Journal of the Arkansas Academy of Science

Volume 62 Article 18

2008

Historical Forest Landscape Changes in the Buffalo River Sub-Basin in Arkansas

Robert C. Weih Jr.
University of Arkansas at Monticello, weih@uamont.edu

A. Dick

Historical Forest Landscape Changes in the Buffalo River Sub-Basin in Arkansas

R. Weih, Jr.[1] and A. Dick[2]

[1]*Spatial Analysis Laboratory (SAL), University of Arkansas at Monticello (UAM), Arkansas Forest Resources Center, School of Forest Resources 110 University Court, Monticello, Arkansas 71656*
[2]*Bureau of Land Management, 4621 East 65th Avenue Lower, Spokane, WA 99223*

[1]Correspondence: weih@uamont.edu

Abstract

Forested areas in the United States have been altered since the time of European settlement. For this reason, research interests have increased in comparing present day vegetation with that of the pre-Euroamerican era to see what changes, if any, have occurred in some of our more outstanding natural areas. Such studies have been conducted in other parts of the United States but limited research has been done in Arkansas. The General Land Office (GLO) surveys of Arkansas were originally conducted between approximately 1815 and 1850 shortly after Arkansas was acquired from France by means of the Louisiana Purchase and provides the only systematic on-ground survey in Arkansas that predates most formal botanical investigations. The GLO surveys used witness trees to define the location of section corners and lines. Descriptions of witness trees included tree species and diameter along with distance and direction to the section corner or line. This historical GLO data was compared to United States Forest Service (USFS) Forest Inventory and Analysis (FIA) data, which represent present vegetation conditions for 62 townships in the Buffalo River Sub-basin. Comparisons indicated that eastern red cedar (*Juniperus virginiana*) increased from 0.7% to 7.8% of the total forest species in the sub-basin, hickory (*Carya spp.*) increased from 8.2% to 14.3%, while oak (*Quercus spp.)* species decreased from 43.0% to 30.1%. Based on this study it appears that post-Euroamerican settlement fire suppression and agricultural practices in addition to other human activities has caused vegetation changes in this area.

Introduction

In 1972, Congress established the Buffalo River as the first National Scenic River in the United States. It is one of the few remaining free-flowing rivers in the lower 48 states beginning in the Boston Mountains of Arkansas and emptying into the White River near Buffalo City, Arkansas. The watershed currently consists of open farmlands, forests, abandoned home sites and small urban areas.

Native Americans have lived in the area for over 10,000 years (USDA 1999a). It is believed that the present tree species occupying the watershed were established approximately 5,000-6,000 years ago after stabilization of climate following the last ice age (USDA 1999a). European settlement in the Ozarks began in the late 1820's and is evident by place names and by many abandoned settlements. Beginning in the early 1900's, fire suppression is believed to have altered tree species composition by favoring less fire-tolerant species (Schroeder 1981, Guyette and McGinnes 1982). Agricultural practices and other human activity since settlement have also significantly impacted tree species composition (Abrams 1998, USDA 1999b).

The Buffalo River Sub-basin represents one of the few remaining pristine waterways in this country, making it an area of great conservation concern. By comparing past and present vegetative conditions it may be possible to understand at least some of the changes that have occurred. For these reasons we implement a study which analyzes pre-Euroamerican Landscape within the Buffalo River Sub-basin. Thus, the objectives of the study were to compare major pre-Euroamerican species groups found in the Buffalo River Sub-basin using the General Land Office (GLO) Surveys and the United States Forest Service (USFS) Forest Inventory and Analysis (FIA) data to see what changes have occurred over time.

Previous work using General Land Office Surveys

Numerous studies in other parts of the United States have used GLO notes to analyze and compare present day vegetation with pre-Euroamerican vegetation. An incomplete listing of studies includes those conducted in Ohio (Whitney 1982), Texas (Schafale and Harcombe 1982), Iowa (Anderson 1996), Pennsylvania (Abrams and Ruffner 1995), Wisconsin (Dorney and Dorney 1989, Manies and Mladenoff 2000, Sickley et al. 2000), Illinois (Fralish et al. 1990, Leitner and Jackson 1980), Michigan (Palik and Pregitzer 1992, Zhang et al. 2000), Louisiana (Delcourt 1976), New York (Loeb 1987), New Jersey (Russel 1981, Loeb 1987), Vermont (Siccama 1971) and West

Virginia (Abrams and McCay 1996). Most of these studies used the GLO notes to develop species lists to determine pre-Euroamerican forest composition.

In Michigan, Palik and Pregitzer (1992) found major differences between pre-Euroamerican and modern vegetation among two different landscapes. These included areas that were dominated by fire sensitive eastern hemlock (*Tsuga canadensis*) and American beech (*Fagus grandifolia*), and areas dominated by fire-dependent red pine (*Pinus resinosa*), white pine (*Pinus strobus*) and jack pine (*Pinus banksiana*). Soil types in the two areas were fairly similar, but disturbance frequency was thought to be quite different based on the GLO survey information. Thus, without human intervention the areas were historically quite different due to differences in microclimate and location. However, both these landscapes have become dominated by bigtooth aspen (*Populus grandidentata*), red oak, and red maple, all of which had been of minor importance in the historical surveys.

Another study (Zhang et al. 2000) investigated vegetation change in the Upper Peninsula of Michigan. The authors found there was very little difference between the composition of the pre-Euroamerican forests and those of the present. Although the species mix was not found to be significantly different, differences in stand density were found. In addition, there was more fragmentation of remaining forestlands and open lands due to human settlement (Zhang et al. 2000).

Little research has been done in Arkansas using the GLO surveys. Foti and Glenn (1990) used the GLO notes in the Ouachitas and Tucker (1990) used the GLO notes in the Ozarks to analyze pre-Euroamerican vegetation and compare it to present conditions. Bragg (2002, 2004a, 2004b) used GLO notes to understand the historical vegetation in western Arkansas and Ashley County Arkansas. However, no GLO-based research has been done specifically for the Buffalo River sub-basin.

Accuracy of General Land Office Surveys

Accuracy and detail of the GLO notes varied depending on the surveyor. Occasionally there were cases of fraud where surveyors would supposedly survey areas in the time it would normally take a person to walk that distance (sometimes even faster). This problem was reported by Lucious Lyon, the Surveyor General for Ohio, Indiana, and Michigan. Lyon is quoted as saying the return for many townships were "grossly fraudulent-the greater portion of the field notes there being wholly fictitious or descriptive of lines and corners that were never established." Lyon stated that at least 150 townships in Lower Michigan would need to be redone due to fraud (Stewart 1935).

More common, however, were cases of negligence and carelessness, where resurveys showed that corner and line trees were not where they were described in the notes. For example, quarter corners on east-west lines were required to be run at random from a section corner to the corner 1.6 kilometers east and then run back for correction. There are many instances reported where surveyors merely set the new corner directly without going back and offsetting the random line appropriately based on the error (Bourdo 1956).

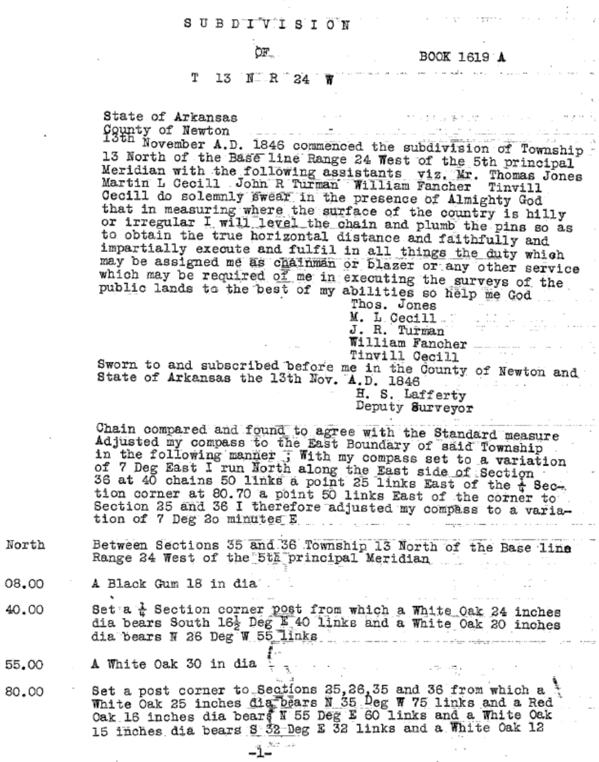
There are other factors that affect the accuracy of the GLO notes. One is that selection of bearing and witness trees was biased by the surveyors, and therefore may not be representative of forest conditions. In Michigan, for example, Bourdo (1956) reported that surveyors chose healthy trees generally, from 25 to 40 cm in diameter, as it was believed these trees provide more permanent marks than smaller or larger trees. There is also some suspicion that certain types of trees may have been favored by some surveyors. This may have been the case in northern Louisiana where Delcourt (1976) interpreted the greater-than-average distance from section corners to pine witness trees as suggestive of a preference for pines over hardwood trees.

Finally, there were great differences in how surveyors recorded what they observed. Some surveyors provided much more detail than did others (Hutchinson 1988, Tucker 1990). Despite these problems, the GLO notes provide us with one of the most systematic on-ground surveys, and in most cases the only inventory of vegetation before Euroamerican settlement.

Material and Methods

The study area consists of 62 townships, each of which covers approximately 6 by 6 miles. Townships were selected if they encompassed any portion of the Buffalo River Sub-basin. The sub-basin is located in north central Arkansas and encompasses most of Newton and Searcy Counties as well as portions of Marion, Boone, Madison, Pope, Van Buren, Stone and Baxter Counties. Of the total area, 38,447 ha are managed by the National Park Service under the National Scenic Rivers Act of 1972. The Buffalo River is approximately 190 kilometers long and begins in the Boston Mountains of Arkansas and empties into the White River near Buffalo City, Arkansas.

General Land Office surveys in Arkansas began on October 27, 1815 with the initial survey of the Fifth Principal Meridian at the confluence of the Arkansas and Mississippi Rivers by Prospect C. Robbins after Arkansas was acquired from France by means of the Louisiana Purchase (Anderson 1996). Surveys in the Buffalo River sub-basin were done between 1830 and 1847 by 18 different surveyors. These surveys included descriptions of topographic features and vegetation cover. Along with tree common names and estimated tree diameters, the GLO notes gave the exact bearing and distances to witness trees from every section corner (Figure 1).


SUBDIVISION

OF BOOK 1619 A

T 13 N R 24 W

State of Arkansas
County of Newton
13th November A.D. 1846 commenced the subdivision of Township 13 North of the Base line Range 24 West of the 5th principal Meridian with the following assistants viz. Mr. Thomas Jones Martin L Cecill John R Turman William Fancher Tinvill Cecill do solemnly swear in the presence of Almighty God that in measuring where the surface of the country is hilly or irregular I will level the chain and plumb the pins so as to obtain the true horizontal distance and faithfully and impartially execute and fulfil in all things the duty which may be assigned me as chainman or blazer or any other service which may be required of me in executing the surveys of the public lands to the best of my abilities so help me God

Thos. Jones
M. L Cecill
J. R. Turman
William Fancher
Tinvill Cecill

Sworn to and subscribed before me in the County of Newton and State of Arkansas the 13th Nov. A.D. 1846

H. S. Lafferty
Deputy Surveyor

Chain compared and found to agree with the Standard measure Adjusted my compass to the East Boundary of said Township in the following manner ; With my compass set to a variation of 7 Deg East I run North along the East side of Section 36 at 40 chains 50 links a point 25 links East of the ¼ Section corner at 80.70 a point 50 links East of the corner to Section 35 and 36 I therefore adjusted my compass to a variation of 7 Deg 2o minutes E

North Between Sections 35 and 36 Township 13 North of the Base line Range 24 West of the 5th principal Meridian

08.00 A Black Gum 18 in dia

40.00 Set a ¼ Section corner post from which a White Oak 24 inches dia bears South 16½ Deg E 40 links and a White Oak 20 inches dia bears N 26 Deg W 55 links

55.00 A White Oak 30 in dia

80.00 Set a post corner to Sections 25,26,35 and 36 from which a White Oak 25 inches dia bears N 35 Deg W 75 links and a Red Oak 16 inches dia bears N 55 Deg E 60 links and a White Oak 15 inches dia bears S 32 Deg E 32 links and a White Oak 12

-1-

Figure 1. General Land Office field notes
(Arkansas Commissioner of State Lands 1999).

A script was written in ArcView to enter the GLO plat map and field notes into a Geographic Information System (GIS) layer referenced to a true coordinate system. The script used a quarter section data layer created by the authors. The first script allows the user to select a section corner or quarter section post (with known coordinates) and type in the bearing and distance of the trees from the known points. This produced a tree (point) layer in the GIS. For line trees a second script was first used that computes the bearing and distance along the section line. Once this was done, the first script could be used and the "Already Selected" option could be selected in the "Quadrant" window to call the bearing from the other script. The fields that are associated with the tree data included Diameter, UTM X and Y coordinates, Species, Quadrant, Azimuth Angle, Distance, Surveyor, Survey Date, Township, Slope, Elevation, and Aspect. The GLO GIS database for the sub-basin included more than 25,000 trees (points).

Another objective of this study was to determine if there were spatial changes by species/species group in regards to slope, elevation and aspect. Slope and aspect were calculated by the GIS using a 30-meter USGS digital elevation models (DEM) for each tree (point). The species groupings were essentially the same as that used for species composition and diameter distribution analysis. Some of the less common tree species were not included in this analysis.

In order to test for surveyor bias, it was necessary to determine if the average distance to each surveyed tree species groups were statistically similar or different from the average distance of other species groups. In order to accomplish this, only trees demarcating section corners were used. Trees along section lines were excluded as they had a fairly predictable intentional spacing of approximately 400 meters. Surveyor bias was analyzed using an analysis of variance with completely randomized design and multiple comparison tests as suggested by Delcourt (1976). All tests were analyzed at an alpha level of 0.05. There are weaknesses in this method of testing surveyor bias as discussed by Grimm (1981) and Whitney and DeCant (2001). Multiple comparison tests were done included the Bon Ferroni Approach, Fisher's LSD, Tukey's HSD, Student-Newman-Keuls and Duncans Multiple Range Test to test surveyor bias.

To determine the present vegetation types in the Buffalo River Sub-basin FIA data from 1999 in the Sub-basin was used. The FIA program (initially known as the Forest Survey) was conceived over eight decades ago by the Congress of the United States. Data from 1999 was used because it included global positioning system (GPS) plots in which points for all trees could be calculated and mapped in a GIS layer. This data layer had more than 1,800 trees.

Results

General Land Office Surveyor Biases

The only species group with a significantly different average distance was walnut/hickory, which was significantly less than average. All other groups were statistically similar to each other. This may suggest either a bias against walnut/hickory, or it may indicate a greater density for this particular group.

Species Composition Comparisons

All trees in the sub-basin were included for this analysis from both time periods. Species were grouped

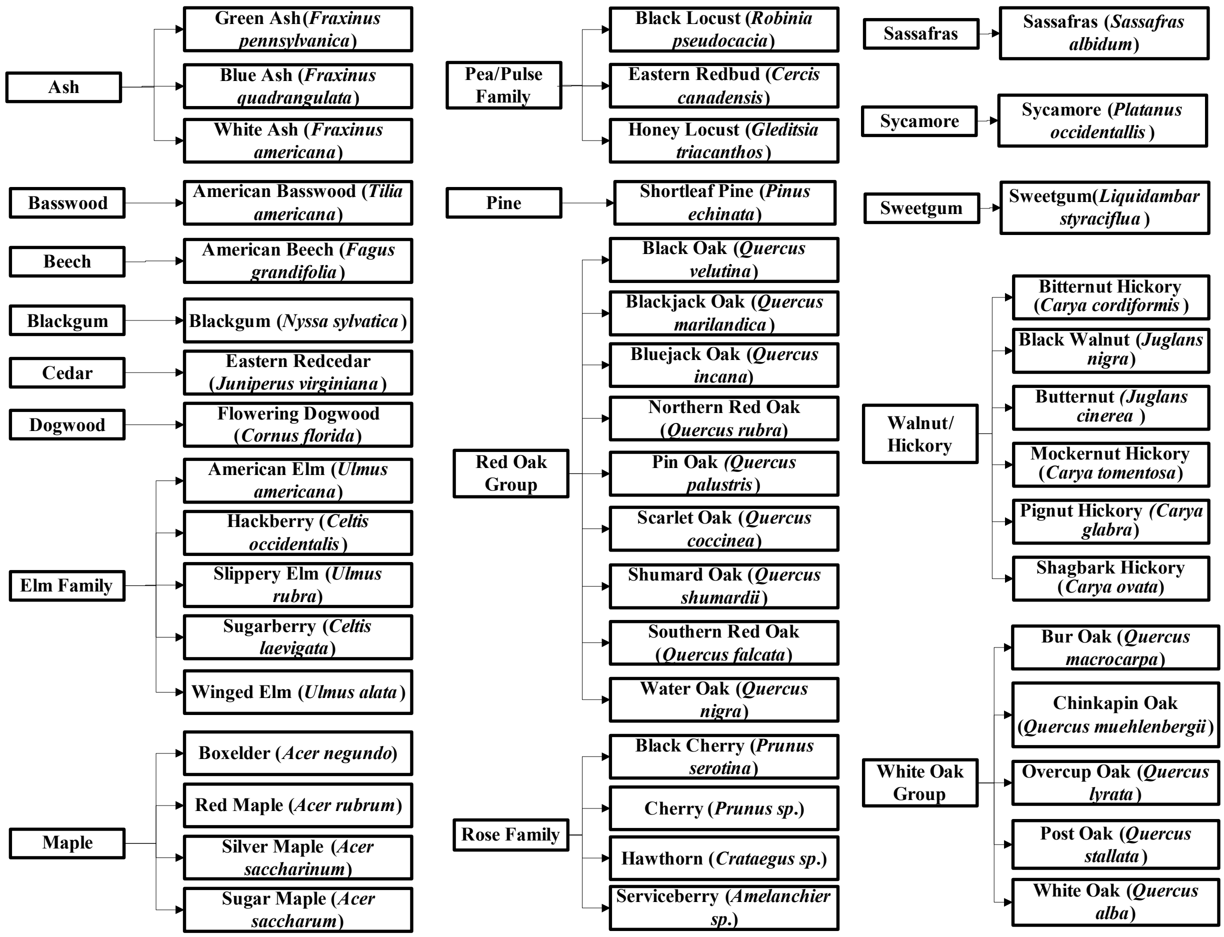


Figure 2. Study species groupings.

for species composition analysis based on individual species characteristics and taxonomic classifications. In the case of some of the less common tree types, it was necessary to group them into family groupings (Figure 2).

Diameters for the FIA and GLO datasets were placed into 5.08 centimeters classes. Trees that were less than 12.7 centimeters were not available for the FIA data used in this study. For this reason trees of this diameter or smaller were also thrown out for diameter distribution and species composition comparisons. Only 1.2% of GLO trees were less than 12.7 centimeters in diameter.

The GLO data contained 25,196 trees in 63 different taxonomic groups. Some of these groupings were the same actual species. For example, the common name 'red oak' and 'Spanish oak' are probably the same species. The GLO database for the sub-basin included 25,196. The FIA data included 1,720 individual trees from 50 species groups taken from FIA plots.

This study found that changes have taken place in the Buffalo River Sub-basin since pre-Euroamerican times. Species composition appears to have changed dramatically. For instance the white oak group comprised 43% of the GLO witness trees and was only 30.1% of the FIA trees measured in 1999 (Table 1). The red oak group also decreased from 29.8% of the total trees prior to settlement to 18.7% in 1999.

Table 1. Species composition as percent of total trees measured.

Species	GLO[1]	FIA[1]
Ash	1.4	2.4
Basswood	0.3	0.3
Beech	0.9	0.8
Blackgum	4.5	3.4
Cedar	0.7	7.8
Dogwood	0.8	0.8
Elm	2.6	2.8
Maple	1.3	4.1
Pea/Pulse Family	0.3	0.7
Pine	4.1	7.8
Red Oak Group	29.8	18.7
Rose Family	0.3	0.7
Sassafras	0.3	0.8
Sweetgum	0.8	3.1
Sycamore	0.4	0.3
Walnut/Hickory	8.2	14.3
White Oak Group	43.0	30.1

[1]Only includes trees that were greater than 12.7 centimeters.

Not all groups declined. Cedar comprised a mere 0.7% of the total prior to settlement, but was 7.8% of all trees in 1999. Maple increased from 1.3% prior to settlement to 4.1% in 1999 and sweetgum increased from 0.8% to 3.1% at the present. Walnut/hickory increased from 8.2% prior to settlement to 14.3% in 1999. Pine increased from 4.1% prior to settlement to 7.8% in 1999.

Topographic Locations of Species Comparisons

Another factor that changed in certain cases was topographic locations of trees. One of the more notable changes was pine, which was generally found on southwest facing slopes with a mean of 195° prior to settlement, but was found on more southeasterly slopes in 1999 with a mean of 127° (Table 2). Mean aspect for the white oak group was close to due south at 176° prior to settlement, but was more southwesterly in 1999 at 195°. Walnut/hickory changed from a mean southeastern slope of 173° to a mean of almost due south at 180°. Sweetgum changed from a mean aspect of 165° to a mean of 172° while maple changed from 182° to 188°. Cedar also changed with a mean aspect of 192° prior to settlement and a mean of 176°. Ash, dogwood and the red oak group, however displayed very little change. The only species that had a statistically significant change in aspect between the two time periods was pine.

Pine, ash, cedar, red oak and white oak displayed significant changes in location as far as slope is concerned (Table 3). Pine was found to be on a relatively gentler slope in 1999 compared to pre-Euroamerican with a mean slope of 12° (21.3%) in the 1800's and a mean slope of 6° (10.5%) at the present. Ash increased in slope with a mean slope of 12° (21.3%) prior to settlement and a mean slope of 18° (32.5%) in 1999. Cedar experienced a less dramatic decrease in slope with a mean of 16° (28.7%) prior to settlement and a mean of 12° (21.3%) in 1999. The white oak group displayed the smallest significant change from 11° (20.0%) prior to settlement to 12° (21.3%) in 1999. Walnut\hickory, maple and sweetgum did not show significant change in mean slope between the pre-Euroamerican period and the present.

Pine displayed the greatest change in elevation between the two time periods with more than a 100 meter increase (Table 4). Pre-Euroamerican pine was found at an average elevation of 324 meters versus 436 meters in 1999. Dogwood decreased significantly in elevation from 438 meters in the GLO survey to 361 meters in the current survey. Finally, sweetgum decreased in elevation from a mean of 336 meters to 281 meters.

Table 2. Mean aspect by species group.

Species	GLO Aspect (degrees)	GLO Confidence Interval[1]	FIA Aspect (degrees)	FIA Confidence Interval[1]	Paired T-tests[2]
Ash	168	±12.0	169	±30.2	No Change
Blackgum	171	±6.48	165	±25.1	No Change
Cedar	192	±13.8	176	±17.9	No Change
Dogwood	159	±15.1	163	±49.9	No Change
Maple	182	±12.6	188	±20.8	No Change
Pine	195	±6.0	127	±15.2	Change
Red Oak	179	±2.4	179	±10.4	No Change
Sweetgum	165	±14.4	172	±24.3	No Change
Walnut/Hickory	173	±4.8	180	±12.6	No Change
White Oak	176	±2.1	195	±8.0	No Change

[1]Based on 95% C.I. [2]An alpha value of 0.05 was used for all data analysis.

Table 3. Mean slope by species group.

Species	GLO Slope (degrees)	GLO Confidence Interval[1]	FIA Slope (degrees)	FIA Confidence Interval[1]	Paired T-tests[2]
Ash	12	±0.9	18	±2.4	Change
Blackgum	12	±0.4	14	±1.8	No Change
Cedar	16	±1.4	12	±1.0	Change
Dogwood	12	±0.9	9	±2.9	No Change
Maple	13	±0.9	14	±1.5	No Change
Pine	12	±0.4	6	±0.6	Change
Red Oak	10	±0.2	13	±0.8	Change
Sweetgum	11	±1.1	9	±1.3	No Change
Walnut/Hickory	12	±0.3	12	±0.9	No Change
White Oak	11	±0.1	12	±0.6	Change

[1]Based on 95% C.I. [2]An alpha value of 0.05 was used for all data analysis.

Table 4. Mean elevation by species group.

Species	GLO Elevation (meters)	GLO Confidence Interval[1]	FIA Elevation (Meters)	FIA Confidence Interval[1]	Paired T-tests[2]
Ash	335	±12.8	337	±32.3	No Change
Blackgum	432	±8.3	488	±31.6	Change
Cedar	270	±14.1	272	±16.6	No Change
Dogwood	438	±17.8	361	±56.7	Change
Maple	427	±17.0	439	±29.9	No Change
Pine	324	±6.1	436	±24.6	Change
Red Oak	398	±3.2	412	±14.7	No Change
Sweetgum	336	±15.0	281	±29.3	Change
Walnut/Hickory	412	±6.0	421	±15.4	No Change
White Oak	421	±2.9	413	±11.2	No Change

[1]Based on 95% C.I.
[2]An alpha value of 0.05 was used for all data analysis.

Diameter Distributions Comparisons

There were differences in diameter distributions between the surveys (Table 5). Avoidance of smaller diameter trees in the GLO surveys was evident by the large discrepancy in percent composition for the 12.7 to 17.8 centimeter diameter classes. It is interesting to note that oak species make up large percentages of each diameter class in the GLO survey including smaller diameter classes.

Table 5. Diameter distribution of trees in percent.

Diameter (cm)	GLO[1]	FIA[1]
<12.7[3]	1.2	NA[2]
12.7 to 17.8[3]	6.7	46.5
20.3 to 25.4[3]	21.8	28.7
27.9 to 33.0[3]	21.0	13.5
35.6 to 40.6[3]	20.7	5.9
43.2 to 48.3[3]	10.0	3.0
50.8 to 55.9[3]	7.2	1.7
58.4 to 63.5[3]	6.1	0.5
66.0+[3]	5.3	0.2

[1]Numbers represent percentage of the total for each survey respectively.
[2]Trees smaller then 12.7 cm were not included in FIA surveys.
[3]Diameters were originally taken in inches as non-decimal values. This is why there are gaps between centimeter groupings.

Table 6 and 7 shows the diameter distributions for 17 species groups. Cedar increased from 1.1% of all trees between 12.7 to 17.8 centimeters prior settlement, but was 10.6% for the same class in 1999. Pine also increased in the 12.7 to 17.8 centimeter class from 1.8% prior to settlement to 5.8% in 1999. Pine increased in importance quite substantially for all diameter classes between 20.3 and 40.6 centimeters from pre-Euroamerican to 1999. Pine also made up larger percentages of the larger diameter groups prior to settlement than at the present time. Red oak made up a larger percentage of the total for the small diameter classes prior to settlement than in 1999. However red oak appeared to make greater contributions to the mid to larger diameter classes in 1999.

Discussion

Although oak species have maintained their position as the most common species (consisting of 48.8% of the total in 1999 versus 72.7% prior to settlement), there have been dramatic drops since the early 1800's. The white oak group has fallen from 42.7% in the GLO surveys to 30.1% in 1999. The red oak group has followed suit with 29.7% in the GLO surveys and 18.7% in 1999. Factors thought to contribute to this trend include fire suppression, insect outbreaks, and various land management practices that favor other tree species (Abrams 1998).

Recent declines in red oak may be attributed to the red oak borer (*Enaphalodes rufulus*) (Heitzman 2003). In 1999 the US Forest Service estimated that severe damage (greater than 75% mortality) existed on 7,800 hectares of the Ozark National Forest, with an additional 9,800 hectares experiencing moderate damage (50-75% mortality) (Smith and Stephen 2001). One of the main contributors to the red oak borer epidemic was years of drought in the late 1990's, which weakened oak populations (Smith and Stephen 2001). It is also possible that land cultivation and harvesting in the Ozarks led to the decline of larger diameter oaks. For instance, Tucker (1990) stated that oaks were preferred for use as railroad ties and that many were harvested for this purpose in the late 1800's.

The movement of shortleaf pine from more xeric, steep southwest facing slopes to gentler, more southeast facing slopes may be due to fire suppression, which may have allowed less fire-resistant species to

Table 6. General land office (GLO) individual diameter distribution in percent.

Species	12.7 to 17.8[2] (cm)	20.3 to 25.4[2] (cm)	27.9 to 33.0[2] (cm)	35.6 to 40.6[2] (cm)	43.2 to 48.3[2] (cm)	50.8 to 55.9[2] (cm)	58.4 to 63.5[2] (cm)	66.0+[2] (cm)
Ash	1.0	1.5	1.5	1.5	1.0	1.3	1.5	0.9
Basswood	0.2	0.3	0.3	0.3	0.2	0.3	0.4	0.0
Beech	0.7	1.2	1.2	1.2	0.6	0.7	0.2	0.2
Blackgum	6.0	6.7	5.9	3.7	2.9	2.1	1.1	0.7
Cedar	1.1	1.3	1.1	0.4	0.2	0.1	0.1	0.0
Dogwood	7.2	1.4	0.0	0.0	0.0	0.1	0.0	0.0
Elm	5.7	4.2	2.7	1.8	1.1	1.0	0.8	0.8
Maple	4.2	2.4	1.3	0.6	0.2	0.4	0.3	0.1
Pea/Pulse Family	0.8	0.6	0.3	0.3	0.0	0.1	0.0	0.0
Pine	1.8	3.5	3.6	3.8	4.5	4.9	7.2	7.8
Red Oak Group	32.5	31.7	30.6	29.3	28.9	27.5	26.7	24.8
Rose Family	0.7	0.6	0.3	0.2	0.1	0.2	0.0	0.0
Sassafras	1.0	0.9	0.2	0.1	0.0	0.0	0.0	0.0
Sweetgum	0.5	0.6	0.7	0.9	0.8	0.7	0.9	1.4
Sycamore	0.5	0.4	0.4	0.3	0.2	0.2	0.3	1.3
Walnut/ hickory	13.6	12.8	10.2	6.8	4.3	3.0	2.7	1.5
White Oak Group	20.5	29.1	39.5	48.7	55.0	57.4	57.9	60.5

[1]Numbers represent percentage of the total for each diameter class.
[2]Diameters were originally taken in inches as non-decimal values. This is why there are gaps between centimeter groupings.

Table 7. Forest Inventory and Analysis (FIA) individual diameter distribution in percent.

Species	12.7 to 17.8[2] (cm)	20.3 to 25.4[2] (cm)	27.9 to 33.0[2] (cm)	35.6 to 40.6[2] (cm)	43.2 to 48.3[2] (cm)	50.8 to 55.9[2] (cm)	58.4 to 63.5[2] (cm)	66.0+[2] (cm)
Ash	2.8	2.6	1.3	2.0	1.9	0.0	0.0	0.0
Basswood	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Beech	0.9	0.2	0.0	0.0	0.0	6.7	33.3	0.0
Blackgum	3.3	2.2	3.4	6.9	5.8	3.3	22.2	0.0
Cedar	10.6	8.7	2.6	1.0	0.0	0.0	0.0	0.0
Dogwood	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Elm	3.9	2.4	2.2	0.0	0.0	0.0	0.0	0.0
Maple	6.1	2.4	3.9	0.0	0.0	3.3	0.0	0.0
Pea/Pulse Family	1.1	0.2	0.9	0.0	0.0	0.0	0.0	0.0
Pine	5.8	9.9	11.2	10.9	0.0	10.0	0.0	0.0
Red Oak Group	11.3	17.1	30.6	32.7	50.0	43.3	22.2	75.0
Rose Family	0.6	1.2	0.0	0.0	1.9	0.0	0.0	0.0
Sassafras	1.1	0.8	0.4	0.0	0.0	0.0	0.0	0.0
Sweetgum	3.0	3.9	3.4	2.0	0.0	0.0	0.0	25.0
Sycamore	0.1	0.4	0.0	2.0	0.0	0.0	0.0	0.0
Walnut/ hickory	18.0	13.0	9.9	8.9	11.5	0	0.0	0.0
White Oak Group	27.8	34.1	29.3	32.7	28.8	33.3	22.2	0.0

[1]Numbers represent percentage of the total for each diameter class.
[2]Diameters were originally taken in inches as non-decimal values. This is why there are gaps between centimeter groupings.

compete in these areas. It seems logical that in the absence of fire, competitive species might have an advantage in these areas and perhaps reduce recruitment of the shade-intolerant shortleaf pine (Kreiter 1995). It is also possible that shortleaf pine has been planted on gentler slopes, or may have seeded in abandoned fields

Increases in maple from pre-Euroamerican times to the present are also of interest. Red maple is very sensitive to fire (Abrams 1998), which may explain why maple comprised 1.3% of all witness trees prior to settlement in the Buffalo Sub-basin, versus 4.1% in 1999. Maple increases due to fire suppression in areas once dominated by oaks have been well documented in other studies (Nelson 1997, Mikan et al. 1994, Shotola et al. 1992, Abrams 1998).

Another dramatic change displayed in the Buffalo River Sub-basin is the increase in eastern redcedar. Prior to settlement redcedar accounted for a mere 0.7% of the trees in the sub-basin, compared to the 7.8% observed in 1999. Part of this increase may have been due to surveyor bias against redcedar due to their generally small size and branchiness. However, it is difficult to prove or disprove bias against cedar. The number of cedar trees that were used as corner trees was so small that looking at average distance to determine bias against cedar was impossible. Redcedar trees represent approximately 1% of each diameter class from 12.7 to 33.0 centimeters and then decrease in the GLO surveys. If cedar was more predominant (especially in its average diameter classes) one would expect a larger percentage in these average diameter classes in the FIA data, which had an average diameter of 17.8 centimeters with a standard deviation of 5.1 centimeters. It was not surprising to see approximately 10% of all trees in the 12.7 to 17.8 centimeter diameter class are cedar. Other studies in the region have found significant increases in cedar, especially in glades and abandoned farmland (Schroeder 1981, USDA 1999b). It is important to note that between 1910 and 1940 much of the settled and cleared land was abandoned (especially during the great depression of the 1930's) and was subsequently sold to timber companies and the US Forest Service (USDA 1999b), undoubtedly creating conditions for cedar establishment. The average redcedar tree in 1999 (approximately 18 centimeters), would be the approximate diameter for a cedar tree that was initiated in the 1930's and 1940's. Cedar is also very sensitive to fire and has been found to decrease in abundance under a prescribed fire regime, which may explain its absence in the GLO surveys (Beilmann and Brenner 1951, Lawson 1990, Nelson 1997).

Based on this study it seems likely that many areas that were once predominantly two species groups (red and white oaks) have now become more mixed with less dominance of any one particular species (Table 1). This is not surprising considering the region's fire history, which in the past would have prevented increases in species such as hickory, cedar and maple that have been observed in the Buffalo River Sub-basin over the last couple of centuries (Strausberg and Hough 1997, Abrams 1998).

Additionally, a substantial portion of the sub-basin is now in pasture or other agriculture land (USGS 1998). This factor, combined with increased competition from other tree species due to fire suppression and European settlement, would appear to contribute to the decrease of oak species in the sub-basin and the increase of other species.

Conclusion

Information on biodiversity of landscapes is available for many areas in the 20th Century, but prior to this period little is known over large areas. The GLO survey notes provide us with the only systematic on-ground survey from 1815 to 1850 in Arkansas and they predate most formal botanical investigations, even though the GLO trees are not a statistically representation of the trees of that time period. Portions of the Buffalo River sub-basin could be restored through policies that allows for mimicking pre-Euroamerican conditions. However, modern-day ownership patterns make full restoration of pre-Euroamerican impossible. There is value in understanding the environmental history of an area, and we advise that any natural resource management conducted in the Buffalo River Sub-basin should take into account the historic vegetation patterns. This research gives us some insight into the changes that have occurred in the last 150+ years, which is important for understanding the ecology of the present landscape.

Acknowledgments

This research would not have been possible with the numerous hours by students reading and translating the GLO notes. The Arkansas Forest Resources Center at the University of Arkansas at Monticello supported this research. The authors would also like to thank the three reviews of this manuscript for their time and comments.

Literature Cited

Abrams M. 1998. The red maple paradox: What explains the widespread expansion of red maple in eastern forests? BioScience. 48:355-364.

Abrams M and **D McCay**. 1996. Vegetation-site relationships of witness trees (1780-1856) in the presettlement forests of eastern West Virginia. Canadian Journal of Forest Resources. 26:217-224.

Abrams M and **R Ruffner**. 1995. Physiographic analysis of witness-tree distribution (1765-1798) and present forest cover through north Pennsylvania. Canadian Journal of Forest Resources. 25:659-668.

Anderson P. 1996. GIS research to digitize maps of Iowa 1832-1859 vegetation. WWW document, http://www.public.iastate.edu/~fridolph/research.html#GLO%20veg. Accessed 2008 March 3.

Arkansas Commissioner of State Lands. 1999. Original General Land Office survey notes and plats for the state of Arkansas 1815 - present. Little Rock, AR.

Beilmann A and **L Brenner**. 1951. The recent intrusion of forests in the Ozarks. Annals of the Missouri Botanical Garden. 38:261-282.

Bourdo E. 1956. A review of the general land office survey and of its use in quantitative studies of former forests. Ecology. 37:754-768.

Bragg D. 2002. Checklist of major species in Ashley County, Arkansas noted by General Land Office Surveyors. Journal of the Arkansas Academy of Science. 56:32-41.

Bragg D. 2004a. Historical reflections on the Arkansas Cross Timbers. Journal of the Academy of Science. 58:32-36.

Bragg D. 2004b. General Office Surveys as a source for Arkansas history: The Example of Ashley County. The Arkansas Historical Quarterly. V 63:166-184.

Delcourt H. 1976. Pre-settlement vegetation of the north of Red River land district, Louisiana. Castanea. V 41:122-139.

Dorney C and **J Dorney**. 1989. An unusual oak savanna in northeastern Wisconsin: the effect of Indian-caused fire. American Midland Naturalist. 122:103-113.

Foti T and **S Glenn.** 1990. Pre-settlement vegetation of the Ozark National Forest. In: Proceedings of the conference, restoration of old growth forests in the interior highlands of Arkansas and Oklahoma. Ouachita National Forest, Winrock International Institute for Agricultural Development: p 49-65.

Fralish J, **F Crooks**, and **F Harty**. 1990. Comparison of pre-settlement, second-growth and old-growth forest on six site types in the Illinois Shawnee Hills. American Midland Naturalist. 125:294-309.

Grimm E 1981 An ecological and paleoecological study of the vegetation in the Big Woods region of Minnesota. Ph.D. dissertation, University of Minnesota.

Guyette R and **E McGinnes**. 1982. Fire history of an Ozark glade in Missouri. Transactions, Missouri Academy of Science. 16:85-93.

Heitzman E. 2003. Effects of oak decline on species composition in a northern Arkansas forest. Southern Journal of Applied Forestry. 27:264-268.

Hutchinson M. 1988. A guide to understanding, interpreting, and using the public land survey field notes in Illinois. Natural Areas Journal. 8:245-255.

Kreiter S. 1995. Dynamics and spatial pattern of a virgin old-growth hardwood-pine forest in the Ouachita Mountains, Oklahoma, from 1896 to1994 [MSc Thesis]. Oklahoma City (OK): Oklahoma State University. 139 p.

Lawson E. 1990. Eastern red cedar. (*Juniperus virginiana* L.). IN: Burns R, Honkala B, editors. Silvics of North America, Volume 2, Hardwoods. USDA Forest Service Agriculture Handbook 654. 675 p.

Leitner L and **M Jackson**. 1980. Presettlement forests of the unglaciated portion of southern Illinois. American Midland Naturalist. 104:290-304.

Loeb R. 1987. Pre-European settlement forest composition in east New Jersey and southeastern New York. American Midland Naturalist. 118:414-423.

Manies K and **D Mladenoff**. 2000. Testing methods to produce landscape-scale presettlement vegetation maps from the U.S. public land survey records. Landscape Ecology. 15:741-754.

Mikan J, **D Orwig**, and **M Abrams**. 1994. Age structure and success ional dynamics of a pre-settlement-origin chestnut oak forest in the Pennsylvania piedmont. Bulletin of the Torrey Botanical Club. 121:13-23.

Nelson J. 1997. Pre-settlement vegetation patterns along the 5th principal meridian, Missouri territory, 1815. American Midland Naturalist 137:79-94.

Palik B and **K Pregitzer**. 1992. A comparison of pre-settlement and present-day forests on two bigtooth aspen-dominated landscapes in northern lower Michigan. American Midland Naturalist. 127:327-338.

Russel E. 1981. Vegetation of northern New Jersey before European settlement. American Midland Naturalist. 105:1-12.

Schafale P and **P Harcombe**. 1982. Pre-settlement vegetation of Hardin County, Texas. American Midland Naturalist. 107:355-366.

Schroeder W. 1981. Pre-settlement prairie of Missouri. *Natural history series number two.* Missouri Department of Conservation. Jefferson City, MO. 27 p.

Shotola S, **G Weaver**, **P Robertson**, and **W Ashby**. 1992. Sugar maple invasion of an old-growth oak-hickory forest in southwestern Illinois. American Midland Naturalist. 127:125-138.

Siccama T. 1971. Pre-settlement and present forest vegetation in northern Vermont with special reference to Chittenden County. American Midland Naturalist. 85:153-172.

Sickley T, **D Mladenoff**, **V Radeloff**, and **K Manies**. 2000. A pre-European settlement vegetation database for Wisconsin. WEB document, http://gis.esri.com/library/userconf/proc00/professional/papers/PAP576/p576.htm. Accessed 2008 March 3.

Smith B. 2002. Forest Inventory and Analysis: a national inventory and monitoring program. Environmental Pollution. 116:S233-S242.

Smith K and **F Stephen**. 2001. *Quercus* lost: avian population responses to large-scale elimination of oaks by the red oak borer in the Ozarks. University of Arkansas-Fayetteville Proposal. Fayetteville, AR. 21 p.

Stewart L. 1935. Public Land Surveys-History, Instructions, Methods. Collegiate Press. Ames, IA. 202 p.

Strausberg S and **W Hough**. 1997. The Ouachita and Ozark-St. Francis National Forests: A history of the lands and USDA forest service tenure. General technical report, SO-121, USDA Forest Service Southern Research Station. 52 p.

Tucker G. 1990. Pre-settlement vegetation of the Ozark National Forest. Proceedings of the conference, restoration of old growth forests in the interior highlands of Arkansas and Oklahoma. Ouachita National Forest, Winrock International Institute for Agricultural Development: 67-75.

United States Department of Agriculture. 1999a. Ozark-Ouachita highlands assessment: terrestrial vegetation and wildlife. General technical report SRS-35. USDA Forest Service, Southern Research Station. Asheville, NC. 220 p.

United States Department of Agriculture. 1999b. Ozark-Ouachita highlands assessment: social and economic conditions. General technical report SRS-34. USDA Forest Service, Southern Research Station. Asheville, NC. 324 p.

USGS Biological Resources Division. 1998. GAP data. http://www.gap.uidaho.edu/. Accessed 2008 March 3.

Whitney G. 1982. Vegetation-site relationships in the presettlement forests of northeastern Ohio. Botanical Gazette. 143(2):225-237.

Whitney G and **J DeCant** 2001 Government land office surveys and other early land surveys. P. 147-172 in The Historical Ecology Handbook: A Restorationist's Guide to Reference Ecosystems, D. Egan and E.A. Howell, eds. Island Press, Washington, DC. 457 p.

Zhang Q, **K Pregitzer**, and **D Reed**. 2000. Historical changes in the forests of the Luce district of the Upper Peninsula of Michigan. American Midland Naturalist. 143:94-110.