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Classification of Land Cover and Assessment of Forested Wetlands in the Cypress Creek Watershed

Final Report to United States Environmental Protection Agency (Assistance Agreement No. CD996242-01-0)

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ABSTRACT

Bottomland hardwood forests are considered important habitats for wildlife and are of value for the conservation of biological diversity. In preparing for a state-wide wetland conservation plan, Texas Parks and Wildlife Department (TPWD), using funding provided by the United States Environmental Protection Agency (EPA), initiated this study on the status of forested wetlands (including bottomland hardwood forests) in east Texas and western Louisiana. Classification and analysis were made for the forested wetlands and other land cover types in the Cypress Creek watershed using Landsat Thematic Mapper (TM) imagery and Geographical Information System (GIS) technology. Color infrared (CIR) aerial photography and information on soils, geology, and topography were also utilized in the process.

The area of Caddo Lake and vicinity in the eastern portion of the Cypress Creek watershed is highly diverse in terms of numbers of plant communities and aquatic species, and importance for wildlife. Fourteen land cover types were identified. Of these fourteen types, 11 are vegetated or forested. Forested wetlands consist of river birch (Betula nigra L.)-black willow (Salix nigra Marsh.), swamp/baldcypress (Taxodium distichum (L.) Rich.) swamp, mixed cypress-hardwood, and water oak (Quercus nigra L.)-overcup oak (Q. lyrata Walt.)-blackgum (Nyssa sylvatica Marsh.). These four types occupy only small areas (3.3%) of the floodplains which were formerly covered principally by bottomland hardwood trees, shrubs, and vines, and by aquatic herbaceous species. The single most significant factor in contributing to the decline of bottomland hardwood forests has been reservoir construction. Other factors include agricultural and silvicultural practices, and urban development.

Key Words: forested wetlands; bottomland hardwood forests; Caddo Lake; Cypress Creek; remote sensing; vegetation classification; land cover type.

INTRODUCTION

Southern forested wetlands, including bottomland hardwood forests, occur throughout the southeastern United States from Virginia to Florida along the Atlantic Coast, and from Florida to

east Texas along the Gulf Coast. Dominant woody species include baldcypress, water tupelo (Nyssa aquatica L.), swamp tupelo (Nyssa sylvatica var. biflora (Walt.) Sarg.), blackgum, water oak, willow oak (Q. phellos L.), basket oak (Q. michauxii Nutt.), overcup oak, river birch, red maple (Acer rubrum L.), green ash (Fraxinus pennsylvanica Marsh.), sweetbay (Magnolia virginiana L.), water hickory (Carya aquatica (Michx. f.) Nutt.), and American elm (Ulmus americana L.). Many other hardwood species and occasional southern pines, mainly loblolly pine (Pinus taeda L.), are also present. These forests usually occupy first terraces of river floodplains, low areas, seepages, and areas along river or creek channels. Hydrology is mainly responsible for the development of these bottomland forests. Flood water periodically or permanently inundates the soil and creates physiological stress for species which cannot tolerate anaerobic conditions.

Due to their high productivity and proximity to the water bodies and river channels, bottomland hardwood forests are important for water resources, wildlife, recreation, and biological conservation. Many historical cultural sites also are located in the proximity of these forests. Forested wetlands play a critical role in controlling erosion, recharging groundwater, and preventing flood damage. On the other hand, these forests are primary sources of income. Many areas were cleared for agricultural purposes (farmland and pasture), timber production (plantation), or permanently-inundated after reservoir construction. From the mid 1950's to the mid 1980's, these developments greatly reduced the acreage of bottomland hardwood forests and wetlands, and at the same time, the quality of these forests were degraded. It is estimated that in Texas, only about 25% of the original bottomland remains. With little doubt, future developments (e.g. demand for hardwood pulpwood required for quality paper products and industrialization) will further reduce and fragment these forests.

In Texas, losses of bottomland hardwood forests have not been very well documented, although the trend of decline is obvious (Hefner and Brown 1985, Frye and Curtis 1990). Attempts to identify intact bottomland hardwood forests have largely been oriented toward random or non-specific surveys (Dahl and Johnson 1991). The only systematic effort to identify and classify forested wetlands was a part of a project designed to classify natural vegetation communities throughout Texas (McMahan et al. 1984). However, that classification was based on Multispectral Scanner (MSS) data acquired in the 1970's with a coarse spatial resolution (approximately 80 x 80 meters). The current project intends to study the current status of bottomland hardwood forests in the Cypress Creek watershed, or the Big Cypress basin, one of the largest natural wetland areas in eastern Texas and western Louisiana, by using recent remotely-sensed satellite imagery with better spatial resolution (25 x 25 meters) and geographic information system technology. This will assist nature conservation organizations with information on the quality and quantity of bottomland forests and other wetland communities, and associated unique habitats in east Texas and western Louisiana.

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The study area is located in northeast Texas and northwest Louisiana with latitudes from 32 30' to 33 14'N and longitudes from 94 01' to 95 22'W. The basin is about 80 km wide and 130 km long. Two major drainage systems are the Big Cypress Bayou and the Little Cypress Bayou. All streams drain southeastward to a naturally formed lake, Caddo Lake, then to the Red River, a major tributary of the Mississippi River system. The area is hilly with elevations ranging from 55 m to 210 m above mean see level. The area, known as sandy hills, is mostly developed from the Eocene Claiborne sandstones and shales. Small portions of the watershed in the southeast and in the north are underlain by the Eocene Wilcox and Wilcox formations (Spearing 1991). Soil texture changes from sandy to sandy-clay from the uplands to the bottomlands. Some areas can be heavy and

clayey, particularly in floodplains and Caddo Lake vicinity. The study area is limited to the spillway located about 3 miles northeast of Mooringsport, Louisiana.

The climate of the area is humid subtropical with an even distribution of precipitation throughout the year. Winters are warm and summers are hot. Average annual precipitation and temperature at Marshall are 1210.3 mm and 17.9 C averaged from 1961 to 1990 (Bomar 1995). The average monthly low temperature in January and the average monthly high temperature in July are 0.1 C and 33.7 C, respectively.

Caddoan Indians inhabited the area for centuries prior to the arrival of the Europeans. These native Americans developed sophisticated agricultural practices and a relatively advanced culture. They sustained self-sufficiency by farming, fishing, and hunting (McClung 1974, Dahmer 1995). However, their presence did not substantially alter the natural environment as the Europeans did in the late nineteenth and early twentieth century. Oil and gas exploration, farming, logging, and reservoir construction have all changed the landscape and hydrological regime of streams in the Cypress Basin (Dahmer 1995). With the advent and expansion of navigation on the Red River, clearing of rafts of logs on the river channel resulted in the almost complete draining of Caddo Lake. Caddo Lake has since been restored, albeit at a lower level, after construction of a spill weir near Mooringsport, Louisiana (Texas Water Development Board 1966, Anonymous 1979). Consequently, the landscape was altered and vegetation was modified and fragmented. Today, few of the old-growth forests can be found in the region. Not much of the original bottomland hardwood forests remains.

The area is a part of the pineywoods region in east Texas and west Louisiana. Shortleaf pine (Pinus echinata Mill.) and loblolly pine dominate forest communities in the uplands and hill slopes. The bottomlands and floodplains are made up of baldcypress and other bottomland hardwood species. Many other oak and hardwood species occupy the understory or codominate in the overstory. These species include post oak (Q. stellata Wangenh.), black hickory (Carya texana Buckl.), sweetgum (Liquidambar styraciflua L.), water oak, willow oak, southern red oak (Q. falcata Michx.), blackgum, blackjack oak (Q. marilandica Muenchh.)), etc. Almost all the vegetation types in the watershed have been subject to human disturbances in the past.

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Two Landsat Thematic Mapper (TM) satellite imagery scenes were acquired from the District Office of the Corps of Engineers in Fort Worth, Texas. These two TM imagery images were originally obtained by the Earth Resources Observation Satellite Company (EROS) on April 7, 1994 (path 25 and row 37) and September 5, 1994 (path 26 and row 37). They contain 6-band data (with band 6 removed) in Universal Transverse Mercator (UTM) projection (Zone 15) with a spatial resolution of 25 meters. In addition to the imagery, color infrared aerial photographs, which cover the whole Caddo Lake area and portions of the watershed, were purchased from USGS EROS Data Center, Sioux Falls, South Dakota. Ancillary data, such as contours, geology, soils, and the drainage system, were obtained from the Corps of Engineers. The watershed boundary was delineated, scanned, and vectorized from USGS 7.5' quadrangle maps. The road network and city limits were based on digital county road maps from the Texas Department of Transportation (TXDOT). ERDAS Imagine (ERDAS Inc. 1994) and Arc/Info were utilized in the data processing, analysis, and classification.

The 6-band image data were subjected to two processes prior to the supervised classification. One was band reduction (from 6 to 3) by Principal Component Analysis (PCA). The 3 bands extracted

account for most of the variation in the 6-band data, hence can be relied on as the primary data source for bottomland hardwood delineation in combination with contour data. The other process was unsupervised classification that categorized the raw 6-band data into 150 classes.

Training samples were collected from three separate field reconnaissance trips to the study area. About 150 signature points/areas were taken. Aerial photos were used to build confidence on photointerpretation of land covers and vegetation. After the field trips, a supervised classification was performed on the 150 unsupervised classes. Major sources of information used in this procedure are color infrared aerial photography, PCA processed imagery, soil types, and topography. A total of fourteen vegetation types were identified. The two scenes of imagery were classified separately. After supervised classification, two image scenes were mosaiked to form a composite classified image.

Groundtruthing and verification of the classified image was conducted in the summer of 1996. A real-time Global Positioning System (GPS) with differential correction was used in data collection. Due to possible errors in GPS (10 meters) and in TM imagery (about 15 meters), minimal patch size for a groundtruth point is limited to 1 hectare (4 by 4 pixels), i.e. no sample point will be taken from a patch of same cover type if the area is less than 1 hectare. An accuracy matrix was calculated from about 450 groundtruth points collected in the field. Owing to the inaccessibility of many areas, groundtruthing was principally conducted along the road network, hence it should not be regarded as a completely random sampling. Therefore, caution must be exercised in interpreting the results. In addition, no groundtruth points were collected from urban areas and for the birch-willow type because of its narrow distribution.

An attempt was also made to compare the differences in acreage of bottomland hardwood forest and other comparable vegetation types by comparing current classified TM imagery with classified MSS imagery processed in the early 1980's by Texas Parks and Wildlife Department (McMahan et al. 1984). Original imagery was acquired between 1972 and 1976. Eleven land cover types were classified in this study area (hardwood, post oak-blackjack oak, pine/pine-hardwood, crops, grasses, urban/sparsely vegetated, water, hardwood-pine, bald cypress swamp/flooded hardwood, young pine forest/eastern mixed hardwood brush/parks/post oak-blackjack oak parks, and unclassified). Water, bottomland hardwood forest, baldcypress swamp, and grassland/crops are the four types which can be compared with current classified types. MSS data was used to create the bottomland hardwood category from the hardwood type by overlaying all hardwood types on the delineated bottomland habitats used in the TM imagery classification. Again, caution must be taken in interpreting the results because of different pixel sizes, potential projection error, accuracy variation among land cover types, and possible misclassification.

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1. Description of Major Land Cover Types

Fourteen vegetation/landcover types are recognized. Water, bare soil and ground, and urban areas are the types not considered as true vegetation types, although portions of these types may be partially covered by vegetation, particularly in the case of urban areas. Vegetation types are pure pine/pine plantation, oak-hickory, pine-oak, pine-hardwood, mesic hardwood, bottomland hardwood, baldcypress-hardwood, baldcypress swamp/swamp, willow-birch, clearcut/cutover, and pasture/ grassland/crops. The following is a description of each land cover type:

Pure pine/pine plantation

This vegetation type is dominated almost completely by loblolly pine and shortleaf pine singly or in

combination, at least in the overstory. In some cases, it may be planted slash pine stands. Stand ages and density vary greatly from place to place. This vegetation type can be found in a variety of habitats except in the wettest areas. Sometimes pines are planted in the areas once predominately occupied by bottomland hardwood species. Species abundance in the understory depends on the age of stands and management. Young or fire-managed plantation stands have little in the understory. Otherwise, southern red oak, sweetgum, water oak, dogwood, and other hardwood species are present. This type is a direct result of silvicultural practice and is distributed throughout the watershed.

Oak-hickory

Species commonly found in this type are post oak, black hickory, blackjack oak, winged elm (Ulmus alata Michx.), and bluejack oak (Q. incana Bartr.). However, the distribution of bluejack oak is very limited. Other associate species include southern red oak, sweetgum, dogwood (Cornus florida L.), and eastern red cedar (Juniperus virginiana L.). Soils are excessively-drained, poor in nutrients, and sandy on the ridges and hill tops. The herbaceous cover is sparse owing to dry conditions.

Pine-oak

Pines, shortleaf and loblolly, make a large proportion of this type (more than 10 percent). Other species and habitats are very similar to the oak-hickory type. Compositional species may also include white oak (Q. alba L.), American elm, water oak, and blackgum. It mainly occurs in the uplands and on slopes with well-drained soils.

Pine-hardwood

This type is a mixture of pines (shortleaf and loblolly pines) and hardwood species other than post-oak, hickory, and blackjack oak as in the oak-hickory type. This type occurs in intermediate sites and on floodplains. In some areas, this type is derived from development of cutover or poorly-managed pine plantation.

Mesic hardwood

Mesic hardwood has few pines and is mainly dominated by hardwood species which prefer intermediate soil moisture. Major species include sweetgum, white oak, red maple, and water oak. It occupies moist slopes of hills with fairly fertile soils.

Bottomland hardwood

Bottomland hardwoods occur on the first terrace of floodplains and flats along river channels. Species commonly found in this type include water oak, willow oak, blackgum, American elm, overcup oak, green ash, water hickory, deciduous holly (Ilex decidua Walt.), and American hornbeam (Carpinus caroliniana Walt.). Periodic inundation prevents establishment of upland species and maintains the functioning of this type of vegetation.

Baldcypress-hardwood

This type is usually a transition between the cypress swamp and bottomland hardwood forest. Proportions of baldcypress and hardwoods vary from place to place. Common species besides baldcypress are water oak, American elm, American hornbeam, deciduous holly, red maple, blackgum, and water hickory. An exotic species, Chinese tallow (Sapium sebiferum Roxb.), can be found occasionally.

Swamp/baldcypress swamp

Floating aquatic species and standing cypress trees characterize the swamp areas, mostly in the vicinity of Caddo Lake. In some areas, baldcypress can be very sparse, while in others, they form dense stands. Water in this type is generally shallow. Common aquatic species are spatterdock (Nuphar luteum subsp. macrophyllum (Small) E. O. Beal.), water-milfoil (Myriophyllum spp.), duckweed (Lemna spp.), hornwort or coon-tail (Ceratophyllum demersum L.), bladderwort (Utricularia spp.), sago-pondweed (Potamogeton pectinatus L.), water-lily (Nymphaea spp.) and floating hearts (Nymphoides spp.). Various species of algae are also abundant.

Willow-birch

The willow-birch type occurs along the river and creek channels, depressed areas, and at the confluence between lakes and creeks. This type exists in narrow strips rarely exceeding 100 meters in width. Other species coexisting in this type include red maple, water oak, sweetgum, pecan (Carya illinoensis (Wangehn.) K. Koch.), sugarberry (Celtis laevigata Wild.), blackgum, and American elm.

Cutover/clearcut

As a consequence of logging, cutover areas do not have a unique signature and may show a collection of several different signatures, such as oak-hickory, mesic hardwood, grassland, or bare soil. Usually pines are removed and left-over hardwood trees are standing. Species composition of this type consists of pioneer successional species and remnant hardwoods such as sweetgum, water oak, southern red oak, sumac (Rhus spp.), and many others. Clearcut areas sometimes are converted to managed pasture or farmland.

Pasture/grassland/crops

These areas are dominated by grasses, graminoids (e.g. sedges and rushes), and other herbaceous species, and are managed for grain, hay production or for raising livestock. The majority of these areas used to be forested areas, but were cut and converted in the past.

Bare ground/soil

These are the areas with no or very little vegetation coverage. Industrial parks, and plowed field are two examples. However, plowed agricultural fields classified as bare soils may be temporary.

Water

This includes water bodies impounded by dams and in oxbow lakes, and open water in river channels with no or little vegetation cover overhead. Submersed aquatic vegetation may present in some areas.

Urban/industrial areas

Urban or industrial areas are delineated by city limits. No signature and groundtruth points were collected, largely owing to the complexity of urban settings and vegetation composition.

2. Patterns of Land Use and Vegetation

Within the watershed boundary, there are three significant water bodies: Caddo Lake, Lake O' the Pines, and Lake Bob Sandlin, which are all built on the Big Cypress Bayou. The latter two lakes were created between the 1950's and 1970's as flood control measures for the region. Caddo Lake is the only large naturally formed lake in Texas.

Current land use shows that the western 1/3 of the watershed is mainly pasture. In the central part, dominant vegetation types are mixed pine-oak and oak-hickory which grow on sandy hills of

substantial topography. Bluejack, or sandjack oak can be found in the extremely sandy hills and ridges in the region. The eastern 1/3 has substantial floodplains and shallow waters, hence baldcypress swamps and bottomland hardwood forests have extensive distribution. However, baldcypress is rarely found above the Lake O' the Pines dam.

Pine plantations are common throughout the regions. All areas are subject to logging and other agricultural activities. No major urban areas exist within the watershed boundary.

3. Status and Distribution of the Bottomland Hardwood Forest

Bottomland hardwood forests are mostly located on the flats and floodplains of Little Cypress Bayou, Big Cypress Bayou, James Bayou, and Black Cypress Bayou and in the vicinity of Caddo Lake. Substantial portions of the original bottomland hardwood stands were lost to artificial lakes, pine plantations, logging, and conversion to farmland and pasture. Remnant stands were further modified by the change in the hydrological regime due to water regulation by dams and fragmentation by other human activities and land use. The mixed pine-hardwood type is very common throughout what originally was bottomland area. Pure pine plantations are also invading the bottomlands (Map 3). Relatively high quality bottomland hardwood forests are located in the areas between Lake O' the Pines and Lake Bob Sandlin and in the proximity of Caddo Lake. There is little doubt that these areas are still subject to frequent inundation of flood waters and the conditions are favorable for bottomland hardwood species.

To restore and maintain bottomland hardwood forests, a hydrological regime similar to pre-dam times has to be maintained or mimicked. If a normal or near normal flooding regime is maintained or implemented, upland species, which cannot withstand wet and anaerobic conditions, may eventually decline. This gives bottomland hardwood species an opportunity to return or remain and perpetuate.

4. Accuracy of Land Cover Classification

A total of 455 groundtruth points were collected in the summer of 1996. An error matrix was constructed from these points (Table 1). Cover types on the classified imagery are listed in the first column and in situ types are in the first row. A percentage on the diagonal is the correct classification for a corresponding type and other percentages in cells of the particular row are the possibilities of misclassification into other types.

About one third of the groundtruth points were collected for pasture/grassland/crop type. The accuracy is 96.8% for this type and varies from 44.4% to 100% for others (Table 1). Water and pine plantation/pure pine are classified with high confidence (100% and 90.6%). Good accuracy was achieved for bottomland hardwoods (84.6%) and pine-oak (84.7%). Accuracy for swamp/baldcypress swamp and cutover/clearcut can be considered acceptable (81.0% and 70.9%). The latter may have mixed signatures and change quickly after logging. Poor accuracy is accessed on the pine-hardwood type (44.4%), which can be easily confused with pine-oak (37.0% of the times). Mesic hardwood (58.6%) has limited distribution in the area and sometimes is not quite distinctive from others types, such as pine-oak and oak-hickory. Oak-hickory was somewhat undersampled (only 17 points were sampled) with an estimated accuracy of 64.7%. The rest of types, cypress-hardwood, birch-willow, and bare soil were undersampled with 3 points each. Therefore the accuracy for these types cannot be estimated.

The total area of the whole watershed is 722,456 hectares. In the current landscape, the pine-oak type is the most prevalent with a total area of 294,790 ha (40.8%), followed by

pasture/grassland/crop (174,267 ha, 24.1%) and oak-hickory (77,483 ha, 10.7%). Only about 2.0% of the watershed can be called bottomland hardwood forest. If birch-willow, swamp/baldcypress swamp, mixed baldcypress-hardwood types were included, the percentage (forested wetlands) increased to about 3.3%.

5. Change of Bottomland Hardwood Forest in the Last 20 Years
There were 22,018 hectares of bottomland hardwood forests according to the classification based on the 1972-76 MSS data (McMahan et al. 1984). Only 14,560 ha bottomland hardwood forest still remains in 1994. This is a 33.9% decrease in acreage. The increase in water bodies (e.g. Lake Bob Sandlin) might be the major reason for the decline because 3,009 ha was added as water during this period. If all proposed reservoirs had been built (Texas Water Development Board 1966, Frye and Curtis 1990), more than 90% of the bottomland hardwood forests in the Cypress Creek watershed would have been eliminated. Logging in bottomland hardwood forests and pine plantations in the bottomlands contributed to the decline as well.

Baldcypress types (baldcypress-hardwood and swamp/baldcypress swamp) showed a 30.3% increase. However, we believe that baldcypress types have been relatively stable in the last 20 years. The increase might be due to the discrepancy in classifications (Figure 1). In the TM classification, swamp may not have baldcypress trees at all and its area may vary from year to year. In the MSS classification, flooded hardwood forest might be part of the bottomland hardwood forest. Therefore, we cannot say that there is a substantial change in the two baldcypress types.

Another type, pasture/grassland/crops decreased from 190,097 ha to 174,267 ha (8.3% drop) in the last 20 years (Figure 1). This is largely a result of abandoned farmland and pasture which grew to forest afterward. This type of vegetation may continue to decline in the future.

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A very small fraction of the original bottomland hardwood forest is still remaining in the Big Cypress basin. Numerous factors contributed to the decline of this important vegetation type in east Texas. The significant factors among them are reservoir construction, logging and pine plantation, and agriculture.

As the demand for hardwood pulp and other resources increases, pressure to preserve older-age bottomland hardwood stands will rise as well. However, for sustainable development and the future of wildlife in the area, some of the bottomland hardwood areas must be preserved and other bottomland hardwood forests be restored. There are some changes which cannot be reversed, such as the building of reservoirs. However, return of a hydrological regime similar to pre-dam times is essential for the restoration and continuation of bottomland hardwood forests and the functioning of current wetland systems. This management option should be considered wherever possible.

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Electronic Data (file name and software in parentheses):
Classified TM imagery of Cypress Creek land cover (vegtm.img, ERDAS Imagine v8.2)
Classified MSS imagery from 1970's (vegmss.img, ERDAS Imagine v8.2)
Road network and cities (road, ARC/INFO 7.0.3)
Drainage system (stream, ARC/INFO 7.0.3)
Contours (contour, ARC/INFO 7.0.3)
Watershed boundary (boundary, ARC/INFO 7.0.3)
Map compositions (cadoeast.map and cadowest.map, ERDAS Imagine v8.2)

Notes: all maps, imagery, and coverage are in UTM projection (zone 15, datum NAD27) and have units in meters. The whole watershed lies within UTM zone 15, therefore distortion of area is minimal.
Electronic data listed above are archived at the GIS Lab, Texas Parks and Wildlife Department, Austin, Texas, and are available upon request.

Various Maps of Cypress Creek Watershed. Click on the caption to download the image in Adobe Portable File (PDF) format.

Map 1. 3D pespective view of Cypress Creek Watershed Vegetation (PDF 164.2 KB)
Map 2. Vector and template layers used in Cypress Creek land cover analysis (PDF 105.1 KB)
Map 3a. Land cover types in Cypress Creek Watershed (Eastern Portion) (PDF 422.3 KB)
Map 3b. Land cover types in Cypress Creek Watershed (Western Portion) (PDF 432.9 KB)

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