DEVELOPING DIGITAL VEGETATION FOR CENTRAL HARDWOOD FOREST TYPES: A CASE STUDY FROM LESLIE COUNTY, KY

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Abstract.—Digital vegetation is the computerized representation, with either virtual images or animations, of vegetation types and conditions based on current measurements or ecological models. Digital vegetation can be useful in evaluating past, present, or future land use; changes in vegetation linked to climate change; or restoration efforts. Digital vegetation can be spatially explicit at various scales: region, subregion, landscape, landtype, forest, or stand. Advances in computer technology allow us to build digital vegetation based on integrated environmental information (i.e., soils, topography, forest types, and vegetation composition).

INTRODUCTION

With recent advances in technology, three-dimensional visualization of forest landscapes has increased in sophistication and applicability (McGaughey 1998). Supplemented with geographic information systems and remotely sensed data, computer-animated pictures and movies can now be used to represent real-world forests in three dimensions. Using this medium allows us to visualize not only forest structure and composition, but also spatial and temporal dynamics occurring in forests. Visualization has advanced as a very useful tool for comparing management options and for analyzing forest dynamics at stand and landscape levels (Orland 1994, McCarter 1997, Wang and others 2006). By generating virtual forests, it helps forest planners and managers experiment with the consequences of various management scenarios; they can quantify and visually compare the differences. This approach allows comparison of various forests and landscapes without time limitations.

To visualize a forest landscape, the data needed include digital elevation models (DEMs), forest-type maps, tree images, tree size, stand densities, and species composition. Other landscape features such as roads, streams, and buildings can also be included to add to the quality of visualizations. Sometimes, however, it is hard to get the necessary information (e.g., tree size and stand density). An alternative is to use existing public datasets collected in ecosystems similar to the landscape desired for visualization. In this study, Forest Inventory and Analysis (FIA) data from the U.S. Department of Agriculture, Forest Service (Miles and others 2001) were used for the visualization of central hardwood forests. FIA data are a public domain database and have been widely used in scientific investigations and resource management. The specific objectives of this study were to: (1) visualize major forest types of the Central Hardwood Forest Region (CHFR) occurring in Leslie County, KY; and (2) discuss the potential applications of visualizations and the limitations of our visualizations of central hardwoods.

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STUDY AREA

The Central Hardwood Forest Region covers approximately 100 million acres in the eastern United States and is one of the largest forest areas in the country (Clark 1989). Climatic factors (i.e., winter temperature and summer drought) provide boundaries for the CHFR on the north, south, and west. The Appalachian Mountains provide a general boundary on the east (Clark 1989). Based on FIA's forest-type classification (Miles and others 2001), our study area contains the following six main hardwood forest types in Leslie County, KY: oak forest, yellow-poplar forest, mixed deciduous forest, oak-pine mixed forest, other mixed forest, and deciduous woodland (Table 1, Fig. 1). These six forest types occupy 86 percent of the county, and mixed deciduous forest (49 percent) is the main type in our study area. The dominant species in these six forest cover types are American beech (*Fagus grandifolia* Ehrh.), black oak (*Quercus velutina* Lam.), chestnut oak (*Q. prinus* L.), northern red oak (*Q. rubra* L.), white oak (*Q. alba* L.), scarlet oak (*Q. coccinea* Muenchh.), red maple (*Acer rubrum* L.), and pine (*Pinus* spp.). Tree heights range from 7 to 135 feet and tree density varies by forest type.

METHODS

Data for this study are from the FIA database (Miles and others 2001), which provides complete information on plot location, stand density, species composition, and height and diameter at breast height (d.b.h.) for individual trees. The DEMs can be downloaded from The National Map Seamless Server (provided by the U.S. Geological Survey, http://seamless.usgs.gov/). They can also be downloaded from The Geospatial Data Gateway (provided by the U.S. Department of Agriculture, Natural Resources Conservation Service, http://datagateway.nrcs.usda.gov/GatewayHome.html).

The FIA dataset was designed for determining the extent, condition, volume, growth, and depletion of timber on the nation's forest lands. Prior to 1999, all inventories were conducted every 7-10 years in the South and every 12-15 years in the North. With the passage of the 1998 Farm Bill, the U.S. Forest Service is required to collect data on 20 percent of the plots annually within each state. The research stations of the Forest Service, in cooperation with each state, are responsible for conducting these inventories and publishing summary reports for individual states and survey units (Miles and others 2001). Variables required for visualization (e.g., tree heights and density) are available in the FIA database.

The FIA data were filtered using combinations of qualifiers (e.g., locations, stand type, ownership, slope, species, d.b.h., and physiographic class) so that different forest types were simulated independently. Locations based on land-cover maps, stand type, age, ownership, and species were used as qualifiers to filter the data in this study.

Table 1.—Area and relative percentage of six forest types in Leslie County, KY.

Land cover type	Area (Hectare)	Percentage
Oak forest	73,715.4	28.50
Yellow-poplar forest	13,928.8	5.38
Mixed deciduous forest	126,043.6	48.73
Oak-pine mixed forest	4,060.4	1.57
Other mixed forest	2,865.2	1.11
Deciduous woodland	2,470.5	0.96
Total	258,679.1	86.24

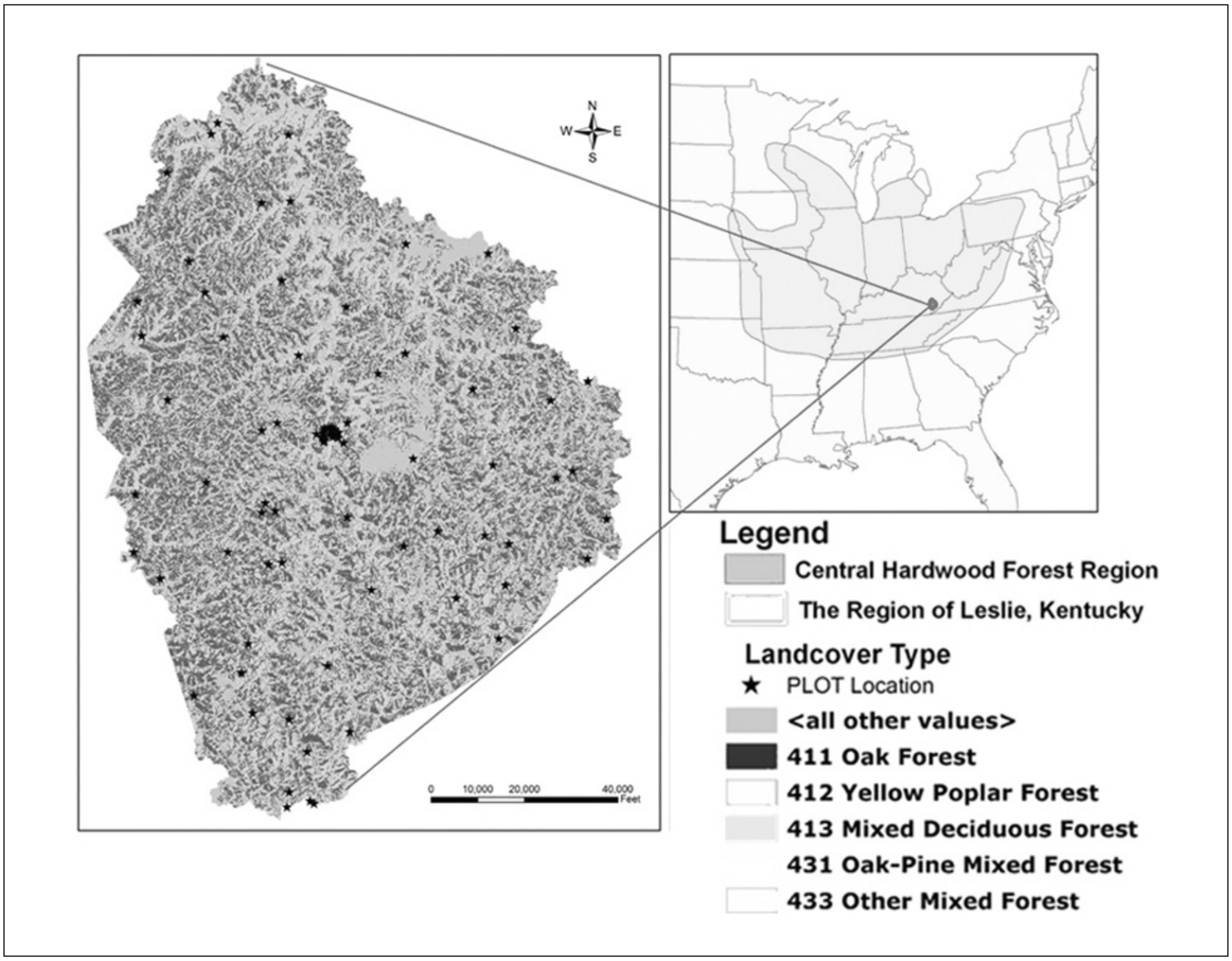

Figure 1.—Central Hardwood Forest Region and forest type map of study area, Leslie County, KY.

The first step of the visualization process is to generate realistic tree images. The detailed images of single trees are a crucial component of high-quality computer visualization. We developed a set of individual tree images of nine species dominant in central hardwood forests (Fig. 2). Different tree species were ranked by their densities in a forest, and the dominant species were chosen based on how many trees existed in this forest type. The individual tree images were generated in a graphics software package called TREE Professional (Onyx Computing Inc.; Fig. 2).

The second step was deriving spatially referenced forest data (tree species, sizes, forest composition, and density) from FIA data (Table 2). This step is critical for designing visualizations of the six major forest types within the study area. Then the vegetation views were visualized by VNS® (Visual Natural Studio; 3D Nature, LLC 2002). A series of images was prepared for each species in each forest type to account for variations in forest age and density. Subsequently, each forest type can be presented by digital vegetation (Figs. 3 and 4).

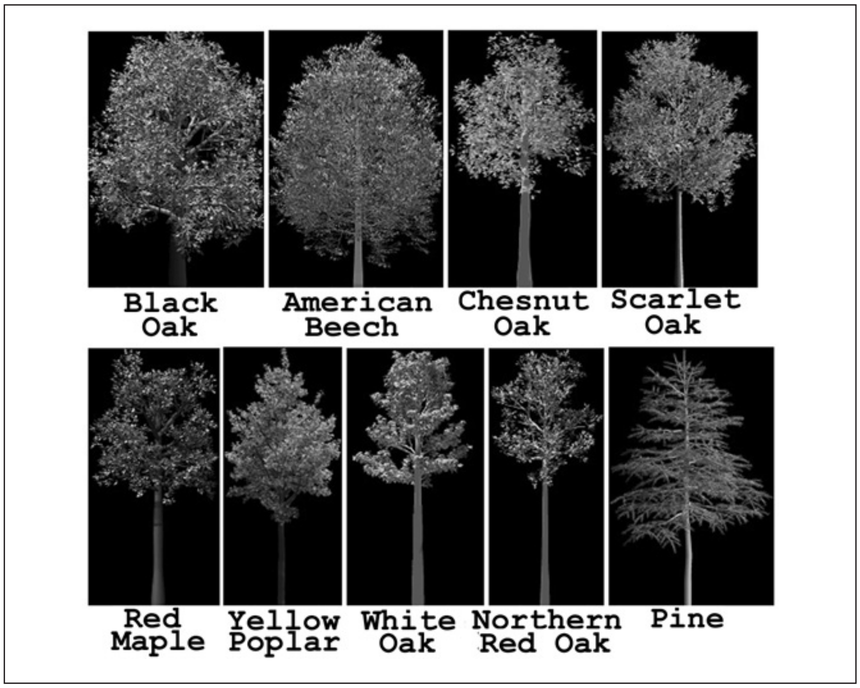

Figure 2.—Individual tree images of dominant species designed in Onyx® for visualization of six forest types in Leslie County, KY.

Table 2.-Species composition of six forest types in Leslie County, KY

Grid Code	Land cover type	Species	Composition	HT min (ft)	HT max (ft)
411	Oak Forest	red maple	26%	9.57	115.65
		yellow-poplar	23%	12.83	112.52
		chestnut oak	17%	8.00	133.00
		American beech	13%	13.78	108.27
		white oak	12%	10.06	77.12
		black oak	9%	26.30	95.04
412	Yellow-Poplar Forest	yellow-poplar	32%	13.00	114.00
		chestnut oak	24%	7.92	131.61
		American beech	17%	14.00	110.00
		white oak	15%	10.16	77.87
		black oak	12%	27.07	97.79
413	Mixed Deciduous Forest	red maple	24%	11.00	133.00
		yellow-poplar	21%	12.83	112.52
		chestnut oak	16%	8.00	133.00
		American beech	12%	13.78	108.27
		white oak	11%	19.00	100.00
		black oak	8%	10.06	77.12
		scarlet oak	5%	22.00	129.00
		northern red oak	4%	26.30	95.04
431	Oak-Pine Mixed Forest	yellow-poplar	35%	7.03	116.84
		chestnut oak	18%	9.97	76.46
		black oak	39%	28.23	102.01
		pine	17%	25.65	84.00
433	Other Mixed Forest	American beech	41%	12.70	111.39
		chestnut oak	37%	10.33	79.20
		black oak	22%	31.00	112.00
441	Deciduous Woodland	chestnut oak	47%	7.18	119.44
		yellow-poplar	38%	10.84	83.09
		black oak	15%	25.59	92.46

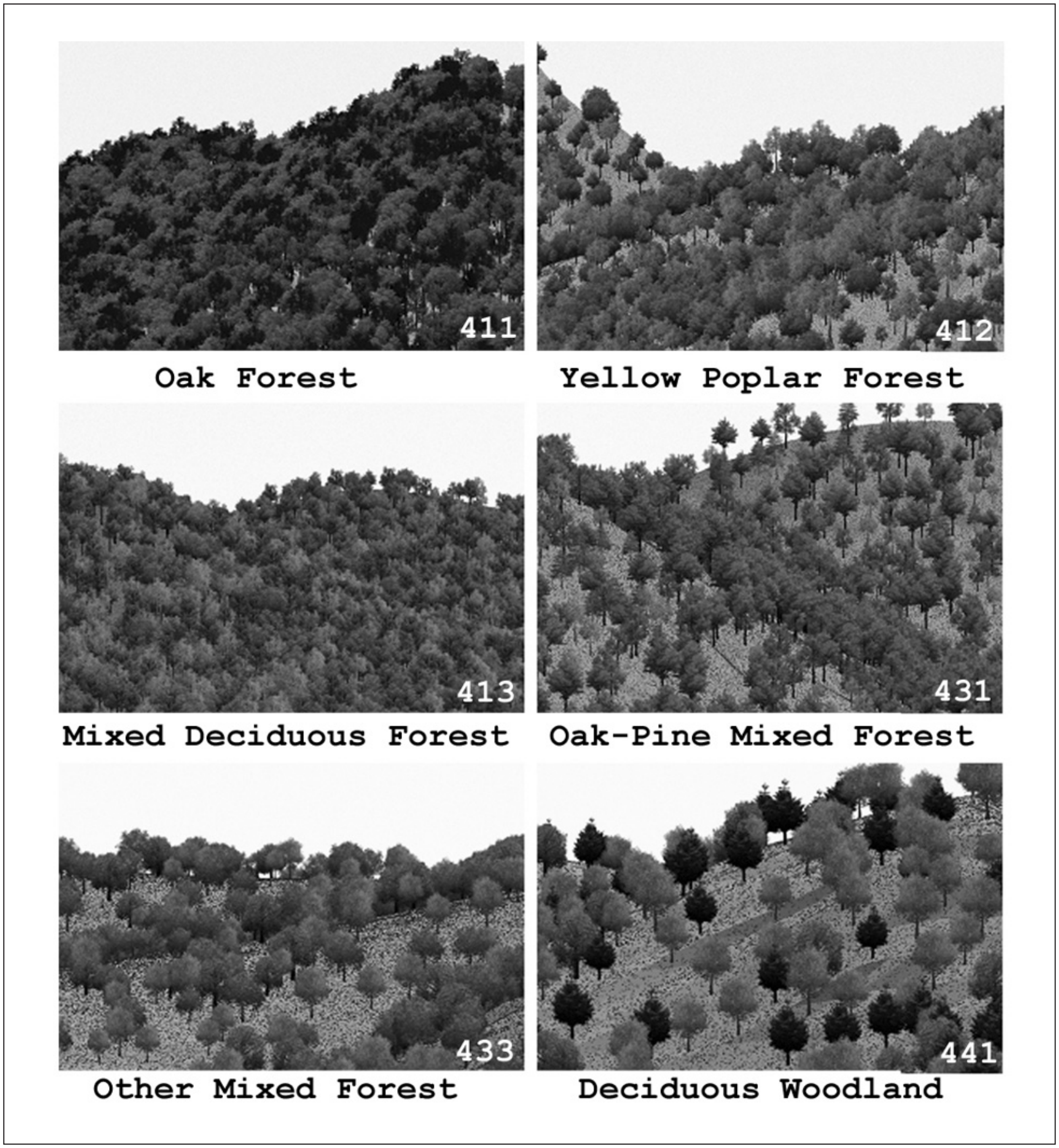

Figure 3.—Visualization of stand view on six forest types in Leslie County, KY.

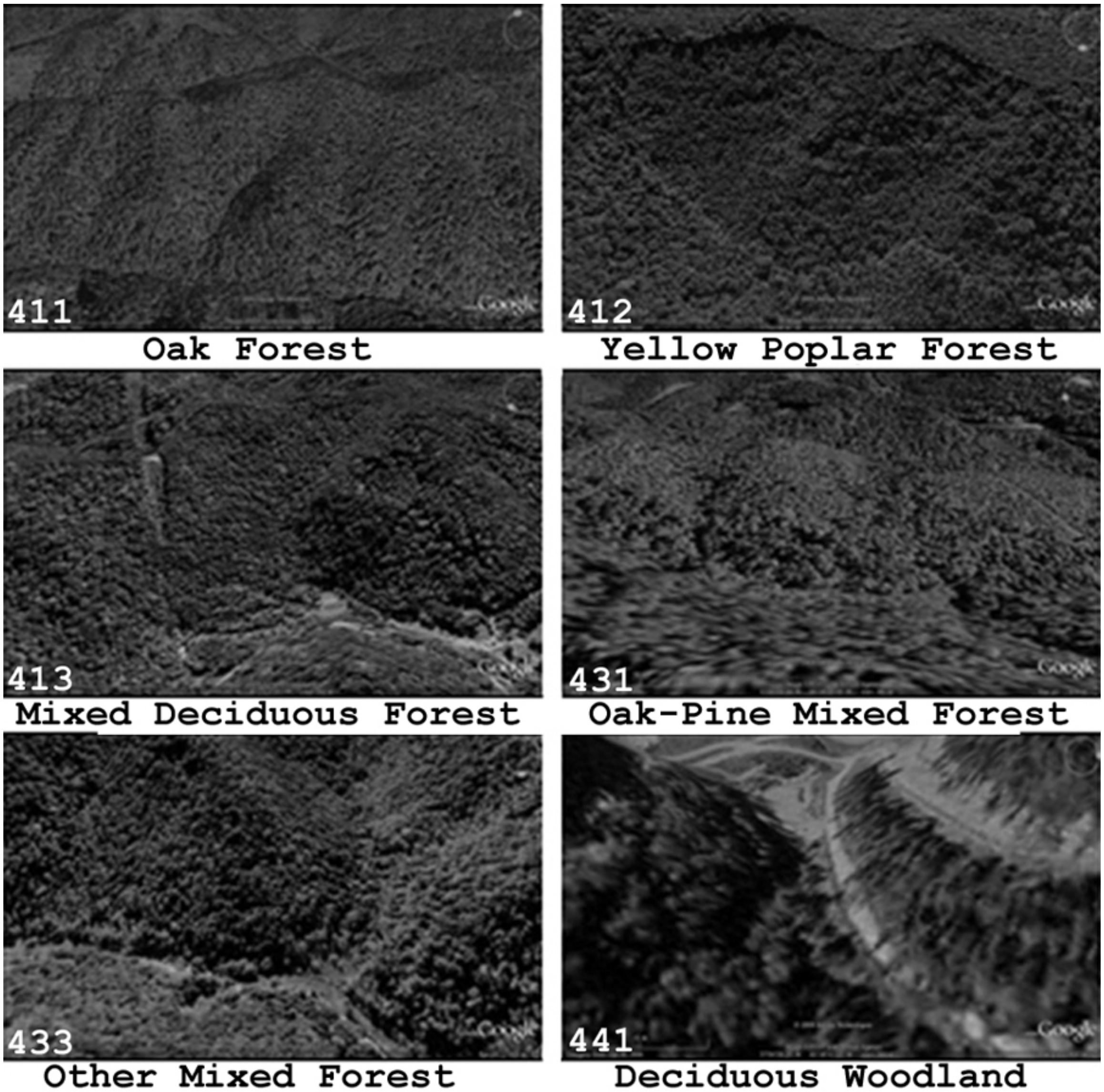

Figure 4.—Visualization of landscape view on six forest types in Leslie County, KY.

RESULTS

Among the six forest types of our study area, mixed deciduous forests occupied the largest area, 49 percent (Table 1, Fig. 1-pink), followed by oak forests, 29 percent (Table 1, Fig. 1-blue). Although the dominant species are similar in oak forests and mixed deciduous forests (e.g., similar percentages for red maple, yellow-poplar, and chestnut oak), the percentage of scarlet oak and northern red oak is higher in mixed deciduous forests (Table 2). According to FIA data, however, the basal area of oak in oak forests (approximately 127,000 sq ft) is almost twice as large as in mixed deciduous forests (approximately 66,000 sq ft). Yellow-poplar forests occupied only 5 percent of our study area (Table 1); dominant species were yellow-poplar (32 percent), chestnut oak (24 percent), and American beech (17 percent, Table 2). The other three forest types—i.e., oak-pine mixed forest, other mixed forest, and deciduous woodland—represent only 4 percent of the area (Table 1).Using the FIA data, virtual forests of the six forest types were visualized using VNS software (Fig. 3). For each type, a location on the DEM was chosen and the FIA data for that forest type were used to distribute the correct tree images to the view of that location. These virtual forest visualizations can be compared to a Google Earth™ aerial view of environments similar to those of the DEM base (Fig. 5).

In addition to production of pseudo-photographic views, the software can produce comparisons or representations that are unavailable in the real landscape. Figure 4 shows a comparison of all six forest types in an overhead view of a single landscape. Such a method would be most appropriate for planning of forest changes.

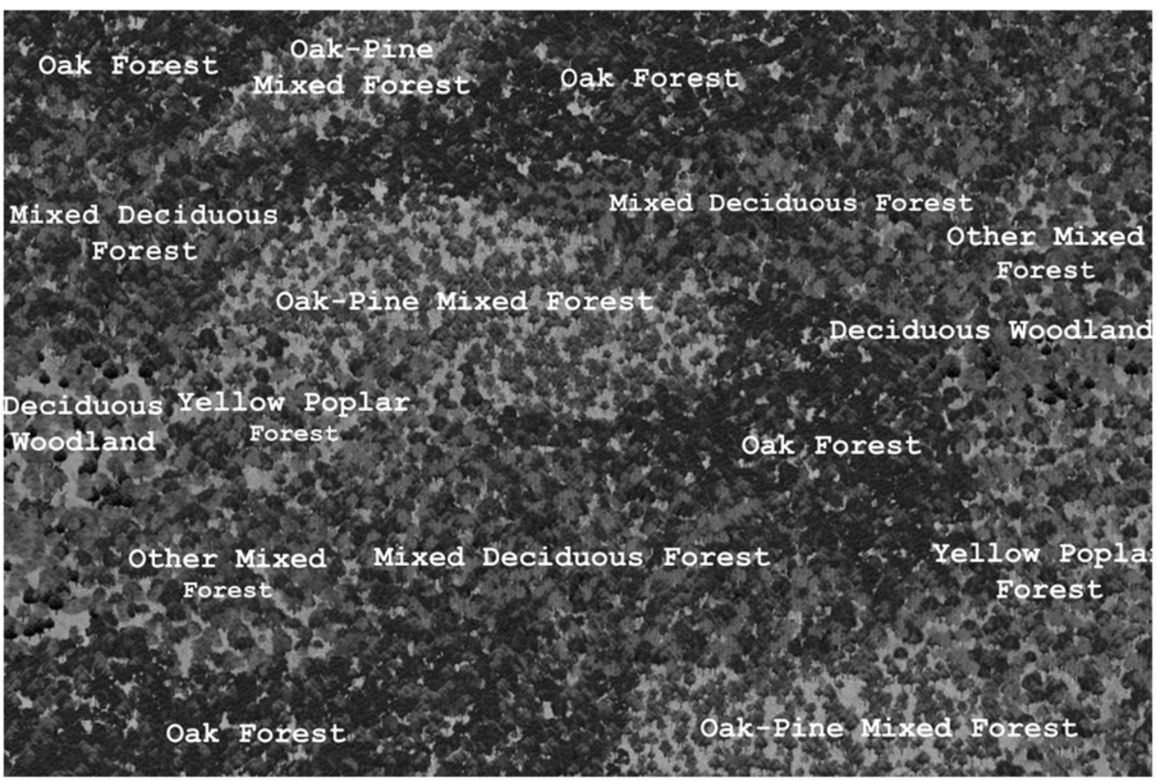

Figure 5.—Google Earth™ aerial views of the positions visualized in Figure 3.

DISCUSSION

These results demonstrate that public datasets can be used for visualization of forests and other landscapes. FIA data are one of the most accessible public forest datasets available, allowing low-cost and convenient visualization anywhere in the CHFR. Likewise, DEM data, at a resolution of 98-ft grid cells, are also freely available for the entire United States. Visualizations could be made using the aggregate data on species, age, size, and density for a randomly chosen county within the CHFR. Publicly available data on terrain shape and forest attributes produced photorealistic views of the two major forest types in this study. Since FIA data are allocated to represent an entire forest area, while the distribution of plots and subsequent representativeness of the data are allocated according to the area of each forest type, minor forest types may have relatively few points and the data may not represent the entire range of tree species, size, and density of the forest type.

Truthfulness and quality of visualizations are essential to forest managers or land owners (Daniel and Meitner 2001). From Figures 3 and 4 it is obvious that visualization based on FIA data is most realistic for the two most common forest types (mixed deciduous forest and oak forest). The quality of realism of the visualization (Figs. 3 and 4) appears to parallel area of the forest type (Table 2). Less common forest types appear much less likely to be visualized satisfactorily for photorealistic depictions. If the goal is depiction of small areas that are in an uncommon forest type, the FIA data do not appear to be sufficient; more detailed field inventory will probably be needed. Overall, the FIA data may be more applicable to non-photorealistic applications such as Figure 4.

This study revealed some of the difficulty that might be encountered when visualization is applied to central hardwoods. Application to a single random location showed that the quality of visualization depended on the representativeness of the original data source. Data collected for determining the extent, condition, volume, growth, and depletion of timber on the nation's forest lands will be concentrated on the most common, abundant species. In this visualization tree images were developed only for tree species that made up more than 5 percent of the overstory. Other minor species are not represented in the visualizations. The range of the CHFR is defined by the joint range of six species (hackberry [*Celtis occidentalis*], swamp white oak [*Quercus bicolor*], pin oak (*Q. palustris*), Ohio buckeye [*Aesculus glabra*], shellbark hickory [*Carya laciniosa*], and bur oak [*Q. macrocarpa*]; Little 1971, Fralish 2003) yet none of these species dominates the common stands of the CHFR. Visualization in this region may well require a very large library of tree images that includes many of the common minor species. Ignoring minor species may have also been a reason for the rather poor representations of four forest types.

Overall, satisfactory visualization can be obtained for major forest types within the CHFR using publicly available DEMs and FIA data. The results were not satisfactory for forest types that were of limited areal extent in this particular county.

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