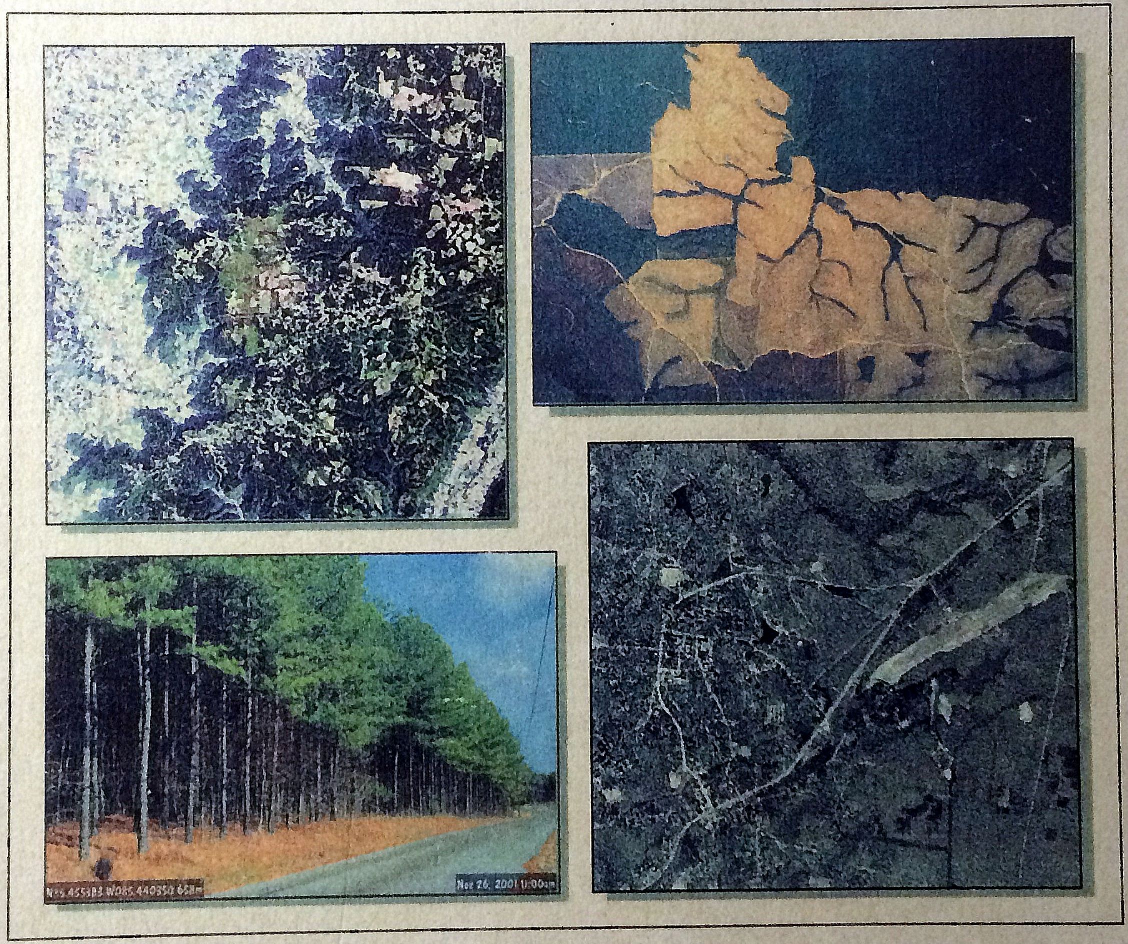
An Assessment of Forest Change on the Cumberland Plateau in Southern Tennessee

Small Area Assessment Forestry Demonstration Project
for the Southern Forest Resource Assessment



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Landscape Analysis Lab

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Executive Summary

Submitted to:
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service

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Executive Summary

Background
Native forests of the southern United States are currently undergoing dramatic changes due to shifting patterns in land use. In recent years, urban sprawl and the creation of pine plantations have emerged as dominant forces of change and have been predicted to be major causes of native forest loss in the future (Wear and Greis 2001). In the southeast where the vast majority of the land base is privately owned, the forests change as a function of the many individual land use decisions made over a period of time. These land use decisions involve not only the myriad of forest owners spread across the region, but also the resource professionals who advise them and the government officials who enforce regulations and provide incentives to them. If forest values such as biodiversity, water quality, and wood fiber are to be sustained in such a mosaic of decision-making, then landscape-level information must be made available to all parties in order to guide land use activities in an informed and comprehensive manner. This is the role of a small area assessment.

The Cumberland Plateau in Tennessee contains some of the largest remaining tracts of privately owned, contiguous temperate deciduous forest in North America. Native forests on the Cumberland Plateau, as defined for the purposes of this study, consist predominately of a mixture of oak (*Quercus* spp.) and hickory (*Carya* spp.) species, along with other hardwood species. These forest tracts represent important neotropical migratory songbird habitat and serve as the headwaters to some of the most biologically diverse, freshwater stream systems found in the world (Ricketts et al. 1999). The Cumberland Plateau has some of the highest predicted herpifaunal diversity of anywhere in the state and one of the most diverse communities of woody plants in the eastern United States. (Durham 1995; Ricketts et al. 1999). The drought-prone, sandy soils of the plateau surface have a low nutrient content that limits productivity, making the system highly sensitive to the nutrient removal effects of whole-tree harvesting and acid precipitation (Adams et al. 2000). The hard mast (acorns) associated with the mature oak canopy of the plateau forest serves as a keystone resource within the food web of this ecosystem. The availability of this oak mast resource directly or indirectly affects the survivorship of hundreds of animal species inhabiting the forest (McShea and Healy 2002).

There has been considerable recent debate as to the rate and scope of forest change in Tennessee as well as debate about the impact of such change on forest values. This Small Area Assessment Forestry Demonstration Project used a 7-county, 616,000 acre portion of the Cumberland Plateau in southern Tennessee as a case study to test current methods and technologies for detecting forest change and to examine the ecological consequences of native forest removal in this region. The Project study area encompassed only the forest ecosystem associated with the surface of the Plateau (Figure 1).

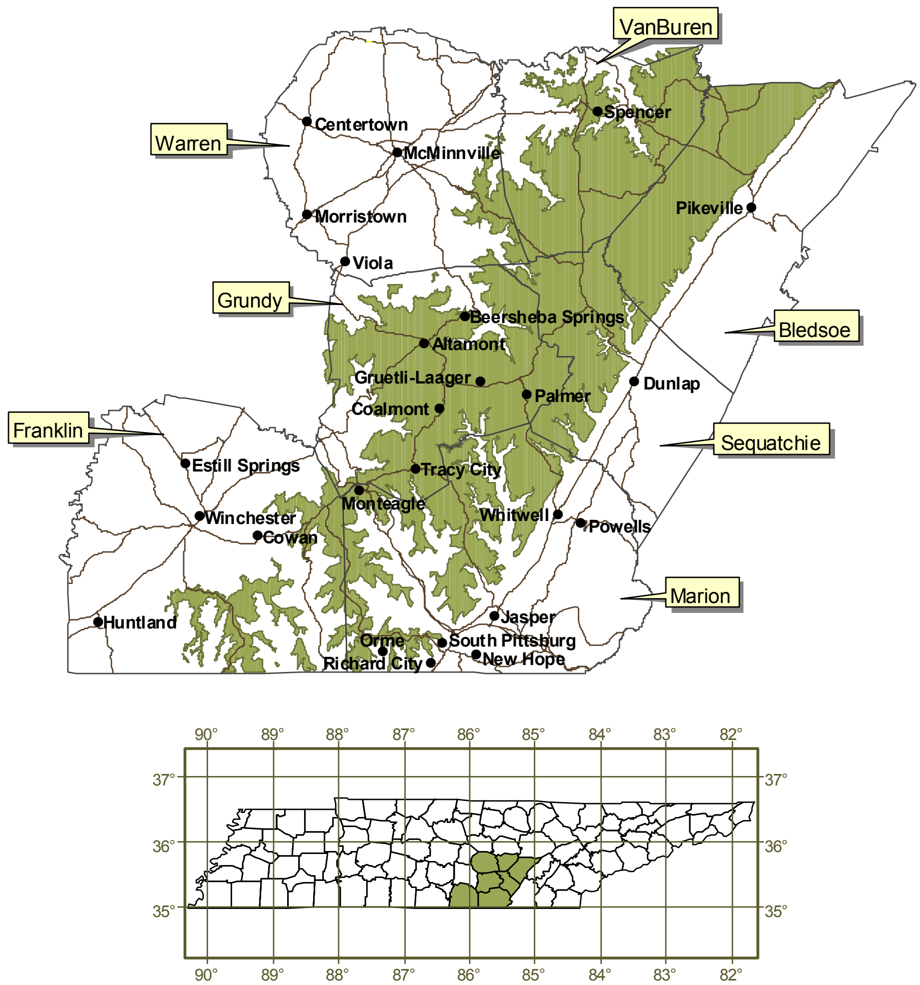


Figure 1. Shaded area represents the Small Area Assessment Demonstration Project study area with major roads, county boundaries and towns highlighted. This area is upland, oak-hickory forest ecosystem associated with the surface of the Cumberland Plateau in southern Tennessee.

The Project had the following specific objectives:

Mapping Patterns of Forest Change

a) To generate comprehensive forest change documentation for the Plateau study area (1981-2000) using remotely sensed data and current Geographic Information System (GIS) technology.
b) To assess the ability to generate such information at spatial and temporal scales relevant to local land use decision makers and in a cost-effective and technologically transferable manner.

Aquatic Biomonitoring

a) To use benthic macroinvertebrates and salamanders as indicators of water quality and the resulting biological integrity of watersheds within the study area.
b) To assess the utility of low cost aquatic biomonitoring as a means of tracking the impacts of land use change on water quality.

Bird Community Response to Forest Change

a) To examine the responses of bird communities to changes in forest structure, composition, and spatial distribution that result from land use change on the plateau.
b) To assess the utility of using birds as indicators for tracking the impact of land use change on plateau forest biodiversity.

This study was funded, in part, by the U. S. Environmental Protection Agency and the U.S. Fish and Wildlife Service as a Small Area Forestry Demonstration Project. The effort was initiated as part of these agencies' overall involvement with the Southern Forest Resource Assessment project, specifically to assist in analysis of the effects of land use change at smaller, sub-regional focus areas. Scientists from these agencies served as the peer review panel for this Report.

Findings

Within the last twenty years, native forests on the Cumberland Plateau have been cleared to create plantations of predominately loblolly pine (*Pinus taeda*), a species that is not native to the Plateau. The following information is based on a detailed, quantitative assessment of land use change on this portion of the Cumberland Plateau, with an emphasis on identifying the role of silvicultural activities in driving this change. Conversion of native forest habitats to pine plantations is a focus of this analysis along with other land use transitions.

Forest Change Mapping

Using aerial and satellite imagery, we created computer-generated maps of land use and forest cover for the study area (see Maps 1 – 8). The major cover categories depicted in these maps included: 1) native forest with an intact canopy; 2) silviculturally thinned native forest; 3) areas that had been recently logged and cleared of trees; 4) pine plantation; 5) areas with partial or no tree canopy in predominately agricultural or residential/urban use. From these maps we were able to track and document patterns of forest change and conversion between 1981 and 2000:

- There was approximately 14% less area with intact native forest canopy on the Cumberland Plateau in southern Tennessee in 2000 than was present in 1981. This represents a net loss of approximately 65,660 acres of native forest during this time.

- The rate and magnitude of pine conversion and native forest loss varied across counties and watersheds within the study area. However, all counties showed a net loss of native forest, with Van Buren County being the highest at 18% (15,868 acres). Pine conversion activity was highly clustered, causing a concentration of impact in certain counties and watersheds.

- Between 1981 and 1997, intact native forest area decreased at a rate of 3012 acres per year. Between 1997 and 2000 the rate of decrease was almost two times greater at 5823 acres per year.

- There was 237% more recently cleared forest area present in 2000 (30,935 acres) than was present in 1981 (9,185 acres).

- Total area in pine plantation (area with planted trees) increased by 170% (24,947 acres) from 1981 to 2000. Total area under intensive pine plantation management in 2000 (includes a proportion of recently cleared area plus area with planted trees) was determined to be 88,208 acres. Pine plantations and associated lands newly cleared for this purpose were responsible for 74% of native forest conversion.

- Total area of native forest converted to agriculture, residential and other non-silvicultural uses increased by 18% between 1981-2000 and was responsible for 26% of native forest conversion.

- About 80% of all newly created pine plantations that appeared in the study area between 1981 and 2000 were derived from either intact or thinned native forests. Less than 3% were derived from lands associated with agriculture. Between 1981 and 2000, most existing or recently converted pine plantations remained as pine plantations and did not transition to other uses.

- From 1997 to 2000, 90% of all native forest removal resulted from clearings that were greater than 40 acres in size (Forest Stewardship Council (FSC) certification limit). 70% of this native forest removal resulted from clearings that were greater than 120 acres in size (Sustainable Forestry Initiative® certification average clearcut size limit --The Sustainable Forestry Initiative® is a registered service mark of the American Forest & Paper Association).

Aquatic Biomonitoring

We surveyed salamanders and aquatic invertebrates (insects, crayfish, etc.) in streams across our study area. We found that streams in clearcuts had significantly lower salamander density than those in intact native forests. However, there were no statistically significant differences between the numbers of salamander species in streams running through clearcuts and streams in intact native forests. Aquatic invertebrates were more abundant in disturbed sites (sites that had some logging around them) than in undisturbed sites (sites surrounded by native forest, perhaps because of increased sediment loads). We calculated several indices of water quality based on the populations of aquatic invertebrates (some invertebrates are more tolerant of water pollution than others, so their populations tell us about water quality). Most of these indices were highly variable and lacked the statistical power to discern any differences in water quality. However, one index of water quality based on the proportions of tolerant and intolerant invertebrates indicated that water quality was significantly lower in disturbed sites. This index of water quality also increased with the width of the buffers of uncut forest that are left around streams in logged areas (known as stream-side management zones, or “SMZs”). This suggests that: (i) SMZs help provide increased water quality, and (ii) that some SMZs in our study area may be too narrow to provide maximal protection.

Bird Community Assessment

Our field surveys of breeding birds found that pine plantations had the lowest bird diversity and had the lowest conservation value, as measured by independently-derived Partners in Flight (PIF) priority scores. The intact native forests had the next highest diversity and PIF conservation value. These intact native forests had some of the highest levels of bird diversity found anywhere in the forests of the south-eastern U.S., indicating that this region offers high quality habitat for forest-dwelling birds. Residential/rural areas (including suburban areas and rural areas with low housing density) and thinned native forests had the highest diversity of breeding birds and the highest PIF conservation value.

Neither pine plantations nor residential areas can support the bird communities found in the native forests of the Cumberland Plateau. However, residential areas provide habitat for several species that are found in no other habitat types on the Plateau. In addition, residential areas, young pine plantations, and thinned native forests all provide habitat for a few specialist bird species that require a more open or grassy habitat. Some of these specialists are also present in patches of natural disturbance in native forests.

Our findings are in broad agreement with field studies conducted elsewhere. There is, however, evidence that the species-rich bird communities of the Cumberland Plateau are more vulnerable to loss of bird diversity when subjected to intensive timber management than are bird communities with relatively low species richness in other regions such as boreal and sub-boreal forests.

Recommendations for Completing Future Small Area Assessments

The primary purpose of this study was to examine changes in land cover and land use over time and the environmental effects associated with those changes at a sub-regional scale. However, another important objective of the study was to develop and identify technologically accessible, cost-effective ways of generating landscape-level information that could be used in future sub-regional focus area assessments across the South. In support of this goal, this study has identified methodologies that governmental and non-governmental organizations can access and afford in their search to generate quantitative, accurate information about current land-use changes occurring in their region. This information should become important pieces of any local, land-use decision-making process. In addition, technologies developed for this project could easily be applied as part of any forest certification process for the Cumberland Plateau, or any other area, to track certain indicators of sustainable forestry operations. The following represents some of the key methodological findings related to completion of future sub-regional focus area assessments with similar project objectives:

Forest Change Mapping

In main Report (Section 2.1 and Appendix E), we present a detailed comparison of the strengths and weaknesses associated with the various assessment techniques we tested for generating digital land use change maps for a small area (less than 1 million acres). While the most expensive to implement, the approach we chose to employ in our study provided the requisite degree of accuracy for our relatively large and complex study area and allowed us to take full advantage of the multiple imagery sources needed to examine a 20-year, historical time frame. The accuracy of any method, however, can be improved by ground verification. This process simply involves individuals traveling to areas that have been classified using remote sensing techniques and visually confirming the calls. Ground verification does not require any computer skills. Thus for a small area, where extensive ground verification is practical, a methodology which is less expensive to implement than ours may provide adequate accuracy. Furthermore, imagery for recent years is available in digital, orthorectified form, so a study whose aim was to only create a base land use layer for the purposes assessing future changes could have considerably lower costs. Additional specific recommendations:

- SAA requires a rigorous post-verification process, including ground assessment by a natural resource professional whose has a good working understanding of the area to ensure appropriate classification of land use or forest cover types from aerial or satellite imagery.

- Simple mensuration in the field such as total tree basal area and canopy height are useful in differentiating cover classes.

- Spectral information from satellite imagery can be useful in speeding up the error assessment process for high resolution aerial photography.

- Farm Service Agency small format slides are useful in identifying cover versus non-cover but are difficult to geocorrect, furthermore FSA slides should be used in conjunction with other data to differentiate between classification calls.

Aquatic Biomonitoring

- Future field studies should, if possible, be conducted after GIS descriptions of the habitat are available. These studies should make use of watershed-based landscape metrics (e.g., fractal dimension, proportion of different habitat types, etc.) to plan field sampling.

- High degrees of replication are required for statistical evaluation of variable datasets.

- The Normalized Differenced Benthic Index (NDBI) developed in this study shows promise for detecting differences in water quality in datasets with low levels of replication and statistical power.

- Our study did not include isolated ephemeral pools. The impact of land use change on these habitats on the Cumberland Plateau is unknown, and we recommend further research on the importance and fate of these habitats.

Bird Community Assessment

- Our study showed very distinct differences in bird communities based on a comparative assessment of land cover in fairly close geographic locations. This suggests that the assessment of a single land cover or very few cover types might not accurately reflect the “true” impact of land use on avian communities. We recommend that future studies continue to make such comparisons across the range of land uses/habitats in an area, rather than studying birds in only one habitat to document the “contributions” of this habitat. We also recommend that all assessments of the effects of urbanization and pine conversion take such comparisons into account.

- There is a need for further information about nocturnal birds, raptors, and bird communities out of the breeding season. Studies of productivity in different habitats would also help evaluate changes in our region.

- An analysis of the effects of variation in bird diversity within the residential-rural habitat class is needed to better understand the effects of different types of housing development.

- The integration of GIS layers with field sampling allowed us to investigate landscape-level effects. The direction of these effects depended on the spatial scale of the analysis; therefore we recommend that spatial analyses continue to be conducted at multiple scales.

Literature Cited

Adams, M. B., J. A. Burger, A.B. Jenkins, and L. Zelazny. 2000. Impact of harvesting and atmospheric pollution on nutrient depletion of eastern US hardwood forests. Forest Ecology and Management. 138:301–319.

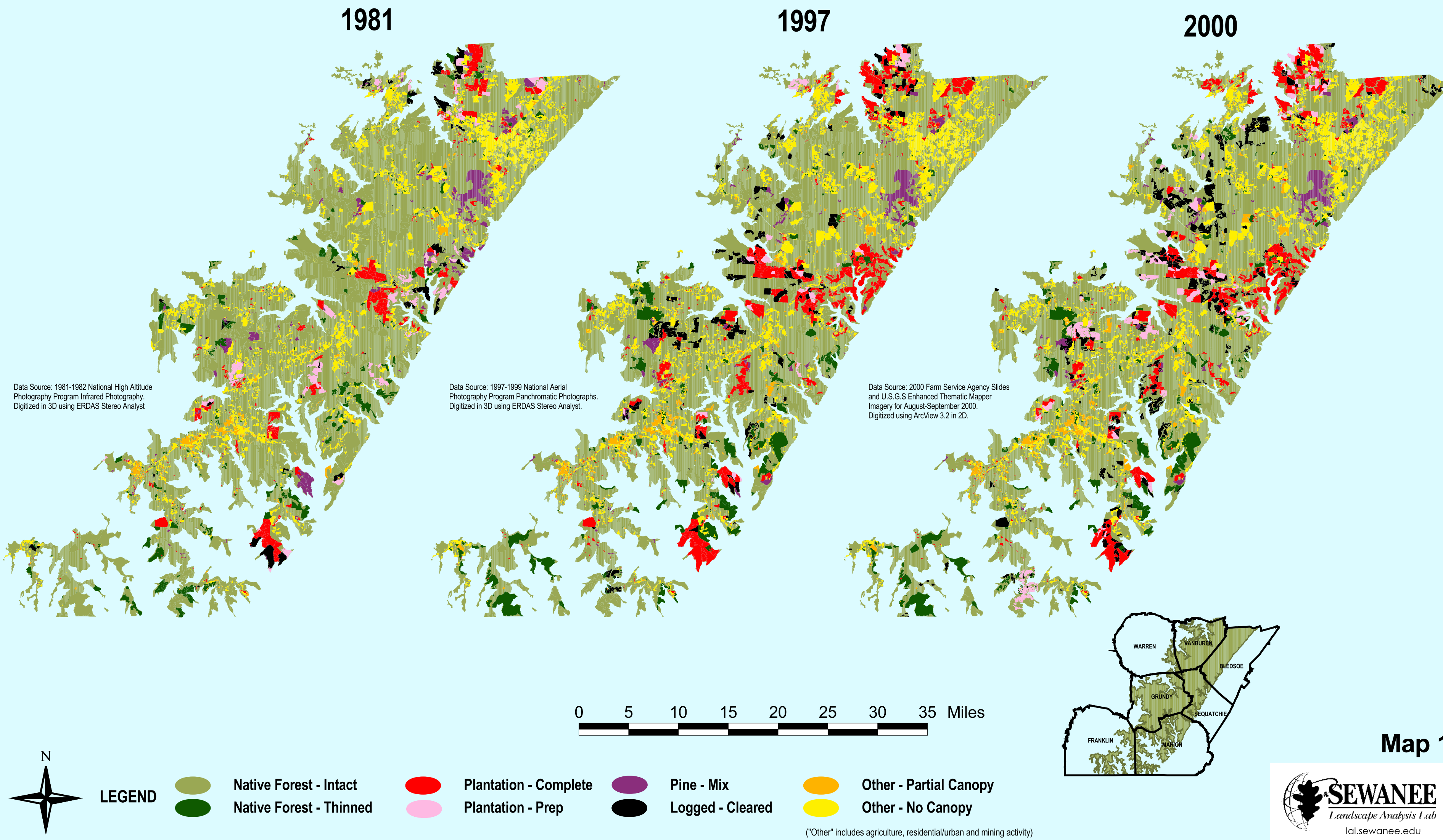
Durham, D. 1995. Managing Natural Resources: A Planning Guide for Franklin County.

McShea, W. J. and W. M. Healy. 2002. Oak Forest Ecosystems. Johns Hopkins University Press, Baltimore, MD.

Ricketts, T. H., E. Dinerstein, D. Olson, C. J. Loucks, W. Eichbaum, D. Della Sala, K. Kavanagh, P. Hedao, P. Hurley, K. Carney, R. Abell, and S. Walters. 1999. Terrestrial Ecoregions of North America. Island Press, Washington, DC.

Wear, D. N., J. G. Greis. 2001. The Southern Forest Resource Assessment Summary Report. U.S. Department of Agriculture Forest Service Southern Research Station and Southern Region.

Canopy Cover Map of the Cumberland Plateau Surface in SouthernTennessee



Map 1

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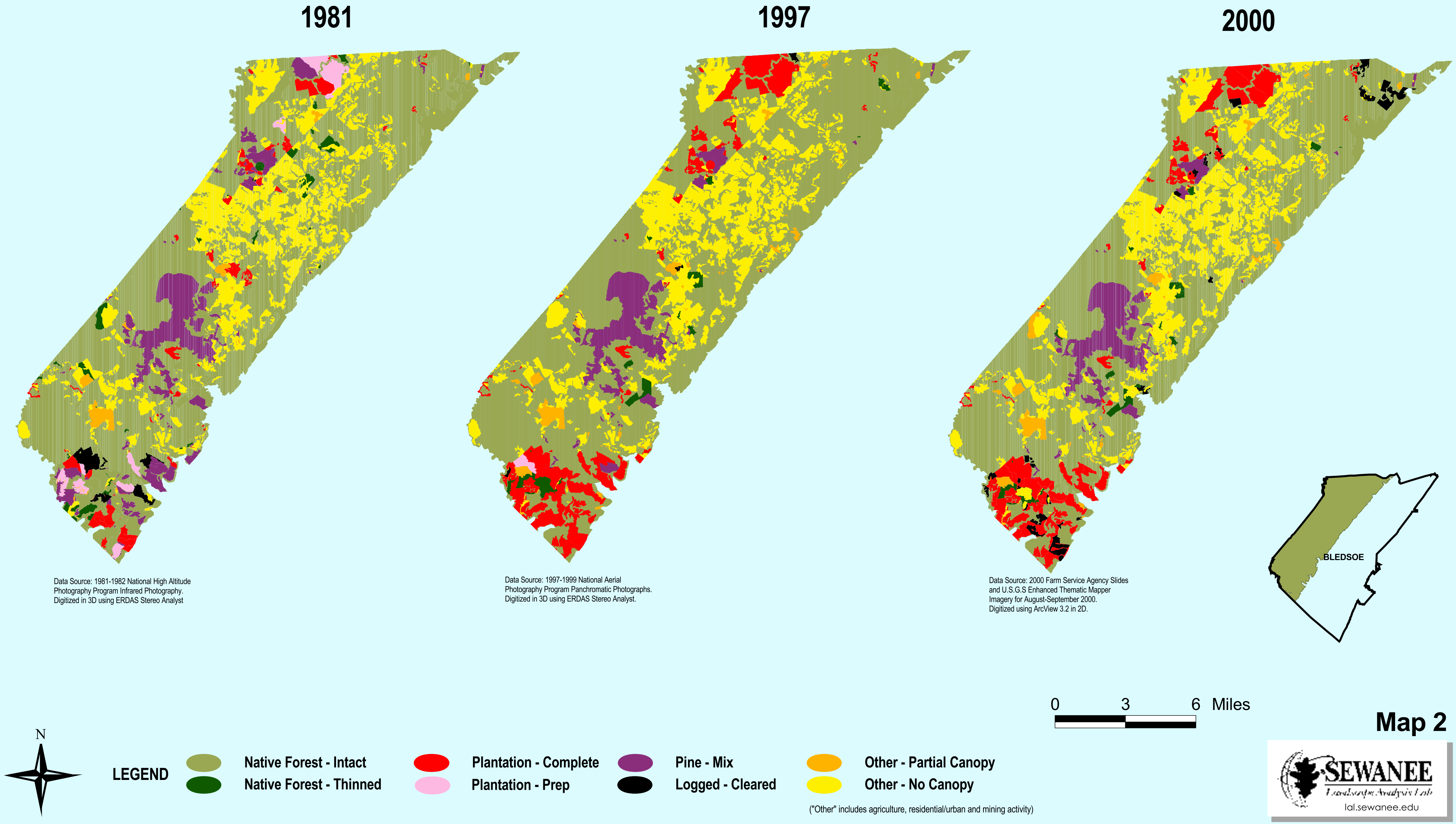
Canopy Cover Map of Bledsoe County, Tennessee - Plateau Surface



Map 2

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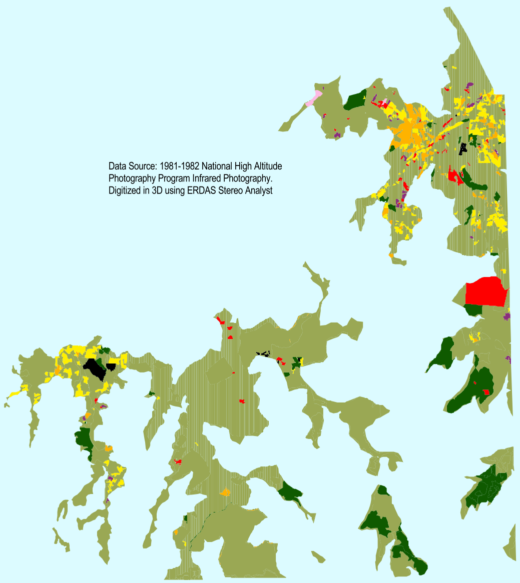
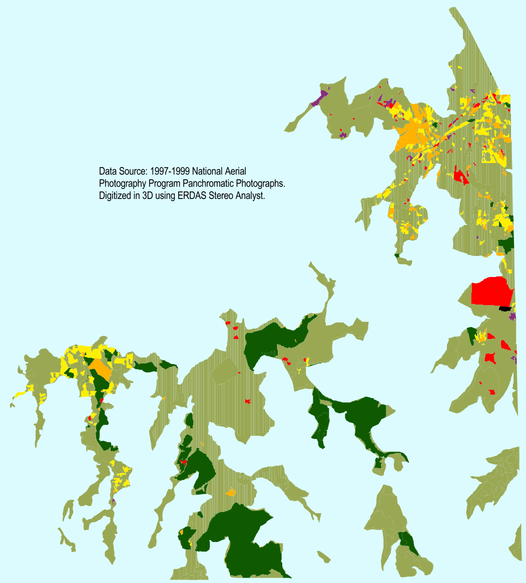
Canopy Cover Map of Franklin County, Tennessee - Plateau Surface

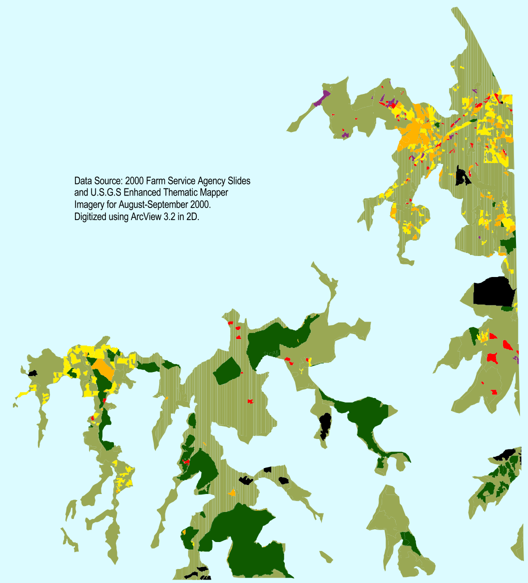
1981



1997



2000



0 5 10 Miles

Map 3

N

LEGEND

- Native Forest - Intact
- Native Forest - Thinned
- Plantation - Complete
- Plantation - Prep
- Pine - Mix
- Logged - Cleared
- Other - Partial Canopy
- Other - No Canopy

("Other" includes agriculture, residential/urban and mining activity)

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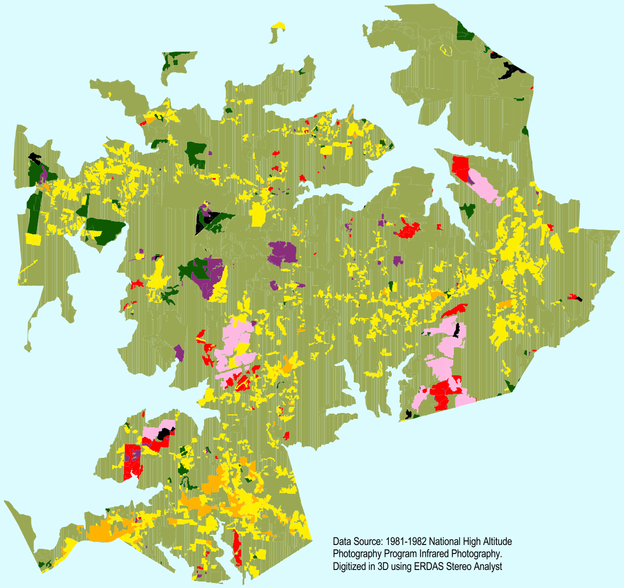
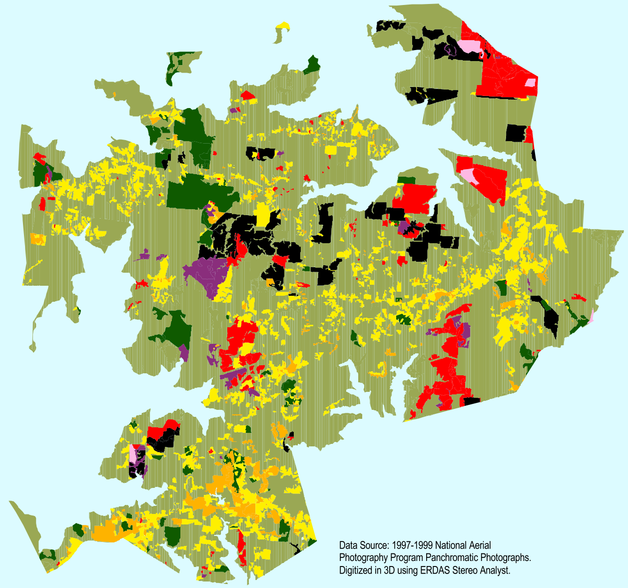
Canopy Cover Map of Grundy County, Tennessee - Plateau Surface

1981



Data Source: 1981-1982 National High Altitude Photography Program Infrared Photography. Digitized in 3D using ERDAS Stereo Analyst

1997



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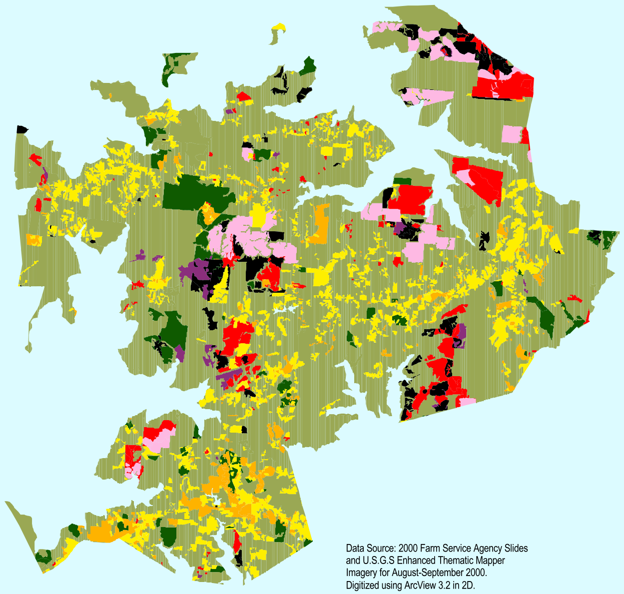
2000



Data Source: 2000 Farm Service Agency Slides and U.S.G.S Enhanced Thematic Mapper Imagery for August-September 2000. Digitized using ArcView 3.2 in 2D.

0 4 8 Miles

Map 4

N

LEGEND

- Native Forest - Intact
- Native Forest - Thinned
- Plantation - Complete
- Plantation - Prep
- Pine - Mix
- Logged - Cleared
- Other - Partial Canopy
- Other - No Canopy

("Other" includes agriculture, residential/urban and mining activity)

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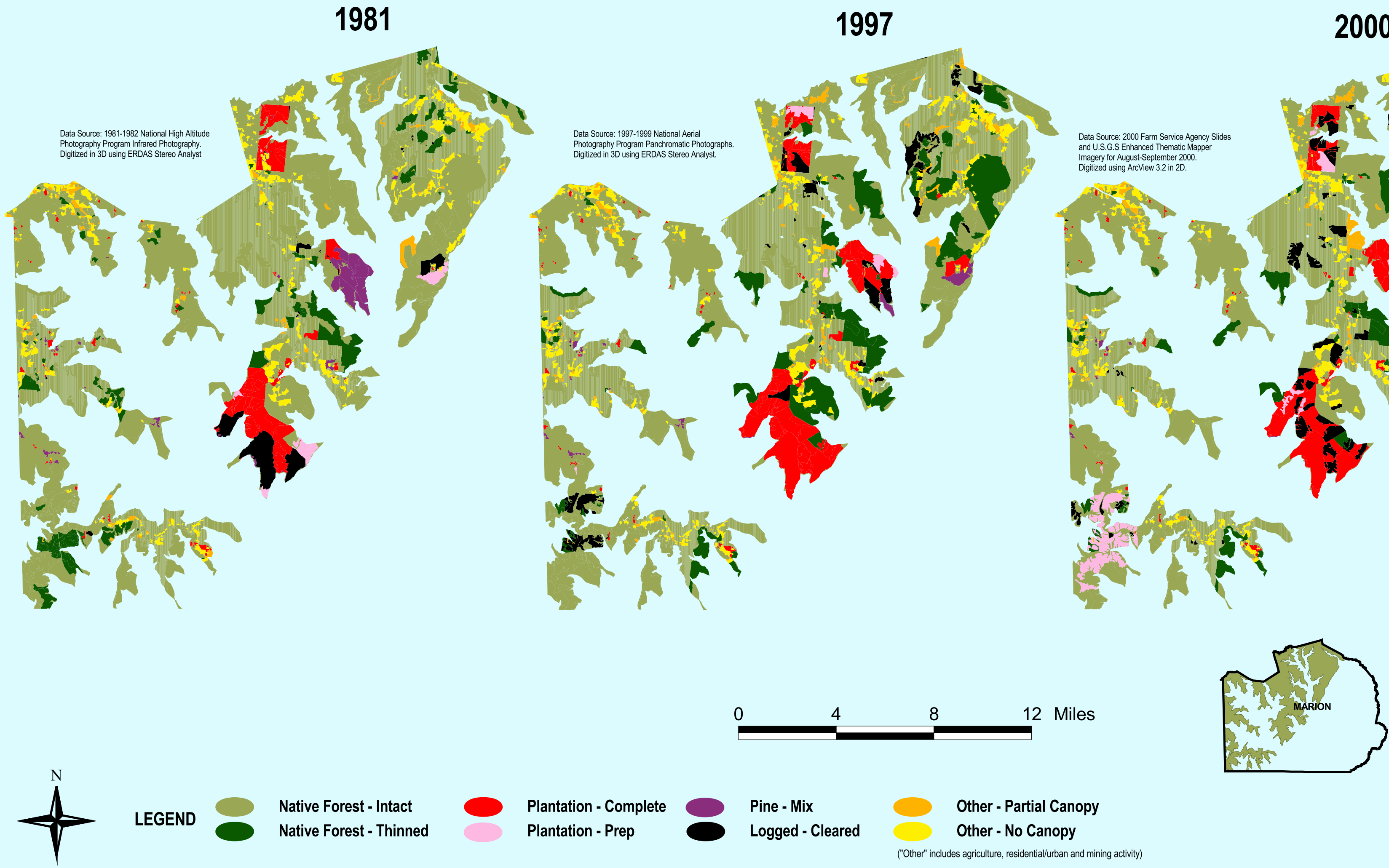
Canopy Cover Map of Marion County, Tennessee - Plateau Surface



Map 5

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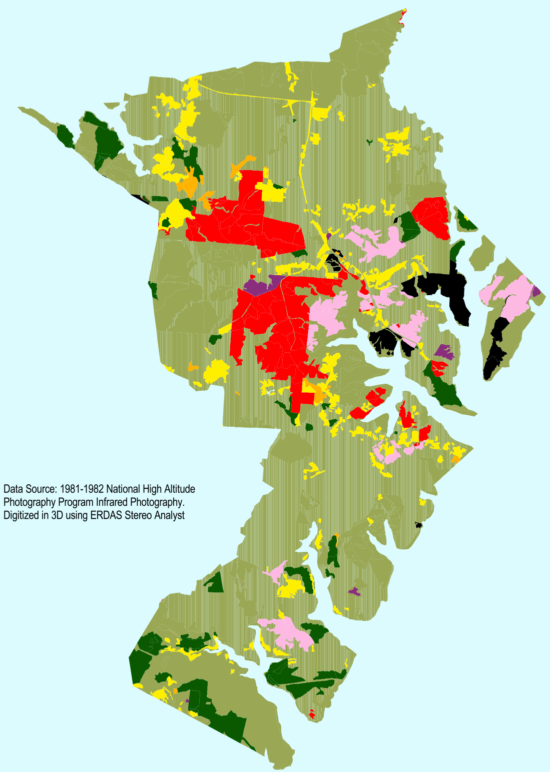
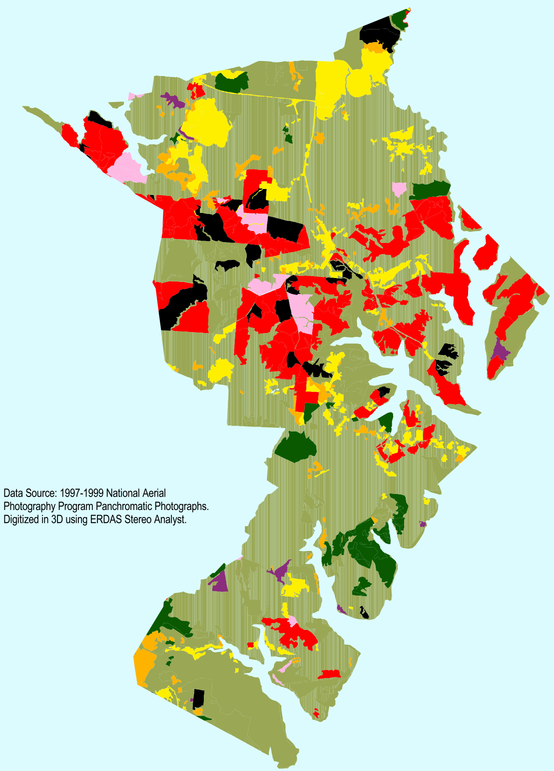
Canopy Cover Map of Sequatchie County, Tennessee - Plateau Surface

1981



Data Source: 1981-1982 National High Altitude Photography Program Infrared Photography. Digitized in 3D using ERDAS Stereo Analyst

1997



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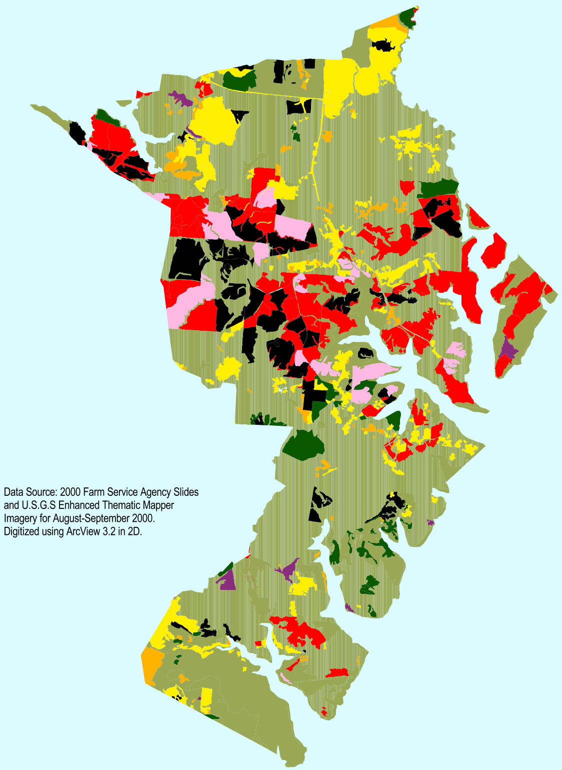
2000



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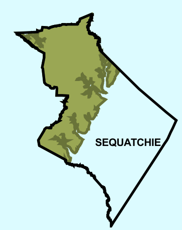
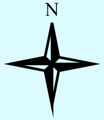
0 3 6 9 Miles



Map 6



LEGEND

- Native Forest - Intact
- Native Forest - Thinned
- Plantation - Complete
- Plantation - Prep
- Pine - Mix
- Logged - Cleared
- Other - Partial Canopy
- Other - No Canopy

("Other" includes agriculture, residential/urban and mining activity)

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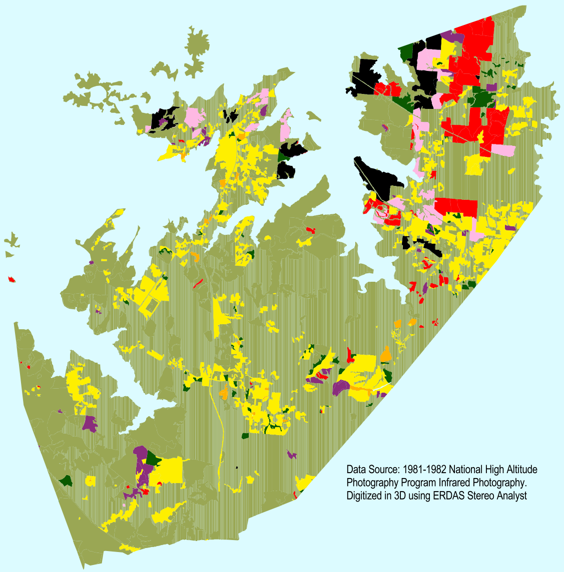
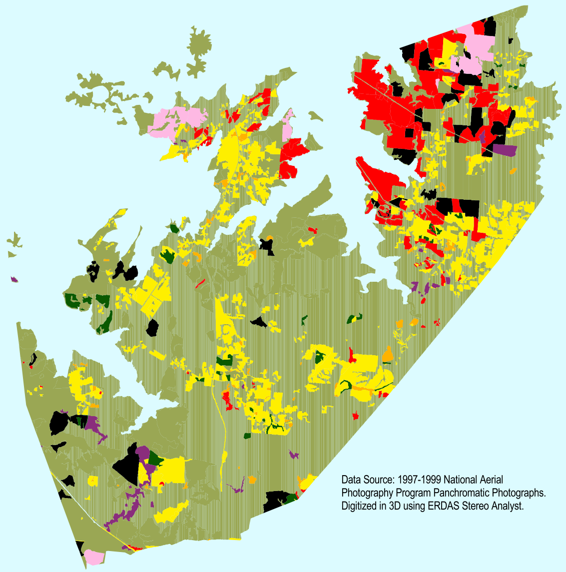
Canopy Cover Map of Van Buren County, Tennessee - Plateau Surface

1981



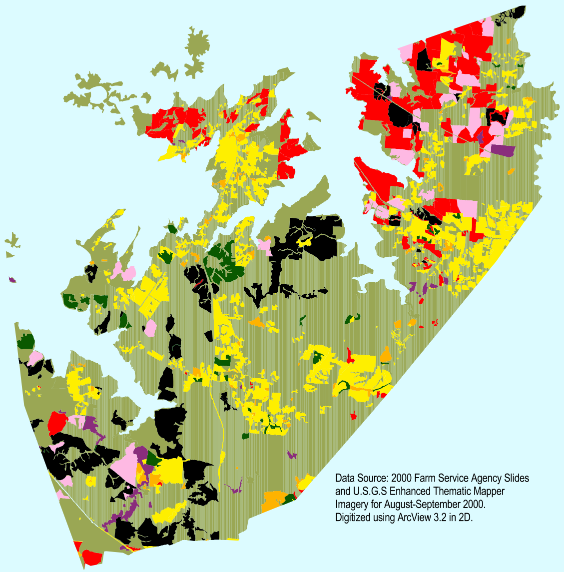
Data Source: 1981-1982 National High Altitude Photography Program Infrared Photography. Digitized in 3D using ERDAS Stereo Analyst

1997



Data Source: 1997-1999 National Aerial Photography Program Panchromatic Photographs. Digitized in 3D using ERDAS Stereo Analyst.

2000



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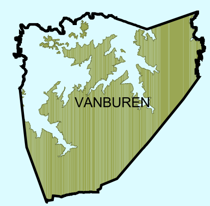

0 6 12 18 Miles

N

Map 7

LEGEND

- Native Forest - Intact
- Native Forest - Thinned
- Plantation - Complete
- Plantation - Prep
- Pine - Mix
- Logged - Cleared
- Other - Partial Canopy
- Other - No Canopy

("Other" includes agriculture, residential/urban and mining activity)

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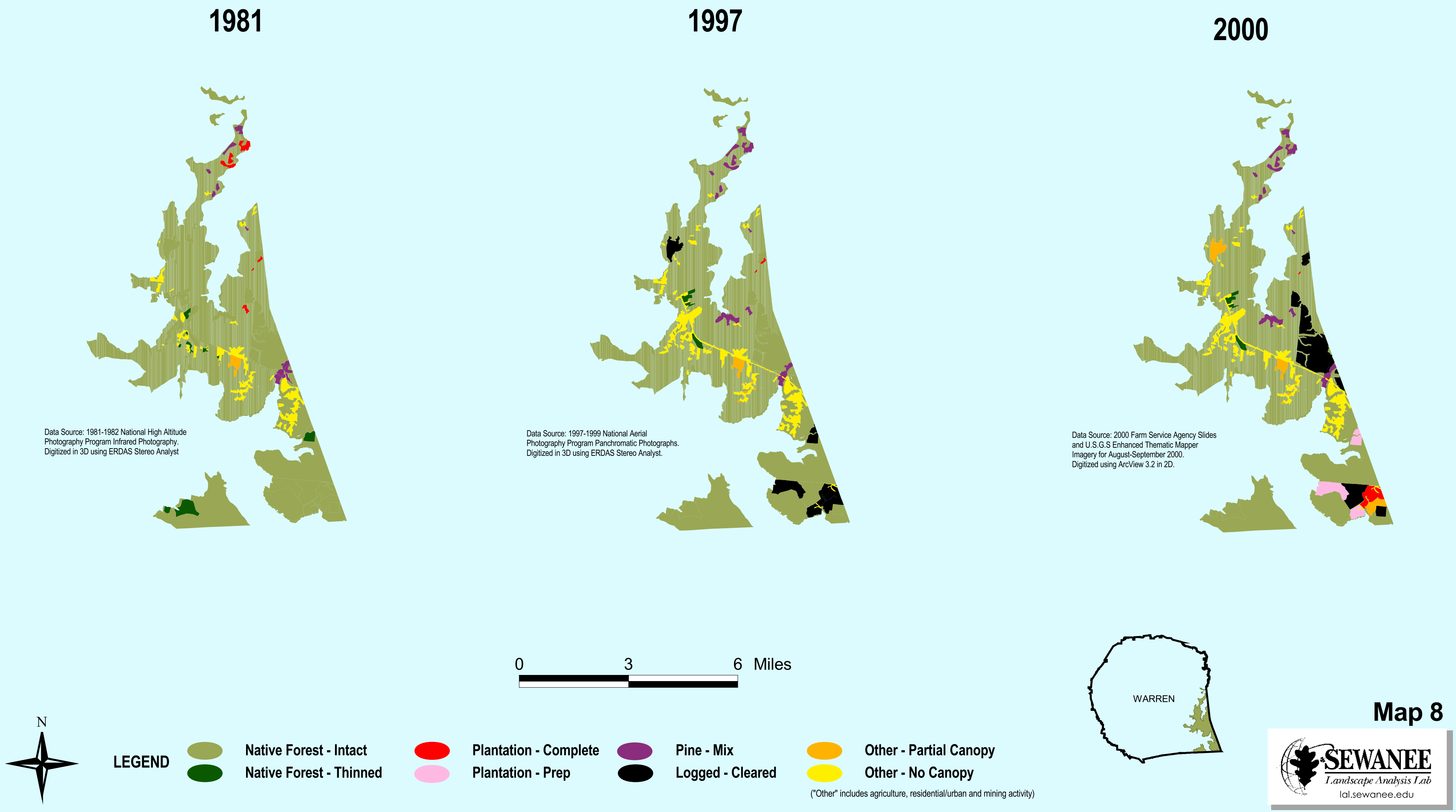
Canopy Cover Map of Warren County, Tennessee - Plateau Surface



Map 8

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