau landscape include the number of patches and mean patch size for various forest types, the minimum and maximum range of spatial extent of a forest types, and the amount of edge density. Similarly, suitable landscape metrics from ATtILA include patch indices, riparian indices, human stressors, and physical attributes within the landscape. ESD will then select those metrics which best indicate the gap between the CPCs and DFCs in the Cumberland Plateau landscape by forest type. These metrics become the ecological indicators for the landscape. The central result of this landscape-scale assessment is the identification of forest types that possess the greatest gaps between CPCs and DFCs at the landscape scale. These forests types are considered at-risk and are receiving the focus of the analysis in Stage 2; however, if possible other forest types may also be analyzed during Stage 2.

2.3 FOREST-TYPE ASSESSMENT

2.3.1 Step 1 Plan of Action

Stage 2 incorporates additional measures of DFCs at a finer scale of analysis than Stage 1. These data can be used to characterize desired structural, compositional, or functional conditions within an at-risk forest type identified by the landscape analysis in this Stage 1. This step is also drawing upon published scientific studies for vegetation within the Cumberland Plateau (Appendix 1) in determining DFCs by forest type in the Northern Cumberlands Project Area. DFCs for each at-risk forest type are also incorporating the presence of conservation targets previously identified by the TTNC (The Nature Conservancy 2003). Conservation areas have been delimited for terrestrial, aquatic, and cave ecosystems in the Cumberland Plateau. This project outlined in this report will likely focus on terrestrial conservation areas. These areas include functional matrix landscapes (>15,000 acres), non-matrix functional landscapes (<15,000 acres), and functional sites.

2.3.2 Step 2 Plan of Action

ESD is identifying readily-available, extant environmental databases for the Cumberland Plateau that should assist in characterizing CPCs. Forest Inventory and Analysis data will likely be used to also provide this finer-scale information. As necessary, either ESD may augment this characterization of CPCs with a field scientist who conducts regional surveys within each at-risk forest type in the Cumberland Plateau. This field research would collect variables on forest attributes not measured in current databases. These variables would provide necessary information for the characterization of CPCs. Additionally, TTNC is also providing in-house databases possibly including land-use/land-cover, land ownership (all tracts > 500 acres), and hydrology to provide a comprehensive characterization of CPCs. As a result, this determination of CPCs is elucidating attributes of the current structure, composition, or function of at-risk forest types in the Cumberland Plateau. These CPCs need to provide insight into trends in forest dynamics and management.

2.3.3 Step 3 Plan of Action

ESD and TTNC are analyzing the metrics of CPCs and DFCs for the Cumberland Plateau quantified in steps 1 and 2 and determining conservation gaps for at-risk forest types. Indicators of these gaps are being selected as a subset from these metrics. These indicators provide not only a measure of ecological condition for a particular forest type but also guidance for the implementation of pressure points that will increase the sustainability of the Cumberland Plateau landscape as a whole.

3. PRODUCTS

The two stages of this research effort contribute a variety of products useful to the conservation goals of The Nature Conservancy. Stage 1 of this study is producing a landscape-scale comparison of CPCs and DFCs from remote sensing imagery, remnant forests, and descriptions of the extent of historical forest types within the Cumberland Plateau. Subsequently, Stage 2 focuses on at-risk forest types identified in Stage 1 and assesses the specific structure, composition, or function of each type. These two stages provide The Nature Conservancy with the requisite information to discern possible pressure points and design strategies to affect them, leading to a more sustainable landscape in the Cumberland Plateau. Second, these stages will also identify methodological refinements and improvements to the integrated-landscape conservation approach that may be incorporated into later stages of research. Similarly, new scientific questions and conservation tasks for the Cumberland Plateau are being generated by this study that can be incorporated into future research. Finally, the results of this study and the ensuing conservation strategies will directly inform other landscape conservation projects of The Nature Conservancy and thus have a far-reaching impact on the course of forest conservation in critical landscapes nationwide.

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APPENDIX A.
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