APPLICATION OF GENERAL LAND OFFICE SURVEY NOTES TO BOTTOMLAND HARDWOOD ECOSYSTEM MANAGEMENT AND RESTORATION IN THE LOWER MISSISSIPPI VALLEY—AN EXAMPLE FROM DESHA COUNTY, ARKANSAS

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Abstract—The lower Mississippi River floodplain supported about 9 million ha of hardwood forests, and now less than 2 million. Reforestation is a priority of resource agencies, but efforts are hampered by uncertainties about species composition and site relations of plant communities. We compared the first land survey notes for an area along the Mississippi River in the 1800's to modern forest. The results suggest that (1) geomorphic surfaces generally provide a good basis for discriminating general patterns of plant community structure and composition, (2) modern forests differ from the forests of the early settlement era in importance of dominant species, suggesting that modern forests may not be appropriate restoration models, and (3) future distribution of plant communities will be altered because the lower Mississippi River has been stabilized, affecting future environments of deposition. Importantly, oak species, the primary material for restoration efforts, have never been particularly dominant on these sites.

INTRODUCTION

Bottomland hardwood forests blanketed most of the alluvial valley of the lower Mississippi River at the time of European/American settlement. These forests were highly diverse, supporting many species of resident, migratory, and wintering wildlife, including several that have since become extinct or regionally extirpated (Fredrickson 1978). Agricultural development has since reduced the original forest from about 10 million ha to less than 2 million ha (Forsythe 1985). Much of the remaining forest is located adjacent to the Mississippi River, inside the mainstem levee system, where flooding conditions and forest composition limit the overall quality and diversity of wildlife habitat available (Klimas 1991). Most remaining forests on the former floodplain are small fragments unconnected to major forest blocks.

In recent years a variety of programs have been initiated to encourage reforestation of floodplains (Allen 1990). These include the Conservation Reserve Program and Wetland Reserve Program, administered by the U.S. Department of Agriculture. Federal and state wildlife agencies are acquiring agricultural land for restoration to meet wildlife objectives. Planning a reforestation project involves selection of species, planting techniques, and maintenance requirements. Traditional forest re-establishment for wildlife or other purposes tends to focus on a few species selected to meet project needs. However, where ecosystem restoration for wildlife habitat is the principal concern, the objective is often to establish a forest community with a species composition and structure reflecting natural conditions for the site (U.S. Fish and Wildlife Service 1994), although usually species that produce hard mast for desired wildlife are emphasized, particularly oak species.

Ecosystem management has recently received emphasis as a direction for management of public lands, including National Forests and National Wildlife Refuges. Ecosystem management is here defined as management "...to restore and sustain ecosystem integrity (composition, structure and function) and produce ecologically acceptable levels of sustainable multiple uses" (USFWS 1994). In the context of ecosystem restoration, this objective requires that fairly specific compositional and structural models be available to guide the restoration design. Modern forests, even those regarded as "old growth" based on structural criteria, may not be appropriate models for restoration projects because of the likelihood that they have been substantially altered by human activity, particularly with respect to the relative abundance of non-dominant trees or of major understory species. Information from early observers and surveyors can provide insights into the character of the pre-settlement ecosystem, but development of fairly specific community characterizations to guide restoration requires a mechanism to relate historic data to specific site conditions in the modern landscape.

The objectives of this study are to

1. Characterize the vegetation documented by the first land survey of the study area in 1837, both over the entire study area and stratified according to ecologically meaningful landforms.

2. For those portions of the study area where the existing vegetation has been characterized, compare existing vegetation as described by Klimas (1991) with that documented by the first land survey.

3. Qualitatively describe the understory vegetation on the selected landforms using the mile notes of the surveyors.

METHODS

Overview

The study area is a portion of Desha County, Arkansas, southwest of the confluence of the Arkansas and Mississippi Rivers (fig. 1). It was selected because of the variety of

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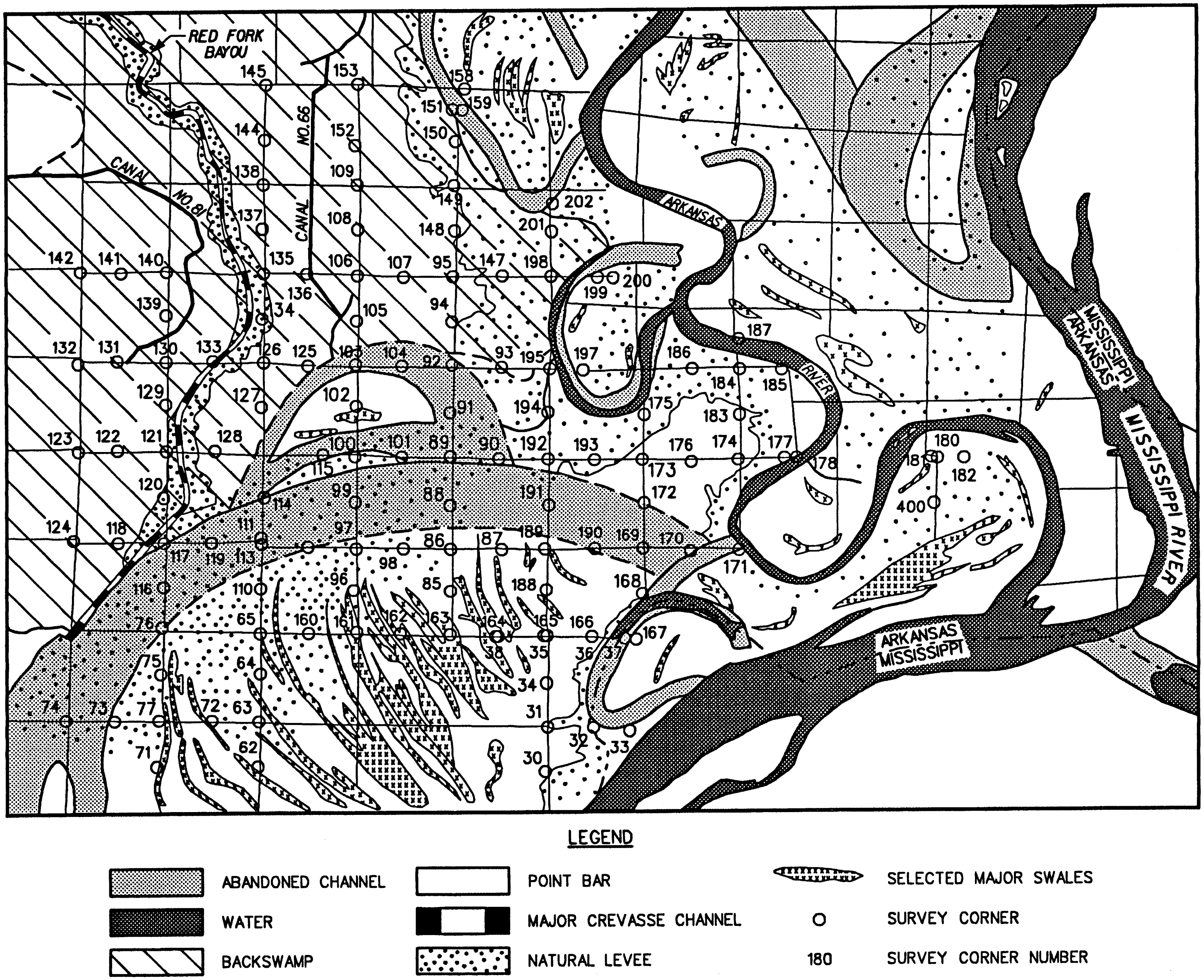

Figure 1—Vicinity map showing the location of the study area relative to the confluence of the Arkansas and Mississippi Rivers.

pertinent information available, and because it is typical of a fairly large segment of the lower Mississippi River alluvial valley with regard to the distribution of major landforms, the distribution and composition of modern forests, and land use history. The resources used included:

1. General Land Office (GLO) notes from the Desha County surveys of 1824 and 1837 (hereafter referred to as the 1837 survey) provided information on land and forest conditions as well as witness tree data suitable for use in deriving quantitative information on forest structure and composition. In this instance, "structure" refers to basal area and density of trees per unit area, by species. The notes recorded the work of two separate surveyors, Nicholas Rightor and Daniel Miller, both of whom recorded witness tree data in consistent and comparable terms. A testament to the difficulty of the working conditions is that Mr. Rightor had six men desert his employ during his first week of work. Data recorded included diameter and species of each tree used to witness section and quarter-section corners, as well as the distance and direction from the corner to the tree. Also, diameter and species of two "line" trees per mile were usually noted (Bourdo 1956, White 1983).

2. The principal source of information on modern forest and site conditions was the Lower Mississippi River Environmental Program (LMREP), which is an inventory and research program initiated and administered by the Mississippi River Commission, U.S. Army Corps of Engineers (Kolb and others 1968). The modern forest data were compiled by Klimas (1988), who sampled 1,100 sites within the confined (leveed) floodplain of the lower Mississippi River in 1984 and 1985 as part of the LMREP. He collected detailed information on overstory and understory composition and structure within one-tenth acre plots, and used multivariate analyses to isolate discrete community types. He then tested those types for their fidelity to specific site conditions reflecting flooding regimes, soil conditions, and similar variables. He found that most of the identified communities are associated with particular combinations of alluvial deposition (as reflected in the CERDS layer Environments of Deposition) and substrate age (as reflected in the meander history mapping described below); this finding is the basis for designating the four major Site Types described below and in table 1.

Table 1—Site type classification

{Private} site type code	Geomorphic description	General interpretation
A	Point bars	Basic alluvial site type
B	Point bars with natural levee deposits	Better drained, often with newer soils
C	Large swales within point bars; abandoned channels; backswamps	Poorly drained
D	Backswamps with natural levee deposits; abandoned channels with natural levee deposits	Poorly drained sites with better drained surface soils

3. One additional resource employed in this study, and also used to construct the vegetation models described in Klimas (1988) is a set of maps of the lower river showing channel meander history since 1765 (Mississippi River Commission 1881-97, 1938, 1941). These allowed us to eliminate from consideration all 1837 witness trees occupying sites that had since been reworked by lateral river migration (and for which, consequently, no ca. 1837 physical site data exist). Thus the mapped geomorphic features could be assumed to be the same basic landforms extant at the time of the survey. Klimas (1988) identified 4 major site types: Point Bars (well-drained sandy deposits); Point Bars with natural levee deposits (better drained than the previous and with newer soils); Swales, Abandoned Channels and Backswamps (poorly drained sites); and Backswamps and Abandoned Channels with natural levee deposits (poorly drained sites but with better internal drainage than the previous) (table 1). Figure 2 shows the geomorphic map and distribution of GLO survey points used in this study.

4. The various resources described above were employed here to investigate the possibility that the modern forest may offer an incomplete model to guide restoration efforts. In particular, we wished to determine if modern communities provide good models of the species composition and dominance patterns appropriate for the sites they occupy, and whether any particular community types are under-represented in the modern forest relative to conditions prior to major modifications due to clearing, differential harvest, and river regulation.

In order to meet the objectives of the study, the following analyses were conducted:

Characterize the vegetation documented by the first land survey of the study area in 1837, both over the entire study area and stratified according to ecologically meaningful landforms.

The witness trees were grouped according to their occurrence on each of the four major landforms or site types (table 1). Initial analysis concentrated on the relative abundance of all trees in the samples, including both corner trees and line trees. Then the data from corner trees only were summarized in terms of tree composition, density, and basal area. . This analysis was limited to corners that had not been reworked by rivers since 1837, as determined by Mississippi River Commission maps of the lower river showing channel meander history since 1765 (MRC 1881-97, 1938, 1941), as reported by Klimas (1988). These corners were eliminated because the site type of reworked corners would not necessarily be the same as that occurring at that corner in 1837, and therefore comparisons of 1837 to present would be meaningless. The analyses are based on treating the trees at each section and quarter-section corner as point-centered quarter samples used to calculate absolute and relative density and basal area for each species after the method of Cottam and Curtis (1956). Programs were checked against examples in Mueller-Dombois and Ellenberg (1974). Relative density and relative

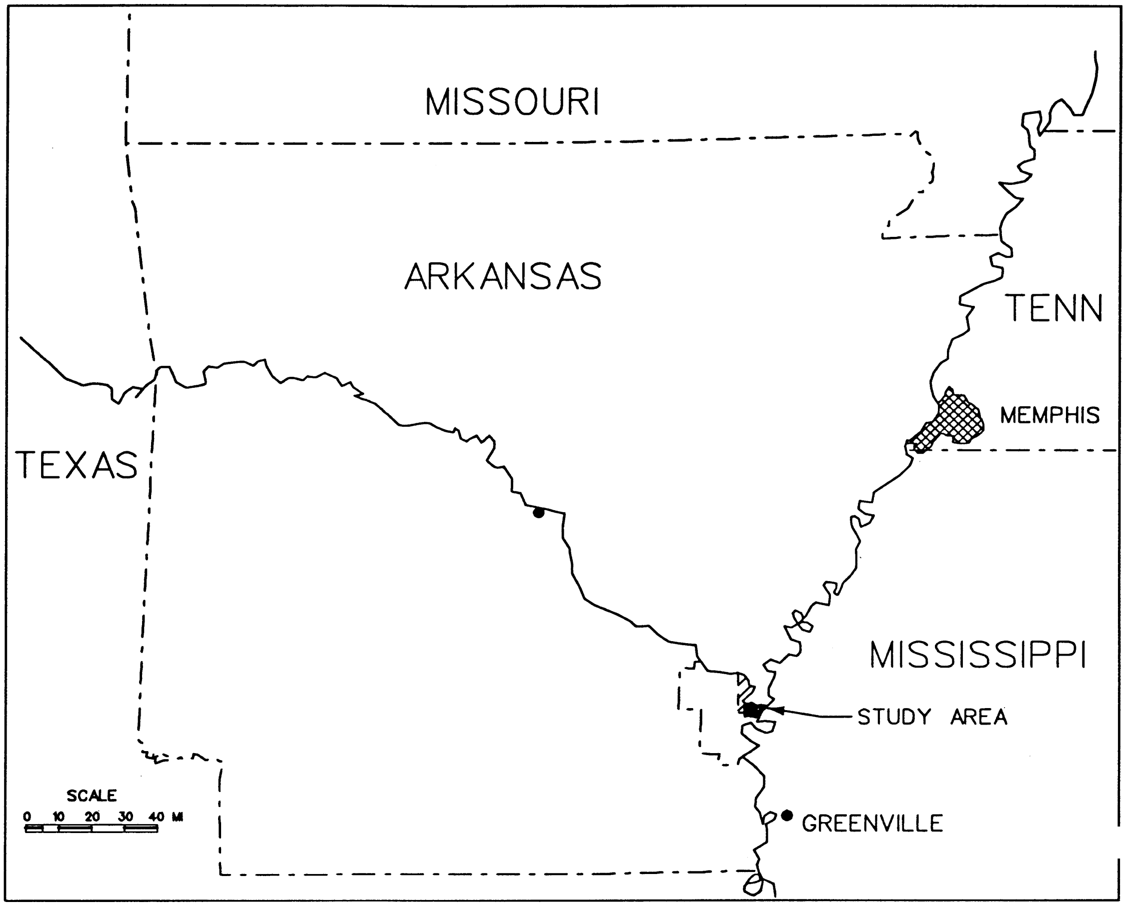

Figure 2—Geomorphology map of the study area displaying the locations of survey corners.

basal area were averaged to obtain species' importance values (IV). Relative frequency was not used in calculations of IV because in corners where only two trees were sampled, frequency could only take one of three values. Other measures which were calculated included geometric mean diameter (the diameter at which the mean basal area occurs) and absolute density.

Two-way Indicator Species Analysis (TWINSPAN; Hill 1979b) as implemented in PC-ORD Version 4 (MJM Software, Gleneden Beach, OR) was used to investigate the relationships among vegetation types.

For those portions of the study area where the existing vegetation has been characterized, compare existing vegetation as described by Klimas (1988) with that documented by the first land survey.
Those trees located on sites inside the modern levee system were summarized by site type. This allowed comparison of the modern forest, which is restricted almost entirely to sites on the river side of levees, to the 1837 forest on the same sites. It also ensured compatibility with data produced by Klimas (1988), who only studied forest on the river side of the levees.

Klimas (1988) described 51 separate plant community types in the lower Mississippi valley. Twenty-seven of these were considered compositionally and structurally consistent with modern forest conditions within the Desha County study area under consideration here. Those 27 communities were described based on 567 plots, which in this study were distributed among the four major geomorphic Site Types in proportion to the area occupied by each Site Type. Thus the modern forest data used in the analysis were not necessarily measured within the study area, but were a synthesis of data taken from those site types across the Lower Mississippi Valley.

For each Site Type, the modern forest data were summarized for all trees greater than 14 cm d.b.h., which is approximately the minimum size of trees selected by the GLO surveyors as witness trees. The data were summarized by combining relative density and relative dominance data, then dividing by two to yield an Importance Value equivalent to the IV calculated for the GLO data.

Two methods were used to compare GLO vegetation/site types to modern forests.

The first comparison involved only those GLO corners that were on the river side of the levees (inside the levees), presently naturally vegetated, and consequently mapped in CERDS. Each tree in the GLO database was associated with the current CERDS cover type for the site. GLO trees having a common current CERDS classification were grouped to investigate correlation between GLO and current vegetation. The IV of each species within each CERDS type was computed. GLO data were also summarized for each Site Type (geomorphic classification) to assess the uniqueness of the associated vegetation communities.

For the second method of comparison, the GLO data were summarized for each Site Type on sites both inside and outside the levee, except those sites that had been reworked by the river subsequent to the survey. This provided additional data points for quantitative comparisons of overstory composition and structure, as well as the understory analysis described below.

Qualitatively describe the understory vegetation on the selected landforms using the mile notes of the surveyors. The surveyor's observations concerning understory conditions were summarized by landform/vegetation types.

The GLO surveyor's comments on suitability of the land for cultivation, apparent flooding depths, general timber type, and understory composition were reasonably consistent within geomorphic site types. The major source of potential confusion was the characterization of these attributes over long distances, often an entire section line (one mile). In some instances he would differentiate segments of the line, for example:

"Land the first 15.49 Chs 1st rate cane bottom The ballance Swamp. Timber Oak gum Cypress Ash &c ("&c" is the GLO surveyor's abbreviation for "etc.") undergrowth green briers privy vines &c" (sic.)

"Land South half tolerable good bottom cane vines &c North half Swamp 10 feet overflow Timber Cypress Oak Ash &c undergrowth vines briers &c" (sic.)

Unless the site was within a zone of river meander activity during the intervening years, such descriptions invariably corresponded well with variations in site type on the modern landscape, when compared to the geomorphic map. In other cases the observation point was within a large area of fairly uniform terrain, and the comments could be assumed to apply to the basic site type dominant in the area. Generally, all comments that could be associated with particular site types were reasonably consistent in describing flood depths and understory. Timber types were more variable, possibly because small stands were included in the overall description. Thus cypress frequently is mentioned in association with almost all site types, suggesting that its occurrence in small swales and channels was sufficient to catch the surveyor's attention. In any case, canopy tree descriptions may be more biased than witness tree data, which are preferable.

However, in the case of the understory the surveyor's observations are the only source of information. As noted above, these observations seem quite consistent, as these examples indicate:

POINT BAR
"...Undergrowth Cane Vines &c"
"...undergrowth vines &c"

POINT BAR WITH NATURAL LEVEES
"...Undergrowth cane & Vines"
"... undergrowth heavy cane vines &c"

ABANDONED CHANNELS, SWALES
"...undergrowth vines brier &c"
"...Undergrowth Cane & Green briers"

BACKSWAMP
"...undergrowth privy vines green briers &c"
"...Undergrowth Switch cane palmetto &c"

BACKSWAMP WITH NATURAL LEVEE
"...undergrowth heavy cane"
"... very heavy cane..."

RESULTS

Table 1 shows the general site types related to vegetation that were designated as the basis for subdividing the data set. Table 2 shows the number of sample trees in each of the designated site types, as well as the distribution of sites in relation to the modern levee system.

Twenty-five species were named in the GLO notes (table 3) along with the likely scientific name to which they refer. Uncertainty as to correct nomenclature exists and is reflected in the table.

Distinctiveness of Site/Vegetation Types

Table 4 shows the composition of each of 4 vegetation/site types based on all trees in the database, both corner trees and line trees. Quantities include number of trees in the database and relative abundance, by species. A total of 229 trees were included in this analysis. Hackberry, sweetgum and ash occurred on all 4 site types and were the most abundant species, averaging from 15 percent to 17 percent of total trees. Persimmon and white oak also occurred on all 4 types, but in much lower abundance, making up just over 5 percent and just under 4 percent of total trees, respectively. Cypress occurred in three site types, and made up over 28 percent of the trees on swales, channels and backswamps (site type C). Pecan occurred on three site types as well, and made up 15 percent of the trees on point bars (site type A).

The summary IV data based only on corner trees are shown in table 5. Detailed data on absolute and relative density and dominance, along with geometric mean diameter by species are available from the third author. As measured by IV, which includes both density and size of trees, sweetgum and ash scored highest, improving on their abundance scores, while hackberry declined somewhat, falling below the IV of cypress, which, because of its large size scored much higher in IV than in abundance. The buttressing of cypress trees may well cause an overestimate of its basal area and IV, relative to density. Persimmon and white oak also score lower in IV than abundance. Considering average IV values over all site types, ash was the most important species, followed by sweetgum, cypress and hackberry. The importance of all oaks combined did not equal the importance of any one of these species.

TWINSPAN analysis (table 6) shows differences in species IV among the site types. Cypress is important only in the

Table 2—Distribution of corner trees with respect to levees (total trees per site type in parentheses)

{Private} site type code	No. trees inside levee	No. trees outside levee	Total number of trees
A	43 (51)	0 (1)	43 (52)
B	32 (44)	8 (11)	40 (55)
C	22 (33)	12 (19)	34 (52)
D	13 (15)	41 (55)	54 (70)
Total	110 (143)	61 (86)	171 (229)

Table 3—Tree species listed in the 1837 GLO surveyor's notes, with probable modern equivalent and scientific name. Unidentified indicates illegibility of the surveyor's notes. "Maple" was not used in the analysis since it occurred only in excluded sites

Surveyor name	Scientific name
Ash	*Fraxinus* sp.
Black oak	*Quercus nigra, falcata, texana*?
Boxelder	*Acer negundo*
Cottonwood	*Populus deltoides*
Cypress	*Taxodium distichum*
Dogwood	*Cornus florida*
Elm	*Ulmus* sp.
Hackberry	*Celtis laevigata*
Honey locust	*Gleditsia triacanthos, G. aquatica*?
Hickory	*Carya* sp.
Maple	*Acer* sp.
Mulberry	*Morus rubra*
Oak	*Quercus* sp.
Overcup oak	*Quercus lyrata*
Pecan	*Carya illinoensis*
Persimmon	*Diospyros virginiana*
Pin oak [willow oak?]	*Quercus palustris, phellos*
Redbud	*Cercis canadensis*
Red oak [cherrybark oak?]	*Quercus pagoda*?
Red priv(e)y [swamp privet]	*Forestiera acuminata*
Sassafras	*Sassafras albidum*
Sycamore	*Platanus occidentalis*
Sweetgum	*Liquidambar styraciflua*
White oak [cow oak?]	*Quercus alba* [*Quercus michauxii*]?
Willow	*Salix nigra*
Cane	*Arundinaria gigantea*
Palmetto	*Sabal minor*
Green briers (or briers)	*Smilax* spp.
Privey (or red privey)	Probably *Forestiera* spp.

poorly drained types (C and D). Hackberry, while important in all types, achieved highest importance in the poorly drained types. Cottonwood and pecan only achieved high importance on the best-drained type (B).

GLO Site/Vegetation Types and Modern Vegetation—Overstory Comparisons

Initial analysis sorted GLO trees according to the CERDS Land Cover type that today occupies the site types where they were located. All trees (corner and line) located on sites that are inside the modern levee were included in the initial analysis, and percentage of total in the CERDS type sites was calculated (table 7).

Ten or more GLO trees occurred in three CERDS vegetation types. Therefore compositional analysis (relative abundance) was limited to GLO trees of Cottonwood (17 trees), Hackberry/American Elm/Green Ash (64 trees, including two that were mapped as pure Hackberry) and Sycamore/Sweetgum/American Elm (59 trees) sites. CERDS vegetation types with fewer than 10 GLO trees include Black Willow, Cypress/Tupelo, Overcup Oak/Bitter Pecan, Pecan, Scrub, Sweetgum and Sweetgum/Oak.

Sites presently mapped as Cottonwood type were dominated by cottonwood (23 percent) in 1837 as well, followed by sycamore, sweetgum and hackberry. Present Hackberry/American Elm/Green Ash cover type sites were dominated in 1837 by ash (25 percent) and sweetgum (23 percent), followed by hackberry and cypress. Today's Sycamore/Sweetgum/American Elm areas were dominated by ash (22 percent), followed by hackberry, sweetgum and cottonwood.

The compositional comparisons between the 1837 forests and modern stands on the same sites are of interest, but composition alone is a limited attribute to compare communities of sites in 1837 to those of today. It is necessary to establish a relationship between identifiable GLO communities, based on both abundance and size, and modern landscape features, such as our site types. Table 8 summarizes importance values and species composition of the four site types within the levees. As measured by importance values, ash, sweetgum and hackberry dominated, in that order. Cottonwood was important only in the relatively well-drained site type A at almost 16 percent. Cypress was only important (34 percent) in swales, backswamps and other poorly drained sites (type C). Pecan was most important on point bars (type A, 9 percent), and honey locust (probably actually water locust) was only important on swales, channels and other poorly drained sites (type C, 9 percent).

These analyses demonstrate that geomorphic Site Types are effective discriminators of GLO overstory vegetation described in terms of both composition and structure. Therefore the summaries of all of the GLO data (except for sites reworked by the river after the survey) were then compared to modern forest data summarized by Klimas (1988) for the same site types to further illustrate differences and similarities between the 1837 forests and those sampled in 1985.

Table 4—Composition of four GLO vegetation/site types based on relative abundance of all trees in the database—corner and line

Species	A		B		C		D		Total trees	
	No.	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*	*No.*	*Percent*
Ash	11	21.15	9	16.36	9	17.31	11	15.71	40	17.47
Black oak	2	3.85	—	—	—	—	—	—	2	.87
Boxelder	1	1.92	3	5.45	—	—	1	1.43	5	2.18
Cottonwood	4	7.69	3	5.45	—	—	1	1.43	8	3.49
Cypress	2	3.85	—	—	15	28.85	5	7.14	22	9.61
Dogwood	1	1.92	—	—	—	—	—	—	1	.44
Elm	1	1.92	3	5.45	1	1.92	6	8.57	11	4.80
Hackberry	6	11.54	10	18.18	7	13.46	15	21.43	38	16.59
Hickory	—	—	2	3.64	—	—	—	—	2	.87
Honey locust	—	—	—	—	3	5.77	1	1.43	4	1.75
Mulberry	—	—	3	5.45	—	—	—	—	3	1.31
Oak	—	—	—	—	—	—	1	1.43	1	.44
Overcup oak	—	—	—	—	1	1.92	—	—	1	.44
Pecan	8	15.38	2	3.64	—	—	1	1.43	11	4.80
Persimmon	1	1.92	5	9.09	4	7.69	2	2.86	12	5.24
Pin oak	—	—	—	—	2	3.85	1	1.43	3	1.31
Red bud	—	—	—	—	—	—	2	2.86	2	.87
Red oak	—	—	—	—	1	1.92	3	4.29	4	1.75
Red privey	—	—	—	—	1	1.92	1	1.43	2	.87
Sassafras	1	1.92	1	1.82	—	—	1	1.43	3	1.31
Sweetgum	12	23.08	9	16.36	4	7.69	10	14.29	35	15.29
Sycamore	—	—	2	3.64	—	—	3	4.29	5	2.18
Unidentified	—	—	—	—	—	—	1	1.43	1	.44
White oak	2	3.85	2	3.64	1	1.92	4	5.71	9	3.93
Willow	—	—	1	1.82	3	5.77	—	—	4	1.75
Total	52	100.00	55	100.00	52	100.00	70	100.00	229	100.00

Table 9 contrasts the importance values of dominant species (all species with an IV of 10 or greater) of the GLO forests on each major site type (inside and outside the modern levee system) with the modern forests inside the levee system. The modern forest descriptions are summarized from sample data taken along the river between Memphis, TN and Baton Rouge, LA. Although this sample area extends well beyond the study area, Klimas (1988) determined that forest communities within this reach are consistent in terms of composition and structure. Although species compositions in 1985 were similar to those in 1837 it is clear that some species have decreased in dominance (sweetgum, cypress, ash) while others have increased (hackberry and boxelder).

GLO Site/Vegetation Types and Modern Vegetation—Understory Comparisons

To summarize numerous observations stated in the mile notes, cane was noted on all site types, but was rare on the heaviest soils (backswamp and abandoned channels – site type C), and reached its greatest importance on natural levee soils wherever they occurred. Palmetto was mentioned occasionally, usually on backswamp sites. Green briers or briers and privey or red privey also were largely restricted to backswamps or abandoned channels, and was not noted on point bars or on natural levee deposits. These latter sites were almost invariably occupied by unspecified vines, unless completely covered by dense canebrake.

A variety of other observations turned up in the notes. The presence of large "windfalls" and references to "prairie cane" suggest that large openings within the canopy were common at the time of the survey. No references to fire were noted, but on at least one occasion the surveyor noted that cypress logs had been downed and prepared to be rafted out of the forest during high water. Occasional mention of farm buildings and roads as reference points make it clear that this was not wilderness. On the other hand, comments about provisioning campsites and difficulties traversing large areas make it equally clear that much of the area had not been substantially altered by the white settlers.

Understory conditions in the modern forest are far more diverse than the GLO notes indicate, but this is certainly a reflection of the surveyor's disinterest in understory plants unless they impeded his progress. Klimas (1988) recorded hundreds of plant species in the forests flanking the lower Mississippi River, including more than two dozen vine species. The species the surveyors noted with regularity are present in the modern forest on the same sites and with the

Table 5—Summary Importance Value (IV) data on all site/vegetation types used in analysis of distinctiveness of site/vegetation types

Species	Site/vegetation types A	B	C	D	Frequency	Average IV
Ash	19.77	17.88	21.05	17.91	4	19.153
Black oak	4.83	—	—	—	1	1.208
Boxelder	1.30	5.63	—	1.18	3	2.028
Cottonwood	15.60	2.36	—	1.00	3	4.740
Cypress	1.78	.3	7.10	12.85	3	12.933
Dogwood	1.21	—	—	—	1	.303
Elm	1.40	1.60	—	6.21	2	2.303
Hackberry	7.70	15.01	10.96	15.69	4	12.340
Pecan	10.82	1.95	—	1.48	3	3.562
Persimmon	1.49	6.74	7.06	2.70	4	4.498
Sassafras	1.40	4.45	—	1.18	3	1.758
Sweetgum	28.53	24.91	2.94	15.18	4	17.890
White oak	4.17	5.29	1.84	3.37	4	4.498
Hickory	—	3.34	—	—	1	.835
Mulberry	—	4.93	—	—	1	1.233
Sycamore	—	4.31	—	11.19	2	3.875
Willow	—	1.60	6.25	—	2	1.963
Honey locust	—	—	6.03	1.26	2	1.823
Pin oak	—	—	5.08	—	1	1.270
Red privey	—	—	1.69	1.18	2	.718
Oak	—	—	—	.93	1	.233
Red oak	—	—	—	3.29	1	.823
Red bud	—	—	—	2.29	1	.573
Unidentified	—	—	—	1.11	1	.278
Total IV	100.00	100.00	100.00	100.00		100.00
Total species	13	14	10	18		

same general patterns of abundance, with the exception of cane. In the modern forest cane tends to follow a similar pattern with respect to general site affinities, with its most extensive and consistent occurrence on natural levee deposits. However, the large, dense canebrakes and cane prairies described by the surveyors are no longer a common feature, and most stands of cane are localized or sparsely distributed in comparison to the conditions described in the early 1800s.

DISCUSSION

The overall objective of this study was to determine if information from the GLO survey could be used to help guide ecosystem restoration activities in the lower Mississippi Valley. Ecosystem restoration implies many possible considerations relating to the ability to recover a broad suite of ecosystem functions, but a basic tenet of most restoration plans is that restored plant communities should eventually have compositional and structural characteristics that reflect undisturbed conditions as closely as possible. In the lower Mississippi Valley, the principal remaining examples of extensive bottomland forests are located along the Mississippi River within the confines of the mainstem levee system. These forests do not meet the “undisturbed” criterion because of a long history of cutting and hydrologic modification, and therefore other sources of information must be employed to develop models to guide restoration.

Klimas (1988) has demonstrated that distinct modern forest types within the levee system are associated with particular geomorphic surfaces (as mapped in CERDS), which suggests a convenient basis for designing forest restorations on cleared lands. However, Klimas (1991) expressed skepticism that modern forest remnants within the levee system provide accurate models of “appropriate” community characteristics for those sites because the existing forests have been subjected to multiple and chronic stresses that may tend to favor certain opportunistic tree species and reduce representation of less resilient species. Stresses in the modern confined floodplain include altered hydrology, altered sediment distribution patterns, arrested channel movement, and a long history of differential harvest of valuable timber species. Much of the modern forest also occupies sites that were farmed in the past. These considerations cast doubt on the use of modern forests to serve as models for restoration, and there is little basis for determining which characteristics of the modern forest are “appropriate” and which are artifacts of human disturbance.

Table 6—TWINSPAN analysis of IV all corner trees, both inside and outside of modern levees. (Value is generalized measure of IV)

	3	1	2	4	
Cypress	4	1	–	3	000
Hickory	–	–	2	–	00100
Mulberry	–	–	2	–	00100
Willow	3	–	1	–	001010
Pin oak	3	–	–	–	001011
Black oak	–	2	–	–	001100
Dogwood	–	1	–	–	001100
Cottonwood	–	4	1	1	001101
Persimmon	3	1	3	1	00111
Honey locust	3	–	–	1	0100
Pecan	–	3	1	1	0101
Ash	4	4	4	4	01100
Hackberry	3	3	4	4	01100
Sweetgum	1	4	4	4	01101
White oak	1	2	3	2	01101
Sassafras	–	1	2	1	01110
Boxelder	–	1	3	1	01111
Red privey	1	–	–	1	10
Sycamore	–	–	2	3	1100
Elm	–	1	1	3	1101
Oak	–	–	–	1	111
Red oak	–	–	–	2	111
Red bud	–	–	–	1	111
Unidentified	–	–	–	1	111
	0	0	0	1	
	0	0	1		
	0	1			

The observations of the GLO surveyors represent a potential opportunity to resolve this uncertainty. The forests they described had certainly been influenced by Native Americans and early European settlers, but they had not been subjected to the fundamental and extensive disruptions imposed over the past century of exploitation and river engineering. However, the unique, site-specific insights contained in the GLO notes cannot be applied to restoration planning without a mechanism to translate the information into community descriptions that can be associated with identifiable features of the modern agricultural landscape.

The analyses described in this paper demonstrate that the information contained in the GLO notes can be usefully translated to the modern landscape on the basis of geomorphic setting. GLO witness tree data describe unique communities when summarized within the same major geomorphic settings used by Klimas (1988) to discriminate among modern forests. This requires consideration of structural data, as simple composition (species presence/absence) does not always differentiate among communities.

Comparisons of GLO data to modern stand data within geomorphic site types indicate that significant shifts in dominance have taken place, and that modern forests may provide misleading models for restoration projects. Shifts may have resulted from biases in harvest or changes in hydrology or other reasons. If the changes noted here are due to biases in removal, then restoration to “original” composition is warranted. If changes are due to hydrologic modifications, then restoration to new communities is needed. Sweetgum and/or ash were the leading dominants on Site Types A and B in the early 1800s, but neither

Table 7—GLO trees of sites occupied today by three CERDS land cover types

Species	Cottonwood		Hackberry/elm/ash		Sycamore/swtg/elm		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Ash	1	5.88	16	25.00	13	22.03	30	21.44
Black oak	1	5.88	1	1.56	1	1.69	3	2.14
Boxelder	1	5.88	1	1.56	3	5.08	5	3.57
Cottonwood	4	23.53	1	1.56	6	10.17	11	7.86
Cypress	—	—	7	10.94	1	1.69	8	5.71
Dogwood	1	5.88	1	1.56	—	—	2	1.43
Elm	—	—	—	—	4	6.78	4	2.86
Hackberry	2	11.76	11	17.19	7	11.86	20	14.29
Honey locust	—	—	—	—	1	1.69	1	.71
Mulberry	—	—	1	1.56	2	3.39	3	2.14
Overcup oak	—	—	1	1.56	—	—	1	.71
Pecan	1	5.88	6	9.38	4	6.78	11	7.87
Persimmon	—	—	—	—	5	8.47	5	3.57
Sassafras	—	—	—	—	1	1.69	1	.71
Sweetgum	2	11.76	15	23.44	7	11.86	24	17.14
Sycamore	3	17.65	—	—	2	3.39	4	3.57
White oak	1	5.88	2	3.13	2	3.39	5	3.57
Willow	1	1.56	—	—	1	.71	—	—
Total	17	100.00	64	100.00	59	100.00	140	100.00

Table 8—Summary of inside-the-levees importance values

Species	Vegetation types								Total	Mean	
	A		B		C		D				
	No.	*IV*	*No.*	*IV*	*No.*	*IV*	*No.*	*IV*	*Number*	*Number*	*IV*
Ash	9	19.77	6	21.28	5	28.10	4	35.02	24	6.00	26.04
Black oak	2	4.83	—	—	—	—	—	—	2	.50	1.21
Boxelder	1	1.30	2	4.48	—	—	1	4.92	4	1.00	2.68
Cottonwood	4	15.60	—	—	—	—	—	—	4	1.00	3.90
Cypress	1	1.78	—	—	5	34.09	—	—	6	1.50	8.97
Dogwood	1	1.21	—	—	—	—	—	—	1	.25	.30
Elm	1	1.40	1	1.96	—	—	—	—	2	.50	.84
Hackberry	5	7.70	6	14.01	3	8.99	3	17.06	17	4.25	11.94
Hickory	—	—	2	4.08	—	—	—	—	2	.50	1.02
Honey locust	—	—	—	—	3	9.09	—	—	3	.75	2.27
Mulberry	3	6.05	—	—	—	—	3	.75	6	1.51	2.08
Oak	—	—	—	—	—	—	1	3.85	1	.25	.96
Pecan	5	10.82	1	2.36	—	—	—	—	6	1.50	3.30
Persimmon	1	1.49	3	6.13	—	—	—	—	4	1.00	1.91
Pin oak	—	—	—	—	1	3.20	—	—	1	.25	.80
Red oak	—	—	—	—	—	—	1	4.61	1	.25	1.15
Sassafras	1	1.40	1	5.24	—	—	—	—	2	.50	1.66
Sweetgum	10	28.53	5	29.22	1	4.34	1	5.84	17	4.25	16.98
Sycamore	—	—	2	5.20	—	—	1	23.32	3	.75	7.13
White oak	2	4.17	—	—	1	2.79	1	5.38	4	1.00	3.09
Willow	—	—	—	—	3	9.40	—	—	3	.75	2.35
Total trees	43	100.00	32	100.00	22	100.00	13	100.00	110	27.50	N/A
Total species	13		11		8		8				

species is particularly important on those sites today. They have been replaced by boxelder and/or hackberry as the leading dominants. In 1837 hackberry was second or third to these species on Site Types A and B and was the leading dominant on site type D. Boxelder had low IV in the 1837 data, but may have been selected against by the surveyors as a short-lived tree. Secondary species (pecan, cottonwood, and sycamore) continue to be present at levels comparable to those noted at the time of the GLO survey on these Site Types. On Site Type C, baldcypress was by far the most important species at the time of the GLO survey, but it now ranks fourth in importance on those sites, having been largely replaced by hackberry, black willow, and boxelder. This change may be real, or may indicate a preference for cypress as a witness tree by the surveyors, or an overestimate of importance because of its buttressed base.

The modern forest inside the mainstem levee system has become dominated by opportunistic species (hackberry and box elder, in particular), largely at the expense of sweetgum and ash on drier sites, and baldcypress on poorly drained sites. Secondary species that were noted in the GLO survey are present in the modern forest, and presumably most understory species continue to occupy their characteristic sites. Thus, overall plant community composition has not been significantly altered, but dominance patterns and community structure have changed dramatically.

GLO surveyor's observations regarding understory conditions are anecdotal and limited to a few common species for the most part. They do not suggest any major changes over time, with one exception. The formerly abundant cane has clearly declined dramatically. This fact has been well-recognized as a region-wide phenomenon, and suggested mechanisms contributing to the decline have included cattle grazing, conversion of cane sites to agriculture, fire suppression, and a reproductive cycle that tends to delay recovery following disturbance (Remsen 1986). The potential significance of such changes is illustrated by the changes that have occurred in abundance over the past 150 years. Even though this species is still common, it no longer dominates community character on many sites, which has implications for a variety of ecosystem elements. For example, the loss of extensive canebrakes has been proposed as a likely cause of extinction for at least one wildlife species, Bachman's Warbler (Remsen 1986) and likely declines in another species, Swainson's Warbler. The wholesale shifts in overstory dominance patterns are likely to have had similarly significant impacts on ecosystem functions, and restoration

Table 9—Comparison between 1837 (GLO) and 1985 (Klimas 1988) dominant vegetation on each of four geomorphic site types

Site type A
Point bars

1837 Forests Leading dominants	IV	1985 Forests Leading dominants	IV
Sweetgum	28	Hackberry	20
Ash	20	Boxelder	17
Cottonwood	16	Pecan	13
Pecan	11	Cottonwood	12
All other species	25	All other species	38

Site type B
Point bars with natural levee deposits

1837 Forests Leading dominants	IV	1985 Forests Leading dominants	IV
Sweetgum	25	Boxelder	18
Ash	18	Hackberry	18
Hackberry	15	Pecan	12
All other species	44	All other species	40

Site type C
Abandoned channels, backswamps, and large swales

1837 Forests Leading dominants	IV	1985 Forests Leading dominants	IV
Baldcypress	37	Hackberry	32
Ash	21	Black willow	14
Hackberry	11	Boxelder	12
All other species	31	All other species	22

Site type D
Abandoned channels, backswamps, and large swales with natural levee deposits

1837 Forests Leading Dominants	IV	1985 Forests Leading Dominants	IV
Ash	18	Boxelder	28
Hackberry	16	Black willow	20
Sweetgum	15	Sycamore	10
Baldcypress	13		
Sycamore	11		
All other species	27	All other species	42

planning should attempt to recover the original dominance patterns.

In addition to providing general guidance regarding the composition and structure of relatively undisturbed forests, this study illuminates some fundamental difficulties in achieving forested wetland restoration within the lower Mississippi Valley.

In particular, the relationship between forest characteristics and geomorphic surfaces highlights the potential significance of the relative lack of geomorphic dynamics in the modern floodplain. Certain species tend to regenerate on substrates that are made available by channel migration, such as cottonwoods on point bars and baldcypress in recently cutoff oxbows. With the stabilization of the river, these habitats are no longer being created to any great extent. Simple analysis of cover type distributions shows that these species remain as common dominants in the region, but more detailed evaluations (Klimas 1988) show that the majority of their occurrences are as relicts of older stands, or on sites recently disturbed by human activity rather than river movement. Much of the remaining baldcypress in the study area, for example, is associated with the perimeter of old, stabilized oxbows or it exists as scattered large trees in stands with other, drier-site species in the understory. Similarly, extensive cottonwood is found most commonly in abandoned agricultural fields, plantations, or on disturbed soils adjacent to levees or borrow pits. There are some extensive cottonwood stands on river islands and similar habitats subjected to regular extreme scour and deposition, but there are relatively few cottonwood sites that correspond to the classic succession patterns on accretion topography such as newly-formed point bars. Whatever unique characteristics such stands had may not be well represented in the modern forest. In the case of baldcypress, the implications are even more problematic, in that the majority of existing stands appear to be remnants of former stands that will not regenerate, and the sites that are typically invaded by cottonwood (old fields, disturbed soils) are not likely to be appropriate baldcypress habitat. The lack of suitable habitat for baldcypress regeneration will cause the gradual loss of this unique component of the Mississippi Valley ecosystem unless special restoration approaches are devised to ensure its persistence.

In general, plant communities are dependent on riverine processes and features and unless we restore the processes we cannot expect the same communities to return.

SUMMARY

GLO information interpreted in the context of geomorphic surfaces appears to provide a good basis for establishing goals regarding restoration of forest composition and structure within the study area. The established relationship between modern forests and geomorphology suggest that this approach is likely to be appropriate throughout the Mississippi Alluvial Valley, if the quality of the surveyor's notes is comparable to those we used. The required geomorphic mapping is available for the entire region (see Saucier and Snead 1989 for basic references).

This study demonstrated that modern forests inside the mainstem levee system do not provide good models for overstory restoration. Chronic severe disturbance has altered their composition and structure substantially. They remain the best available source of information on potential understory conditions, except that the characteristics of the modern cane populations have been shown to be substantially different from pre-settlement conditions.

The application of GLO/geomorphic models to restoration must be approached thoughtfully. For example, changes in flooding patterns would affect the applicability of GLO data, although the consistent site affinities of secondary and understory species tend to offset this concern. A more fundamental consideration has to do with the curtailment of river meander behavior. Although existing forests do not yet fully reflect this change, it is inevitable that communities which are directly associated with river migration, such as many black willow, cottonwood, and baldcypress forests, will eventually be greatly reduced as elements of the overall forest matrix. Restoration planners should strive not only to reestablish appropriate patterns of community composition and structure, but also find ways to offset the chronic disturbance and loss of ecosystem dynamics that have resulted from wholesale stabilization and confinement of the river.

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